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Space poverty driving heat stress vulnerability and the adaptive strategy of visiting urban parks

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ABSTRACT

Climate change and urbanisation have exacerbated social inequities. Increasing urban heat has made high-density housing units a vulnerability hotspot. Alternatives to extended air-conditioning are required. This research sought evidence on using urban parks as a sustainable alternative by low-income households deprived of adequate living space. We interviewed occupants of tiny flats (approx. 10 m^2), known as subdivided units, and compared their park visiting routines and thermal comfort practices with other urban dwellers in Hong Kong. The substandard conditions of these small units have contributed to dwellers' sensitivity and lower capacity to adapt to summer heat, resulting in heat-related illness. The space-poor households have taken a wider range of adaptive actions and visited urban parks more frequently for cooling. Their higher mobility between home and nearby parks has shortened their home-stay time that would otherwise demand residential space cooling. The findings are important for reconsidering and redressing the uneven distribution of urban green spaces. Poor housing conditions and heat stress have forced disadvantaged households to seek refuge from natural cool spaces, such as vegetated and shaded areas of urban parks. Measures for increasing their accessibility, availability and capacity for heat mitigation are conducive to pro-poor and pro-climate spatial planning.

1. Introduction

Warming trends and increasing temperature extremes have been observed across most of the Asian region over the past century (Hijioka et al., 2014). In some Asian cities, the thermal environment has deteriorated due to global climate change and densifying urban developments, exacerbating the effects of urban heat island (UHI) (Estoque et al., 2017; Lin et al., 2017). People of lower socio-economic status are particularly vulnerable to urban heat than the rest of the population (Farbotko & Waitt, 2011; Mitchell & Chakraborty, 2018; Sampson et al., 2013).

The incidence of high-temperature impacts is unequal (Paavola, 2017). There is established literature indicating that certain demographic groups, such as elderly, chronically ill individuals, low-income households, children, and women, have experienced greater thermal stress during extreme heat events (Arnberger et al., 2017; Bartlett, 2008; van Steen et al., 2019). An emerging research agenda is exploring the societal conditions for vulnerability to heat and the everyday settings that produce vulnerabilities (Brown & Walker, 2008; Maller & Strengers, 2011; Wilhelmi & Hayden, 2010; Wolf et al., 2010). Housing conditions are one of the contextual factors that constrain urban dwellers' adaptation to the rising temperatures (Maller & Strengers, 2011; Mees et al., 2015).

Asia is known for its large populations and sprawling cities. Small housing units have proliferated in highly dense built environments to accommodate fast population growth and urban development. In Hong Kong, for example, tall residential buildings of 60 or more storeys high are increasingly common (Yeh & Yuen, 2011). However, the housing supply has failed to meet demand, driving up prices (Leung et al., 2020). The East Asian city has witnessed the median price of a private apartment (USD 919,102) 20.9 times higher than the median annual household income (USD 43,974), far exceeding the second most unaffordable city Vancouver (12.6 times) (Cox & Pavletich, 2019). Notwithstanding the high incomes, the high housing prices have shrunk the median residential floor area to only 40 m^2, or 15 m^2 per capita (Census and

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Statistics Department, 2018), which is significantly lower than the more developed regions and worse than some less developed countries (United Nations, 2000).

Subdivided units (SDUs) in Hong Kong are situated at the bottom of the floor-area spectrum at usually about 10 m^2, or 5.3 m^2 per capita. For comparison, the United Nations (2000) adopted 20 m^2 per capita as a threshold. They considered the indoor living space as an indicator of sustainable development, the deprivation of which constitutes a threat to health (United Nations, 1996). Space poverty refers to the significant deprivation of indoor space in a residential unit, perfectly illustrated by Hong Kong's SDUs. SDUs are a special form of private rental housing created by landlords to tailor to the affordability of low-income families. They are found in inner-city areas and formed by dividing a small (and usually old) flat into several tiny units (Fig. 1). The extremely small dwelling space has led to overcrowding and poor environmental quality, including indoor air pollution (Cheung & Jim, 2019c; Lai et al., 2017). Heat stress, in particular, is intensified by UHI effects, poor ventilation and constraints on space cooling (Cheung & Jim, 2021; Yip et al., 2020). SDU tenants with pre-existing social and health issues are at a high risk of heat-health problems and suffer the most from the thermally stressful environment.

The use of air-conditioning during summer is widespread in affluent, subtropical cities. However, the extensive use of residential air-conditioning risks increasing electricity bills, reducing incentives to adapt to temperature variability, increasing reliance on energy-intensive technology and infrastructure, exacerbating UHI effects through the heat pumped into the ambient air, and increasing greenhouse gas emissions (Farbotko & Waitt, 2011; Hatvani-Kovacs et al., 2018; Maller & Strengers, 2011). Urban green infrastructure, such as urban parks, can provide an alternative. Urban parks with abundant vegetation and covered areas can ameliorate people's heat stress by reducing ambient temperatures and providing shading (Bowler et al., 2010; Byrne et al., 2015; Jim et al., 2015; Lafortezza et al., 2009; Lin et al., 2017). Thus, park visiting can be seen as a passive cooling strategy that helps people adapt to warm temperatures. Such strategies are particularly important to vulnerable groups, such as elderly and low-income tenants, who tend to avoid using air-conditioning because of costs, physiological reactions to colder temperatures, and structural and legal constraints of the dwelling unit (Sampson et al., 2013; Farbotko & Waitt, 2011).

However, Arnberger et al. (2017) have indicated that little research has demonstrated the role of urban parks in shaping the thermal comfort practice of specific vulnerable groups. In Hong Kong, Yip et al. (2020) have suggested that some SDU tenants, as a vulnerable group stricken by (energy) poverty, used urban parks in preference to air-conditioning at home, but their evidence is piecemeal and incomplete. Thus, despite some recent attempts (Byrne et al., 2016; Mabon & Shih, 2018), the utility of urban parks in addressing socio-economic vulnerability to urban heat remains poorly understood.

This paper aims to identify and analyse the vulnerability of Hong Kong's SDU households to urban heat and their stated thermal comfort practice, focusing on the use of residential air-conditioners and urban parks. It examines whether or not space-deprived households have a higher demand for urban parks as a cooling space and discusses whether this can potentially substitute air-conditioner use. The research will indicate how poor housing conditions shape thermal comfort practice as a carrier of socio-economic vulnerabilities. The findings have significant implications for spatial planning, especially regarding the distribution of green infrastructure against climate justice requirements (Ambrey et al., 2017; Byrne et al., 2016). The study can offer new ways to illuminate the complex relationships between vulnerability to temperature extremes and housing conditions (Maller & Strengers, 2011; Wilhelmi & Hayden, 2010). It can also provide new insights to inform pro-climate, pro-poor planning and related policy-making (Ambrey et al., 2017; Hatvani-Kovacs et al., 2018; Mabon & Shih, 2018; Mees et al., 2015).

The remainder of this paper begins with an elaboration on heat stress vulnerability and spatial constraints on vulnerability reduction. It is followed by an introduction of SDUs and urban parks in Hong Kong. The ensuing section describes the empirical research involving two separate questionnaire surveys. Findings are then discussed in broader terms pertaining to the contributions of urban green space to pro-poor climate change adaptation in the context of substandard housing in a high-density environment.

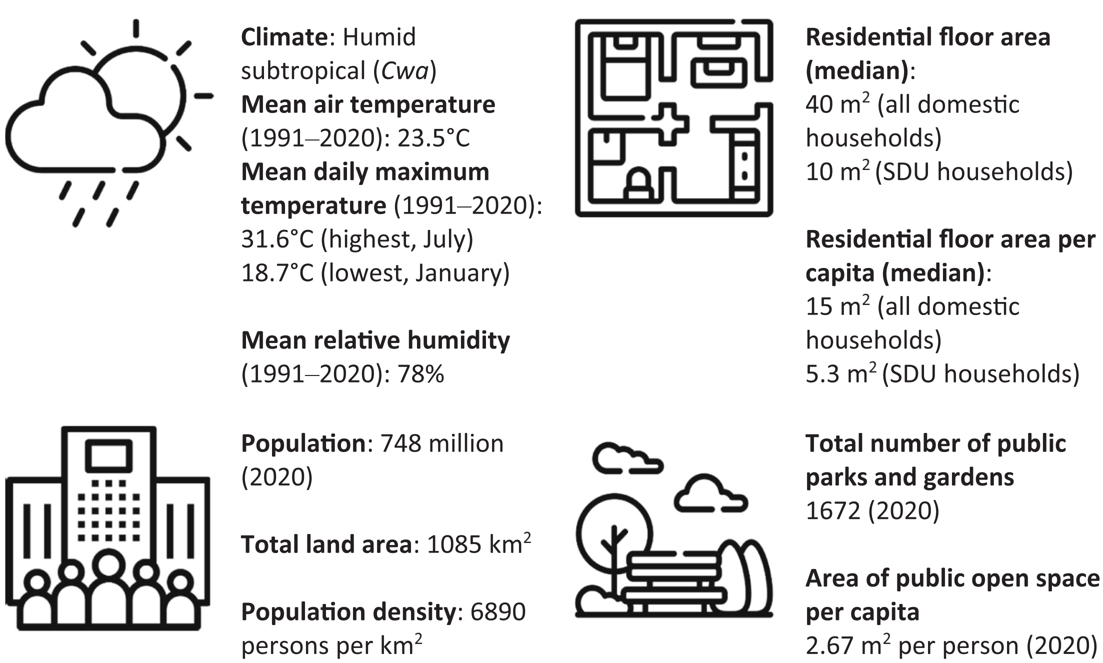

Fig. 1. Basic information about weather, population, and land in Hong Kong.
Sources: Climate: The Hong Kong Observatory (https://www.hko.gov.hk/en/cis/normal/1991_2020/normals.htm). Population and land: Hong Kong Annual Digest of Statistics 2021, Census and Statistics Department (https://www.censtatd.gov.hk/en/EIndexbySubject.html?pcode=B1010003&scode=460). Residential floor area: Census and Statistics Department (2018). Images from Flaticon.com.

2. Heat stress vulnerability and household space

Heat stress vulnerability is the propensity or predisposition to be adversely affected by higher temperatures. The household and the individual are exposed to heat through their location in warmer regions and densely built neighbourhoods, and their everyday routines, such as commuting and outdoor working (Zander et al., 2018). Heat stress vulnerability also arises from specific inherent characteristics of the household or individual, which are described in terms of sensitivity. Older people, for example, are less able to thermo-regulate and more likely to have susceptible pre-existing medical conditions (Brown & Walker, 2008; Paavola, 2017). Children are sensitive to heat because of their more rapid metabolisms, immature organs and nervous systems, developing cognition, limited experience and behavioural characteristics (Bartlett, 2008). As Brown and Walker (2008, p. 364) have indicated, our understanding of vulnerability to heat stress is based largely on the epidemiological analysis of mortality and morbidity data, which tends to focus on demographic factors, such as age. There are few attempts to explain heat stress vulnerability in terms of wider contextual and structural factors.

Neighbourhood and housing conditions are some of these contextual and structural factors. Heat stress increases with population densities (Zander et al., 2018). Top-level flats experience greater thermal impacts due to heat influx through the roof slab (Paavola, 2017). Houses with dark roofs and poor insulation exacerbate thermal experience during heatwaves (Byrne et al., 2016). Tenancy restrictions may discourage or prohibit the tenant from fitting cooling amenities, such as air-conditioner, into the residential unit (Farbotko & Waitt, 2011; Zografos et al., 2016). In compact cities, some residents opening their windows would find air pollutants and odours intruding from the nearby traffic, restaurants and industrial operations and would rather close windows to live with the cloistered discomfort (Yip et al., 2020). Thus, the organisation of dwelling space and barriers to re-organisation are critical constraints on the capacity for adapting to heat extremes.

Most of the existing studies report experiences from low- to medium-density communities. In Asia, high-density urban neighbourhoods are characterised by their small apartment size, mixed land use, and more restrictive building upgrading and retrofitting requirements due to shared or public ownership and centralised management. These constraints have reduced the feasibility of some building, spatial and behavioural adjustments to urban heat. For example, in New Zealand, a cooler hallway can be used as an alternative for placing a baby cot during a warm night (O'Sullivan & Chisholm, 2020), but a hallway or even a separate living room is a luxury to those living in a unit of less than 20 m^2. Moving to the coolest or warmest niches due to seasonal temperature change in a dwelling (Nicol & Roaf, 2007) would not be an effective strategy if there is limited mobility space and limited scope to optimise orientation. Covering the roof with a lighter colour (Hatvani-Kovacs et al., 2018) is not a choice, as the large majority of people reside in multi-storey buildings away from the roof. Similarly, wall insulation (Byrne et al., 2016; Howden-Chapman et al., 2007) demands collective action because the exterior walls of the building block are a shared asset, and stringent building regulations restrict structural modifications. In any case, the building fabric in tropical cities is often not equipped with thermal insulation (Bojic et al., 2001). Most dwellings are too small to have a private courtyard or deck to indulge a children's swimming pool for cooling (Zografos et al., 2016). Even opening the windows, the second most common cooling method among residents of an Australian medium-density (Soebarto & Bennetts, 2014), could be problematic if the building block is too close to offensive or unsafe sources (Sampson et al., 2013; Yip et al., 2020).

The above assessment suggests that the organisation of the living space and the availability of resources are key determinants of thermal comfort practice. We argue that limited space and affordability inherently constrain some otherwise viable options for heat stress mitigation while enabling others. In Asia's compact cities, the working class has remarkably high mobility between home and public or communal spaces. For example, in Hong Kong and Indonesia, neighbourhood parks act as an extended 'living room' for the bulk of the population, who live in tiny residential units and lack space for indoor entertainment and socialisation (Rahmi et al., 2001; Xue & Manuel, 2001). The exceptionally compact built-up environment of Hong Kong permits proximity to and hence convenient access to public green spaces (Tian et al., 2017). In Japan, the lack of space in residential apartments and the high household density have resulted in a fragmented and nomadic urban life. Caballero and Tsukamoto (2006) have found in Tokyo that a combination of public and private facilities, such as karaoke boxes, café and convenience stores, are used to perform some domestic functions, such as family parties, playing video games, and working from home, that could have been completed in a bigger home free from interference. Space limitation has driven urban dwellers to seek refuge from the 'third place' (neither home nor workplace), including public libraries, bookstores and parks (Oldenburg, 1989).

Therefore, domestic spatial constraints shape the household's vulnerability to heat stress and thermal comfort practice. We expect the space-poor household to be more likely to utilise third places for cooling. We further suggest that they are more likely to visit urban parks than other privately managed third places because access is less restrictive and costly. More importantly, the higher mobility of disadvantaged households between home and third places may displace an unsustainable thermal comfort practice, namely, air-conditioning. Smaller residential units accommodate smaller households. Lower affordability, higher mobility and smaller household size could make air-conditioning less viable or unnecessary during the daytime when the home is unattended (which is more likely for smaller households). Thus, prohibitive spatial constraints may result in park visiting substituting air-conditioning, suggesting a potential role of green infrastructure provision in advancing climate justice to benefit disadvantaged social groups (Ambrey et al., 2017; Byrne et al., 2016). We explore these possibilities using a sample of SDU tenants in Hong Kong who are spatially and economically deprived.

3. Substandard housing and urban parks in Hong Kong

Hong Kong has a monsoon-influenced humid subtropical climate. The summer (May–October) is hot and humid, with the highest mean daily maximum temperature of 31.6 °C and a mean relative humidity of 78% (Fig. 1). The city's average temperatures increased by 0.21 °C per decade during 1990–2019, a much faster rate than the historical rate of 0.13 °C per decade during 1885–2019 (Hong Kong Observatory, 2020). The city is warming due to global climate change superimposed on the urban heat island effect (Environment Bureau, 2015).

3.1. Subdivided units (SDU)

Overcrowding is the biggest stressor to SDU tenants. According to the Census and Statistics Department (2018) of Hong Kong, SDUs accommodated a total of 209,700 people (including some 2500 foreign domestic helpers), or 2.9% of the total population. In the latest survey, the SDU tenants increased to 226,340 dwelling in 100,943 units (Task Force, 2021). Over 95% of SDUs were smaller than 20 m^2. The median per capita floor area of SDUs was 5.3 m^2. A previous study has found a lower average of 3.8 m^2 (Lai et al., 2017), while other reports have documented a variable range, such as 2.5–5.6 m^2 (Hong Kong Sheng Kung Hui, 2018) and 8.8–12.6 m^2 (Cheung & Jim, 2019c). Regardless of the wide unit size range, most SDU households have to squeeze their furniture, electrical appliances and other household items into one small area (Fig. 2). All daily activities, including cooking, occur within this small and often unpartitioned area, leaving little space for movement and creating hygienic and indoor air pollution problems (Cheung & Jim, 2019c).

The indoor environment is generally cramped. Most SDUs are

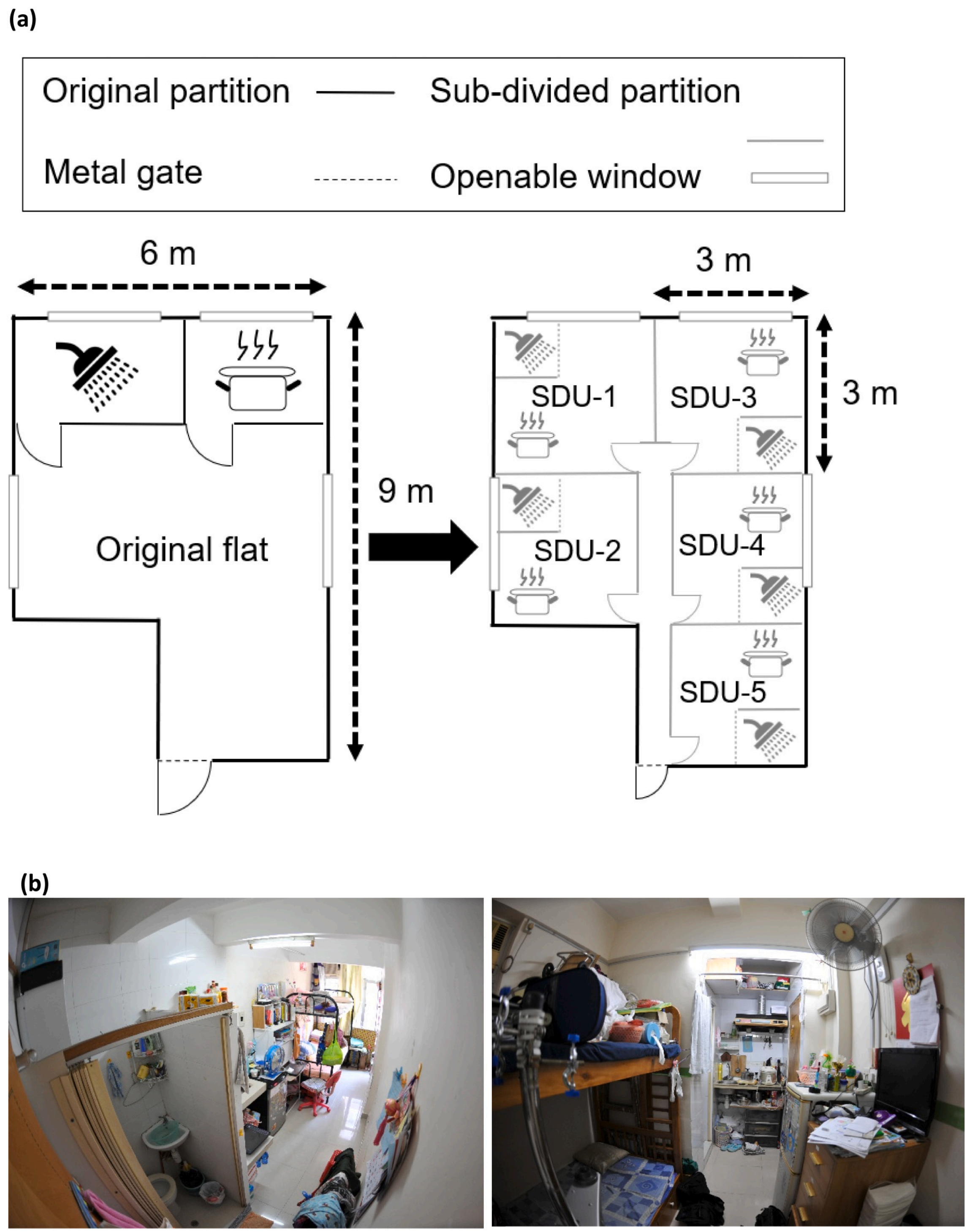

Fig. 2. Sub-divided units (SDU) in Hong Kong. (a) An example of the illegal sub-division of an approved residential flat into five tiny SDU. (b) Photographs of the cramped interior of two sampled SUD. In a typical SDU, the kitchen, bathroom, bedroom, and living room are squeezed into one small area with or without flimsy partitions. The median residential floor area of an SDU is 10 m^2 or 5.3 m^2 per capita; 95.9% of SDUs had independent toilets, while 72.4% had independent kitchens. Around a quarter (25.6%) of SDU households had at least one household member being a new migrant from Mainland China, and 18.1% of the SDU population (207,233, excluding foreign domestic helpers) were younger than 15 years, both figures higher than the entire population of Hong Kong (Census and Statistics Department, 2018).

situated in old and derelict buildings with restricted ventilation. Lai et al. (2017) have reported that about 16% of the SDUs in their sample have no window. The windows of some units are only open to narrow gaps (<4.5 m) between buildings (Cheung & Jim, 2019c). Nearly 57% of all SDUs are concentrated in Kowloon, an exceptionally compact built-up area in Hong Kong with a population density of 48,930 persons per km^2, which is higher than the city as a whole (Fig. 1) (Census and Statistics Department, 2018). The proximity to road traffic and industrial establishments has caused ambient air pollutants and noises (Yip et al., 2020).

Temperatures are higher in SDUs. Cheung and Jim (2021) have found that the mean minimum indoor temperature (30.1 °C) across a sample of eight SDUs during summer was 2.3 °C higher than the outdoor (27.8 °C). The differences were larger at night due to poor ventilation and the heat sink effect of larger external walls. The resulting thermal discomfort is intensified by high humidity (Lai et al., 2017; Society for Community Organization, 2018). Odours, water leakages, and pests are widely reported (Hong Kong Sheng Kung Hui, 2018; Lai et al., 2017). Stresses on mental health, domestic relations, and child development are chronic and enormous (Hong Kong Sheng Kung Hui, 2018; Society for Community Organization, 2018).

Many SDU tenants live on the margin. According to the Census and Statistics Department (2018, p.9), 3.6% of all domestic households in Hong Kong resided in SDUs. Most of them are working-class households. The median monthly household income was HK$13,500 (approx. US $1741) among SDU tenants, much lower than the whole population (HK $25,000, or approx. US$3225). As many as 23,510 (25.6% of total) SDU households had at least one member recently (within 7 years) relocated from Mainland China. Only 4.7% of all domestic households in Hong Kong were in the same situation (Census and Statistics Department, 2018). In addition, there were more children below 15 in SDU households (18.1%) than the whole population (11.8%). The lower incomes and the higher proportion of migrant and younger members can increase SDU households' sensitivity to environmental stressors.

3.2. *Urban parks and their thermal benefits*

Active cooling is a common strategy for Hong Kong people to mitigate heat stress during summer. In 2018, air-conditioning accounted for 38% of the total residential electricity consumption, rising from 32% in 2008 (Electrical & Mechanical Services Department, 2020). However, more widespread air-conditioning would contribute to more greenhouse gas emissions and air pollution, given that coal is responsible for 48% of the locally generated electricity (Environment Bureau, 2017). This would also create a higher economic pressure on SDU households, who have fewer resources to cover the additional costs of electricity during the long summer (Society for Community Organization, 2018).

Green infrastructure offers a more sustainable way of adapting to urban heat. Effective passive cooling mechanisms in urban parks, for example, provide a cooler environment for visitors than their surrounding areas (Bowler et al., 2010; Chen & Wong, 2006). In urban parks, tree and shrub covers can significantly reduce air temperature and improve thermal comfort (Cheung & Jim, 2019a). Many parks in the urban core of Hong Kong have a combined tree and shrub coverage of over 50% (Cheung & Jim, 2019b), making them an ideal place to escape from the urban heat. The shading effect of trees is particularly important to reducing heat stress in subtropical regions where solar radiation is strong (Lin et al., 2017). Cheung and Jim (2018a) have shown in Hong Kong that a single isolated Chinese Banyan (*Ficus microcarpa*) providing shading to an open space can reduce 90% of the 'very strong heat stress' time on the Universal Thermal Climate Index (UTCI) scale, comparing with an exposed space.

Hong Kong people recognise the importance of urban parks in providing shading and regulating air temperatures (Lo et al., 2017; Lo & Jim, 2010). However, what remains unknown is the preference of a disadvantaged social group (i.e., SDU tenants) for using this specific form of urban green infrastructure to cope with the heat.

4. Methods

Our objective was to understand the urban heat vulnerability and thermal comfort practice of SDU tenants and highlight the implications for spatial and green space planning. Based on this goal and the literature review presented in Section 2, we developed three research hypotheses:

1. The space-poor household is more likely to utilise public parks for cooling than other households;
2. The space-poor household is more likely to visit public parks than other privately managed third places;
3. The space-poor household who frequently visits public parks uses their residential air-conditioner for shorter hours.

A structured questionnaire was designed to gauge information about the living conditions and thermal comfort practice of SDU tenants. It included factual information such as floor area, cooling and ventilation appliances, household size and other demographics. The questionnaire also recorded the incidence of heat-related illness, self-assessment of ventilation performance and home temperature, and frequencies of visiting urban parks, using an air-conditioner, and practising other heat-coping strategies (e.g., visiting air-conditioned shopping centres).

The questions about heat-related illness included a brief description of main symptoms, such as 'small red itchy papules' and 'no sweating', based on the official information provided by a local health authority (Department of Health, 2011). In addition, the questions about heat-coping strategies were articulated in the context of a 'Very Hot' day as an extreme weather warning, officially declared when local temperatures rise to a level that puts people at risk of heatstroke and sunburn, typically at 33 °C or above. In the summer of 2017, the Hong Kong Observatory issued 29 Very Hot day warnings, which stayed active for a total of 57 days (Hong Kong Observatory, 2022). The exact wording of these questions is presented in Appendix Table A1.

SDU tenants are hard to reach for interviews. SDUs are informal housing, and not all households have mailbox and landline, making postal surveys and phone interviews challenging. Identifying an SDU tenant from open areas is not cost-effective because of their relatively small population. Moreover, some SDU tenants are reluctant to be interviewed due to perceived social stigma and concern about losing their tenancies (Leung et al., 2020). As Leung et al. (2020) have adopted, the best sampling strategy is snowballing. We obtained referrals from three non-government organisations that support SDU households, including the Concerning Grassroots' Housing Rights Alliance, the Hong Kong Subdivided Flats Concerning Platform, and the Caritas Community Centre, and successfully interviewed 63 SDU tenants. We then sought further referrals from these respondents and completed another 89 interviews. The remaining 22 respondents were identified and interviewed in open areas (e.g., parks). A total of 174 SDU tenants participated in the survey.

To present clearer evidence, we compared the SDU sample with a sample of ordinary Hong Kong residents, who typically occupy larger non-SDU flats. The other survey was conducted in May 2018 by a professional survey centre of a local university. A random sampling strategy was employed to increase demographic representativeness, and a standard 'Computer Assisted Telephone Interviewing' technique was used to identify respondents via telephone. A total of 515 individuals completed the questionnaire. Both surveys were conducted in Cantonese, which is the main local language.

We used ANOVA and Chi-square tests to compare SDU and non-SDU respondents across various available demographic, perceptual and behavioural variables. For multivariate analysis, we created a combined sample and used multinomial modelling with the forward stepwise function to identify key predictors of thermal comfort practice, focusing on the effects of air-conditioner use and housing type.

5. Results

5.1. *Comparisons between SDU and non-SDU respondents*

The key characteristics of the interviewed SDU tenants, compared with the random sample (hereafter known as 'non-SDU' respondents), are summarised in Table 1. Over 70% of our SDU respondents resided in a unit smaller than 150 ft^2 (13.9 m^2), typically shared by three household members. Few of them shared their flats with elderly members at 65 or above, but many have children at 12 or younger. The two samples

Table 1
Characteristics of respondents by housing type.

Attribute	Value (%) (unless stated otherwise)		F statistic[c]	χ^{2c}
	SDU (N = 174)	Non-SDU (N = 515)		
Floor area below 150 ft^2 (13.9 m^2)[a]	72.4	0.6		440.986***
Average floor area per person[a]	44.73 ft^2 (4.16 m^2)	184.40 ft^2 (17.13 m^2)	273.634***	
Average HH size (persons)	3.01	3.55	22.096***	
At least one HH member aged 65 or above	9.8	41.9		60.145***
At least one HH member aged 12 or below	67.8	21.6		125.442***
At least one HH member with chronic diseases	26.0	26.2		0.002
Tertiary degree[b]	2.3	30.1		56.616***
Monthly HH income higher than HK $25,000[b]	1.7	64.0		195.120***
Aged 60 or above[b]	6.3	28.2		35.397***
Female[b]	91.4	59.0		61.750***

[a] Floor area was recorded as categories. Floor area per person was calculated by dividing the mid-point of each category by household (HH) size. Median values: 41.67 ft^2 (3.87 m^2) (SDU), 162.5 ft^2 (15.09 m^2) (non-SDU).

[b] Sex, age, household (HH) income and qualification were recorded as categories. Sex categories included Male (0) and Female (1). Age categories included '15–19' (1), '25–29' (3), '35–39' (5), '45–49' (7), '55–59' (9), and '65 or above' (11). HH income categories included '$1999 or less' (1), '$4000–5999' (3), '$8000–9999' (5), '$15,000–19,999' (7), '$25,000–29,999' (9), '$40,000–59,999' (11), and '$100,000 or more' (14). Qualification categories included 'Primary or below' (1), 'Secondary' (2), 'Tertiary (non-degree)' (3), and 'Tertiary (degree)' (4).

[c] *** and ** denote significance at the 0.01 and 0.05 levels, respectively.

had a similar number of household members with chronic diseases. Our SDU respondents were less educated, had lower incomes, and were generally younger than their non-SDU counterparts. Full details of the respondents' demographics are included in Appendix Table A2.

Our sampling strategy resulted in a larger proportion of female respondents from SDUs. Most SDU tenants who made regular contacts with non-governmental organisations and community centres were females. Male SDU tenants did not spend much time at home during the daytime due to long and often irregular work hours, and few were available for the interviews. Referrals mainly to female friends and neighbours had sustained the number of women in our sample. Nonetheless, there was no gender difference in the park visiting frequency. ANOVA tests for both samples returned no significant results on two key variables: visiting parks during summer and 'Very Hot' days (see Appendix Table A3). Women are no more likely than men to visit urban parks for cooling (shading).

Table 2 compares the perceived thermal performance of the two housing types. SDUs were poorly ventilated and much warmer than other residential units. Consequently, SDU tenants reported a higher frequency of heat-related illnesses, especially heat rash, suggesting their higher vulnerability to heat stress. Most SDUs had air-conditioners, fans and windows to provide thermal relief or ventilation. However, non-SDU residential units typically have more appliances, especially air-conditioners. The discrepancy indicates a greater capacity of non-SDU households in coping with high temperatures. Nevertheless, the number of hours using the air-conditioner at home was comparable between the two groups. This similarity indicates a relatively higher demand or more reliance of SDU tenants for home cooling, given their smaller units, smaller household size, lower affordability, and fewer air-conditioners installed.

The two groups were clearly differentiated in the frequency and duration of visiting urban parks (Appendix Table A4). The average SDU tenant visited urban parks every week during summer and stayed over 45 min, much more frequent and longer than non-SDU respondents. SDU tenants took a longer time (about 6 to 10 min) to reach the nearest urban parks by walking than their non-SDU counterparts. The difference suggests that the ease of access might not have contributed to a higher frequency of visits or willingness to travel longer to reach the thermal relief sites. Frequent visits may be related to the amount of discretionary time. Nonetheless, SDU household members were less likely to spend longer hours at home in the daytime (Appendix Table A4). Considering the larger proportion of non-working home-makers among SDU households (15.5%) than the rest of the population (8.8%) (Census and Statistics Department, 2018), a shorter home time implies that members of SDU households had longer stays at third places, i.e., neither home nor workplace.

Respondents used various strategies to cope with the heat during 'Very Hot' days (Table 3). The most common one was active cooling through directly controlling indoor air temperature. It included using residential air-conditioners and visiting air-conditioned third spaces, such as shopping centres. Both of these strategies differentiated between SDU and non-SDU respondents, but the largest difference was found in the frequency of visiting urban parks. SDU tenants more frequently visited parks during 'Very Hot' days than non-SDU respondents,

Table 2
Perceived ventilation capacity, thermal comfort, heat-related impacts, and the use of cooling and ventilation appliances by housing type.

Attribute		Category	Mean		F statistic[b]
			SDU (N = 174)	Non-SDU (N = 515)	
Ventilation capacity	Window	'Strongly disagree' (1), 'Disagree' (2), 'Neither' (3), 'Agree' (4), 'Strongly agree' (5)[a]	2.82	4.37	321.280***
	Ventilation		2.44	4.08	316.036***
Thermal comfort	Perceived home temperature relative to outdoor environment	'Much cooler' (1), 'Slightly cooler' (2), 'About the same' (3), 'Slightly warmer' (4), 'Much warmer' (5)	4.52	3.41	132.985***
Heat-related illness	Heat rash	'Never' (1), 'Not often' (2), 'Sometimes' (3), 'Frequently' (4)	2.65	1.50	197.024***
	Heat cramp		1.41	1.05	73.930***
	Heat syncope		1.93	1.27	101.169***
	Heatstroke		1.28	1.09	24.733***
Cooling and ventilation appliances	Air-conditioner	Number of appliances at home	1.14	2.96	387.065***
	Cooling fan		1.98	2.81	49.124***
	Exhaust fan		0.97	1.83	135.588***
	Window	'No window' (0), 'With windows' (1)	0.92	1.00	39.224***
AC hours	Duration of using air-conditioner at home during summer	Number of hours	10.08	10.21	0.067

[a] Higher values denote greater satisfaction with the home in terms of the number of windows or ventilation effectiveness. See Appendix for the exact wording.

[b] *** and ** denote significance at the 0.01 and 0.05 levels, respectively.

Table 3
Use of urban parks and thermal comfort practice by housing type.

Attribute		Category	Mean SDU (N = 174)	Mean Non-SDU (N = 515)	F statistic[b]
Park visit during summer	Frequency	'Fewer than once a month' (1), 'Monthly' (2), '2–3 times a month' (3), 'Weekly' (4), '2–6 times a week' (5), 'Everyday' (6)	4.67	2.88	123.988***
	Duration (minutes)	'1–15' (1), '16–30' (2), '31–45' (3), '46–60' (4), '60–120' (5), '>120' (6)	4.24	2.95	77.600***
Proximity to the nearest urban park	Time of walking from home (minutes)	'1–5' (1), '6–10' (2), '11–15' (3), '16–30' (4), '31–45' (5), '46–60' (6), '≥60' (7)	1.98	1.55	24.391***
Thermal comfort practice during 'Very Hot' days[a]	Switch on air-conditioner	'Not often' (1), 'Sometimes' (2), 'Frequently' (3)	2.26	2.44	7.344***
	Open doors to improve ventilation		1.97	1.71	10.546***
	Take longer or more showers		1.91	1.85	0.706
	Avoid outdoor exercise		1.91	2.05	3.417
	Visit urban parks		1.95	1.13	285.393***
	Visit shopping centres (air-conditioned)		2.11	1.86	11.861***
	Go swimming		1.46	1.46	0.005

[a] The Hong Kong Observatory issues a 'Very Hot Warning' when the local temperature exceeds 33 °C, a level that may impart health risks such as heat stroke and sunburn. In our questionnaire, a 'Very Hot' day was recorded when such an official warning was in force.
[b] *** and ** denote significance at the 0.01 and 0.05 levels, respectively.

confirming the first hypothesis specified in Section 4. They were also more likely to open doors to improve ventilation and visit shopping centres for cooling but less likely to use air-conditioners than non-SDU respondents. Contrary to the second hypothesis, SDU respondents visited shopping centres more frequently than urban parks, but the difference between SDU and non-SDU respondents was larger for urban parks. This shows the proactive enlisting of a wider range of adaptive actions by SDU tenants.

5.2. Multinomial regression analysis

Results of a multinomial regression analysis are displayed in Table 4. The dependent variable was the stated frequency of visiting urban parks for cooling during 'Very Hot' days. Individuals 60 or older were more likely to visit urban parks frequently. Non-SDU respondents were less likely than SDU tenants to do so. The two interaction terms warrant attention. The number of hours using air-conditioners at home reduced the likelihood of frequent visits only when interacting with the dummy variable representing SDU respondents. This suggests that the shorter the hours of using residential air-conditioners, the more likely they will

Table 4
Multinomial regression for the stated frequency of visiting urban parks.

Attribute	Stated frequency of visiting urban parks for cooling during 'Very Hot' days			
	Coefficient[a] (standard errors)		Odds ratios (95% confidence interval)	
	Sometimes	Frequently	Sometimes	Frequently
Intercept	−0.401 (0.338)	0.282 (0.301)		
AC hours × Housing (non-SDU)	−0.018 (0.035)	−0.120 (0.080)	0.982 (0.92–1.05)	0.887 (0.76–1.04)
AC hours × Housing (SDU)	−0.013 (0.025)	−0.049** (0.025)	0.987 (0.94–1.04)	0.953 (0.91–1.00)
Housing (non-SDU)	−2.071*** (0.527)	−3.561*** (0.792)	0.126 (0.05–0.35)	0.028 (0.01–0.13)
Aged 60 or above	0.668 (0.344)	1.096** (0.506)	1.95 (0.99–3.83)	2.991 (1.11–8.07)
AIC	687.606			
−2 Log likelihood	667.606			
χ^2	192.220			
Sig.	0.000			
Nagelkerke R^2	0.358			

[a] *** and ** denote significance at the 0.01 and 0.05 levels, respectively.

visit urban parks frequently. The *p* values of the two interaction terms indicate that this effect was only significant for respondents who lived in SDUs, but not others. This finding corroborates the third hypothesis.

This effect is limited to park visiting. Shopping centres and swimming pools are two other accessible third places that can be used for communal cooling. (In Hong Kong, few homes have its own swimming pools. Most swimming pools are either open to the public or shared by many private property residents.) As shown in Tables 5 and 6, frequent visits to shopping centres and swimming pools were associated with different demographic variables, but not the number of hours using an air-conditioner. The interactions between housing type and air-conditioning hours did not show any significant effect. The duration

Table 5
Multinomial regression for the stated frequency of visiting shopping centres.

Attribute	Stated frequency of visiting shopping centres (air-conditioned) for cooling during 'Very Hot' days			
	Coefficient (standard errors)[a]		Odds ratios (95% confidence interval)	
	Sometimes	Frequently	Sometimes	Frequently
Intercept	0.945** (0.436)	0.745 (0.419)		
AC hours × Housing (non-SDU)	0.020 (0.020)	0.024 (0.020)	1.020 (0.98–1.06)	1.025 (0.99–1.07)
AC hours × Housing (SDU)	0.022 (0.023)	0.008 (0.022)	1.022 (0.98–1.07)	1.008 (0.97–1.05)
Aged 60 or above	−1.189*** (0.281)	−0.506** (0.243)	0.304 (0.18–0.53)	0.603 (0.38–0.97)
Floor area below 150 ft^2 (13.9 m^2)	−0.718** (0.354)	0.298 (0.328)	0.488 (0.24–0.98)	1.348 (0.71–2.57)
Ventilation capacity - windows	−0.281*** (0.095)	−0.288*** (0.090)	0.755 (0.63–0.91)	0.750 (0.63–0.90)
AIC	1286.789			
−2 Log likelihood	1262.789			
χ^2	50.522			
Sig.	0.000			
Nagelkerke R^2	0.090			

[a] *** and ** denote significance at the 0.01 and 0.05 levels, respectively.

Table 6
Multinomial regression for the stated frequency of swimming.

Attribute	Stated frequency of swimming for cooling during 'Very Hot' days			
	Coefficient (standard errors)[a]		Odds ratios (95% confidence interval)	
	Sometimes	Frequently	Sometimes	Frequently
Intercept	−1.313*** (0.241)	−3.140*** (0.414)		
AC hours × Housing (non-SDU)	0.010 (0.019)	0.011 (0.029)	1.010 (0.98–1.05)	1.012 (0.96–1.07)
AC hours × Housing (SDU)	−0.009 (0.020)	0.012 (0.029)	0.991 (0.95–1.03)	1.012 (0.96–1.07)
Aged 60 or above	−0.788*** (0.285)	−0.370 (0.447)	0.455 (0.26–0.80)	0.691 (0.29–1.66)
At least one HH member aged 12 or below	0.948*** (0.213)	1.554*** (0.328)	2.580 (1.70–3.92)	4.731 (2.49–9.00)
HH income higher than HK $25,000	0.511** (0.234)	0.906** (0.387)	1.667 (1.05–2.64)	2.475 (1.16–5.28)
AIC	1000.026			
−2 Log likelihood	976.026			
χ^2	63.821			
Sig.	0.000			
Nagelkerke R^2	0.122			

[a] *** and ** denote significance at the 0.01 and 0.05 levels, respectively.

of active air-conditioner use was not related to these two third places.

6. Discussion

Our results indicate that SDU tenants in Hong Kong are highly vulnerable to urban heat. Low incomes have restricted the housing choice of the marginalised group, trapping some of them in cramped and tiny flats situated in old and compact neighbourhoods. The substandard housing conditions, especially the grave shortage of space and poor ventilation, have reinforced the combined heat stress impacts of UHI and the warming climate. This impoverished segment of the population, with a higher proportion of new migrants and children in the household (Census and Statistics Department, 2018), is also disadvantaged by a higher exposure to air and microbial pollution (Cheung & Jim, 2019c; Lai et al., 2017). The convergence of unfavourable circumstances has exacerbated their vulnerability to urban heat and brought more heat-related illnesses. Nonetheless, the unsatisfactory residential environment has triggered heat-mitigating behaviour and increased the mobility between home and third places. Such responses have shaped routine cooling practices and promoted some thermal-comfort practices less commonly adopted by other urban dwellers.

Scholarly investigations of space limitation with reference to heat stress vulnerability have remained inadequate. Some studies have focused on (older) age as a key driver of vulnerability (Wolf et al., 2010; Maller & Strengers, 2011; Brown & Walker, 2008; Farbotko & Waitt, 2011). Others have assessed the income and race effects in the climate-change context (Byrne et al., 2016; Mitchell & Chakraborty, 2018; Sampson et al., 2013; Zografos et al., 2016). These analyses have not attempted deep and dedicated evaluations of the specific space-poverty theme. Moreover, they tend to focus on low- to medium-density cities and do not cover high-density or compact metropolises.

Researchers such as Wilhelmi and Hayden (2010), Hatvani-Kovacs et al. (2018), Howden-Chapman et al. (2007) and Byrne et al. (2016) have identified housing and building conditions as important heat risk factors. However, their underlying assumption is that home occupants have the means to overcome these constraints by modifying the building structure or re-organising their activity space. The proposed or attempted strategies include re-painting the roof surface with a light-coloured reflective coating (Hatvani-Kovacs et al., 2018), retrofitting a residential green roof (Wilkinson & Feitosa, 2015), installing a swimming pool (Zografos et al., 2016), and shifting a bed to a cooler hallway (O'Sullivan & Chisholm, 2020). These heat-stress mitigating strategies are either unaffordable or impractical to the space-poor individuals beset by barriers such as insufficient resources (including income and space) and tenancy restrictions.

Visiting cool public green spaces offers a promising pro-poor strategy for heat stress mitigation (Farbotko & Waitt, 2011; Sampson et al., 2013). Our results show that SDU tenants suffering from acute space limitation are more likely to use urban parks as a refuge from the heat. Even though air-conditioning is widespread in Hong Kong, SDU tenants have taken a wider range of alternative actions for cooling than other urban dwellers. These include visiting urban parks with shading and air-conditioned shopping centres. They demonstrate more proactive exploration of different heat mitigating measures with little cost implications and convenient access. Thus, the resilience of these individuals to the heat impact partially rests upon their access to these third places, especially urban parks.

Urban parks usually have a high vegetation cover, especially trees, to ameliorate people's heat stress through shading and evapotranspiration cooling to lower the ambient temperature (Arnberger et al., 2017; Byrne et al., 2015; Lafortezza et al., 2009; Lo et al., 2017). However, for many people living in the tropical or subtropical climate zone, parks are not usually taken as the first choice to obtain the cooling service on hot days. In summer, the high temperature and humidity discourage Hong Kong people from staying in an urban park for an hour (Cheung & Jim, 2018b). Our results indicate that those who can afford higher energy costs rely on space cooling instead of park visits, which is the least commonly adopted thermal comfort practice of non-SDU residents, as given in Table 3.

However, some circumstances could push people to use parks as a heat refuge even on hot days. Poverty can induce a prudent energy consumption practice, pushing people to seek alternative cooling strategies (Yip et al., 2020). Our findings suggest that park visits can substitute the use of air-conditioners – but only among SDU tenants. The higher mobility of the SDU group moving between home and third places and their recurrent park sojourns have shortened their home time that would otherwise demand residential space cooling. Nevertheless, only the park-visit frequency, and not other cooling strategies, is negatively related to air-conditioning hours in SDUs. This negative relationship expresses a conscious motivation to enlist the cleaner and cheaper cooling option to replace an energy-intensive and relatively costly technology. The SDU tenants' propensity to visit urban parks implies adopting the viable alternative as a dodging tactic to achieve the twin objectives of better thermal comfort and lower electricity bills.

Therefore, urban parks can play a practical role in redressing climate injustice. Temperature extremes, becoming more frequent and acute due to climate change, threaten to propagate social inequalities due to the uneven distribution of impacts and adaptive capacities (Ambrey et al., 2017; Mitchell & Chakraborty, 2018; Zografos et al., 2016). Wealthier areas have more green spaces (Richards et al., 2017) and the benefits of greening tend to accrue disproportionately to more affluent and privileged groups (Mabon & Shih, 2018). Space-poor individuals have a greater need and desire to use vegetated open spaces to keep their electricity bills affordable. This observation suggests that less affluent and underprivileged residents more earnestly tap urban parks as a heat refuge.

Enhancing the supply of this urban greening amenity can potentially reduce the vulnerability of the urban poor to the warming trends and rising energy costs of space cooling. A green space network with high spatial connectivity and proximity to residential areas can enhance the quality and functionality of a city's passive health resource (Tian et al., 2011; Ward et al., 2019). Adopting a socially inclusive design to attract patronage by people with diverse socio-economic profiles and preferences, especially people dwelling in low-income neighbourhoods, could alleviate environmental injustice (Haase et al., 2017; Smiley et al., 2016). SDU residents visiting urban parks can bring collateral health benefits of outdoor recreation, particularly children's physical and mental development (Goldsby et al., 2016; Zhang et al., 2021). The comprehensive benefits could justify the high costs of improving green urban infrastructure using public funds. Government shouldering the construction and maintenance responsibilities can shield economically-deprived residents from the price impacts of park provision.

Some measures could facilitate urban parks' contributions to climate-warming adaptations. Moulding the distribution pattern of the green infrastructure can improve the availability and accessibility of neighbourhood parks, especially in high-density residential areas. Park landscape design can optimise cooling and thermal-comfort capabilities, such as increasing tree and vegetation cover, providing more seats under tree shades and pavilions, and installing more water features such as paddling pools, ponds and drinking fountains (Arnberger et al., 2017; Cheung & Jim, 2019a; Lafortezza et al., 2009; Lo & Jim, 2010). Some existing green-cum-cool spaces are spatially concentrated rather than diffuse in the urban matrix. In the context of tropical and subtropical cities with exceptionally high housing densities, such venue clustering could improve access and therefore be construed as pro-poor and pro-climate. It signifies an essential role of spatial green-space planning in alleviating the dual housing and thermal inequities vis-a-vis climate-change trends, population growth, and densification in compact cities.

Article 11 of the International Covenant on Economic, Social and Cultural Rights promulgates an acceptable standard and continuous improvement of living conditions, including housing (United Nations, 1966). Similarly, the international human rights law stipulates that every person has the fundamental right to an adequate standard of living which encompasses housing. Adequate housing incurs the provision of not just an enclosed shelter with four walls and a roof. It must satisfy the conditions of habitability, embracing the guarantee of physical safety and sufficient space as well as “protection against the cold, damp, heat, rain, wind, other threats to health and structural hazards” (United Nations, 2014). The right to proper housing could be associated with the right to a life with dignity (Perez, 2018). The SDU phenomenon denotes an unfortunate shortcoming and anomaly in the relatively affluent Hong Kong, tantamount to a modernised form of urban slum hidden in old high-rise residential blocks in low-income neighbourhoods. It is hoped that our findings can trigger a policy shift towards a lasting solution to the chronic shortage of affordable and decent housing for many deprived citizens in Hong Kong and other cities.

7. Conclusion

This paper has reported on the urban heat vulnerability and thermal comfort practice of SDU households in the compact city of Hong Kong, who live on the margin and have few housing choices but a tiny flat with sub-standard amenities. Space limitation, poor ventilation, and high energy costs have contributed to their sensitivity and lower capacity to adapt to summer heat, resulting in a higher incidence of heat-related illness. Compared with other urban dwellers, these space-poor households have taken a wider range of adaptive actions and are more likely to use urban parks as a cooling space. Park visits by SDU households can potentially substitute the maladaptive use of air-conditioner, which requires higher costs to run and contributes to more greenhouse gas emissions and the urban heat island effect.

The findings are important for reconsidering and redressing the uneven distribution of urban green spaces to benefit more affluent and privileged groups. The impacts of warming and temperature extremes aggravated by global climate change will disproportionately affect existing vulnerable populations, such as SDU households. Processes of urban consolidation and densification that fail to balance the social costs of high-density housing models are likely to perpetuate these miseries, especially in parts of Asia, where the urban populations continue to grow quickly. Poor housing conditions and heat stress have forced SDU households to seek refuge from third spaces. Their high inter-space mobility makes natural cool spaces, such as urban parks with abundant vegetation and shading, a viable adaptation option for this section of the population. Measures for increasing the accessibility and availability of urban parks and improving their capacity for heat mitigation are conducive to pro-poor and pro-climate spatial planning.

CRediT authorship contribution statement

Alex Y. Lo: Formal analysis, Writing – original draft. **C.Y. Jim:** Conceptualization, Methodology, Investigation, Data curation, Writing – review & editing, Supervision, Funding acquisition. **Pui Kwan Cheung:** Investigation, Writing – review & editing. **Gwendolyn K.L. Wong:** Investigation. **Lewis T.O. Cheung:** Investigation.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary data

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