# DESIGNING URBAN PARKS THAT AMELIORATE THE EFFECTS OF CLIMATE CHANGE

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## 1. Introduction

More than half of the people in the world now live in urban areas and that proportion is increasing, inducing urban growth both in size and in density (Seto et al 2011). Physical characteristics of cities such as little vegetation, predominance of hard surfaces, and anthropogenic heat sources all contribute to the occurrence of the well-documented urban heat island (UHI) (e.g. Oke 2003; Golden et al. 2006). This poses challenges for urban residents, as the inadvertent thermal environment causes discomfort, lower work productivity (Daanen et al 2013) and health hazards in certain circumstances, such as heat waves (Harlan et al., 2006, Golden et al. 2008). Most of the growing cities are situated in temperate and warm climate regions (Köppen-Geiger zones *Af, Bsh, Cfa, BWh, Dfa*). In the context of global climate change, projections of higher summertime air temperatures will cause these problems to worsen (McCarthy et al 2010). Therefore, the way cities are built must respond to these challenges and provide better thermal conditions for urban residents.

There are various options to provide cooling in cities. The best documented are urban parks and green spaces, which have the potential to provide thermally comfortable environments and help to reduce vulnerability to heat stress. These areas are known in the literature as 'park cool islands' (PCIs) (e.g. Oke 1987, Upmanis 1998, Chow et al. 2011; Declet-Barreto et al., 2013). Studies have demonstrated that the air temperatures in parks are typically lower than in the surrounding urban environment (Spronken-Smith and Oke 1998; Bowler et al 2010; Vanos et al. 2012a), and the cool air can extend some distance into downwind neighbourhoods (e.g. Yokohari et al 2001, Slater 2012). Studies of PCIs have focused primarily on air temperature, yet human thermal sensation is affected by other microclimatic aspects, such as solar and terrestrial radiation and wind (e.g. Fanger 1970, Mayer and Höppe 1987, Brown and Gillespie 1995, Parsons 2003). However, results vary with respect to the local climate and the methods used for assessment.

While air temperature and humidity can be modified slightly by large areas of green space, wind and radiation can be greatly modified through small-scale design interventions and can have a substantial effect on human thermal comfort (Shashua-Bar et al., 2011; Lin, 2009; Ahmed, 2003; Brown and Gillespie 1995). The parameters of wind and radiation vary widely in different parts of the world; hence, we expect that park elements must not be a 'one-size-fits-all' schematic, but account for the spatiotemporal variability of specific climate parameters. In order to design parks that will have the greatest cooling effect on people during hot summertime weather, a landscape architect needs to know the relative impact of various design interventions. Hence, design guidelines are needed to create climatically sensitive park designs appropriate for earth's various climate zones. Further, evidence-based and climate-responsive design of urban greenspaces is increasingly important.

Accordingly, the goal of this study was to investigate the effects of urban park characteristics on people's thermal comfort in different climate zones, both now and in the future. The results will allow landscape architects to design parks that mitigate negative effects of overheated cities in the context of global climate change. Our main research question was: in a range of climate zones, and under various hot season weather conditions (as well as future scenarios from the International Panel on Climate Change (IPCC)), what is the effect on microclimate caused by landscape characteristic alterations on the thermal comfort (via energy budget modelling) of people in outdoor areas? We focused on the parameters that are expected to have the greatest effect on human thermal perception: air temperature, short wave radiation, and windspeed (Brown and Gillespie 1995).

## 2. Methods

To answer these research questions, we used current climate data for five highly urbanised cities in different climate zones. Based on these data, we analysed the thermal comfort effects of different hot climate situations, and also those based on future climate scenarios developed by the IPCC (2007). Using these climate simulations, we modeled the effects of different types of microclimate modifications, using the human thermal comfort model 'COMFA' (Kenny et al., 2009a,b; Vanos et al., 2012b,c).

### a. Study Areas

We selected study sites in five climate zones. Selection was based on experiencing hot weather for at least one season of the year, presence in various climate zones, and large city size. We used published climate data to represent typical conditions from the following five cities: Kuala Lumpur, Malaysia (*Af*), Lahore, Pakistan (*Bsh*), Alice Springs, Australia (*BWh*), Kyoto, Japan (*Cfa*), Toronto, Canada (*Dfa*).

### b. Modeling the Thermal Comfort of People in Outdoor Environments

Through the use of the COMFA model, we simulate the effects of changes in microclimate caused by landscape characteristic alteration on the thermal comfort of individuals in outdoor environments. The COMFA model takes inputs of typical weather data that are

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universally available (air temperature, windspeed, solar radiation, and relative humidity) and estimated thermal sensation levels based on quantifiable energy budget values. The COMFA model has been validated through extensive testing in complex outdoor environments (Brown and Gillespie, 1986; Kenny et al., 2009a,b; Vanos et al., 2012b,c). It also provides a detailed output of the magnitude of each element in the human energy budget so that the effects of landscape modification can be evaluated individually and collectively. COMFA is based on the energy budget (EB, W $m^{-2}$) of a person as follows:

$$\mathbf{EB = M + R_{abs} - C - E - L} \qquad \textbf{(1)}$$

Heat gains occur from metabolic heat production (M) and short/longwave radiation absorption ($R_{abs}$), and heat losses occur from convection (C), evaporation (E), and the emitted longwave radiation (L). The model requires the following inputs: air temperature (ºC), relative humidity (%), wind velocity ($ms^{-1}$), static clothing resistance, and clothing vapour resistance ($sm^{-1}$), metabolic activity ($Wm^{-2}$), and total absorbed radiation ($Wm^{-2}$). All simulations were modeled based on a standing person (metabolic activity = 116 $Wm^{-2}$), in clothing typically worn in each location (clothing resistance range: 78–110 s $m^{-1}$). The total radiation absorbed by a human is estimated using a field validated and the following equation (Kenny et al. 2008; Vanos et al., 2012a):

$$R = A_{eff} \frac{K_{in(abs)} + K_{up(abs)} + L_{a(abs)} + L_{g(abs)}}{A_{cyl}} \qquad [2]$$

where $K_{in(abs)}$ and $K_{up(abs)}$ are incoming and ground reflected solar radiation absorbed by a human, respectively. $L_{a(abs)}$ and $L_{g(abs)}$ are absorbed atmospheric and ground surface longwave radiation, respectively, $A_{cyl}$ is the outer surface of the body cylinder ($m^2$), and $A_{eff}$ the effective area of a standing person (0.78) (Campbell and Norman, 1998). An average albedo of 0.25 was applied in all relevant radiation calculations to represent a grassy surface.

The calculated energy budget was translated in two ways: thermal comfort and health vulnerability. An energy budget in the range –20 to 120 $Wm^{-2}$ was considered neutral (thermally comfortable), 121–200 $Wm^{-2}$ was warm, and >201 $Wm^{-2}$ was hot, for a standing person (Kenny et al., 2009a, Harlan et al., 2006). In terms of effects on health, energy budgets between –20 and 120 $Wm^{-2}$ were considered safe, while there is vulnerability to heat stress when the energy budget is in the range 121–200 $Wm^{-2}$, heat stress danger is likely between 201 and 339 $Wm^{-2}$, and there is extreme danger of heat stress when the energy budget is 340 $Wm^{-2}$ or higher (Harlan et al, 2006).

**c. Simulations**

We simulated different warm climate situations in COMFA for the five cities representing the Köppen-Geiger zones *Af, Bsh, Cfa, BWh, Dfa*. Table 1 displays the temperature variables and climate zones for each of the cities. Energy budget (EB) simulations were calculated for the hottest month of the year, as determined by the 30-year climate averages. Average daytime maximum temperatures ($T_{max}$) (~1500h) included in the simulations ranged from 26.2 to 38.9ºC, while the average daytime minimum temperatures ($T_{min}$) (~0300h) ranged from 15.1 to 28.9ºC. To simulate a "typical" summertime daytime temperature, the average daytime temperature (0800–1800h) was determined for the warmest three months for each city. This was used as a control situation for comparison to typical extreme heat simulations.

We first performed a control simulation representing an average summer daytime mean temperature, based on 30-year climate normals for the three hottest months of the year in each city tested (see Table 1). Energy budget modeling was then completed for the three following scenarios for the warmest month for the given city, on the 15th day, with values listed in Table 1:

1) Typical $T_{max}$ and $T_{min}$ based on 30-year climate norms (*Typical*), as discussed above.
2) $T_{max}$ and $T_{min}$ during a heat wave (*Heat wave*)
3) $T_{max}$ during a heat wave that is projected to occur by mid-century and by late-century.

**Table 1: Descriptive data of each city, with average climate extremes during the hottest months for each simulation and city.**

| City | Köppen | Critical times | Hottest month | $T_{max}$ [a] | $T_{min}$ [a] | *Heat wave*[b] *$T_{max}$* | Avg $T_a$ [c] |
|---|---|---|---|---|---|---|---|
| Kuala Lumpur | Af | Hot, humid all year | Mar | 32.8 | 23.2 | 37.8 | 30.1 |
| Lahore | Bsh | Dry, hot summer | June | 38.9 | 28.9 | 43.9 | 35.0 |
| Kyoto, Japan | Cfa | Hot, humid summer | Aug | 32.6 | 22.7 | 37.6 | 28.8 |
| Alice Springs | BWh | Dry, hot all year | Feb | 38.9 | 20.2 | 43.9 | 31.9 |
| Toronto | Dfa | Hot, humid summer | July | 26.2 | 15.1 | 31.2 | 23.0 |

[a]*Climate averages (30 year)*
[b]*WHO guideline = +5°C at least for 3 days (Frich et al., 2002).*
[c]*Control; average daytime (8am-8pm) air temperature during warmest three months for each city*

The second simulation involved weather conditions during a 'heat wave', which according to the World Meteorological Organization's (WMO) guideline, is when the daily $T_{max}$ of more than five consecutive days exceeds the average $T_{max}$ by 5°C compared to the climate normal (>30 years) (Frich et al., 2002). As this is consistent between climate zones, we apply the definition by adding 5°C to the typical daily $T_{max}$ and $T_{min}$ values for EB modeling for consistency. Hence, the daytime $T_{max}$ for heat waves ranged from 31.2 to 43.9ºC.

For the final simulation, future climate projections from the IPCC (2007) scenarios were utilized (from the Special Report on Emissions Scenarios (SRES; Nuakovich et al., 2000)). The three IPCC scenarios applied in the current study were B1 ('lower emissions'), A1B ('balanced'), and A2 ('high emissions'). For each city, region-specific projected changes (in °C) in 20-year return values of the annual maximum of the daily $T_{max}$ were obtained from the SRES report for mid-century (2046–65). We averaged the $\Delta T_{max}$ values of the three SRES scenarios for use in modeling plausible human EB alterations with a changing climate. As climate models project that some regions will see more intense, more frequent, and longer-lasting extreme heat events in the second half of this century (O'Neill and Ebi 2009; Meehl and Tebaldi 2004), predicting those effects on the human energy budget can provide vital information to landscape architects in designing for future climates.

To evaluate the impact of the urban and landscape design interventions, environmental characteristics of air temperature, shade (reduction of incoming shortwave radiation), and wind velocity were altered (see Table 2). For each simulation, $T_a$ was lowered by 1 to 6°C, at 1°C intervals to model the potential impact of a PCI (Bowler et al 2010). These are consistent with typical landscape design interventions. All remaining variables were held constant while one was altered in order to demonstrate the sensitivity of the EB to individual variable alterations.

**Table 2: Shading and wind alterations applied to each energy budget simulation**

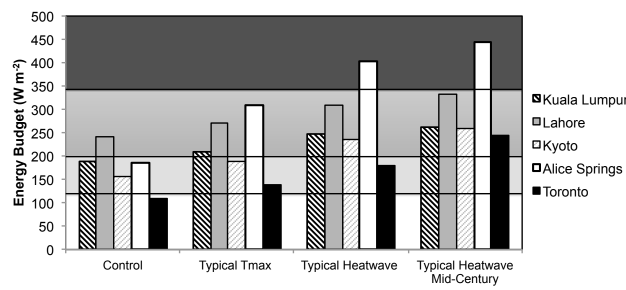
| Shade | | Wind | |
|---|---|---|---|
| % Transmissivity (τ) | **Example trees** | **% from monthly climate mean** | **Classification** |
| 100 | open sky | -80 | strong wind block |
| 50 | Honey Locust | -40 | light wind block |
| 38 | White Oak | 0 | no change |
| 30 | Japanese Maple | 60 | fast breeze* |
| 20 | Cottonwood/red maple | 200 | fastest breeze* |
| 14 | Norway Maple | | |
| 0 | Building | | |

**Beaufort windscale*

## 3. Results and Discussion

We first present results under open-sky observed control conditions for each city, prior to landscape modifications (Figure 1). For the controlled simulation, the average human would experience energy budgets that ranged from neutral (108 $Wm^{-2}$) in Toronto, to warm in Kyoto, Alice Springs, and Kuala Lumpur, to hot and in danger of sunstroke (241 $Wm^{-2}$) in Lahore. When the typical $T_{max}$ during the hottest month of the year was modeled, vulnerability to heat stress was pronounced in all cities, with energy budgets in Kuala Lumpur, Lahore, and Alice Springs exceeding 200 $Wm^{-2}$ (also displayed in top left corner of Table 3). For a typical summertime heat wave (simulation 2), EB values in Alice Springs were in the extreme danger zone while all the other test cities, excluding Toronto, were in the danger zone (Table 3). Simulation 3 demonstrated that the EB values resulting from projected mid-century modeling (based on the IPCC scenarios) placed all cities in the danger category or higher (see Figure 1).

**Figure 1: Energy budgets (W $m^{-2}$) based on a typical average summer daytime temperature (control); typical $T_{max}$ during the hottest month of the year; typical heat wave; projected heat wave for each city included in the simulations. Background colours represent EB ranges as listed in Section 1.**




### a. Microclimatic Landscape Alterations

We first simulated the effects of reductions in $T_a$ based on magnitudes reported in the literature (Chow et al., 2012, 2011; Vanos et al., 2012b; Slater, 2010) (see Table 3). As the PCI intensity increased to 6°C, the impact on the energy budget was increasingly more pronounced, with average reductions in energy budgets ranging from –48 to –62 $Wm^{-2}$ for the average summer daytime $T_a$ and $T_{max}$ heat wave scenarios, respectively. Overall, the effect of 'park cooling' linearly decreased energy budgets by –7 to –19 $Wm^{-2}$ per °C decrease in $T_a$. These interventions were increasingly effective in proportion to temperature (i.e., heat wave and climate change scenarios), with Alice Springs displaying energy budget reductions up to –112 $Wm^{-2}$. These results suggest that PCI design interventions have a modest cooling effect on the thermal comfort sensation of urban residents, although due to modeling at the most extreme temperatures, most simulations demonstrated that individuals would remain in the dangerous to extreme danger ranges of energy budget values.

Alice Springs, Australia displayed the warmest temperatures and most uncomfortable/dangerously hot bioclimate, but also had the greatest benefit from reducing $T_{max}$. For example, if a 6°C reduction could be achieved via a PCI, the energy budget would be reduced by 112 $Wm^{-2}$, and also positively alter the zone of heat stress from 'extreme' to 'moderate'.

**Table 3: Energy budget (EB) estimations calculated for the implementation of air temperature reduction. Comparisons are displayed for typical daytime max temperature ($T_{max}$) as well as for heat wave extremes. Change (Δ) from typical temperature and heat wave also displayed**.

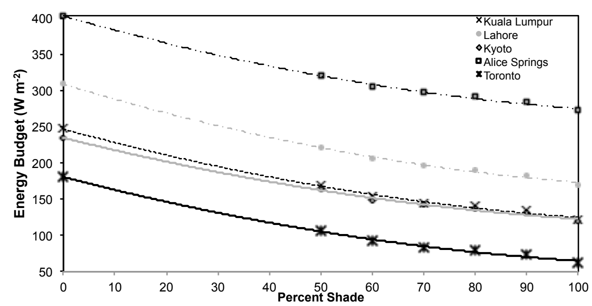
| | $T_{max}$ (daytime high) | | | |
|---|---|---|---|---|
| City | A. Typical $T_{max}$ | Δ from A | B. Typical Heat wave | Δ from B |
| Kuala Lumpur | 209^ | 0 | 247^ | 0 |
| Lahore | 270^ | 0 | 309^ | 0 |
| Kyoto | 189† | 0 | 235^ | 0 |
| Alice Springs | 309^ | 0 | 403* | 0 |
| Toronto | 138† | 0 | 181† | 0 |
| ΔTa | –1°C | | –1°C | |
| Kuala Lumpur | 202^ | –7 | 239 | –8 |
| Lahore | 262^ | –8 | 301^ | –8 |
| Kyoto | 180† | –9 | 226^ | –9 |
| Alice Springs | 292^ | –17 | 383* | –20 |
| Toronto | 129† | –9 | 172† | –9 |
| ΔTa | –2°C | | –2°C | |
| Kuala Lumpur | 195† | –14 | 231^ | –16 |
| Lahore | 255^ | –15 | 293^ | –16 |
| Kyoto | 172† | –17 | 217^ | –18 |
| Alice Springs | 275^ | –34 | 364* | –39 |
| Toronto | 121† | –17 | 163† | –18 |
| ΔTa | –3°C | | –3°C | |
| Kuala Lumpur | 187† | –22 | 224^ | –23 |
| Lahore | 248^ | –22 | 285^ | –24 |
| Kyoto | 163† | –26 | 207^ | –28 |
| Alice Springs | 259^ | –50 | 345* | –58 |
| Toronto | 112 | –26 | 154† | –27 |
| ΔTa | –4°C | | –4°C | |
| Kuala Lumpur | 180† | –29 | 216^ | –31 |
| Lahore | 240^ | –30 | 278^ | –31 |
| Kyoto | 154† | –35 | 198† | –37 |
| Alice Springs | 243^ | –66 | 327^ | –76 |
| Toronto | 104 | –34 | 145† | –36 |
| ΔTa | –5°C | | –5°C | |
| Kuala Lumpur | 173† | –36 | 209^ | –38 |
| Lahore | 233^ | –37 | 270^ | –39 |
| Kyoto | 145† | –44 | 189† | –46 |
| Alice Springs | 228^ | –81 | 309^ | –94 |
| Toronto | 95 | –43 | 138† | –43 |
| ΔTa | –6°C | | –6°C | |
| Kuala Lumpur | 166† | –43 | 202^ | –45 |
| Lahore | 225^ | –45 | 263^ | –46 |
| Kyoto | 137† | –52 | 180† | –55 |
| Alice Springs | 212† | –97 | 291^ | –112 |
| Toronto | 85 | –53 | 128† | –53 |

*†heat vulnerability (121–201$Wm^{-2}$); ^likely sunstroke/heat exhaustion (201–339 $Wm^{-2}$); *extreme danger for heat stress, sun and heat stroke likely (EB>339 $Wm^{-2}$) (Harlan et al., 2006).*

In the other four test climates, the effects of air temperature reductions on energy budgets were less than half the magnitude of Alice Springs.

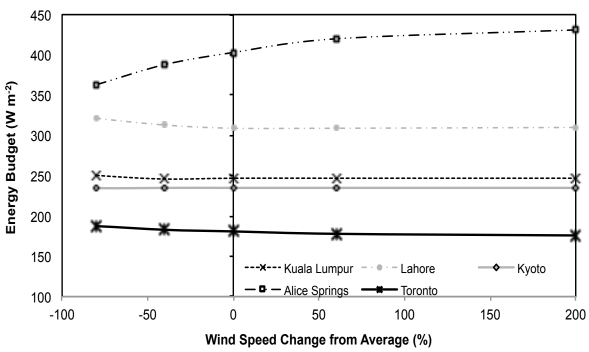
Results from reduction of solar radiation are displayed in Figure 2 and Table 4. The magnitude of cooling due to shade was the most effective overall, with a 50% increase in shade resulting in an average energy budget decrease of –78 W $m^{-2}$ across the five cities (versus –5 W $m^{-2}$ for wind speed increases). The energy budget reductions were similar between simulations 1 and 2. Interventions that reduced incoming shortwave radiation by 100% (e.g., solid structure) reduced energy budgets by an average of –126 $Wm^{-2}$. For typical summer $T_{max}$ conditions in Kyoto, Kuala Lumpur, and Toronto, these shading interventions greatly reduce vulnerability to heat stress, and resulted in changes in thermal sensation from 'vulnerable' or 'danger' to 'safe'. The magnitude of the cooling was greatest in the cities that experience the most hours of full sunshine: Alice Springs and Lahore. Lahore, Pakistan, displayed energy budget reductions reaching –87 $Wm^{-2}$ for 50% shade, and –139 W $m^{-2}$ for full shade.

**Figure 2: The impacts of shading interventions on energy budgets (W $m^{-2}$) at heat wave typical $T_{max}$ for all cities**




The potential cooling effect of wind during typically hot summertime days was shown to be the least useful cooling design strategy (e.g., 60% more wind resulted in a mere –1 $Wm^{-2}$ decrease in the energy budget (range: –6 to +4 $Wm^{-2}$) (see simulation 2 results in Figure 3) During both typical and summer $T_{max}$ and heat wave $T_{max}$ for all cities, the cooling effect of increasing wind speeds on energy budgets was very minimal. The resulting energy budget changes ranged from –10 $Wm^{-2}$ in Toronto to +7 $Wm^{-2}$ in Alice Springs. Under typical $T_{max}$ heat wave conditions, increasing wind speeds by 200% resulted in a mere 5 $Wm^{-2}$ energy budget decrease in Toronto; had no effect on energy budgets in Kuala Lumpur and Kyoto; and actually increased energy budgets by 1 W $m^{-2}$ and 28 W $m^{-2}$ in Lahore and Alice Springs, respectively. The same intervention during a mid-century heat wave in Alice Springs produced a 39 $Wm^{-2}$ increase in the EB. It is important to note that these increases result from convective heat gains to the body, as ambient air temperatures approached and exceeded 40°C. This is because the amount of convective cooling from a person is a direct function of the difference in temperature between a person's skin and the air. The mean normal skin temperature of a person ranges from 28.0°C to 37.0°C at ambient temperatures of 9.5 and 35.0°C, respectively (Koehler 1996). This will occur in dry climates, such as Alice Springs, without evaporation and the resulting latent heat cooling, convection dominates the EB.

**Figure 3: The impacts of wind alterations on energy budgets (W $m^{-2}$) at heat wave $T_{max}$ for all cities.**




The findings of this study clearly demonstrate that shading interventions have the largest positive effect on human thermal comfort in all climate zones and all scenarios. Apart from that, decreasing air temperature through a 'park cooling island' design was also important, linearly decreasing energy budgets by –7 to –19 $Wm^{-2}$ per °C decrease in $T_a$. These interventions were increasingly effective in proportion to temperature (i.e., heat wave and climate change scenarios), and can be used in combination to ameliorate the effects of heat stress on urban populations.

These findings are similar to other summer EB evaluation studies (e.g. Shashua-Bar et al., 2011; Shahidan et al., 2010; Lin et al., 2010; Lin, 2009; Cheng et al., 2010; Ahmed, 2003). Within all of the climate zones included in our study, shading interventions (especially those which reduced incoming solar radiation by more than 50%) enhanced thermal comfort, and perhaps most importantly, greatly reduced vulnerability to heat stress during warm summer conditions, as well as current and projected heatwave scenarios. As supported by Shashua-Bar et al. (2011), these impacts are due to sharp reductions in the amount of incoming solar radiation, and in the amount of solar radiation that is reflected from the ground surface and subsequently absorbed by the human body.

Although many researchers have placed emphasis on the provision of greenspaces in ameliorating the impacts of the UHI, these findings suggest that careful attention must be given to how shading interventions are incorporated within green spaces and urban environments. In short, in the future we should include more "shaded green space" rather than "green space" in the design of urban areas. However, the notion of bioclimatic-sensitive design, where the amount and types of trees in parks has to differ between climate zones, is important to consider (Brown et al 2011). In the very hot and sunny climate zones that have little seasonal variability, the amount of shade should be maximal all year round. For instance, in Lahore, parks would ideally look like forests. In climates where the cold seasons also ask for sunny open spots overhead to offer thermal comfort, yet wind breaks for the cold N/NW winds (e.g. in Toronto), the parks should incorporate a mixture of patches with coniferous and deciduous trees, as well as open landscaped areas. Also in the cities, where partly cloudy situations exist, such a mixture of open areas and groves is recommendable because these parks provide more choices for the different radiation situations. A large challenge also is present in hot dry climates, where adequate water may not be available for abundant greenery needed to obtain EB reductions; this creates a paradox (Jenerette et al. 2011).

## 4. Conclusions

Overall the energy budget analysis indicated that reduction in solar radiation through shading was the most important effect that green spaces can have on the thermal comfort sensation of residents, yet the magnitude of the effect varied with location. Perhaps most importantly, reduction of solar load to the human body greatly reduced vulnerability to heat stress during warm summer conditions, as well as in current and projected heatwave scenarios.

Decreasing air temperature through a 'park cool island' was also effective in reducing heat stress, linearly increasing with decreasing $T_a$. The potential cooling effect of wind during typically hot summertime days was shown to be the least useful cooling design strategy

The current design of 'green spaces' in cities as open areas, rather than shaded, will result in increasingly detrimental heat stress conditions in the future. These findings will be translated into a biometeorology-based framework for the design of thermally Comfortable Outdoor Open Landscapes (COOL). By offering simple design guidelines for urban park elements for different climate zones, we can support effective adaptation and mitigation strategies to extreme heat. This type of bioclimatic planning for urban parks worldwide can result in cooler, healthier, more effective park design (shade and not just low lying vegetation) and more comfortable cities during the hottest times of the year. For example, providing future tree plantings in the parks of all climate zones, trees should be 'climate-proof' meaning that they need to fit the current climate zone, as well as the future climate.

**Table 4: Impact of shading alterations on human EB (W $m^{-2}$) under typical, heat wave, and mid-century heat wave $T_{max}$ conditions for all five cities.**

| City | A: Typical $T_{max}$ | Δ from 'Open Sky' (0% shade) of **A** | B: Heat wave $T_{max}$ | Δ from 'Open Sky' of **B** | C: Mid-Century Heat wave | Δ from 'Open Sky' of **C** |
|---|---|---|---|---|---|---|
| **% Shade** | **0%** | | **0%** | | **0%** | |
| Kuala Lumpur | 209^ | 0 | 247^ | 0 | 262^ | 0 |
| Lahore | 270^ | 0 | 309^ | 0 | 334^ | 0 |
| Kyoto | 189† | 0 | 235^ | 0 | 258^ | 0 |
| Alice Springs | 309^ | 0 | 403* | 0 | 445* | 0 |
| Toronto | 138† | 0 | 181† | 0 | 244^ | 0 |
| | **50%** | | **50%** | | **50%** | |
| Kuala Lumpur | 132† | −77 | 169† | −78 | 184† | −78 |
| Lahore | 183† | −87 | 222^ | −87 | 247^ | −87 |
| Kyoto | 117 | −72 | 163† | −72 | 186† | −72 |
| Alice Springs | 227^ | −82 | 321^ | −82 | 363^ | −82 |
| Toronto | 67 | −71 | 106 | −75 | 170† | −74 |
| | **60%** | | **60%** | | **60%** | |
| Kuala Lumpur | 116 | −93 | 154† | −93 | 169† | −93 |
| Lahore | 167† | −103 | 205^ | −104 | 230^ | −104 |
| Kyoto | 104 | −85 | 149† | −86 | 172† | −86 |
| Alice Springs | 211^ | −98 | 305^ | −98 | 347^ | −98 |
| Toronto | 48 | −90 | 92 | −89 | 156† | −88 |
| | **70%** | | **70%** | | **70%** | |
| Kuala Lumpur | 108 | −101 | 145† | −102 | 161† | −101 |
| Lahore | 158† | −112 | 196† | −113 | 221^ | −113 |
| Kyoto | 96 | −93 | 142† | −93 | 165† | −93 |
| Alice Springs | 203^ | −106 | 297^ | −106 | 339^ | −106 |
| Toronto | 40 | −98 | 84 | −97 | 148† | −96 |
| | **80%** | | **80%** | | **80%** | |
| Kuala Lumpur | 103 | −106 | 140† | −107 | 156† | −106 |
| Lahore | 152† | −118 | 191† | −118 | 215^ | −119 |
| Kyoto | 91 | −98 | 137† | −98 | 160† | −98 |
| Alice Springs | 197† | −112 | 291^ | −112 | 334^ | −111 |
| Toronto | 35 | −103 | 80 | −101 | 144† | −100 |
| | **90%** | | **90%** | | **90%** | |
| Kuala Lumpur | 96 | −113 | 134† | −113 | 149† | −113 |
| Lahore | 144† | −126 | 183† | −126 | 208^ | −126 |
| Kyoto | 85 | −104 | 131† | −104 | 154† | −104 |
| Alice Springs | 190† | −119 | 284^ | −119 | 327^ | −118 |
| Toronto | 29 | −109 | 73 | −108 | 137† | −107 |
| | **100%** | | **100%** | | **100%** | |
| Kuala Lumpur | 84 | −125 | 122† | −125 | 137† | −125 |
| Lahore | 131† | −139 | 170† | −139 | 194† | −140 |
| Kyoto | 74 | −115 | 120 | −115 | 143† | −115 |
| Alice Springs | 178† | −131 | 272^ | −131 | 364^ | −281 |
| Toronto | 18 | −120 | 62 | −119 | 114 | −130 |

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