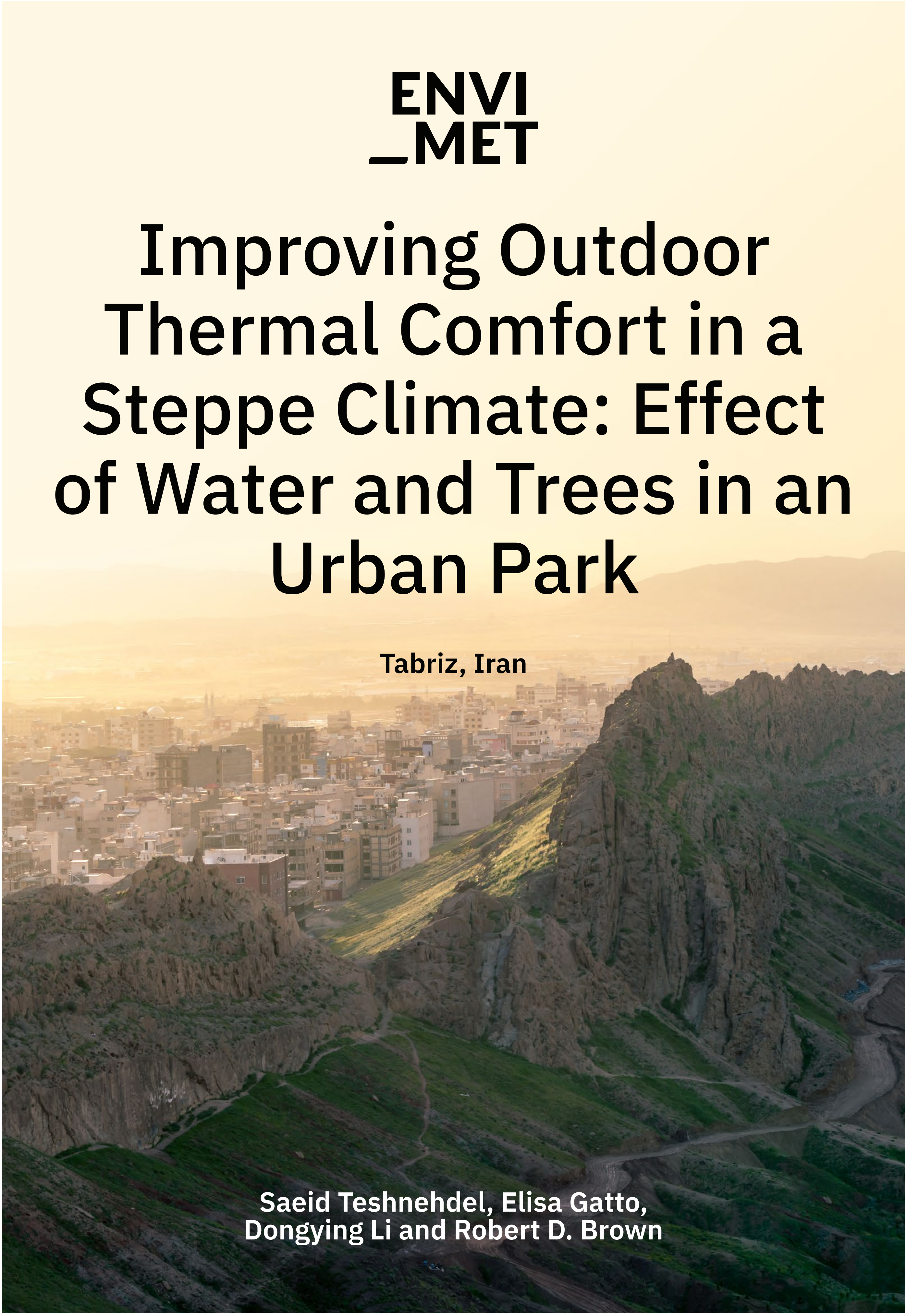
ENVI_MET

Improving Outdoor Thermal Comfort in a Steppe Climate: Effect of Water and Trees in an Urban Park

Tabriz, Iran



Saeid Teshnehdel, Elisa Gatto, Dongying Li and Robert D. Brown

Introduction

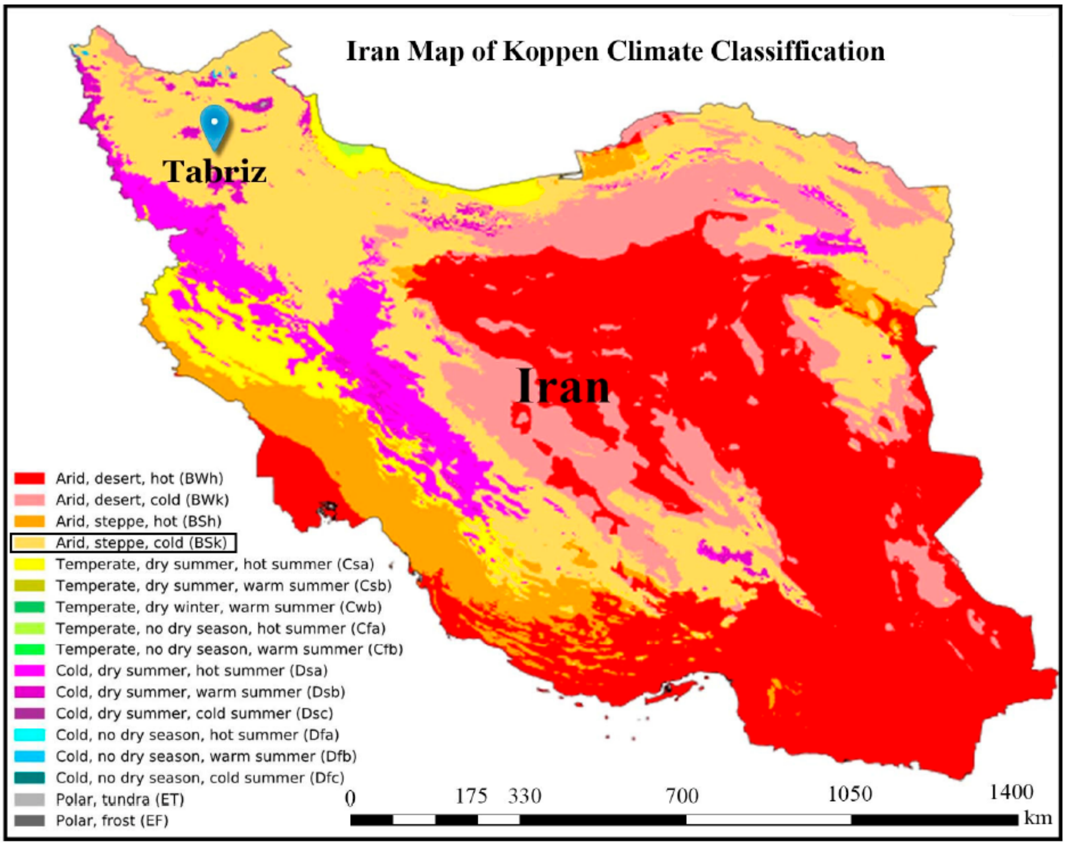
Effects of Water and Trees in an Urban Park

Projected warming from climate change is a significant challenge for the urban environment which is superimposed on the local phenomenon known as the urban heat island (UHI).

Projected warming from climate change is a significant challenge for the urban environment which is superimposed on the local phenomenon known as the urban heat island (UHI). The effect of UHI and urbanization is causing uncomfortable hot summer environments.

Numerous studies focusing on ways for improving urban microclimate and human thermal comfort by planting trees, adding water bodies, using cool surfaces and changing the urban form have been conducted.

In this research, the effect of water body with trees on microclimate and human thermal comfort in an urban park in Tabriz have been investigated. Numerical simulations were performed by the micro-meteorological model ENVI-met, validated for Ta and MRT data, on four different scenarios. Rayman model 2.1 was used to calculate PET.



Saeid Teshnehdel, Elisa Gatto, Dongying Li and Robert D. Brown

Study Area

Why?

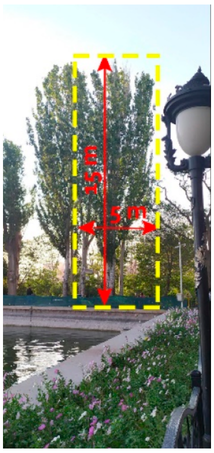
The chosen study area was optimal for investigating the effectiveness of heat mitigation strategies in a steppe climate zone, specifically the effect of trees, pavement types, and water on the microclimate and human thermal comfort.

Tabriz (3880 N; 48150 E; 1350 m elevation) is a metropolis in the mountain area in the northwest of Iran. It is influenced by the local steppe climate and it is characterized by little rainfall throughout the year. El-Golu Park, as a large historic park containing an artificial lake in the southeast of Tabriz, was chosen as a case study because it has a large artificial lake, which is unique to this area.

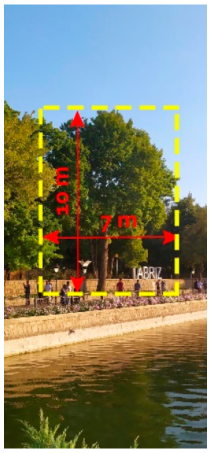
The highest percentage of district surfaces are covered in, respectively: trees (36%); water body (27%); granite pavement (sidewalk, 21%); asphalt surface (13%); and buildings (3%). The total number of trees in the site is 417, with three different types of trees (Figure 1). Almost all the trees at the site are deciduous (Poplar, Beech), and the number of coniferous trees (pine) at the site is quite limited (Table 3).

Coniferous tree (Pine)

Deciduous tree (Poplar)



Deciduous tree (Beech)

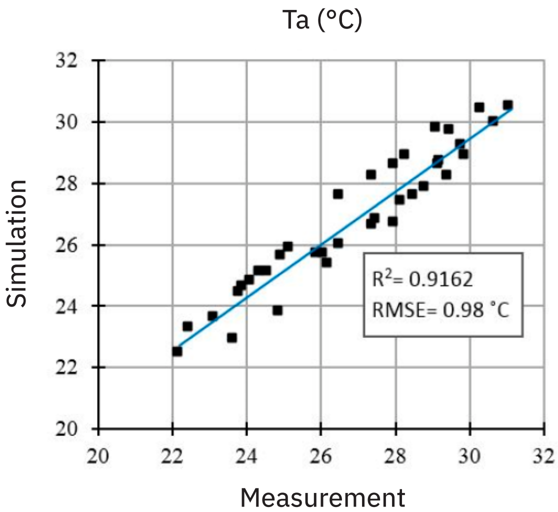


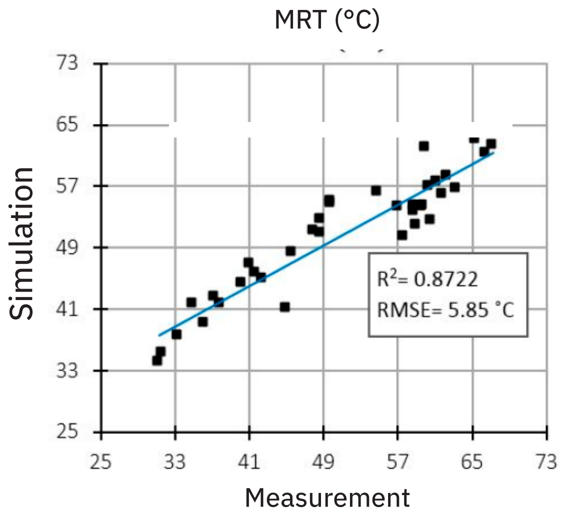
Step 1: ENVI-met Validation

In order to validate the ENVI-met model, values measured at 4 different locations within the park (Figure 2) have been compared with the predicted air temperature (Ta) and Mean Radiant Temperature (MRT). The instruments were placed 1.5 m above the ground of the study site. By using a statistical method, the measured and simulated Ta and MRT of this area were analyzed. The data were measured at different times on 28 July 2019 from 09:00–17:00 in local time.

Figure 2:
Measurement points on the site of El-Golu park

Based on the simulated and measured results, the maximum air temperature occurred at about 13:00–16:00. The Ta difference between the results of simulated and measured is about 1.3 °C at the highest point, while the average difference is 0.5 C. On the other hand, the maximum MRT occurred at 12:00 to 15:00 in both the simulated and measured results.

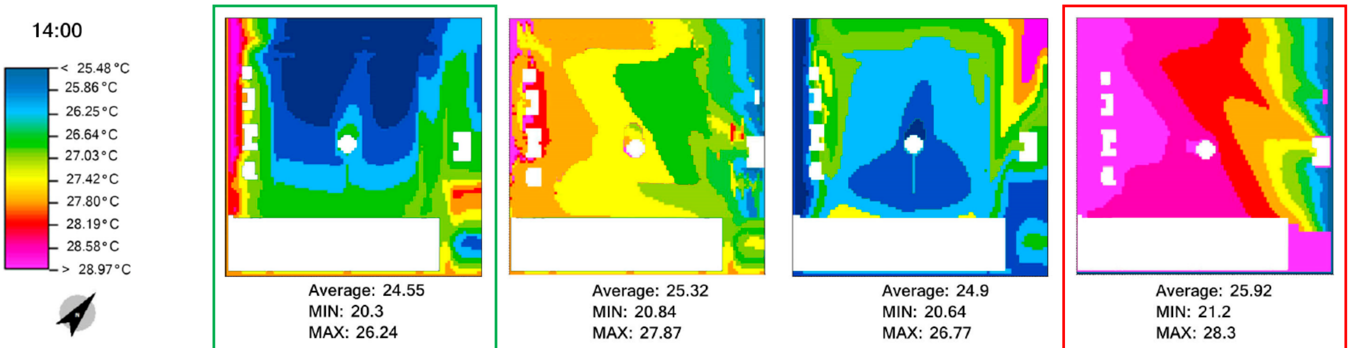




The model represented very similar results between the measured and simulated data of Ta

Step 2: ENVI-met Simulation

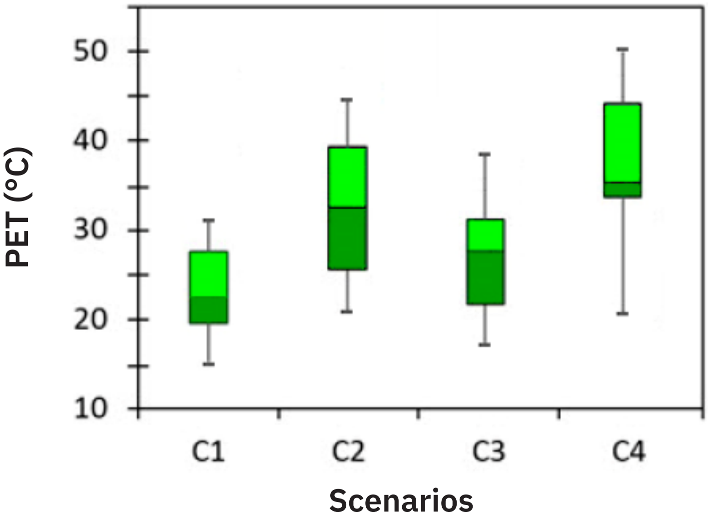
Simulation of Land Use	Current Scenario (Case 1)	No Vegetation Scenario (Case 2)	No Water Body Scenario (Case 3)	Soil and Granite Scenario (Case 4)
Water surface	27%	27%	-	0%
Asphalt surface	13%	13%	13%	13%
Building	3%	3%	3%	3%
Granite pavement	21%	21%	48%	48%
Soil	-	36%	36%	36%
Overall area of tree cover	36%	-	-	-



Best

Tair
at a height of 1.5 m agl averaged for all scenarios

Worst



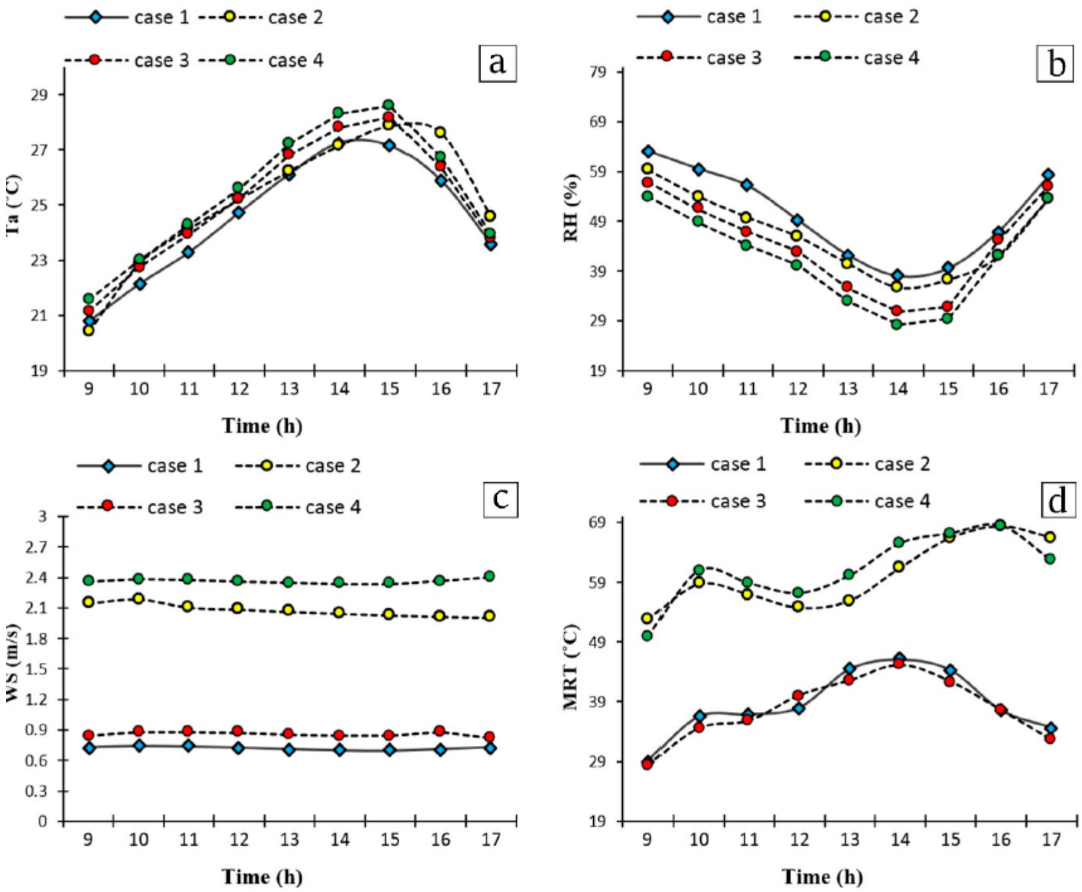


Figure 4. a) Average of PET values at the site (1.5 m agl) in all scenarios, during on the hottest day of the year b)Average air temperature values at the site (1.5 m agl) in all scenarios: (a) during on the hottest day of the year ;(b) relative humidity; (c) wind speed; and (d) mean radiant temperature.

According to the results, the average Ta and MRT vary depending on the presence of trees and water body in all scenarios. As shown in Figure 4b, the average Ta and MRT of the current scenario (c1) during the summer day are respectively 25.9 and 37.7°C. Therefore, the average Ta in scenarios (c2–c4) compared to the scenario c1 have increased 0.4°C, 0.2°C and 0.4 °C respectively.

Also, shading by trees has a positive impact on the sunlight reduction. These differences have created a wide zone of “mean radiant temperatures” in different parts of the site. The average MRT compared to c1 has increased c2: 18.2°C, c3: 1.6°C, and c4: 22°C, respectively.

With regard to simulation results, scenario c2 (no vegetation scenario) provides the same results as the scenario c4, while scenario c1 and c3, have a cooling assistance benefit compared to scenarios c2 and c4. It should be noted although case 3 (no water body scenario) like case1 has improved PET, while the relative importance of the water body on air temperature reduction is quite impressive in case 1 (vegetation + water body) (Figure 4a).

In detail, the daily average Ta in cases 1 and 3 are 24.6°C and 25.1°C respectively. Overall, it can be seen that water alone has dropped air temperature by 0.55 C.

Results and Conclusions

Based on the results of the surfaces tested, the water body was more effective in reducing heat island compared with the granite pavement.

Based on the results of the surfaces tested, the water body was more effective in reducing heat island compared with the granite pavement. The reduction was achieved because the evaporation of water decreased the surface temperature. However, it also increased the humidity, which reduced the positive impact on thermal comfort. However, the combination of water body with trees which reduced MRT represents better performance in the regulation of urban microclimate and thermal comfort.

According to simulation results, **scenario c1, characterized by 36% trees, 27% water body, and 21% granite pavement, is an optimal scheme for summertime.** The results of this case can be summarized:

1.) The average air temperature and mean radiant temperature were decreased by **0.5°C and 22°C** respectively by water body compound with trees on the hottest day of the year;

2.) According to **PET results**, the cooling benefits from water body with tree cover in urban areas have a positive effect on human thermal comfort levels from **“hot” to “comfortable”** sensation in the hottest day of summertime;

3.) Based on PET index, numerically expressed by 37.5 C (c4: without all trees and water body) to 23 °C (c1: current situation including all trees and water body) which is around to the comfort zone in the hottest day.

Results of this study illustrate that using systematical principles from water body and tree-planting in urban areas can be an effective strategy for cooling urban temperature and improving human thermal comfort conditions, and can provide design recommendations and guidelines for urban designers and policymakers.