International Journal of Architectural Engineering & Urban Planning, Volume 33, Number 2, 2023
DOI: 10.22068/ijaup.700

Research Paper

The Impact of Trees on Thermal Comfort Conditions in Urban Micro-Climate in Cold Weather

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Received: March 2022, **Revised:** January 2023, **Accepted:** March 2023, **Publish Online:** May 2023

Abstract
Nowadays, global climate change makes urban planners and designers pay more attention to thermal islands to enhance thermal comfort conditions in cities. The present study aims to investigate the effects of evergreen and deciduous tree placement patterns, tree canopy height, and tree canopy diameter on the enhancement of ambient temperature and improvement of thermal comfort conditions. The ENVI-met model was used to replicate the research region and site. It was validated by comparing the outputs of the model with the values from field measurements. Finally, the recommended scenarios were simulated in the model to discover those scenarios with better performance in enhancing outdoor thermal comfort and temperature on days with low temperatures. At low-temperature situations, planting evergreen trees irregularly had a stronger impact on the improvement of thermal comfort (PMV) compared to deciduous trees. Furthermore, in all models, Populus nigra and Platanus showed the worst performance in boosting ambient temperature. Landscape designers and urban planners might use the findings to improve urban green space, construct sustainable cities, and enhance air temperature.

Keywords: *Thermal comfort, ENVI-met, Planting design, Urban environment.*

1. INTRODUCTION

With more than half of the world's population living in cities, it is now generally known that cities are more densely populated than villages (Salata, Golasi, de Lieto Vollaro, & de Lieto Vollaro, 2016), approximately 3.4 billion, with a predicted 60% increase by 2030, i.e. 5 billion people (Karakounos, Dimoudi, & Zoras, 2018). In addition, as the rate of urbanization has increased, the temperature of cities has increased due to population (Oke, 1982). The urban ecosystem is being damaged by the rise of constructions in cities and the unequal distribution of urban infrastructure. Hence, the influence of the urban heat island is increasing (Jin, Bai, Luo, & Zou, 2018). Heat islands exacerbate heat stress in urban areas, and diminishing thermal comfort in general decreases and jeopardizes the health of city dwellers (Lu et al., 2017). Urban regions with a high albedo, the use of high thermal capacity materials in urban buildings, a lack of effective ventilation and trapping of long-wave radiation, air pollution, and a lack of appropriate vegetation are all factors that can enhance urban thermal islands. Finally, it was discussed how urban surroundings might reduce evaporation and relative humidity (Gromke et al., 2015). Because trees and green spaces have such a large impact on the regulation of micro-meteorological conditions, it is urgently needed to research essential aspects and characteristics of green spaces (Abdi, Hami, & Zarehaghi, 2020). They improve solar absorption and limit long-wave radiation transmission by replacing hard urban surfaces with natural components, and the trapping of short-wave radiation in the near-Earth atmosphere raises the heat of the atmosphere (Wu & Chen, 2017). Trees play a more effective role in reducing climate and ambient temperature than other

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plant parts (El-Bardisy, Fahmy, & El-Gohary, 2016; Lee, Mayer, & Chen, 2016).

By providing shade and maximizing shortwave radiation, trees can adjust air and ambient temperature and promote thermal comfort (Lee, Holst, & Mayer, 2013; Lee, Mayer, & Kuttler, 2020; Lee, Mayer, & Schindler, 2014). The quantity of shade, evaporation, and transpiration of trees are all affected by the shape and size of tree leaves (Perini, Chokhachian, & Auer, 2018). The type of tree leaves (broadleaf or coniferous leaves) can help increase cooling and decrease ambient temperature (Hami, Abdi, Zarehaghi, & Maulan, 2019). With suitable planting patterns and tree location, it is feasible to lower air temperature during hot seasons and days while increasing it during cold seasons and days (Zhang, Zhan, & Lan, 2018). Green infrastructures, which improve microclimate conditions by reducing hot air flows, evapotranspiration, and shading, are one of the most successful techniques for reducing the detrimental effects of warming urban environments. Green infrastructure, which consists of a mix of natural and semi-natural features like green areas, trees, water features, and other natural elements, provides several ecosystem services, including climate modification (Koc, Osmond, & Peters, 2018). Many elements, including the influence of patterns, arrangement, and composition of different plant species in the night and winter, varying shapes of trees and shrubs, and other aspects that have not yet been investigated, can alter the cooling effect of plants and green areas. It was discovered that combining these plant kinds improved the appearance of climatic circumstances (Hami et al., 2019).

2. MATERIALS AND METHODS

In this study, the ENVI-met4.4.6 model was used to simulate the desired area in the first stage. The model's validity was next tested by comparing the model's output with field measurements. Finally, after examining and analyzing the scenarios and patterns in the simulated model, better and more relevant scenarios, and patterns for enhancing temperature conditions and thermal comfort in the environment were determined. Twelve scenarios with two different planting patterns (Figure 1) were used to try to address these problems (six scenarios as one-meter crown distance and two rows irregularly and six scenarios as regular crowns) ENVI-met software was used to simulate a variety of various directions. Then, the air temperature, PMV, and PET indicators were compared in each scenario. The findings of this study can help landscape specialists, designers, and urban planners introduce appropriate planting patterns for the desired climate, as well as improve planting design and landscape planning to improve climatic conditions, reduce heat stress, and establish thermal comfort in the environment.

2.1. Physiological Equivalent Temperature (PET) and Predicted Mean Vote (PMV)

The PMV index, which is based on the theories of thermal regulation and Fanger's thermal equilibrium, is one of the most widely used indices for assessing temperature and environmental comfort (El-Bardisy et al., 2016). The average anticipated vote is a group of people's average assessment of how warm they feel (extremely hot = +3, very cold = -3), which is related to the predicted percentage of displeasure (PPD) that decides the outcome. What is the percentage of people who are unhappy with the current temperature? (Coccolo, Kämpf, Scartezzini, & Pearlmutter, 2016). Climatic variables such as air temperature, humidity, wind speed, and solar radiation of short and wavy surfaces, which are impacted by physical features of surfaces such as albedos, are compared and investigated in relation to climate variables (climatic variables such as air temperature, humidity, wind speed, and solar radiation mentioned by Barakat et al (2017) and Lobaccaro & Acero (2015) (Barakat, Ayad, & El-Sayed, 2017; Lobaccaro & Acero, 2015). PET stands for Physiological Equivalent Temperature, which is the air temperature at which the human body's thermal balance is established by equating the temperature of the skin and within the body with their typical levels (Coccolo et al., 2016). The temperature ranges of the PET and PMV indices are shown in Table 1.

2.2. Study Site

The study area is the surrounding area of the Faculty of Agriculture of the University of Tabriz, East Azerbaijan province, located in northwestern Iran. Tabriz is Iran's third largest city after Tehran and Mashhad, with a total area of 23,756 square kilometers (Fazelpour, Soltani, Soltani, & Rosen, 2015). Tabriz had a population of 1.6 million people according to the 2017 census (Sharafkhani et al., 2019). The average annual precipitation in this city is 380 mm, while the average annual temperature is 12 ° C (reference period for both data: 2013-2014). In the summer, the prevailing winds in Tabriz are usually from the east and west (Fazelpour et al., 2015). The simulation was held on October 10, 2020, one of the coldest days of the year. East Tabriz Meteorological Station provided data on the minimum and maximum temperatures, minimum and maximum relative humidity, wind speed at a height of 10 meters, and wind direction. Table 2 shows the ENVI-met software's input data. On the simulation day, the East Tabriz Meteorological Station near the University of Tabriz measured 3-hour air temperature, relative humidity, and water vapor pressure.

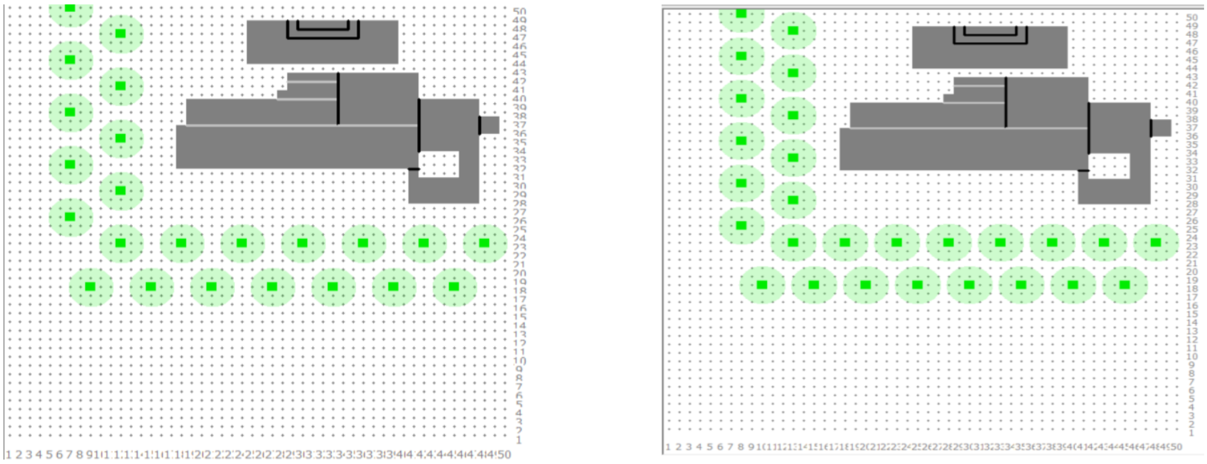


Fig 1. Proposed Planting Patterns of the Research

Table 1. The Temperature ranges PET and PMV Indices (Barakat et al., 2017; Morakinyo et al., 2017)

PET	PMV	Perception of Heat	Physiological Stress
< 13	< -3	Very cold	Too much cold stress
13-17	-3	Cold	High cold stress
17-21	-2	Cool	Mild cold stress
21-25	-1	Slightly cool	Very little cold stress
25-29	0	Moderate	No physiological stress
29-33	1	A little warm	Very low heat stress
33-37	2	warm	Mild heat stress
37-41	3	Hot	High heat stress
> 41	> 3	Very hot	Excessive heat stress

Table 2. Weather Data and Software Setting

Variable	Value
Longitude, Latitude	46°18′E, 38°04′N
Horizontal grid resolution	2m × 2m
Vertical grid resolution	2m
Model rotation out of grid north	16.6°
Simulation date	10.10.2020
Maximum air temperature	19.6 °C
Minimum air temperature	9.4°C
Wind speed at 10m	3.3m/s
Wind direction	90°
Name of location	Tabriz, East Azerbaijan Province, Iran

2.3. Simulated Models

ENVI-met4.4.6 software was used to run all of the simulated scenarios in the present study. This software is a non-hydrostatic microclimatic model that can simulate the climate in metropolitan areas with a network resolution of 0.5 to 10 meters in space and a physical resolution of 10 seconds in three dimensions (Karakounos et al., 2018). This urban climate model is usually used in architecture, building design, and environmental design. Vegetation is viewed in this model not just as a porous barrier in front of wind and solar radiation, but also as a living entity with physiological activities such as evapotranspiration and photosynthesis. In this model, various varieties of vegetation with unique characteristics can be employed. This model includes a plant database that may be enlarged. The model can determine the shadow, absorption, and radiation of short and long waves by taking into account other plant parameters such as leaf height and density (Morakinyo, Kong, Lau, Yuan, & Ng, 2017). The number of rows of trees, the distance between tree canopies, the planting distance in a row, tree height, canopy diameter, foliage density, ground cover, soil moisture, and the surroundings are all elements that affect climatic indices and thermal comfort. The desired trees are considered the same in all patterns. The spatial resolution used in this study's simulations was 2 meters horizontally and 2 meters vertically. The Leonardo V4.4.4 sub-model was also used to capture ENVI-met4.4.6 software's two-dimensional maps and climatic data. The PMV index was also calculated using the Biomet V1.5.exe model.

2.4. Measurement and Validation

Because of the station's vicinity to the study site and the region's climate similarity, the required meteorological data such as air temperature, relative humidity, direction, and wind speed at a height of 10 meters were gathered at East Tabriz Meteorological Station (Figure 2).

2.5. Scenario Preparation

In general, in this research, the selected trees were investigated and contrasted in two planting patterns. Platanus, Populus nigra, Fraxinus excelsior, Ulmus minor, Cupressus Arizonica, and Pinus nigra are some of the most common trees in Arizona (Table 3). In an L-shape planting pattern with two alternatives, 12 scenarios (Using the SPACE tool, six scenarios with a crown distance of one meter, and two rows irregularly and six situations with overlapping crowns) were simulated irregularly in the south and west (southwest and northwest) of Tabriz College of Agriculture Trees.

Two types of planting patterns were studied in general, each with different physical features (six scenarios were planted considering a canopy distance of one meter, two rows were planted irregularly, and six scenarios were planted as overlapping canopies). It should be mentioned that just one type of tree is planted in two rows as patterns (No. 1 and 2). As a result, the influence of each tree and pattern is investigated by looking at the program output. Each of these tree-planting patterns and combinations was chosen from the patterns found in urban green zones.

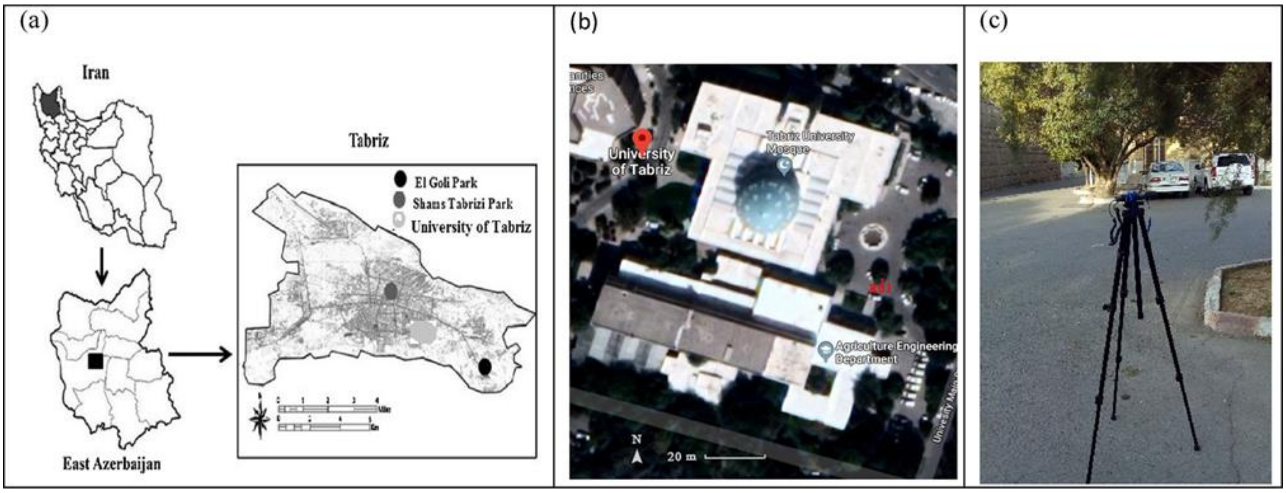
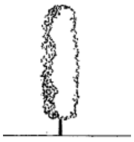
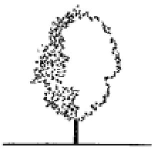
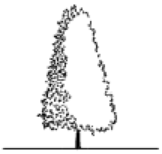
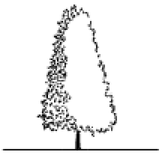


Fig 2. (a) Tabriz location; (b) Google map of the study area; (c) measuring instrument.

Table 3. Physical Characteristics of Trees

Species	Crown diameter	Canopy form	Tree height
Platanus	8m	 Spreading	10m
Populus nigra	4m	 Columnar	12m
Fraxinus excelsior	8m	 Oval	10m
Ulmus minor	6m	 Round	7m
Cupressus Arizonica	6m	 Conical	8m
Pinus nigra	5m	 Conical	7m

3. RESULTS

The results reveal that, on cold days, all scenarios raise the PET index, air temperature, and improve the PMV index compared to the original state without planting. When comparing the output parameters, it shows that trees in pattern No. 1 (two rows of trees with a 1-meter distance between the canopies) perform better than trees in pattern No. 2 (planting two rows of trees with overlap crown). The existence of a one-meter space between the canopies of trees and the passage of airflow and sunshine, which enhance the air temperature (rise) on cold days, are the causes for the high temperature in pattern No. 1. Furthermore, due to the continuity of the canopy of trees, the average air temperature in model No. 2 restricts air movement and sunlight to the environment, resulting in inferior performance than model No. 1.

3.1. Air Temperature

Despite the existence of trees, the temperature in all scenarios was higher compared to the base condition without trees, according to the results of the temperature simulation. On cold days, the presence of planting trees enhances and improves the average ambient temperature compared to the environment without planting trees, according to the results and diagrams derived from the simulation of the trees and planting patterns 1 and 2. The results showed there is a difference between the scenarios with and without trees. In addition, the more trees there are, the greater the impact observed (Figure 3). The results also indicated that planting trees with no distance (overlap canopies) performs in raising Ta (Table 4). Also, evergreen trees (16.880 °C) had a greater effect on increasing the temperature of the urban environment than deciduous trees (16.702 °C) on average (Table 4). The data also revealed that during the hours when the air temperature was colder, the ambient temperature increased, Furthermore, planting all trees without canopy overlapping has a stronger impact on enhancing and raising the temperature on cold days than planting the same trees in overlapping patterns. Deciduous trees have less influence on increasing the ambient temperature than evergreen. In general, Pinus trees had greater increase (16.900 °C), whereas Platanus had the lowest increase (16.563 °C) in average urban ambient temperature (Table 4 and Figure 3).

Also, Table 4 revealed that air temperature has increased in patterns with evergreen trees slightly more than increasing in deciduous patterns. Moreover, both patterns had an increasing effect on the air temperature compare to field measurements.

3.2. Thermal Comfort (PMV)

The results indicated that planting trees at no distance causes improving PMV. Also, as shown in Table 5, evergreen trees (-0.375) had a greater effect on improving the PMV index of the urban environment compared to deciduous trees (-0.694). The arrangement appears to be more inviting and less frigid. The smaller and closer to zero the PMV index, the more comfortable a person feels in that situation, according to the order of the scenarios from best to worst. Furthermore, the findings demonstrate that planting trees with distance between canopies has a stronger impact on enhancing people's temperature comfort in comparison to planting the same trees with overlapped canopies. Evergreen trees had a stronger impact on lowering PMV coefficients and boosting individual temperature comfort and satisfaction than deciduous trees.

Table 4. Average Ta in each Planting Pattern and Ta differences between the Field Measurement and Simulation Results

Pattern	Base	Fraxinus	Ulmus	Platanus	Populus	Cupressus	Pinus	Average Ta	
Not overlapping	15.7	16.754	16.848	16.579	16.657	16.877	16.900	Deciduous	Evergreen
Overlapping canopies		16.748	16.834	16.563	16.630	16.861	16.882	16.702	16.880
T differences		1.054	1.148	0.879	0.957	1.177	1.2	1.02	1.18

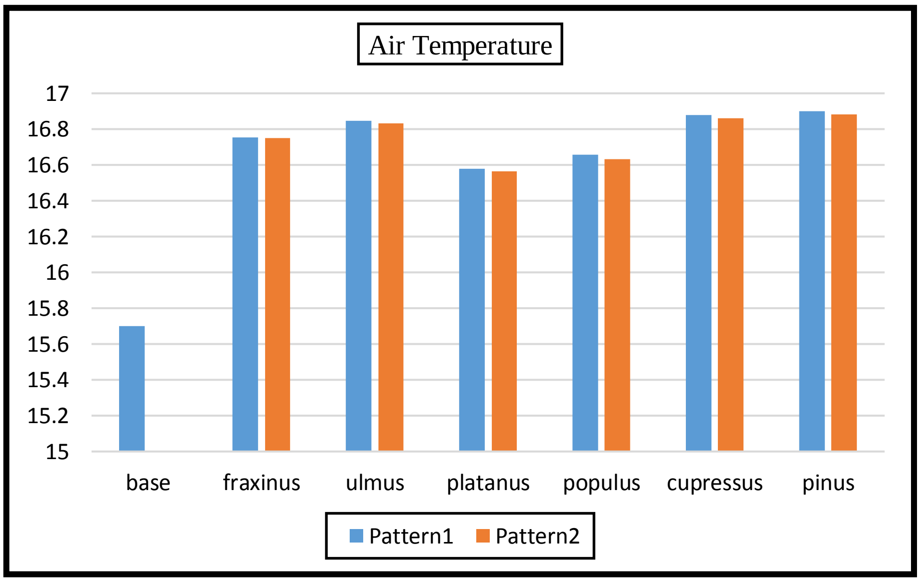


Fig 3. Mean Ta after planting trees (blue pattern # one-meter spaces between canopies, orange pattern # no space between canopies) (average over 10: 00-18: 00 LST).

Table 5. Average PMV in each Planting Pattern

Pattern	Base	Fraxinus	Ulmus	Platanus	Populus	Cupressus	Pinus	Average PMV	
1	-0.290	-0.573	-0.426	-0.951	-0.719	-0.336	-0.327	Deciduous	Evergreen
2		-0.576	-0.434	-1.035	-0.836	-0.423	-0.414	-0.694	-0.375

3.3. Physiological Equivalent Temperature (PET)

The results showed that planting trees with no distance (overlap Canopies) had better profit in raising PET (Table 6). Also, as Table 6 shows evergreen trees (23.384 °C) had a greater effect on improving the PET index of the urban environment compared to deciduous trees (21.085 °C). The findings also illustrate the physiological temperature at various times of the day, with the maximum physiological temperatures occurring at 14:00, 13:00, and 15:00 pm, respectively. That is, according to the table, persons have the highest physiological temperature during these hours compared to the baseline and the temperature closest to the stable body temperature (1).

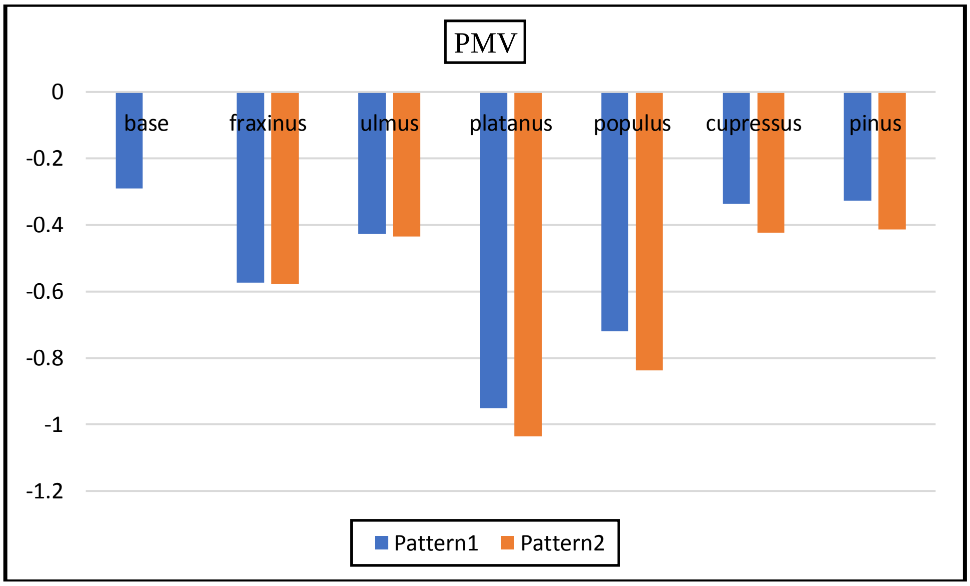


Fig 4. The mean coefficient of change of the thermal comfort index (PMV) in the desired eight hours (10 am to 6 pm) of trees, simulated in both planting patterns at a height of 1.8 m, showing that evergreen trees outperformed deciduous trees in terms of improving the environmental PMV index. Shows on cold days and low temperatures.

Table 6. Average PET in each Planting Pattern

Pattern	Base	Fraxinus	Ulmus	Platanus	Populus	Cupressus	Pinus	Average PET	
1	24.275	22.15	23.125	18.975	21.075	23.662	23.762	Deciduous	Evergreen
2		22.112	23.062	18.337	19.85	23.025	23.087	21.085	23.384

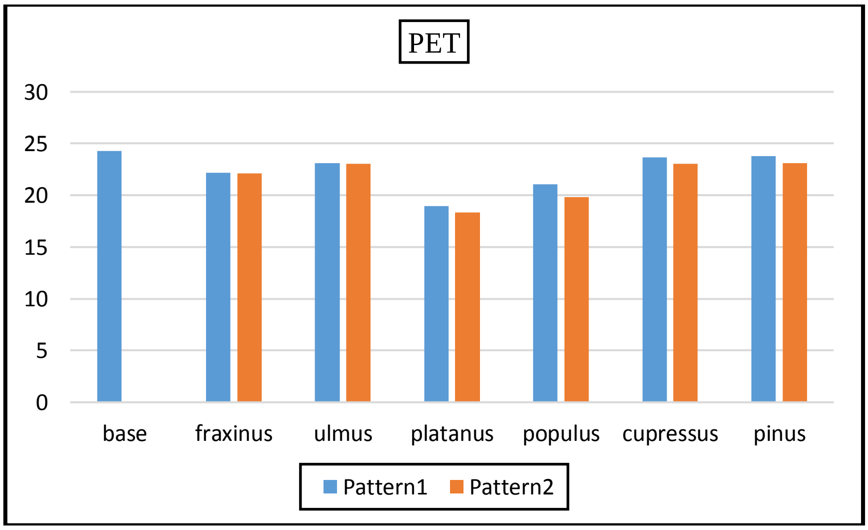


Fig 5. The mean change in physiological equivalent temperature index (PET) in the desired eight hours (10 am to 6 pm) of the trees, which were simulated at a height of 1.8 m in both planting patterns, revealed that evergreen trees outperformed deciduous trees. Cold and low-temperature days perform better in increasing the environment's PET index

4. DISCUSSION

Trees are perennial plants in the environment and their effects on PMv and PET are annual; however, this study attempted to figure out what type of trees and scenarios show the lowest and highest effect on thermal comfort and equivalent temperature index in cold seasons, since many researchers have proven the effects of plants on improving PMV and PET in hot seasons such as (Hami et al., 2019). The findings of the current research help landscape designers to use design patterns that show the lowest effect of cold seasons. In the present study, the findings of microclimatic simulation suggest that planting trees increases air temperature, improves thermal comfort conditions, and increases the physiologically equivalent temperature on cold days. Previous studies (El-Bardisy et al., 2016; Lee & Mayer, 2018; Morakinyo, Lau, Ren, & Ng, 2018; Sun et al., 2017; Zhang et al., 2018) backed up the findings presented. They revealed that urban green space increases thermal comfort. Green space helps lower outdoor human heat stress in the daytime, according to Lee and Mayer (2018) , who compared urban green space in various layouts. The findings of this study revealed that tree planting pattern, tree leaf type, and tree height all had an impact on the Ta index, thermal comfort conditions (PMV), and physiological equivalent temperature (PET) of the environment. The type of tree leaves had the most important influence on these traits.

4.1. The Effect of Planting Patterns on Ta, PMV, and PET

The results demonstrated the planting pattern with a one-meter distance between canopies had a larger effect on improving climatic factors such as Ta, PMV, and PET compared to planting patterns with overlapped canopies (Table 7). When the area of the tree cover is the same, the planting pattern is an essential component in lowering the PET index, according to Morakinyo and Lam (2016). Because wind flow, albedo, and sunlight are the main factors to enhance temperature in the cold season. Also, the amount of wind flow, sunlight, and other factors, as well as their speed and direction, are influenced by tree placement. Yang et al. (2018) investigated the impact of various tree planting patterns on thermal comfort with varying degrees of light, airflow, and shade. The findings point to the importance of tree planting patterns in optimizing environmental ventilation and shade (Fig. 6). Changes in wind direction, the amount of shading provided by trees in different planting patterns, and the quantity of light flowing through the trees and their canopies can all contribute to these oscillations in air temperature (Ta), PMV index, and physiological equivalent temperature. Despite the rate of change of climatic variables in two patterns, evergreen trees increase the air temperature (Ta) more than deciduous trees do. Trees with canopy distance also have a greater impact on increasing air temperature (Ta), improving thermal comfort conditions, and increasing the physiologically equivalent temperature (Figure 6). Outdoor thermal comfort is influenced by evergreen species because they reduce wind speed and block direct sunshine (Zhang et al., 2018). As a result of correct and reduced shadowing, evergreen trees with a lower canopy height and a smaller diameter perform better in increasing ambient temperature (Ta), and improving PMV and PET indices (Table 7). Because the lower branches of evergreen trees with shade throughout the day provide better and more sunshine as well as less albedo, they increase thermal comfort conditions, whereas deciduous trees with taller branches provide more shading, less light flow, and more albedo. They are less effective at lower temperatures. Ventilation in cities is influenced by planting patterns and tree layouts (Zhang et al., 2018). The amount of shadow in the surroundings, as well as wind speed and direction, are affected by the tree layout (El-Bardisy et al., 2016). As a result, the best planting pattern and type of trees planted in urban spaces to increase air temperature (Ta), improve climatic conditions and thermal comfort, and increase the PET index at low temperatures are the pattern and trees that increase proper ventilation, provide less shading, allow the transmission of more light and less absorption of light.

4.2. The Effect of Tree Canopy Height and Diameter on Ta, PMV, and PET

Evergreen trees with a smaller canopy diameter with a lower height (Pinus nigra and Cupressus Arizonica) had a positive effect on raising ambient temperature (Ta) and enhancing climatic conditions and comfort compared to deciduous trees with a bigger canopy diameter and a higher height (Platanus, Populus nigra, Fraxinus excelsior, and and Ulmus minor) (Table 8). Also, based on the comparison of the output parameters, it appears that deciduous trees with a lower canopy height and a smaller diameter, outperform other deciduous trees with a higher crown height (Table8). The effect of evergreen trees on increasing air temperature (Ta) was the largest, whereas deciduous trees had the least influence (Ta). Planting evergreen trees at a distance had a stronger influence on improving climatic conditions. This greater beneficial effect could be attributed to the regulation of wind speed and direction, as well as decreased shade and sunlight absorption by evergreen tree leaves. Evergreen trees, on the other hand, outperformed deciduous trees in terms of enhancing the PMV and PET indices (Fig. 7 and Table 8). Coniferous trees diminish the PMV index more than deciduous trees, according to El-Bardisy et al. (2016), which is consistent with present findings. Deciduous trees with a higher canopy height and a larger diameter perform significantly better. They have left a lot of heat behind. The relative humidity of evergreen and deciduous trees differed. Due to their larger leaf area, deciduous trees have a greater impact on improving the relative humidity of the environment than evergreen and coniferous trees. When planting trees, keep in mind that deciduous trees have a varied effect on decreasing temperature and providing thermal comfort in hot seasons with high air temperatures. However, the goal of this study was to look at this effect throughout the winter months and on chilly days (Fig. 7). Speed reduction and blocking of sunlight direction by evergreen trees are the main reasons for mitigating the PMV index (Zhang et al., 2018). One of the advantages of ENVI-met software over similar simulation models is that it considers trees as active bodies and simulates the evapotranspiration process of various plant species, which is an important aspect in microclimatic conditions. Additionally, this software can simulate several plant species with various features such as leaf area index, tree shape, height, crown diameter, leaf type, and other plant variables that might affect micro-climatic conditions. The model can be seen here. The software's drawbacks include its inability to accurately reproduce the shape of plants with various geometric designs, as well as buildings and curved and round roads. Evergreen trees reduce the PMV index more than deciduous trees do.

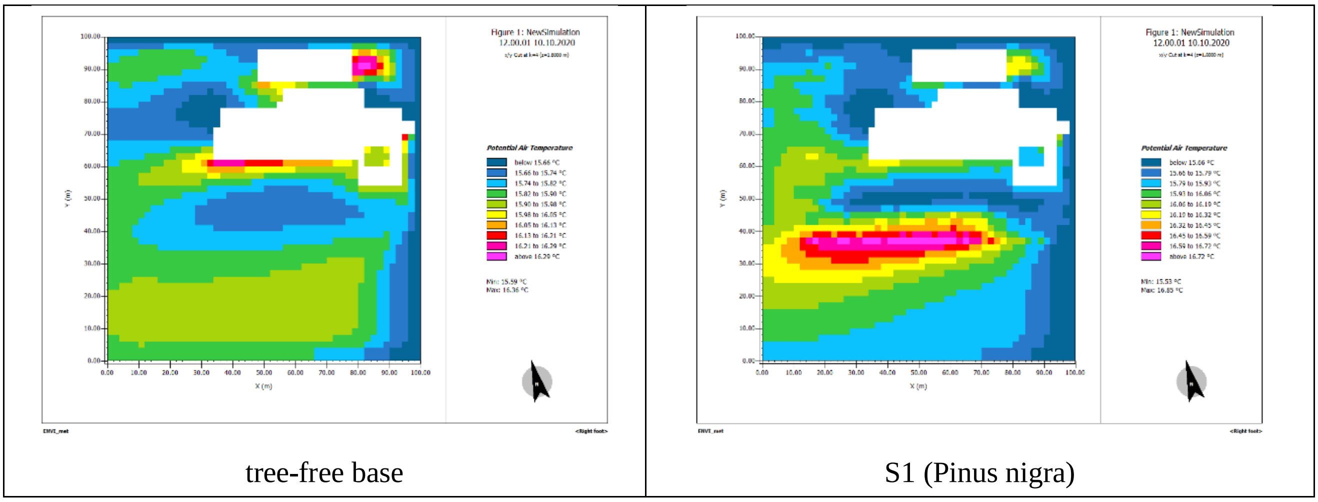


Fig 6. Difference in simulated air temperature (Ta) between the environments without trees and with pine trees in pattern No. 1 at a height of 1.8 m at 12:00 LST (more than 1 hour on average).

Table 7. Average PMV and PET of all Patterns

			Pattern	Ta	PMV	PET
Canopy	C_1	Ulmus minor	P_1	16.848	-0.426	23.125
			P_2	16.834	-0.434	23.062
	C_2	Fraxinus excelsior	P_1	16.754	-0.573	22.15
			P_2	16.748	-0.576	22.112
	C_3	Populus nigra	P_1	16.657	-0.719	21.075
			P_2	16.630	-0.836	19.85
	C_4	Platanus	P_1	16.579	-0.951	18.975
			P_2	16.563	-1.035	18.337
	C_5	Pinus nigra	P_1	16.900	-0.327	23.762
			P_2	16.882	-0.414	23.087
	C_6	Cupressus arizonica	P_1	16.877	-0.336	23.662
			P_2	16.861	-0.423	23.025

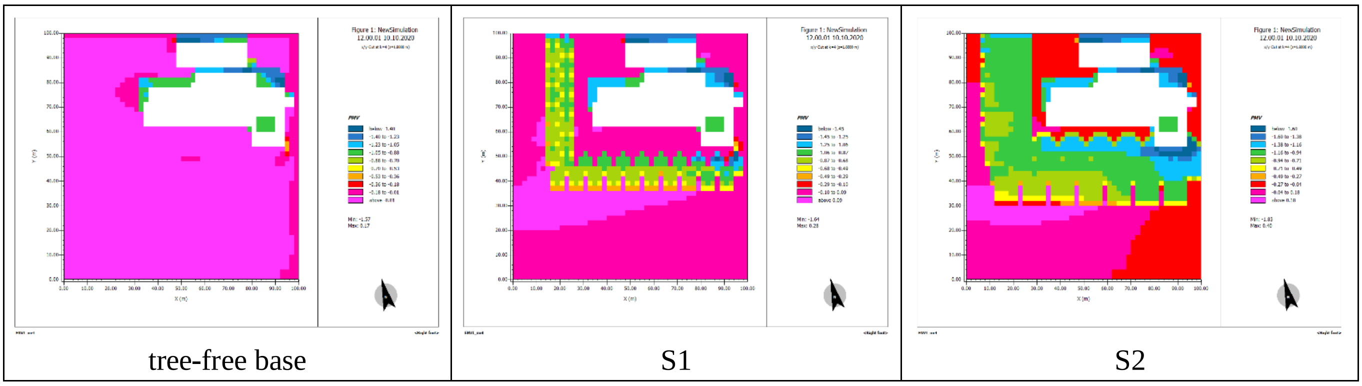


Fig 7. Thermal comfort index (PMV) values of environments without trees with evergreen trees (S1), and deciduous trees (S2) at 2:00 LST

Table 8. Mean Differences of PET, PMV, and Ta of all Patterns

			Pattern	Ta	PMV	PET
Canopy	C_1	Ulmus minor	P_1	1.148	-0.135	1.15
			P_2	1.134	-0.144	1.212
	C_2	Fraxinus excelsior	P_1	1.054	-0.282	2.125
			P_2	1.048	-0.285	2.162
	C_3	Populus nigra	P_1	0.957	-0.428	3.2
			P_2	0.930	-0.546	4.425
	C_4	Platanus	P_1	0.879	-0.661	5.3
			P_2	0.863	-0.744	5.937
	C_5	Pinus nigra	P_1	1.200	-0.036	0.512
			P_2	1.182	-0.123	1.187
	C_6	Cupressus arizonica	P_1	1.177	-0.045	0.612
			P_2	1.161	-0.132	1.25

5. CONCLUSION

In metropolitan areas, trees play a significant role in enhancing microclimate conditions. As a result, studying the important causes and traits of trees is critical. In this study, we looked at and compared the effects of different tree planting patterns on microclimate and temperature comfort. The results showed that the pattern of planting evergreen and deciduous trees with a crown diameter of one meter (pattern No. 1) has the best performance in terms of improving temperature comfort. Also, the pattern of planting trees with no canopy spacing shows the worst performance in terms of boosting temperature comfort. Evergreen trees (Pinus nigra and Cupressus Arizonica) also had a greater impact on overall temperature comfort than deciduous trees. Moreover, the environmental impact of planting broadleaf and deciduous trees with smaller canopy height and diameter has been greater than that of other deciduous trees, i.e. smaller trees with higher planting density and trunk spacing. Due to the performance of deciduous trees in warm seasons compared to cold seasons in improving and reducing the coefficient of temperature comfort and tree permanence in the environment for many years, it is suggested to use a combination of both species to improve temperature comfort. Planting trees in such a way is in conjunction with planting patterns.

In general, the pattern of planting evergreen and coniferous trees with a crown diameter of one meter (pattern No. 1) showed better and more suitable performance in improving micro-climatic conditions and thermal comfort of the environment in cold seasons (autumn) compared to the pattern of planting deciduous trees (Platanus, Populus nigra) without a distance of canopy. The findings of this study can be used to better design and plan green space and urban environments for long-term city growth by landscape designers and urban planners. Climate change and enhancing temperature comfort for city dwellers, as well as decreasing and conserving energy, should all be examined and implemented. When designing urban surroundings and places, urban planners and designers should pay close consideration to the local climate's thermal comfort. It is advised to pay attention to the pattern of plants in the design of urban green spaces, the direction of the prevailing wind, the direction of the sun, and the native plants of the region in order to achieve these aims. Planting evergreen and deciduous trees (with short crowns and diameter) with a one-meter diameter between canopies is suggested. Bigger deciduous trees with larger canopy widths should be utilized in the environment. Also, if necessary, employing a tree planting design with a crown diameter of one meter and evergreen and coniferous trees to improve climatic conditions and temperature comfort may be more appropriate due to greater ventilation and wind movement. As an overall conclusion, adding trees in this area, particularly deciduous trees, are suggested. However, some results that the scenario without trees are better pattern for cold seasons, which is as findings of the study are considered. This result doesn't show that the trees shouldn't be planted in the cold seasons, BUT it is essential to add trees, which lose leaves in the cold seasons. These trees' canopy allows sunlight transition into the surface, and finally, causes an increment of temperature in cold seasons. It is also recommended to utilize broadleaf trees, particularly Platanus and Populous nigra trees, to improve relative humidity and provide shade in hot weather due to their good performance in these issues.

ACKNOWLEDGMENTS

We are thankful to the Research and Innovation Center of the University of Tabriz for providing facilities for conducting the research. Also, many thanks go to Dr. Dabbagh for his kindness and assistance in providing instruments for collecting experimental data.

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HOW TO CITE THIS ARTICLE

Osan, S., Hami, A., Mariapan, M. (2023). The Impact of Trees on Thermal Comfort Conditions in Urban Micro-Climate in Cold Weather. *Int. J. Architect. Eng. Urban Plan,* 33(2): 1-13, http://doi.org/10.22068/ijaup.700

URL: http://ijaup.iust.ac.ir