Journal of Environmental Engineering and Landscape Management
ISSN 1648–6897 / eISSN 1822-4199
2018 Volume 26 Issue 3: 219–227
https://doi.org/10.3846/16486897.2018.xxx

# INFLUENCE OF PLANTING DESIGNS ON WINTER THERMAL COMFORT IN AN URBAN PARK

Nima Karimi AFSHAR[1], Zahra KARIMIAN[2*], Reza DOOSTAN[1],
Majid, Habibi NOKHANDAN[3]

[1]*Department of Geography, Faculty of Letters and Humanities, Ferdowsi University of Mashhad, Mashhad, Iran*
[2]*Department of Ornamental Plants, Research Center for Plant Sciences,*
*Ferdowsi University of Mashhad, Mashhad, Iran*
[3]*Climatologically Research Institute (CRL), Mashhad, Iran*

Received 15 September 2017; accepted 26 February

**Abstract.** Various planting designs behave in different ways on microclimate and thermal comfort due to mainly distinct features of vegetation type and ratio. The papers simulated the microclimate behavior and thermal comfort of different planting design scenarios of an urban park using ENVI-met model. We measured temperature, relative humidity and wind velocity during the coldest period of 2016. Seven scenarios of planting design with different types and ratios of vegetation were simulated. In scenario of evergreen trees, humidity was relatively high while temperature and wind velocity were decreased. Simulated grass covered park and deciduous trees showed higher temperature and wind velocity. Scenario of grasses and the scenarios with high ratio of deciduous trees in comparison with other scenarios indicated lower wind speeds. The findings can be seen as a possibility of improvement of winter thermal comfort, considering a proper planting design as an important step in order to achieve Citizen Satisfaction.

**Keywords:** cold seasons, planting design, thermal comfort, urban landscape, vegetation.

## Introduction

In the metropolises and densely populated areas, one of the important functions of vegetation is to improve the urban microclimate. Vegetation mainly affects the microclimate in various ways was, including shading, controlling the humidity and wind break (Ali-Touder 2005; McPherson 1994). Several studies focusing on vegetation and its positive influences in urban microclimate, human thermal comfort, and also the physical and mental health of citizens (McPherson 1994; Brown, Gillespie 1995; Akbari 2002; Streiling, Matzarakis 2003; Feyisa *et al.* 2014; Abreu-Harbich *et al.* 2015; Thoma *et al.* 2016).

According to Thani *et al.* (2013), the relations of climate and life for designing an urban landscape is necessary due to its strong relationship with climate, nature and living environment. Existing researches indicate that vegetation can improve the urban microclimate and influence outdoor thermal sensation (Ferrante, Mihalakakou 2001; Streiling, Matzarakis 2003; Feyisa *et al.* 2014; Abreu-Harbich *et al.* 2015; Thoma *et al.* 2016). Mean radiant temperature (Tmrt) is a key parameter influencing outdoor thermal comfort is defined as the uniform temperature of an imaginary black enclosure in which an occupant would exchange the same amount of radiant heat as in the actual non-uniform enclosure (ASHRAE 2001). Studies indicate that vegetation can clearly change Tmrt and also thermal comfort. The canopy that provides shadow can reduce Tmrt and thus affect the thermal bioclimate in micro scale conditions. The shadow quality produced by vegetation; depend on different factors such as position, height and size of the tree, crown geometry, leaf size and structure and also planting location (Kotzen 2003; Brown, Gillespie 1995).

A few studies have investigated the winter microclimate and thermal sensation in the urban landscape. Compared to the warm periods of the year, in the cold periods, vegetation has different effects on outdoor thermal comfort. For instance, Brown and Gillspay (1995) found deciduous trees have a negative effect on thermal comfort during winter. As Toy and Yilmaz (2010) have shown, in cold climate regions, under dense shadowy environments like spaces with dense plantation may people feel cold stress.

---

*Corresponding author. E-mail: *zkarimian@um.ac.ir*

Planting design plays a key role in the landscapes where we live, play, work, study, gather for community functions, and where we enjoy our leisure (Robinson 2004). Microclimates, the result of interaction between prevailing climate and objects in the landscape, can be modified through design (Brown, Gillespie 1995). On the planning levels and the rapid urbanization, the absence of an efficient landscape pattern originally is a contributing factor to creating spaces with uncomfortable thermal sensation (Ali-Toudert 2005). Outdoor thermal comforts of users in the recreational areas such as urban parks with different planting designs have not been fully explored in the cold periods of the year.

Many human thermal indices such as PMV (Predicted mean vote), PET (Physiological Equivalent Temperature), PT (Perceived Temperature), UTCI (Universal Thermal Climate Index) and SET (Standard Effective Temperature), have been developed to assess human thermal conditions. Predicted mean vote (PMV) that developed by Fanger (1972) is regarded as more sensitive than the other indices. The microclimate elements, including temperature, humidity, air velocity, and Tmrt and also the subjective features of an individual, such as metabolism and the amount of clothing worn is considered in PMV (Jeong *et al.* 2015). When the index lying around zero (–0.5 to +0.5) PMV indicates comfort while the deviation from zero is referred to as thermal stress and varies on a seven-point scale between –3 (cold stress) and +3 (heat stress). ENVI-met as a microclimate model can calculate and simulate PMV (Ali-Toudert 2005).

Our aim was to quantify the microclimate behavior of various planting design scenarios in an urban park. We also have focused on outdoor thermal comfort by ENVI-met as a numerical model for the different planting design scenarios. Such knowledge is important in the development of urban landscape programs based on the various planting designs in urban parks.

Figure 1. The urban park (Golha) in Mashhad City, Google earth software 2017

## 1. Methods

As the main idea of this paper is to study winter thermal sensation in green areas like parks, simulation of different planting designs is crucial. Recently, some modeling softwares such as ENVI-met, have been developed for numerical simulations that can easily simulate such study area. In the present study we simulated micro-scale thermal interactions with ENVI-met Version 3.1 BETA V (Bruse 2013) to investigate effects of different planting designs on the winter thermal sensation. ENVI-met is a non-hydrostatic prognostic and three-dimensional numerical model that can simulate the surface-plant-air interactions of urban environments with a typical resolution of 0.5-10 min. It nearly has the complete capability to simulate built environments from microclimate scale to local climate scale in any location. Main variables of the ENVI-met software are air temperature, humidity, wind velocity and direction, turbulence, radiative fluxes, bioclimatology and gas and particle dispersion. In the ENVI-met program four user interfaces has been planned. The First interface edits the input of the digital maps of the area. The second one or the configuration editor is the databases for entering temperature, humidity, soil types etc.  In the third interface or the modeling area, additional parameters are presented and the modeling process implemented. The last interface is LEONARDO where the input data is interpreted and visualized (Ozkeresteci *et al.* 2003).

### 1.1. Study area

Our study was conducted in Mashhad (36°26′05″ N; 59°61′68″ E; 985 m elevation) in the northeast of Iran, Khorasan province. Mashhad, with a population of 2.7 million, is the second-largest city in Iran. It has a local steppe climate (Köppen BSk) with hot summers and cool winter, the average annual precipitation of 251.5 mm and the temperature of 14.3 °C (Salahi *et al.* 2016). Over the course of a year, the temperature typically varies from –3 °C to 35 °C and is rarely below –8 °C or above 38 °C. The study area was an urban park (Golha) that has an area of 2.8 ha surrounded by medium-density urban buildings. This park has been located in a crowded residential area of Mashhad city that many people visit the park during the year. Golha park is surrounded by many buildings including one to four floors which can be seen from three sides of the park and another side of this park is located in paralell with a high traffic street (Figure 1).

### 1.2. Measurement of environmental and vegetation parameters

To collect data, two places were selected in the park where being used by more users to relax and sit there. Micro-meteorological stations installed near the bench at 1.5 m meters above the ground (Figure 1). The microclimatic parameters were measured during the coldest period of the year, 8 days. The period was calculated based on the weather data for the past 20 years from Mashhad weather station. During the coldest period of 2016, we obtained hourly temperature, relative humidity, wind velocity and other data that have been mentioned in Table 1. Finally, one of these days (8 days), when the sky was clearly sunny (January 10, 2016) for estimating was selected.

The vegetation data required by ENVI-met for the evaluation and simulation was collected on-site. Three vegetation types including trees, shrubs and grass were identified. In the study area Plane tree (*Platanus orientalis*) as a deciduous and Eldarica Pine as an evergreen (*Pinus eldarica*), Privet (*Ligustrum vulgare*) as a shrub and Smooth meadow-grass (*Poa pratensis*) as a grass were modeled. Plane tree is a deciduous with maple-like leaves. It can reach up to 80 feet in height. Plane tree has very strong branches and is quite useful as a shade tree. Eldarica Pine is an evergreen that grow rapidly when young, it reaches heights of 30 to 40 feet and is quite dense.

Privet is a semi evergreen shrub, growing to 3 m tall. It is a popular hedging plant in the urban area. Smooth meadow-grass is a perennial grass that forms a valuable pasture plant and also can use in the urban landscape as a cover plant (Rajabali 2010). The selected plants are proper options for using in the urban areas which commonly apply in the landscaping of Mashhad. The LAD values, its vertical distribution in 10 different heights and root depth for plants were calculated by Lalic, Mihailovic (2004); Schenk, Jackson (2002), respectively.

Table 1. Meteorological inputs for the configuration file of the ENVI-met model on simulation day

| No. | Parameter | Value |
|---|---|---|
| 1 | Air Temperature | 4 °C |
| 2 | Relative Humidity | 60% |
| 3 | Wind Velocity | 2.6 m/s at 10 m height |
| 4 | Ground Temperature | 7.55 °C from 0–20 cm,<br>8.15 °C from 20–50 cm,<br>9.95 °C below 50 cm |
| 5 | Ground Humidity | 32.1% from 0–20 cm,<br>19.5% from 20–50 cm,<br>18.4% below 50 cm |

## 1.3. Simulation scenarios

To simulate the effect of the current and also other planting designs in the park on winter thermal sensation on January 10, 2016, seven different scenarios was simulated:

- Scenario A: The current park, including asphalt surfaces, buildings in the vicinity and with a planting design including 50% grass, 40% deciduous and 10% evergreen trees.
- Scenario B: Scenario A but different in terms of planting design, including 100% deciduous trees.
- Scenario C: Scenario A but different in terms of planting design, including 100% evergreen trees.
- Scenario D: Scenario A but different in terms of planting design, including 100% grass.
- Scenario E: Scenario A but different in terms of planting design, including, 50:50% deciduous and evergreen trees.
- Scenario F: Scenario A but different in term of planting design, including, 70:30% deciduous and evergreen trees, respectively.
- Scenario G: Scenario A but different in term of planting design, including, 30:70% deciduous and evergreen trees, respectively (Figure 2).

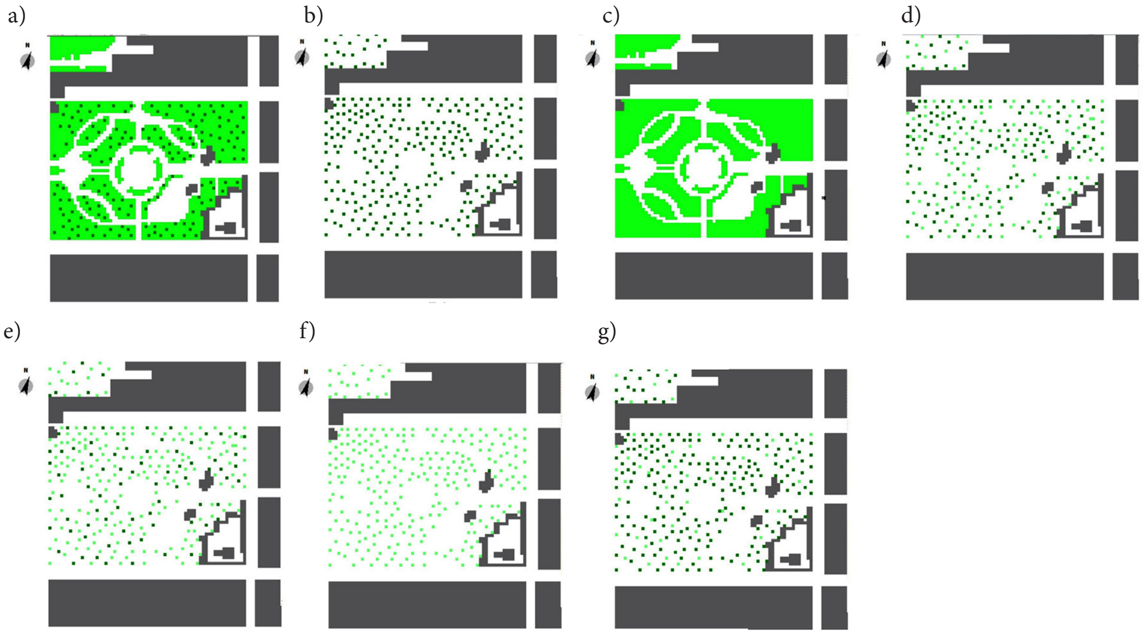

Figure 2. Simulated scenarios in the park with different planting design, a): the current park, b): 100% evergreen trees, c): 100% grass, d): 50:50% deciduous and evergreen trees, e): 70:30% deciduous and evergreen trees, f): 100% deciduous trees and g): 30:70% deciduous and evergreen trees. EVI-Met software 3.0., Leonardo 3.0

The scenarios were simulated in the time period of 8 hours (8–16 hours) that the people spend more time outdoors. Differences among the mentioned scenarios could indicate the effect of landscape design in terms of the planting ratio of deciduous and evergreen trees and also grasses on human thermal sensation in the winter.

## 2. Results

### 2.1. ENVI-met model validation

The comparison between recorded and simulated values of mean air temperature, relative humidity and wind velocity of the current park in the period time from 08:00–16:00 is presented in Figure 3. The parameters that were estimated by the model strongly agreed with the recorded value of air temperature, relative humidity and wind velocity it is evident from higher value of $R^2 = 0.99$, $R^2 = 0.99$, $R^2 = 0.84$ respectively. According to the above results, it could be concluded that the model fitted with the simulation model was suitable for the present purpose.

As can be seen in Table 2, simulated weather parameters including potential temperature (Tp), relative humidity (RH) and wind velocity (WV) were significantly different between the various scenarios and the time period.

The highest temperature was observed in the scenario of 100% grass (9.11 °C) and the lowest temperature was found in 100% evergreen, 30:70% deciduous: evergreen and also 50:50% evergreen: deciduous (mean 5.51 °C) that the mentioned scenarios had significant difference with each other and also other scenarios (Figure 4). During simulated time period from 08:00 to 13:00 and then from 13:00 to 16:00, temperature indicated a significant increasing and decreasing trend, respectively (Figure 4).

The outputs of ENVI-met model showed that relative humidity between scenarios of 50:50% evergreen: deciduous, 30:70% deciduous: evergreen and 100% evergreen with 100% grass was significantly different while among other scenarios was not found any difference (Figure 5).

The trend of relative humidity changes during simulated time period from 8–16 was generally rising. The greatest humidity difference was recorded between 08:00–09:00 that was statistically significant (Figure 5). Simulated date indicated only between scenarios of the current park and 100% evergreen with other scenarios there was a significant difference. Overall, the trend of wind velocity changes during simulated time period from 08:00 to 16:00 was decreasing. The highest wind velocity was achieved at 08:00 (2.1 m/s) (Figure 6).

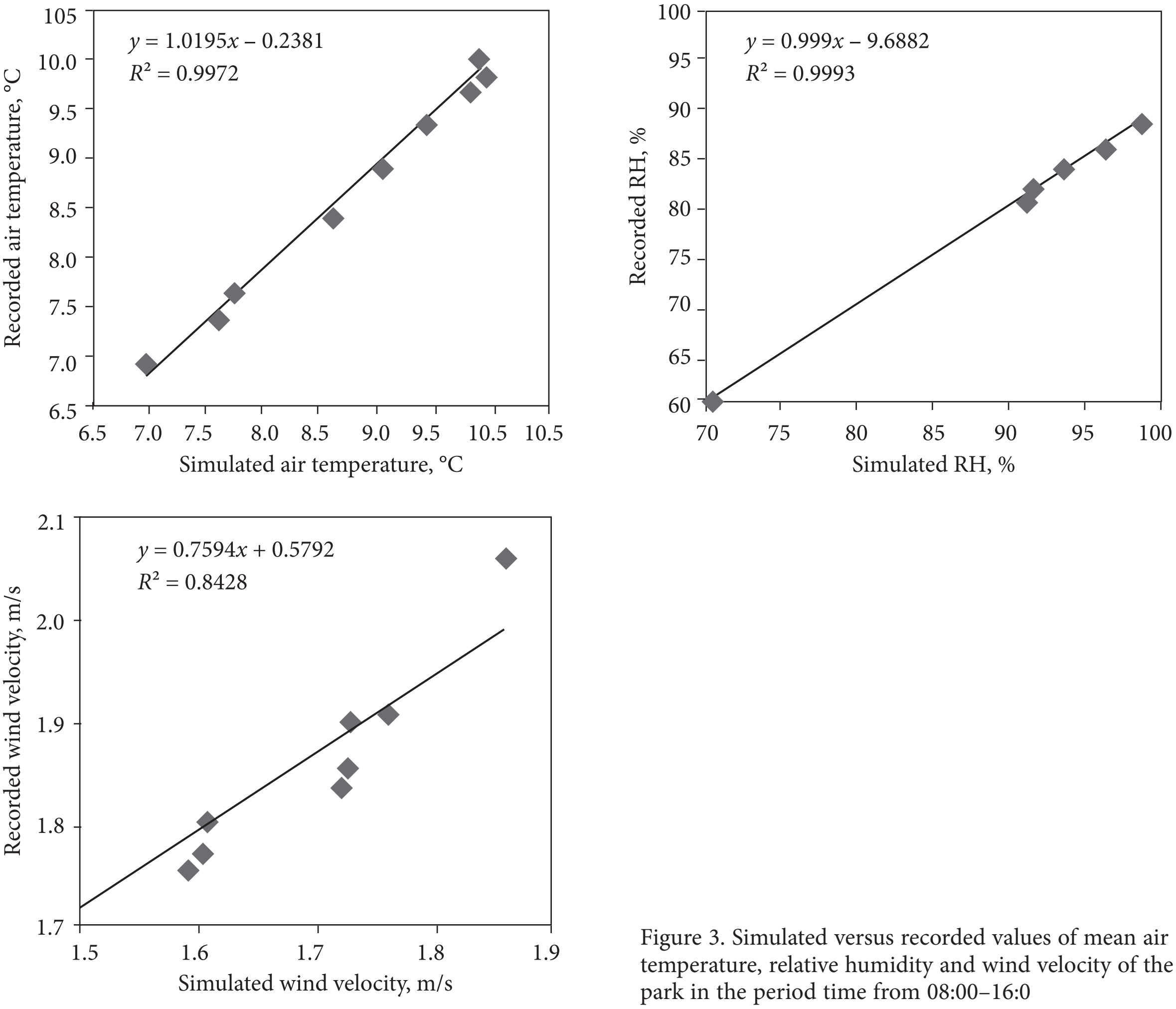

Figure 3. Simulated versus recorded values of mean air temperature, relative humidity and wind velocity of the current park in the period time from 08:00–16:0

Table 2. Analysis of Variance of weather parameters (Tp, RH and WV) in different scenarios and the time period

| Source of Variation | Parameters | Degree of freedom | Sum of square | Mean square | F-ratio | Significance level |
|---|---|---|---|---|---|---|
| Scenarios | Tp | 6 | 2.72 | 0.45 | 35.39 | 0.000 |
| | RH | | 9.12 | 1.52 | 3.97 | 0.003 |
| | Wv | | 0.4 | 0.07 | 14.63 | 0.000 |
| Time | Tp | 8 | 71.65 | 8.95 | 0.88 | 0.000 |
| | RH | | 3669.25 | 458.66 | 1196.89 | 0.000 |
| | Wv | | 0.55 | 0.07 | 14.82 | 0.000 |
| Error | Tp | 43 | 0.61 | 0.01 | – | – |
| | RH | | 18.39 | 0.38 | – | – |
| | Wv | | 0.22 | 0.00 | – | – |
| Total | Tp | 62 | 74.99 | – | – | – |
| | RH | | 3696.76 | – | – | – |
| | Wv | | 1.118 | – | – | – |

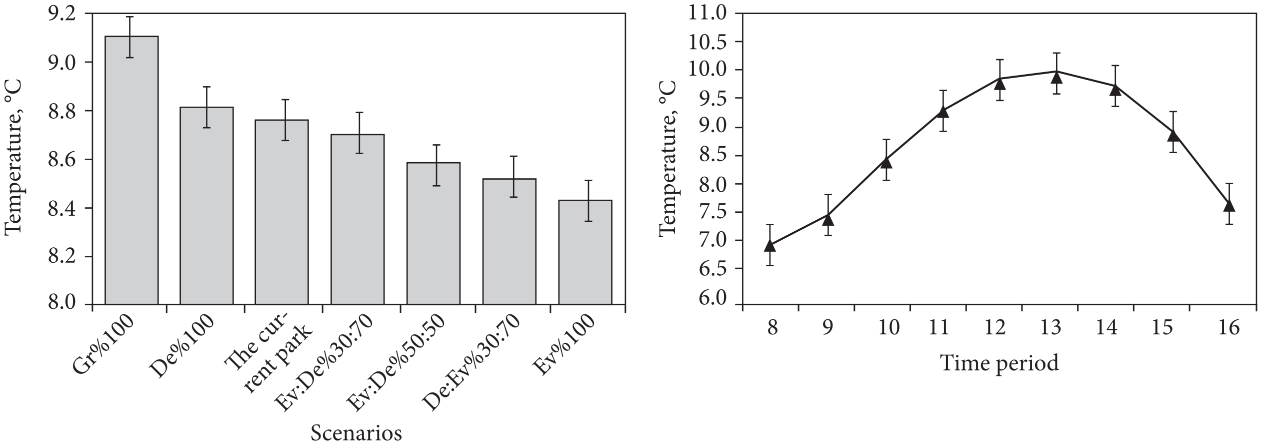

Figure 4. Comparison of temperature in the various simulated scenarios and in the period time (08:00–16:00)

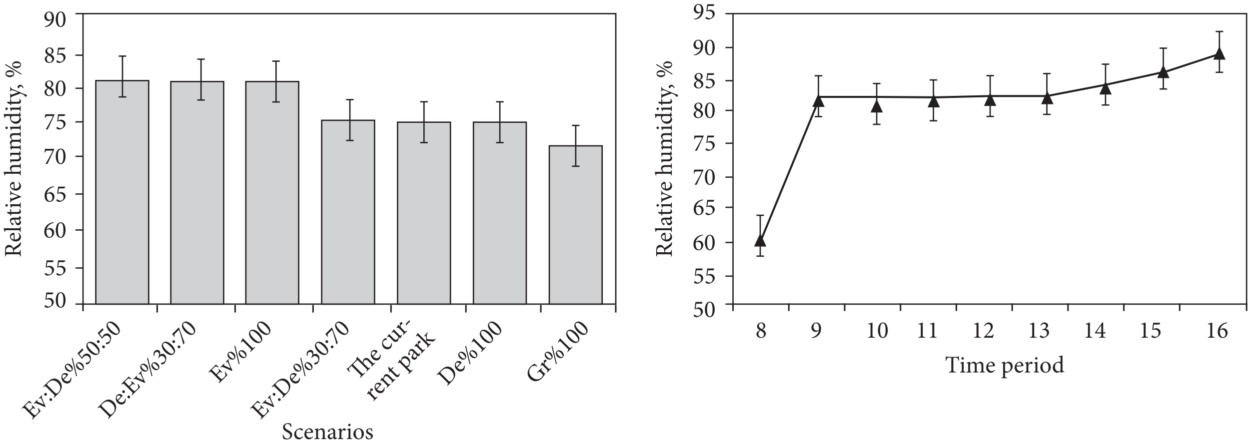

Figure 5. Comparison of RH in the various simulated scenarios and in the period time (08:00–16:00)

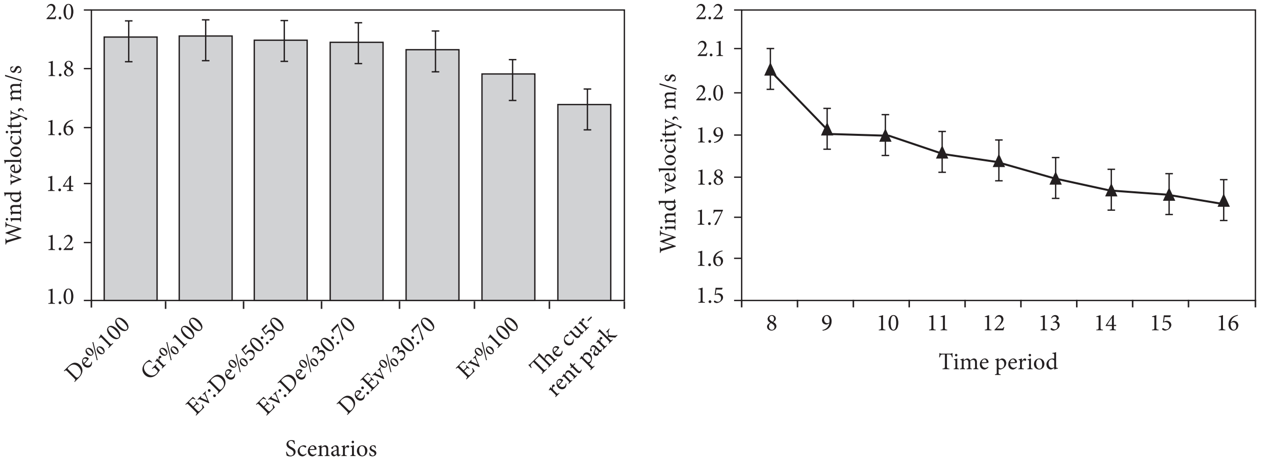

Figure 6. Comparison of WV in the various simulated scenarios and in the period time (08:00–16:00)

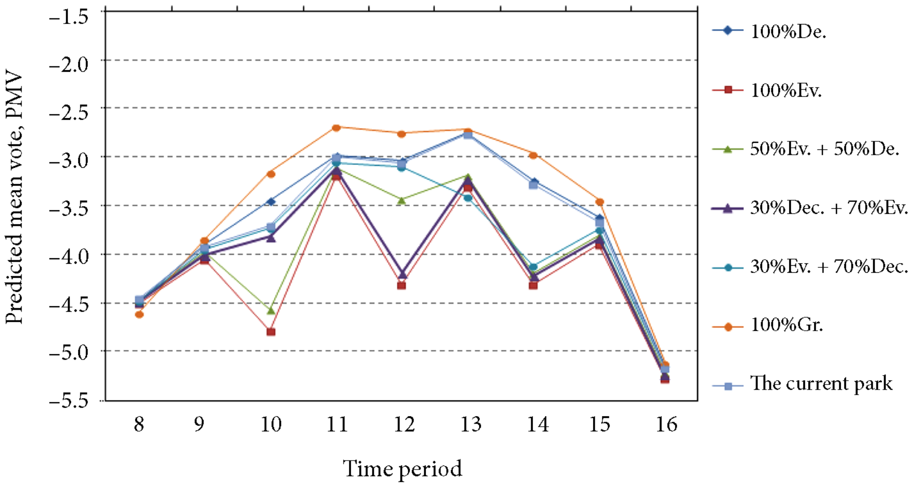

Figure 7. Comparison of PMV in the various simulated scenarios during the period time 08:00–16:00

Figure 6 shows PMV index in various simulated scenarios and during the period time from 08:00–16:00 was between –2.7 and –5.2, values considered inside the limits of strong cold stress (–3.5 < PMV< –2.5) and extreme cold stress (–3.5 > PMV). The lowest PMV was obtained in 08:00, 10:00 and16:00. Most of the scenarios studied between 11:00 to 13:00 had values of PMV between –2.8 and –3.4 (the greatest values). Scenarios of 100% grass and 100% deciduous tree indicated the highest mean PMV (nearly equal to –3.5 and –3.6 respectively) while the 100% evergreen showed the lowest mean PMV (equal to –4.2). Moreover, most of the hours studied in the scenario of 100% grass (66.7%) and then 100% deciduous tree (55.5%), were inside the range of less cold stress (PMV < –3.5) (Figure 7).

## 3. Discussion

The main purpose of this paper is to study how to design an urban park by different types of plants including the species of deciduous and evergreen trees, shrubs and lawns to improve the microclimate during the cold periods of the year for urban park users. Three climate key parameters to estimate the human thermal comfort are temperature, humidity and also wind velocity (Jeong *et al.* 2015). Based on an extensive bibliographic survey, the main characteristics of vegetation that can affect the urban microclimate including evapotranspiration, transmission, albedo and permeability. Evapotranspiration phenomenon causes to the reduction of air temperature. Transmission and albedo related to the impact of vegetation on solar and daylight access that varied during the year in particular for deciduous trees. Permeability is a parameter related to the penetrance of vegetation to wind (Dimoudi, Nikolopoulou 2003).

In order to test the various planting designs, numerical simulations using ENVI-met took place in an urban park with some scenarios. Simulating of different planting design scenarios indicated that when selecting only evergreen trees, humidity was relatively high in the park, while simulated temperature and wind velocity were decreased during the studied period. Additionally, the ratio of evergreen trees was greater, the temperature was lower but humidity and wind velocity were higher. Some previous studies proved that evergreen trees due to the effects of permanent canopy and therefore permanent shadow can reduce the temperature in the winter (Wang *et al.* 2015; Ali-Toudert 2005; Akbari 2002). In addition, evapotranspiration from vegetation could reduce air temperature and increase humidity (Shahidan *et al.* 2012; Middel *et al.* 2014). Evergreen trees due to permanent canopy reduce the cold wind blowing in the winter. Moreover, the evapotranspiration of vegetation in particular from leaves, adds moisture to the environment which could raises humidity (Akbari 2002).

Simulated grass covered park and also deciduous trees showed higher temperature and wind velocity. Grasses than deciduous trees and in the next level evergreen trees due to limited shading and thus more light emission in the ambient, can cause further rise in temperature in the winters. Compared with evergreen trees, evapotranspiration of deciduous trees and also grasses is relatively small during the wintertime, because deciduous trees do not have foliage and grasses have smaller leaf area in the time, therefore evergreen trees can cause a higher relative humidity in the ambient (Ali-Toudert 2005). As the grass height is low than a tree and also to drop the leaves of deciduous trees in the cold seasons, scenario of grasses and the scenarios with high ratio of deciduous trees in comparison with other scenarios indicated lower wind speeds. Evergreen trees can deflect or block the wind and may act like a solid barrier (Ali-Toudert 2005). According to Wang (2016) evergreen trees lowered winter temperatures, hence, deciduous trees that do not lower winter temperature have more benefits for human comfort compared to evergreen trees.

Vegetation as an important design element could improve urban microclimate and outdoor thermal comfort for dwellers. As mentioned in the results section, the comfort level in all scenarios was uncomfortable. Although in the simulated scenarios of 100% grass and also 100% deciduous trees PMV value (averagely –3.5) was increased. The PMV value was better than the "extreme cold stress" thermal condition experienced at all other scenarios in particular for 100% scenario of 100% evergreen trees (–4 > PMV) within modeled park. With rising percentage of evergreen trees in simulated scenarios, the PMV value was also increased. Three important climatic factors that affect PMV index (temperature, humidity and wind speed) can also affect by vegetation through shading, humidification and wind break.

Eldarica Pine as an evergreen tree, due to its rapid growth and drought resistance are planted extensively in semiarid and arid regions like Iran. From the microclimate point, some researches indicated that the evergreen trees arenot the right option for planting in the urban area with a cold climate winter (Wang *et al.* 2016; Middel *et al.* 2014; Ali-Toudert 2005).

Deciduous trees due to temporal changes of canopy are considered as an opportunity for shading in the summers and solar permeability during the winters. In the temperate climate, deciduous trees are suitable option to improve the urban microclimate during the winter because of allowing solar radiation and heating the ambient (Ramesh 2016).

Plane tree (*Platanus orientalis*) is a very large and wide tree deciduous. Its native range is Eurasia from the Balkans to at least as far east as Iran. This tree due to broad and thick leaves and also wide canopy, creates a pleasant shade in the summer seasons The plane trees are widely planted to improve the microclimate (Pourkhabbaz *et al.* 2010). Some studies that prove that deciduous trees are a good option to plant in the urban areas with hot summers and cold winters (Ramesh 2016; Toy, Yilmaz 2010; Ali-Toudert 2005).

Smooth meadow-grass (*Poa pratensis*) is a perennial and cool season grass that is native to Europe and Asia. This grass can survive in the coldest winters and commonly used as lawn and pasture seed in the various countries in particular cold regions (Tarasoff *et al.* 2007). The effectiveness of vegetation morphology (presence or absence leaves in plants, leaves size and angle, plant height, crown density and permeability) in terms of controlling climatic elements is clearly reflected in studies by Ali-Toudert and Mayer (2006), Ong (2003) and McPherson (1994).

## Conclusions

From our findings, it can be seen that planting design is an influencing factor in the winter microclimate and thermal comfort. The vegetation type and ratio could improve winter thermal comfort in an urban microclimate. PMV as an important thermal comfort index could be affected by vegetation. Although the results indicated that neither of the simulated scenarios were in the range without thermal stress (comfortable), However when more percentage of deciduous trees and also grass were simulated in planting design of the park, the temperature (as a key parameter in microclimate) was increased and winter thermal comfort improved. Despite the importance of evergreens trees in the urban planting design, results of the present study indicated that the evergreens such as Eldarica Pine, mainly due to the creation of permanent shadow, might not be the right option in the regions with cold winters. Unlike the evergreens, deciduous trees such as Plane tree due to lose of leaves in the autumns and pass the more sunlight through their canopies are a suitable option for planting in the urban areas with cold winters. Considering that grasses such as Smooth meadow-grass could also improve thermal comfort, with the cold season approaching, it can be planted in the playground. Planting design needs to be appropriate for cold climate cities and future climate changes.

The findings presented in this study is an applied result for urban landscape designers that should consider the potential of different vegetation types and the ratio of them to mitigate of severe cold and improving winter thermal comfort.

## Acknowledgements

This work was financially supported by Vice President for Research and Technology, Ferdowsi University of Mashad-Iran [37462, 12/05/2015]; Master Thesis, Plan No. 3.

## References

Abreu-Harbich, L.V.; Labaki, L.C.; Matzarakis, A. 2015. Effect of tree planting design and tree species on human thermal comfort in the tropics, *Landscape and Urban Planning* 138: 99–109. https://doi.org/10.1016/j.landurbplan.2015.02.008

Akbari, H. 2002. Shade trees reduce building energy use and $CO_2$ emissions from power plants, *Environmental Pollution* 116: 119–126. https://doi.org/10.1016/S0269-7491(01)00264-0

Ali-Toudert, F. 2005. *Dependence of outdoor thermal comfort on street design in hot and dry climate*: PhD thesis. University of Freiburg, Germany.

Ali-Toudert, F.; Mayer, H. 2006. Numerical study on the effects of aspect ratio and orientation of an urban street canyon on outdoor thermal comfort in hot and dry climate, *Building and Environment* 41(2): 94–108. https://doi.org/10.1016/j.buildenv.2005.01.013

ASHRAE. 2001. *ASHRAE Fundamentals Handbook 2001*. (SI Edition). American Society of Heating, Refrigerating, and Air-Conditioning Engineers.

Brown, R. D.; Gillespie, T. J. 1995. Microclimatic landscape design: creating thermal comfort and energy efficiency. New Yourk, USA: Somerset, John Wiley & Sons.

Bruse, M. 2013. ENVI-met 3.1 BETA V. Retrieved from http://www.envi-met.com/

Dimoudi, A.; Nikolopoulou, M. 2003. Vegetation in the urban environment: microclimatic analysis and benefits, *Energy and Buildings* 35: 69–76. https://doi.org/10.1016/S0378-7788(02)00081-6

Fanger, P. O. 1972. *Thermal comfort: analysis and applications in environmental engineering*. McGraw-Hill Companies, 244.

Ferrante, A.; Mihalakakou, G. 2001. The influence of water, green and selected passive techniques on the rehabilitation of historical industrial buildings in urban areas, *Solar Energy* 70(3): 245–253. https://doi.org/10.1016/S0038-092X(00)00100-6

Feyisa, G. L.; Dons, K.; Meilby, H. 2014. Efficiency of parks in mitigating urban heat island effect: an example from Addis Ababa, *Landscape and Urban Planning* 123: 87–95. https://doi.org/10.1016/j.landurbplan.2013.12.008

Jeong, D.; Park, K.; Song, B.; Kim, G.; Choi, C.; Moon, B. 2015. Validation of ENVI-met PMV values by in-situ measurements, in *9th International Conference on Urban Climate jointly with 12th Symposium on the Urban Environment*, 20–24 July 2015, Toulouse, France.

Kotzen, B. 2003. An investigation of shade under six different tree species of the Negev desert towards their potential use for enhancing micro-climatic conditions in landscape architectural development, *Journal of Arid Environments* 55: 231–724. https://doi.org/10.1016/S0140-1963(03)00030-2

Lalic, B.; Mihailovic, D. T. 2004. An empirical relation describing leaf area density inside the forest for environmental modeling, *Journal of Applied Meteorology and Climatology*, 43(4): 641–645. https://doi.org/10.1175/1520-0450(2004)043<0641:AERDLD>2.0.CO;2

McPherson, E. G. 1994. *Energy-saving potential of trees in Chicago. Chicago's urban forest ecosystem: Results of the Chicago urban forest climate project*. USDA forest service, General Technical Report NE, 186, 95-113.

Middel, A.; Häb, K.; Brazel, A. J.; Martin, C. A.; Guhathakurta, S. 2014. Impact of urban form and design on mid-afternoon microclimate in Phoenix Local Climate Zones, *Landscape and Urban Planning* 122: 16–28. https://doi.org/10.1016/j.landurbplan.2013.11.004

Ong, B. L. 2003. Green plot ratio: an ecological measure for architecture and urban planning, *Landscape and Urban Planning* 63(4): 197–211. https://doi.org/10.1016/S0169-2046(02)00191-3

Ozkeresteci, I.; Crewe, K.; Brazel, A. J.; Bruse, M. 2003. Use and evaluation of the ENVI-met model for environmental design and planning: an experiment on linear parks, in *Cartographic Renaissance, Proceedings of the 21 International Cartographic Conference* (ICC), 2003, Durban, South Africa.

Pourkhabbaz, A.; Rastin, N.; Olbrich, A.; Langenfeld-Heyser, R.; Polle, A. 2010. Influence of environmental pollution on leaf properties of urban plane trees, *Platanus orientalis* L., *The Bulletin of Environmental Contamination and Toxicology* 85: 251–255. https://doi.org/10.1007/s00128-010-0047-4

Rajabali, M. S. 2010. *Color atlas of ornamental plants of Iran*. Ir: Taraghi Press.

Ramesh, S. 2016. Energy efficient landscape for thermal comfort in buildings and built-up areas, *International Journal of Engineering and Technology* 8(5): 338–344. https://doi.org/10.7763/IJET.2016.V8.909

Robinson, N. 2004. *The planting design handbook*. UK: Ashgate Press.

Salahi, B.; Nohegar, A.; Behrouzi, M. 2016. The modeling of precipitation and future droughts of mashhad plain using stochastic time series and standardized precipitation index (SPI), *International Journal of Environmental Research* 10(4): 625–636.

Schenk, H. J.; Jackson, R. B. 2002. Rooting depths, lateral root spreads and below ground/above-ground allometries of plants in water-limited ecosystems, *Journal of Ecology* 90(3): 480–494. https://doi.org/10.1046/j.1365-2745.2002.00682.x

Shahidan, M. F.; Jones, P. J.; Gwilliam, J.; Salleh, E. 2012. An evaluation of outdoor and building environment cooling achieved through combination modification of trees with ground materials, *Building and Environment* 58: 245–257. https://doi.org/10.1016/j.buildenv.2012.07.012

Streiling, S.; Matzarakis, A. 2003. Influence of single and small clusters of trees on the bioclimate of a city: a case study, *Journal of Arboriculture* 29: 309–316.

Tarasoff, C. S.; Ball, D. A.; Mallory-Smith, C. A. 2007. Extreme ionic and temperature effects on germination of weeping alkaligrass (*Puccinellia distans*), Nuttall's alkaligrass (*Puccinellia nuttalliana*) and Kentucky bluegrass (*Poa pratensis*), *Weed Science* 55: 305–310. https://doi.org/10.1614/WS-06-170.1

Thani, S. K. S. O.; Nik Mohammad, N. H.; Idilfitri, S. 2013. Amelioration of Urban temperature through landscape design approaching hot-humid climate: a review, *Asian Journal of Environment-Behaviour Studies* 4(13): 13–28.

Thoma, J. K.; Couttsa, A. M.; Broadbenta, A. M.; Tapper, N. J. 2016. The influence of increasing tree cover on mean radiant temperature across a mixed development suburb in Adelaide, Australia, *Urban Forestry & Urban Greening* 20: 233–242. https://doi.org/10.1016/j.ufug.2016.08.016

Toy, S.; Yilmaz, S. 2010. Thermal sensation of people performing recreational activities in shadowy environment: a case study from Turkey, *Theoretical and Applied Climatology* 101: 329–343. https://doi.org/10.1007/s00704-009-0220-z

Wang, Y. 2016. *The effect of urban green infrastructure on local microclimate and human thermal comfort*: PhD Thesis. Wageningen University, Netherlands.

Wang, Y.; Bakker, F.; de Groot, R.; Wortche, H.; Leemans, R. 2015. Effects of urban trees on local outdoor microclimate: synthesizing field measurements by numerical modelling, *Urban Ecosystems* 18(4): 1305–1331. https://doi.org/10.1007/s11252-015-0447-7