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Effects of different floor covering materials on thermal comfort in landscape design studies

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1. Introduction

In the context of this study, effects of six different floor covering materials (grass, travertine, empenyel wood, andesite, soil and asphalt) on thermal comfort are determined. Three different landscape design projects covering 500square meters with different floor materials are analysed for thermal comfort. During July in cloudless days, PET (Physiologically Equivalent Temperature) values were measured by using RayMan Pro program with surface temperatures, air temperature, wind and humidity data obtained at 12:00. The findings show that according to PET values (grass: 25.9°C, travertine: 26.1°C, impregnated wood: 28.9°C, andesite: 27.1°C, soil: 27.5°C and asphalt: 28.5°C); PET value was calculated as 26.3°C in the first project in which surfaces mostly covered with grass and travertine; in the second project mostly covered with wood and asphalt, PET value was 28.1°C; and finally in the third project, PET was calculated as 27.02°C. In conclusion, design based suggestions related to the use of floor materials in urban areas are made for decreasing urban heat island effects and for designing comfortable places in hot climate cities.

Urban population increases all over the world. According to 2012 UN Report, 52% of world population lives in urban areas (3.6 bl.), which is expected to reach 6.3 bl. by 2050 (Aguiar et al., 2014). Increase in urban population brings many problems together. While urban areas enlarge, impervious and reflecting surfaces also increase, rangelands, grasslands, wetlands and other natural rural areas decrease. Such changes on the earth surface bring together some climatic unfavorable changes among which urban heat island (UHI) take place as the hot topics for the last years (Oke 1982; Chen et al., 2007; Memon et al., 2008; Takebayashi and Moriyama, 2009; Connor et al., 2013;).

Urban people live dependent on natural and rural areas for energy, nutrient and water supply. Among the factors increasing energy consumption, UHI is very effective. It is known that in thermally comfortable cities, energy demand is less. In many studies, urban thermal comfort conditions are evaluated in literature and the effect and importance of green areas on the mitigation of UHI are reported (Unger 1999; Gulyas et al. 2006; Yilmaz et al. 2008; Matzarakis and Endler 2010; Toy et and Yilmaz 2010).

There is a strong relationship between land surface temperature (LST) and landscape matrices. Urban landscape configuration has also effects on UHI formation (Li et al., 2011; Zhou et al., 2011; Connor et al., 2013; Li et al., 2014).

Due to increasing population and urban areas cultural landscapes are created however; inevitable problems in natural landscapes are also seen. Therefore, significant responsibilities are granted to landscape architects. It is very important to consider the thermal conditions of urban areas while carrying out landscape works and shaping earth surface in order to decrease the rate of UHI formation.

Landscape architecture is among the disciplines contributing to shaping urban and rural landscapes, by planning, designing, restoring, protecting and managing them. In landscape planning, decision making on land uses and in landscape design works decisions on plantation and surface covering materials are vitally important factors. Materials and plants preferred in especially urban landscape works are also effective on urban climate. Each design work can cause a microclimate in it and close environment.

Effects of different surface covers and their colors, extensive impervious surfaces like car parks, alternative covers and different plant species are studied on UHI and thermal conditions and energy consumption (Synnefa et al., 2007; Yilmaz et. al., 2008; Aguiar et al., 2014; Lagouarde et al., 2012; Takebayashi and Moriyama, 2009; Leuzinger et al., 2010)

The aim of the present study is to show that covering materials used in landscape architecture works may be effective on UHI formation and mitigation. Grass, travertine, impregnated wood, andesite, soil and asphalt preferred mostly in landscape works were evaluated in 3 different landscape design projects for the calculation of thermal comfort using these covering materials at different rates. The project prepared in the scope of the study is among the first studies where thermal comfort can be calculated before the application of the project.

2. Material and Method

The study was carried out in the study of Erzurum, east of Turkey (Figure 1). Ata Botanical Garden located in the city center shelters grass, travertine, impregnated wood, andesite, soil and asphalt surfaces and surface temperatures were measured using Infrared Thermometer (CEM-DT-8812) at the Garden, on arid days at 12.00 in July one of the warmest months of the year in the city.

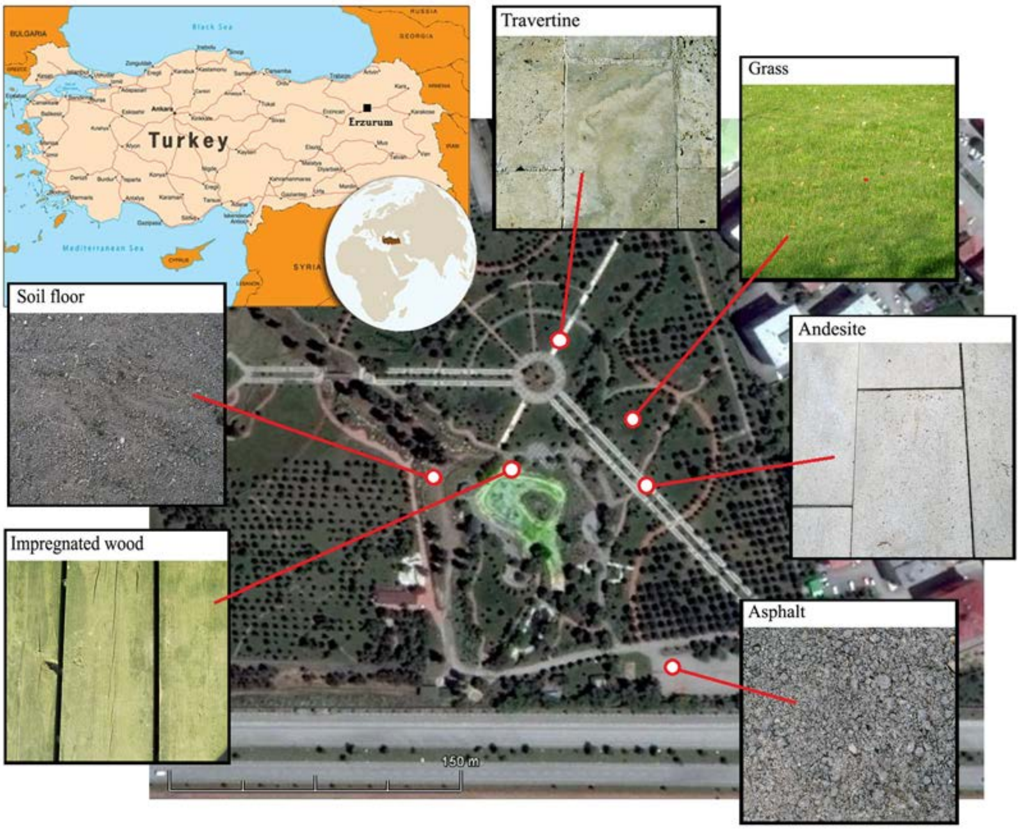


Figure 1.Location of the study area and measurement surfaces

In addition to surface temperature, air temperature, relative humidity, wind and cloudiness were also taken into consideration by obtaining them from official weather station while calculating thermal comfort values PET (Physiologicall Equivalent Temperature) using RayMan Pro Models (Figure 2; Matzarakis et al., 1999; 2007). PET values were also evaluated and classified according to Table 1 (PET Index Comfort Intervals) and effects of different surfaces were determined on thermal comfort.

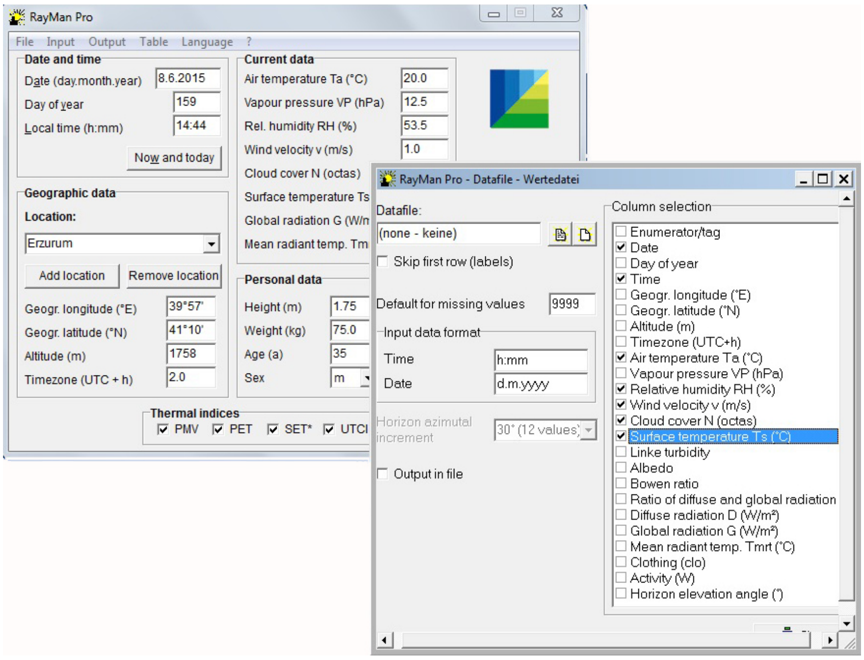


Figure 2. RayMan Pro Model and interfaces

Table 1. PET Index Comfort Intervals (Matzarakis et al. 1999)

PET (ºC)	**Thermal perception**	**Grade of physiological stress**
< 4	Very cold	Extreme cold stress
4,1 - 8,0	Cold	Strong cold stress
8,1 - 13,0	Cool	Moderate cold stress
13,1 - 18,0	Slightly cool	Slight cold stress
18,1 - 23,0	Comfortable	No thermal stress
23,1 - 29,0	Slightly warm	Slight heat stress
29,1 - 35,0	Warm	Moderate heat stress
35,1 - 41,0	Hot	Strong heat stress
>41,0	Very hot	Extreme heat stress

Three different landscape design projects were prepared involving grass, travertine, impregnated wood, andesite, soil and asphalt surfaces at different rates. At these simulation projects, totally 500 - m^2 house garden was taken into evaluation. Each of the design was evaluated for comfort values (PET) considering the rates of surface covering materials with different PET rates.

3. Results

PET values were calculated for each material using the data measured during July and other climatic data of the city RayMan Pro Model (Table 2).

Table 2. Air temperature and PET at 12.00 over different covers

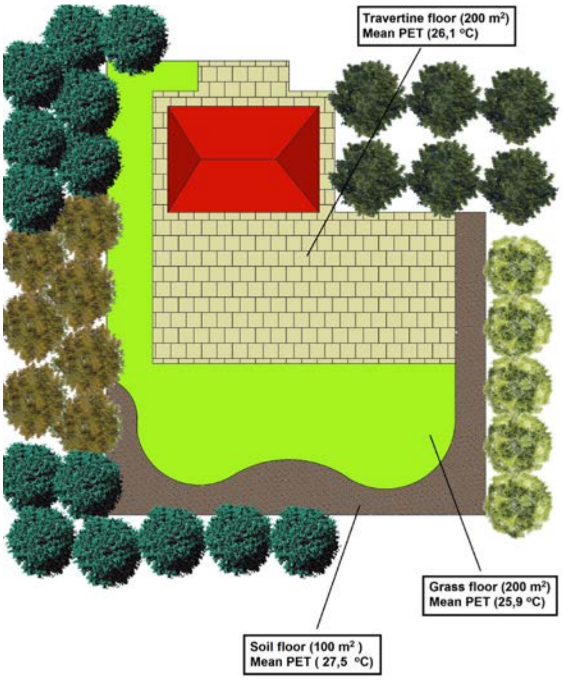
Hour	**Sunny day**	**Andesite (PET °C)**	**Travertine (PET °C)**	**Impreg. Wood (PET °C)**	**Soil floor (PET °C)**	**Asphalt (PET °C)**	**Grass (PET °C)**	**Air (°C)**
12:00	10	31	29.4	34.5	30.3	32.7	28.9	30.5
12:00	11	29	28.7	30.8	28.8	30.6	28.5	27.8
12:00	12	34.3	33.1	35.9	35.2	35.9	31.9	32.6
12:00	13	35	34	36.8	36.6	36.6	34.1	34.5
12:00	14	32.7	31.3	33.5	31.9	32.8	31.3	30.9
12:00	15	26.2	25.3	27.9	26	27.3	25.3	24.8
12:00	16	26.7	25.2	29.6	27.5	27.9	25.5	26.4
12:00	17	25.1	23.6	26.3	25.5	26.3	23.8	23.7
12:00	18	33.2	32.1	32.4	33.4	34.1	31	32.9
12:00	19	28.7	27	27.6	27.8	30.3	26.4	26.2
12:00	20	21.1	20.3	23.4	21	22.1	20.5	19.6
12:00	21	30	28.5	32.8	31.5	31.7	28	28.0
12:00	22	20.8	20.5	22	21.5	22.2	20.5	19.9
12:00	23	23.6	22.4	24.9	24.4	25.1	23.3	22.4
12:00	26	30.1	29.3	32.5	31.5	32.5	30	29.4
12:00	27	29.1	29.1	32.4	30.1	31.1	28.5	28.5
12:00	28	13	12.3	12.1	12.2	13.3	12.2	12.7
12:00	29	20.8	20	23.8	21.4	22.5	20.3	19.3
12:00	30	22.5	21.6	25.2	23.2	24.2	21.5	20.6
12:00	31	29	27.7	33.2	30.9	31.6	27.6	27.1
Mean PET (°C)		**27.1**	**26.1**	**28.9**	**27.5**	**28.5**	**25.9**	**25.9**

All the PET values calculated were found to be in the range of Slight heat stress (23.1 – 29.0 °C). Grass and travertine covers represented the lower PET values while impregnated wood and asphalt gave the higher comfort values. Grass and travertine surfaces offer the closest range to comfortable conditions.

By considering these values, a 500-m^2 area of house garden was designed and 3 different landscape design projects were prepared for the same area by using the different rates of these surface covering materials. By rating surface area and PET values each project was attained to a mean PET value.

3.1. Landscape Design 1

In the Landscape Design Project 1 (LDP 1), designed for a hose under the conditions of Erzurum grass, travertine and soil surfaces were used and in the rates of 200 m^2, 200 m^2 and 100 m^2 , respectively (Figure 3).

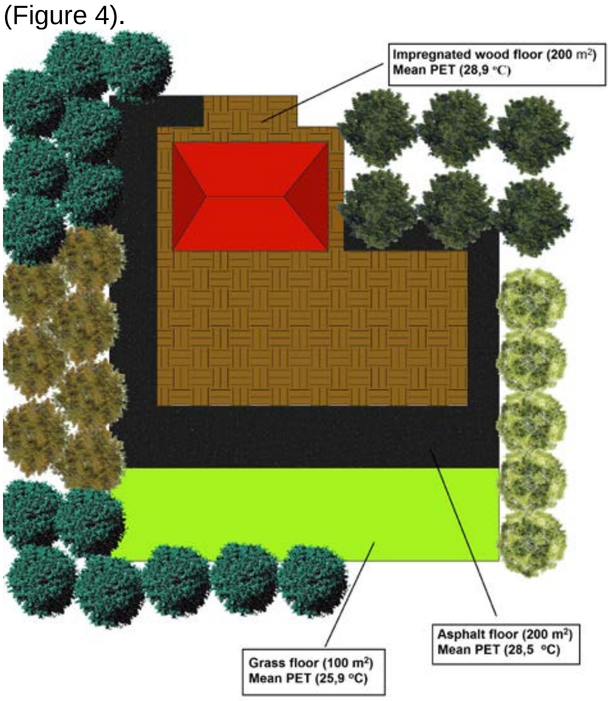


Means of PET values for the surfaces in LDP1 were 26.1 °C, 27.5 °C and 25.9 °C, for travertine, soil and grass used in the rates of 200 m^2, 100 m^2 and 200 m^2 respectively and overall PET mean was calculated to be 26.3 °C.

Figure 3. Landscape design 1

3.2. Landscape Design 2

In LDP 2, grass, wood and asphalt surfaces were used in the rates of 100 m^2, 200 m^2 and 200 m^2, respectively (Figure 4).



Mean PET value was found to be 28.9 °C, 25,9 °C and 28,5 °C for impregnated wood, grass and asphalt used in the rates of 200 m^2, 100 m^2 and 200 m^2 and overall mean of PET was 28.1 °C.

Figure 4. Landscape design 2

3.2. Landscape Design 3

In LDP 3, grass, andesite and soil surface were used in the rates of 100 m^2, 200 m^2 and 200 m^2 (Figure 5).

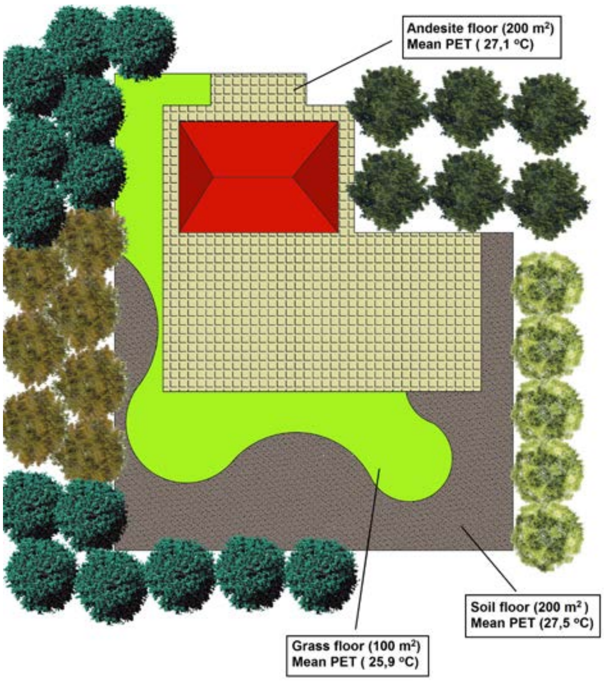


Figure 5. Landscape design 3

Mean PET value was found to be 27.1 °C, 25,9 °C and 27,5 °C for andesite, grass and soil used in the rates of 200 m^2, 100 m^2 and 200 m^2 and overall mean of PET was 27.0 °C.

4. Discussion and Results

Different comfort values were obtained by applying different LDP in the same area. There is a difference of 1.8 °C PET between designs dominated by grass and travertine and asphalt and wood even in a small surface area of 500 m^2.

It is shown in the present study through measurements and evaluations that a landscape architect can offer climatically comfortable areas even in a 500 - m^2 area through his/her suitable materials for surface covers.

In order to mitigate UHI and provide comfortable areas in urban landscape architecture overtake serious responsibilities. There is a need to know surface temperatures of materials used in the projects and design projects by considering thermal comfort. In even small areas, comfort conditions should be calculated and the values should be considered in the designs and thus partially mitigating UHI.

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