THERMAL COMFORT ASSESSMENT OF THE URBAN MEDITERRANEAN CLIMATE IN FETHIYE, SOUTHWEST ANATOLIA, TURKEY

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Abstract— Recent rapid growth and expansion of urbanized areas has brought an increase in the effects of lowered thermal comfort levels in outdoor spaces within the cities. With the increases in urbanization and tourism in summer period at coastal Mediterranean locations, urban planners and architects are looking more closely at the effect of climate on urban planning for climate adaptation.This study, has been done to reveal the change of thermal perception in this increasing urbanization during the summer when the tourist activities increase. Physiological Equivalent Temperature(PET) values were calculated by using hourly meteorological data individually measured by automatic weather station in the shade and an open spacein July and August month in which urban bioclimatic conditions are most uncomfortable for coastal Mediterranean cities. During the day, when tourism activities are more intense, large thermal differences between the shady and open spaces were obtained; in open spaces the thermal conditions were very hot for a long period. Significant result was close PET and temperature values in the morning until the mid of the day between open and shady observation site. When the wind breeze begin in the mid of the day from cooler sea surface, PET values in the shaded site have decreased quicker than open one until the end of the certain day time. Shading effect has become evident with wind breeze. In the evening, we obtained no difference between shady and exposed areas, when conditions were generally cold and comfortable. Results revealed that the significance of summer wind breeze between sea-land interaction, reduction of long-wavelength radiation of buildings in urban areas, formation of deep urban canyons for thermal comfort in Mediterranean climate. PET values should be considered in urban planning and architectural design for a healthy and sustainably comfortable urban life.

Keywords— Urban Bioclimatic Comfort, Sustainable Cities, Urban Development, Climate Change, PET.

I. INTRODUCTION

Southwest Anatolia is one of the most attractive tourist areas in Turkeydue to its historical ruins and location on the coast. One of most attractive and well-known touristic city of the region is Fethiye district as a result of regularly applied special natural protection laws on ecologically significant heritages.Tourism has brought on rapid urbanisation and the growth of small coastal towns. This has letthe developmentof different microclimates within growing urban areas. In the summer, hot and dry conditions affect urban and bioclimatic conditions. Built-up areas, open areas and green areas in the city createmore comfortablespaces than ruralareas. The need for evaluating urban comfort is because vegetationin cities alters the energetic balance of the local climate. Green areascreate variations in theamount of solar radiationreaching the surface, wind speeds,ambienttemperature and humidity [1]. Urban form and the properties of surface materials have a strong influence on the microclimate around buildings and throughurban design,there is promiseimproving the thermal comfort of outdoor environments. However, outdoor thermal comfort is generally given little importance in planning and design processes [2].

One of the most common indexes of bioclimatic conditions is the Physiological Equivalent Temperature (PET).This index is based on the models which thermal conditions of the human body in a physiologically relevant way [3].PET can be estimated using free software packages (e.g. RayMan) and include additional factors such as air temperature, air humidity, wind speed, human clothing and activity [4]. An urban landscape comprises networks of enclosures, spaces and facilities. Unlike indoor, air-conditioned environments, the urban microclimate is dynamic. For example in an open urban park, the changing nature of solar radiation, wind and shade from trees means the environment fluctuates. Unlike an urban transport facility like a railway station, outdoor thermal comfort is affected by radiant and latent heat.

II. STUDY AREA AND METHODOLOGY

2.1. Study area

Fethiye is situated along the coast where the Mediterranean Sea and Aegean Sea meet, in southwest Turkey (Figure 1). Fethiye has a worldwide reputation for The Blue Lagoon Sea, Babadag Paragliding Mountain, Butterfly Valley, Kaya Villageand the ancient cities.It welcomes around 1,250,000 foreign and domestic tourists for each year. The population of the town was 8,386 in 1965 and by 2015 it reached 145,643. Growing population has led to the development of residential areas and the city has become increasingly urban.

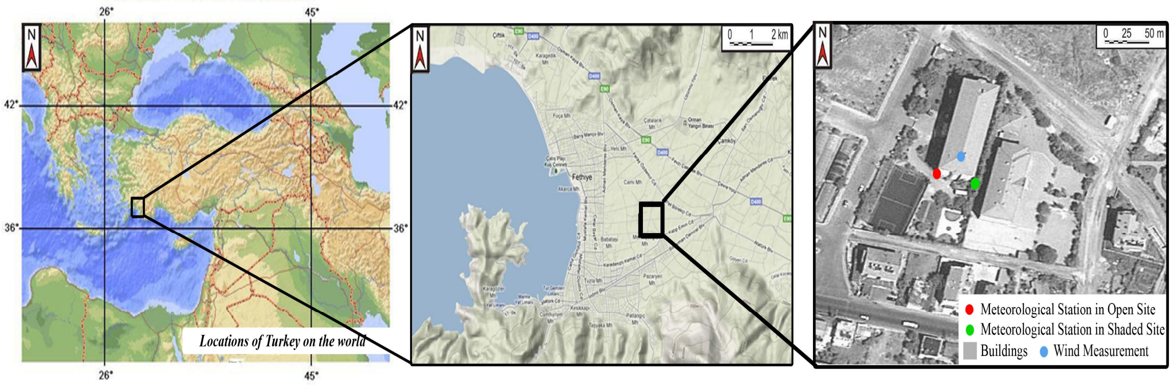

Figure 1.Location map of study area and automatic meteorological station (36°37' N and 29°07' E).

Fethiyehas a Mediterranean climate consisting of very hot, long and dry summers with an average of 34°C; winters are cool and rainy with an average of 18.5°C. Average monthly temperature ranges from 10.0°C to 27.5°C (Figure 2). The mean annual total precipitation is 840mm with average relative humidity of 76% and sunshine duration is at about 145 hours in January and 360 hours in July. Average low temperature is 10.5°Cin January and average maximum one is 27.7°Cin July. Observed maximum temperature is 44.3 in June and minimum temperature is -6.6 in January in the observation period of 1940-2015. The prevaling wind direction is WSW (from sea surface during day time) and NNE at the maximum average of 11.8 km/h in February and at the minimum average of 6.4 km/h in July. Thorntwaite climatic model is B2, B'3, s2, b'3 of humid, mezotermal, water deficiency is the highest in summer and under coastal effect. The vegetation is phytogeographic Mediterranean consisting of mainly pines, mixed broad-leaf groves and Mediterranean bush (maquis) at lower altitudes.

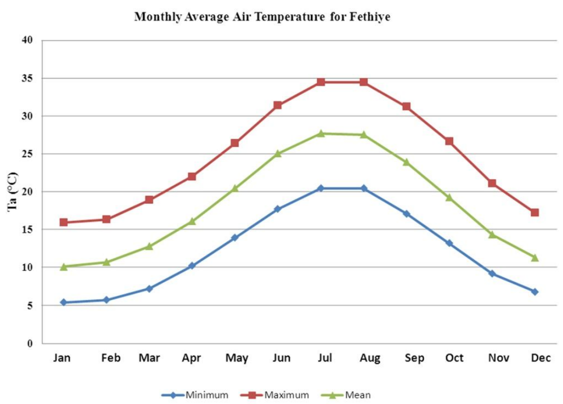

Figure 2.Monthly average of air temperature for study area.

2.2. Applied Bioclimatic Index

This study measured one of the most widely-used bioclimatic indices, PET, which is based on anaccessiblevariable on temperature (°C), which indicates thermal stress and comfort (Table 1). This makes the results easily comprehensible for potential users. This is especially important for planners, decision-makers, and even the public, who might not be familiar with human-biometeorological terminology. PET evaluates the thermal conditions in aphysiologically significant manner [5-8].

Table 1. Ranges of PET for different levels of thermal perception by human beings and physiological stress on human beings. Internal heat production: 80 W, heat transfer resistance of clothing: 0.9 clo. (following 12).

PET (°C)	Thermal	Grade of physiological
PET<4	Very cold	Extreme cold stress
4≤PET<8	Cold	Strong cold stress
8≤PET<13	Cool	Moderate cold stress
13≤PET<18	Slightly cool	Slight cold stress
18≤PET<23	Comfortable	No thermal stress
23≤PET<29	Slightly warm	Slight heat stress
29≤PET<35	Warm	Moderate heat stress
35≤PET<41	Hot	Strong heat stress
PET≥41	Very hot	Extreme heat stress

PET enables users to compare the combined effects of complex thermalconditions outdoors with their own experience indoors. In addition, PET can be used throughout the year and in different climates [e.g. 5-9]. Meteorological parameters influencing human energy balance are also represented in PET values, for example, air temperature, air humidity, wind speed and short and longwavelength radiation. PET also considers the heat transfer resistance of clothingand internal heat production [7-10].

2.3. The RayMan model

Recent studieshave used RayMan, a radiation and bioclimate model that is well-suited tocalculate radiation fluxes (e.g. 11-13). All our calculations for mean radiant temperature(T_{mrt}) and PET were performed using this model[10].The main advantage of RayMan is that it facilitates a reliable determination of microclimatological modifications of different urban environments, since the modelestimates the radiation effects of the complex surface structure (i.e. buildings, trees) very precisely. Besides meteorological parameters, the model requires input datafor surface morphological conditions and personal parameters [7,13].

2.4 Data

In this study, measurements were made at two locations in the campus ofthe FethiyeASM KocmanVocational High Schoolduring July and August 2014 (Figure 1). The first location was south of the high school, where air measurements were made in an open space. The second location was 25 m from the first,next to a *Jacaranda mimosifolia*tree with a 2.8 m-diameter trunk, which created a8m-diameter shady area.Wind measurements were made at a height of 10 m on the roof of the high school and wirelessly transferred to the data logger via Davis Vantage Pro2 station in office. Wind speed was reduced to 1.5 mlevel by using transformation table which is applied in State Meteorological Office of Fethiye in accordance with World Meteorological Organisation (WMO) standarts. Local summer time for Turkey was used in the study (GMT+3).

III. RESULTS AND DISCUSSIONS

In order to track daily changes in PET and stress values in shadyand open urban spaces, graphs were made using data from the 1st,11th and 21st of July and August (Figure 3). Daily PET showsextreme heat stress in open space at noon; in the shade, it is moderate to strong. However, the important determining factor in PET is weak winds [9]. For example, on July 1, 2014 at noon, the wind speed exceeded 9 ms^{-1}, which reducedPET stress in open space and increasedit in the shade. Between 10.00pm and 6.00am, PET values were similar, indicatingcomfortable to slightly cold stress conditions in both open and shaded spaces. This is because additional downward, long-wavelength radiation emitted from the canopy of the trees reduced the effective long-wave radiation within the spacesurrounding the trunkexperienced as in [6-13] studies.

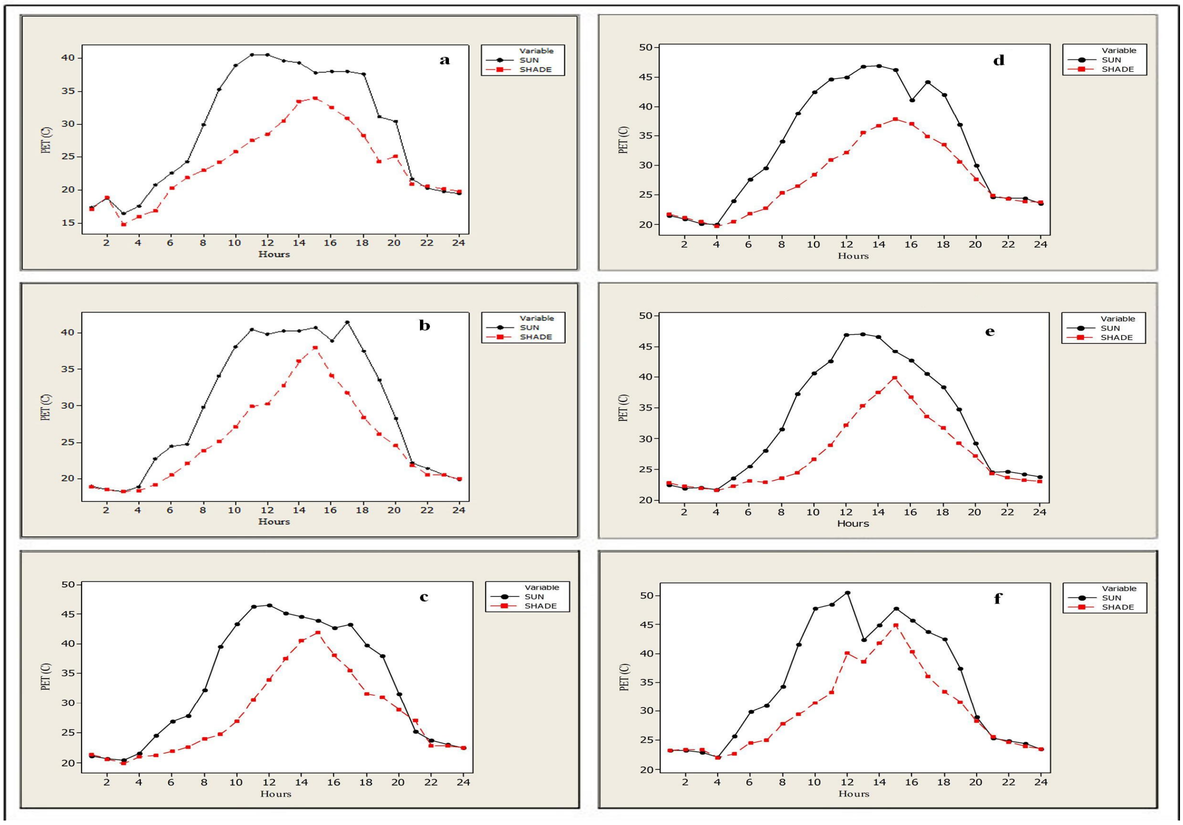

Figure 3. The change of Physiological Equivalent Temperature (PET) in open and shaded sites during certain days of July and August 2014 where a, b, c is for first, second and last decadal day of July respectively and d, e, f is for first, second and last decadal day of August respectively.

Figure 4; shows daily average PET and air temperature (T_a) for decadesin July and August. In open space, PET values range from slightly cool to very hot thermal perception. In evening hours at the beginning of July, thermal perception was slightly cool and becamecomfortable in the middle of July, which continued in August. In open space, conditions were hot between 8.00am and 10.00am. After 10.00am,conditions werevery hot, which generally continueduntil 8.00pm;hot conditions continueduntil 10.00pm. In the shade, thermal perception did not generally reach very hot, but did so for a few hours at a time at the end of August. The difference between $T_a$and PET is less in the shade than in open space. During evening hours, the difference was around 5.0°C in the open space andincreased to over 10.0°C at midday.

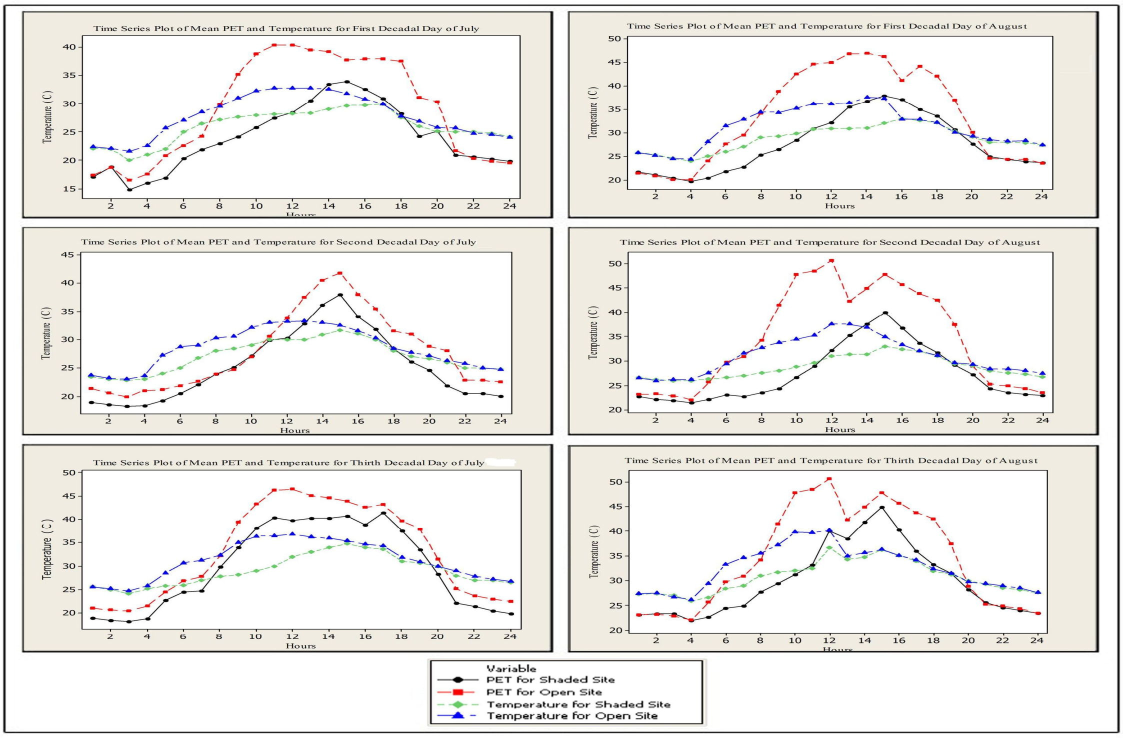

Figure 4.Daily change of PET and T_a in means for July and August, 2014.

When daily changes inT_a and PET values are examined, PET is higher than $T_a$between 8.00am and 8.00pm. After 10.00pm, air temperature decreases since long-wavelength radiation in the open space is not blocked. Breezes on the Mediterraneancoasts cause PET to fall below T_a.The study of [9]state that the most important factor affecting summer PET is weak wind. This is important in terms of town planning, which was emphasized in studies by [15] and [16]. The study of [16] also showed that breeze in Lisbon created temperature differences of more than 4.0°C between the city centre and the coast. Under a tree canopy, $T_a$and PET values were similar. This is caused by buildings and trees [17] whichdecrease wind speed and prevent long-wavelength radiation of tree canopies in the evening examined obviously as in the study of [18] which is cited frequently in climatic and bioclimatic studies for sustainable urban development.

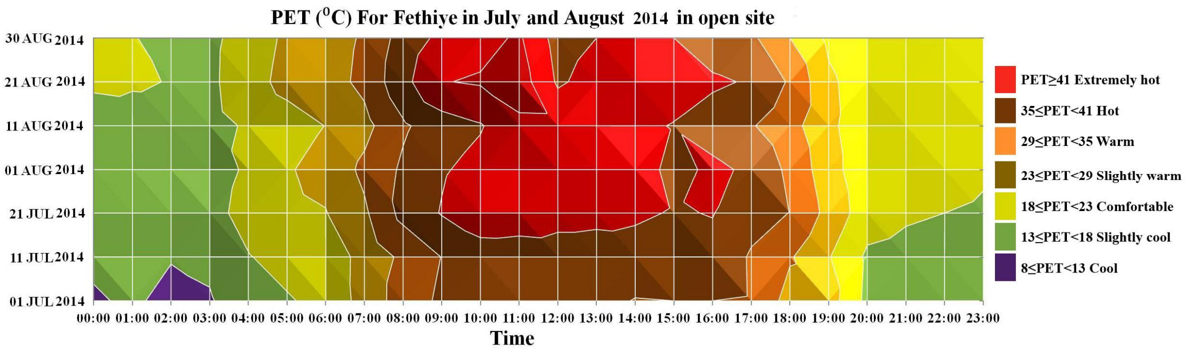

Figure 5.Hourly changes of PET in open spacein certain days of July and August of 2014.

PET ranges from cool to hot in the beginning of July in the open space. After midnight, conditions are cool; at noon, conditions are hot(Figure 5).In the middle of the night, PET ranges from cool to comfortable from the beginning of July to the end of August. At middle of the night the change from hot to very hot in the beginning of July is significant. From 9.00am to 4.00pm, conditions were very hot; this was the longest thermic period of the day. During this period, tourist activities are most frequent, and those in open spaces may cause heat stress and related health problems, especially among older tourists. There are no large differences between open and shaded areas in the evening (8.00pm–5.00am). However, there are large differences during the day. In the shade, conditions were very hot around 2.00pm and in open spaces these conditions lasted for most of the day (Figure 6). The impact of urban parks as green surfaces [19] instead of constructional formations in decreasing radiation absorption and shading effect during day time and decreasing long-wavelength radiation storage during night time should be considered in urban planning and architectural design.

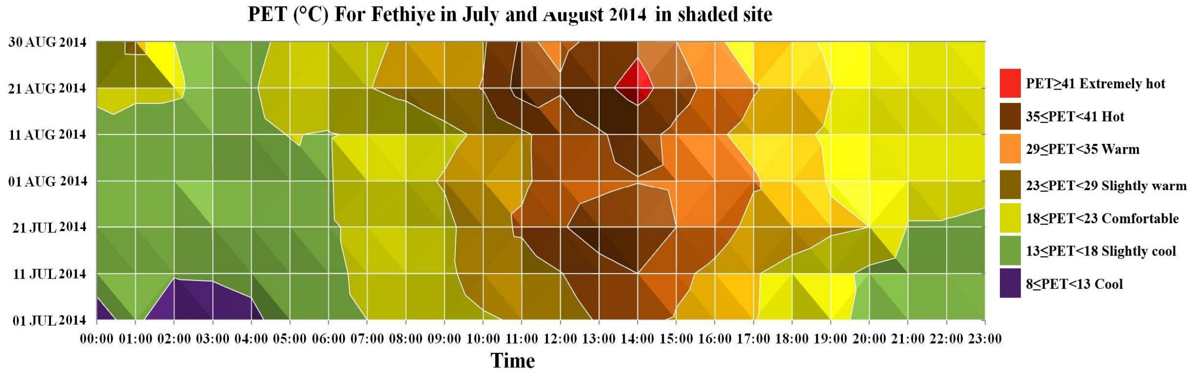

Figure 6. Hourly change of PET in the shade during certain days of July and August of 2014

In the evening, unblocked long-wavelength radiation in the open space caused a temperature decrease. In the shade, enduring long-wavelength prevents temperature decrease. This reduces the difference between open and shaded areas in the evening. Slightly cool and comfortable conditions in the evening ensurean increase in activities of both local residents and tourists in open spaces.

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CONCLUSION

T_a and PET in the shade, during July and August in Fethiyewere never higher than the ones in open spaces during the day time. The long-wavelength radiation of the trees' canopy layer is effective during the day. For this reason, open spaces showvery hot stress, especially at midday, which reduces tourist activities. Shopping diminishes and tourists relax in hotels. Some of local people immigrate high locations during July and August as a result of suffering urban bioclimatic conditions.

In study area, the PET difference between open and shaded spaces in July and August is similar in the evening, while during the daytime the difference increases to over 10.0°Cin some days. This agrees with the results of [14, 21-25],indicating that wind speed is an important factor in PET. Increasingwind speed decreasesthe difference in PET between open and shady spaces.

Open-space $T_a$values, between 10.00pm and 8.00amis higher than PET, largely due tosummer breezes, showing that winds change thermal perception.This situation needs attention in urban planning and building designs. For winds to be effective in the city centre, a boulevard should be constructed that descends to the coast and high buildings should not be built. In accordance with SW and NE prevailing wind direction and coastal location SW- NE direction should be always open for sustainable regional and urban development. In the evening hours, PET is lower than T_a, making it more comfortable for local residents and tourists in open spaces. People sit and chat for long periods in parks and gardens and many people go shopping in the evening.

The longest lasting thermal perception is very hot in open space and comfortable in the shade. In order to diminish the very hot thermal perception during daytime, precautions in urban planningshould be taken to reduce long-wavelength radiation in urban areas. For this reason, measures to increase shade should be implemented such as forming the deep urban canyons that are very common in classical Mediterranean architecture. The study [20, 26-33]also showed that,these canyons in hot climates are an important factor in decreasing PET. Otherwise, heat stress in city centreswill increase, with concomitant health complications for residents and tourists alike.

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