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Effect of Urban Road Trees on Temperature Caused by Surface Materials

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ABSTRACT

Urban roads play a significant role for analyzing the complex structure of the city. The climatic features of the city provide information about the comfort of the inhabitants. The climate changes may be observed on a micro-scale due to the increase of impermeable surfaces. Surfaces such as concrete and asphalt contribute to the formation of an urban heat island as they store the temperature. This study aims to determine the effects of plant material, which is a significant element of urban roads, on temperature arising from surface materials. In this context, the effect of *Ficus retusa-nitida* on the formation of temperature caused by the surface material has been revealed. The study was carried out in Iskenderun, the second largest district of Hatay province in terms of population, in 3 stages in a periold of 6-months between July and December 2020. In the first stage, the studies on the subject were brought together and the points to be measured in the area were determined. At this stage, asphalt (shade-under *F.retusa-nitida*, sun) and parquet (shade-under *F.retusa-nitida*, sun) surfaces were selected at a total of 8 points located mutually on the main road axis. The second stage of the study is the stage where surface temperature measurements are made. Measurements were performed once a month at 06:00, 09:00; 12:00, 15:00; 18:00; 21:00 and 24:00 using an infrared thermometer at a height of 150 cm from the surface with 3 repetitions. At the third stage, all data were transferred to GIS using ArcGIS 10.5 software and modelled by using the Kriging Interpolation Method. In line with the results obtained, suggestions for the selection of surface material and the use of plant materials on urban roads have been developed.

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Introduction

The city, which is considered as a complex organism, is a structure where social-economic-physical dynamics come together. The roads are also among the effective parameters in analyzing this structure of a city (Naryaprağı and Polat, 2020). Cities can offer living spaces with various comfort features to the inhabitants with their climatic characteristics. However, today, micro-scale climate change occurs in the urban area due to the increase in impermeable surfaces (concrete, asphalt, etc.) that prevent the water from meeting the soil. These surfaces cause the formation of urban heat islands with their temperature storage properties, and have unhealthy comfort properties for the inhabitants of the city as a result. The increase in green tissue in the urban area prevents the increase in surface temperature (Alkan et al., 2017). Temperature is accepted as one of the effective factors in the planning or design of the city. Increasing temperatures due to reasons such as heat absorption or heat generation by the built environment in the urban area harms human health (Lehoczky et al., 2017). Surface materials used extensively in the urban space include asphalt, concrete, parquet, brick, wash concrete, stone (andesite, etc.), grass, vegetable material (tree, shrub, ground covering plants) (Çetin *et al.*, 2020; Bozdoğan Sert et al., 2021). As the surface material changes, the heat island effect also changes. The temperature level of these areas is higher than that of soil and plants (Aguiar et al., 2014). Hard surfaces store heat and increase the surface temperature (Alkan et al., 2017). For example, in Mediterranean coastal cities, the temperature on by the asphalt surface during the summer at noon can reach up to 50°C. Parquet surfaces can also reach temperatures similar to the ones of asphalt surfaces (Bozdoğan Sert et al. 2021). In a study conducted in Osaka, it was reported that the asphalt surface had a temperature 14.7°C higher than the grass surface in the summer period (Takebayashi and Moriyama, 2009). Parquets are used extensively as a surface coating material in parks, walking paths, urban roads and sidewalks in the urban area due to their low maintenance cost, easy to work with, having the desired characteristics (size, color, pattern) and being inexpensive (Atıcı and Ersoy, 2008; Mümin et al., 2010; Kaya and Karakurt, 2016). Compared to the rural environment with the effect of the built environment in the urban area, artificial surfaces reveal higher temperatures

than natural surfaces in heat island formation. Determination of surface temperature is considered as an effective method in revealing this effect (Takebayashi and Moriyama, 2009; Schwarz et al., 2012).

The concretization experienced in the cities in recent years has increased the need for green areas. In this context, vegetated roads contribute to the increase of green texture in the urban area (Yılmaz and Aksoy, 2009; Aklıbaşında and Erdoğan, 2016). Urban roads are an important part of urban green areas and an important factor that directs urban development. At the same time, they have numerous contributions (functional, aesthetic, ecological) to the city. Vegetation of the median refuge and sidewalks in the boulevards and streets that provide transportation within the city has many significant tasks, especially improving the city climate (Aslanboğa, 1986; Karakaya and Zülfikar, 2013). Planting on urban roads can connect various forms of use in the city and direct vehicle and pedestrian movements. In addition to the aesthetic contributions that road trees can provide, it has many functional contributions such as preventing the formation of temperature by creating a shade effect (Küçük and Gül, 2005; Söğüt, 2005). Studies in Türkiye have shown that many natural or exotic plant species are used for the plantation of urban roads. 77 plant species are used in the median refuge in the boulevards in the city center of Adana province. Among these plants, 8 trees and 5 shrub species are among the native species of our country (Söğüt, 2005). In the urban roads of Isparta province, 13 tree species were used in the median refuge and 4 tree species were used in the sidewalks. 8 of these species are native (Küçük and Gül, 2005). 14 of the 24 species identified on urban roads in Çankırı province are trees and 8 are shrubs. 8 of these species are native (Bilgili et al., 2012). It has been determined that a total of 37 plant species, 25 of which are trees and 12 of which are shrubs, are used on urban roads (median refuge, sidewalks and intersections) in Kastamonu. 14 of these plants are native (Sakıcı et al., 2014). All these studies indicate that the natural or exotic status of the plant material used in urban roads should be taken into consideration more in the species selection. However, the natural species used on urban roads vary between 16-47%. Foreign species are much more preferred compared to the natives. Increasing the number of natural species is important in terms of contributing to urban ecology.

This study aims to determine the effects of plant material, which is a significant element of urban roads, on temperature arising from surface materials. In this context, the effect of *Ficus retusa-nitida* species, which is used extensively thanks to its shading feature on urban roads in Iskenderun, the Mediterranean coastal city, on the formation of temperature caused by the surface material has been revealed. It is thought that the data obtained from the study will contribute to the selection of surface materials and plant species on urban roads in cities where the Mediterranean climate prevails.

Materials and Methods

Materials

The study was carried out in Iskenderun, which is the second largest district of Hatay province in terms of population, in the period of 6 months between July and December 2020. In the city, where the Mediterranean climate prevails, summers are hot and dry, and winters are warm and rainy. The study area consists of a part of Lala Mustafa Paşa Street, which has a building-sidewalk-road section in the city and has *Ficus retusa-nitida* species, which is also used extensively in the city landscape on its sidewalks. The location of the study area is seen in Figure 1 and the visuals of the general status of the area are seen in Figure 2. The buildings on both sides of the street are generally 4 floors and have a garden. There is a 2 meter wide pavement on both sides of the approximately 10 meter wide road and *F.retusa-nitida* with height and crown diameter of 3 meter planted at regular intervals. This species, which has a coarse texture and is always green, is used for providing shades.

Figure 1. Location of the study area

Figure 2. General views of the study area (Original, 2020)

Methods

The study was conducted in 3 stages. In the first stage, the studies on the subject were brought together and the points to be measured in the area were determined. At this stage, asphalt (shade-under *F.retusa-nitida*, sun) and parquet (shade-under *F.retusa-nitida*, sun) surfaces were selected at a total of 8 points located across each other on the main road axis. The second stage of the study is to measure the surface temperatures. Surface temperature measurements in the area were carried out in a period of 6 months between July 2020 and December 2020 once a month at 06:00, 09:00, 12:00, 15:00, 18:00, 21:00 and 24:00 using an infrared thermometer at 150 cm height for 3 repetitions. The third stage of the study is to evaluate the obtained data. At this stage, the average values of the surface temperatures arising from the surface materials are given as hourly according to the months. And also, surface temperature data were systematized using Microsoft Office Programs. Then, their coordinates were matched with the obtained points. Data were transferred to the geographic information system using ArcGIS 10.5 software and modeled using the Kriging Interpolation Method. In line with the results obtained, suggestions for the selection of surface material and the use of plant materials on urban roads have been developed.

Results and Discussion

The data of the surface temperature measurements made between 06:00, 09: 00; 12:00, 15:00; 18:00; 21:00 and 24:00 once a month in a period of 6 months period between July 2020 and December 2020 are given in Table 1. When the evaluations are made based on the seasons, July-September represents the summer period, September-October-November represents the autumn period, and December represents the winter period. The maps obtained using these data are also given in Figure 3.

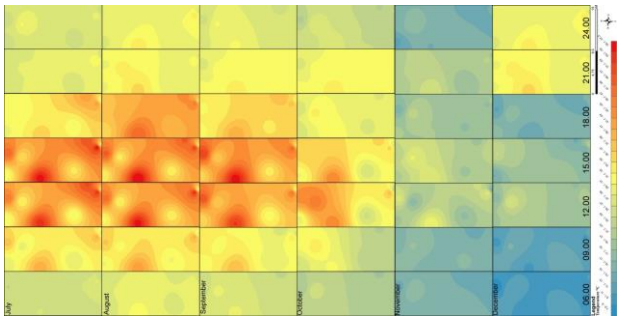

Figure 3. Monthly Temperature Maps With Measurement Hours

Looking at the summer data, it was determined that the highest temperature among the surface materials in July was formed on the asphalt surface at 15:00 with 56.32°C. The highest temperature on the parquet surface was determined to be 49.62°C at the same hour. This value is 6.7°C lower than the asphalt. When all the values at the same hour were examined, the temperature in the shade of the vegetation (*F.* retusa-nitida) was 21.42°C lower in asphalt and 17.17°C lower in parquet. Within all hours, the lowest surface temperature value was 25.47°C at 6:00 on the parquet surface in the shade of *F. retusa-nitida*. When the measurements of the surface materials made according to the hours in August were evaluated; the highest temperature was determined on the asphalt surface at 12:00 at 55.32°C. The highest temperature in the parquet was determined as 49.68°C at 15:00. This value is 5.64°C lower than the asphalt. When all values are examined, lower temperature values of 21.87°C in the asphalt in its shade and 15.96°C in the parquet are revealed. Within all hours, the lowest surface temperature value was 27.67°C at 6:00 on the parquet surface in the shade of *F. retusa-nitida*. All these data reveal the effect of reducing the temperature level of the vegetable material in the summer period. According to the temperature values by the surface materials in the summer period, except for the temperature obtained at 12:00 in the shade of *F.* retusa-nitida in July, the asphalt always generated higher heat than the parquet. These data are similar to the data obtained by Adıgüzel et al. (2022) in Iskenderun during the summer period. The temperature level on the asphalt surface was obtained higher than the parquet. The temperature obtained on the parquet surface in the shade of the *F.retusa-nitida* species was approximately 24°C lower than in the sun. Similarly, Çetin et al. (2020) determined the surface temperature of the asphalt (51°C) at 13:00 as approximately 4°C higher than the parquet surface. The temperature obtained on both surfaces at noon is higher than in the morning and lower than in the evening. This situation reveals that asphalt increases its temperature with the sunrise; it reaches the highest level at noon and then quickly loses the heat it has.

Considering the data of the autumn period, it was determined that the highest temperature among the surface materials in September was formed on the asphalt surface at 15:00 with 52.70°C. The highest temperature on the parquet surface was determined to be 48.60°C at the same hour. This value is 3.1°C lower than the asphalt. When the values at the same hour were examined, the temperature level consisting of the surfaces in the shade of *F. retusa-nitida* was 17.07°C lower on asphalt and 13.72°C lower on parquet. Within all hours, the lowest surface temperature value was 24.73°C at 6:00 on the parquet surface under sun. In October, the highest temperature among the surface materials was formed on the asphalt surface at 12:00 at 41.57°C. The highest temperature on the parquet surface was determined to be 38.87°C at the same hour. This value is 2.7°C lower than the asphalt. When the values at the same hour were examined, the temperature level consisting of the surfaces in the shade of *F. retusa-nitida* was 4.97°C lower on asphalt and 11.0°C lower on parquet. Within all hours, the lowest surface temperature value was 20.88°C at 6:00 on the parquet surface under sun. In November, the highest temperature among the surface materials was formed on the asphalt at 12:00 with 29.97°C. The highest temperature on the parquet surface was determined to be 26.53°C at the same hour. This value is 3.44°C lower than the asphalt. When the values at the same hour were examined, the temperature level consisting of the surfaces in the shade of *F. retusa-nitida* was 8.16°C lower on asphalt and 11.65°C lower on parquet. Within all hours, the lowest surface temperature was 13.68°C at 6:00 on the sun-parquet surface. This is an indication that the vegetable material has a more moderate effect in the autumn period. In September and October, asphalt under the sun always have higher temperature than parquet. In November, the asphalt under the sun has always had a higher temperature than the parquet, except for 12:00 and 21:00 in the shade of *F. retusa-nitida*.

Table 1. Temperature Levels on Different Surface Materials in Lala Mustafa Paşa Street

Month	Time	Temperature (°C)			
		Parquet-Sun	Parquet-Shadow	Asphalt-Sun	Asphalt-Shadow
July	06.00	25.73	25.47	28.15	26.58
	09.00	36.97	29.00	40.27	29.78
	12.00	48.65	33.75	54.08	32.30
	15.00	49.62	32.45	56.32	34.90
	18.00	37.03	31.02	39.02	32.13
	21.00	29.07	27.42	31.80	28.82
	24.00	27.01	26.13	29.53	28.26
August	06.00	27.93	27.67	31.28	29.20
	09.00	35.22	30.73	41.22	31.53
	12.00	47.25	32.10	55.32	33.45
	15.00	49.68	33.72	54.82	33.98
	18.00	40.75	35.43	47.55	39.63
	21.00	30.18	29.68	34.02	31.52
	24.00	29.88	28.83	34.32	30.05
September	06.00	24.73	27.02	27.92	28.17
	09.00	30.83	29.95	36.57	31.28
	12.00	45.00	33.35	50.17	34.48
	15.00	48.60	34.88	52.70	35.63
	18.00	35.48	32.92	39.03	34.58
	21.00	29.67	31.25	33.28	31.27
	24.00	27.12	29.06	30.86	30.33
October	06.00	20.88	22.50	23.12	24.32
	09.00	27.07	25.28	27.97	28.97
	12.00	38.87	27.87	41.57	36.60
	15.00	35.80	29.88	40.38	32.15
	18.00	28.38	28.53	31.60	31.17
	21.00	23.68	25.82	26.67	27.52
	24.00	21.80	24.58	24.86	26.71
November	06.00	13.68	16.07	14.35	17.48
	09.00	14.70	16.60	15.75	18.28
	12.00	26.53	18.37	29.97	18.32
	15.00	22.07	22.98	26.23	24.97
	18.00	17.68	21.43	19.77	21.42
	21.00	14.00	17.25	15.53	18.87
	24.00	15.38	16.05	15.44	18.24
December	06.00	8.53	12.30	9.23	12.57
	09.00	11.60	14.10	10.50	14.80
	12.00	18.37	20.18	21.93	23.68
	15.00	19.90	19.07	17.35	21.00
	18.00	13.18	17.58	13.70	17.38
	21.00	10.03	14.97	10.23	15.45
	24.00	9.65	12.92	9.17	13.56

Considering at the data from winter period, it was revealed that the highest temperature among the surface materials in December was formed on the asphalt surface in the shade of *F. retusa-nitida* at 23.68°C at 12:00. The highest temperature on the parquet surface was determined to be 20.18°C in the plant shade at the same time. This value is 3.50°C lower than the asphalt. When the values at the same hour were examined, the temperature level consisting of the surfaces in the *F.* retusa-nitida shade was 1.75°C higher on asphalt and 1.81°C higher on parquet. Within all hours, the lowest surface temperature value was 8.53°C at 6:00 on the parquet surface under sun. These data revealed that the temperature level was higher in the area in the shade of the tree in the winter period. This is an indication that the vegetation has a more moderate effect in the winter period. In December, the heat on the asphalt surface under sun is higher than the parquet except for 09:00, 15: 00 and 18:00.

Conclusion

According to the data obtained as a result of this study, in which the effect of the temperature level of *Ficus retusa-nitida* species on urban roads in Iskenderun, the second largest district of Hatay province in terms of population, was determined, it was determined that urban road trees have a significant role. Within the scope of climate change, the quality of life decreases as a result of the warming of cities. In this city where the Mediterranean climate prevails and the summer period is very hot, the level of temperature on surface materials can be reduced by vegetation studies. The heat generated by asphalt and parquet surfaces, which are used extensively throughout the city, can be reduced by the use of vegetable materials. In this context, the temperatures arising from the surface materials were evaluated seasonally and as a result, the highest temperature on the asphalt surface in the summer period

was determined as 54.82°C in August at 15:00; and the highest temperature on the parquet surface was determined as 49.68°C in August under the sun. The asphalt had a temperature of 5.14 °C higher than the parquet. The highest surface temperature on the asphalt in the autumn period is 52.70°C in September at 15:00 under the sun; 4.1°C higher than the parquet. In December, representing the winter period, the highest temperature of the asphalt surface was 23.68°C at 12:00 in the shade of *F.retusa-nitida* species; the highest surface temperature formed by the parquet surface was 3.5°C lower under the same conditions. The potential of surface materials used in urban areas to contribute to the increase in temperature in the urban area should be taken into consideration in determining the selection criteria. Thus, it will be ensured that healthy and livable cities are formed. The data obtained in this context revealed that the asphalt increased the temperature level more than the parquet surface. For this reason, parquet can be preferred as a surface material in the urban area.

Urban roads should be designed as areas effective for increasing the quality of urban life. In this context, the aesthetic and functional characteristics of the selected species should be evaluated in the vegetation of the roads. Attention should be paid to the presence of naturalness among the selection criteria of the species. Urban road trees play an important role in reducing the impact of high surface temperature materials such as asphalt and parquet used on roads. Therefore, species with high shading properties and large crowns are more preferred. *Ficus retusa-nitida* species evaluated within the scope of the study may be one of the species that can be preferred in urban roads due to its effect on reducing the temperature level caused by surface materials.

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