INVESTIGATION OF GREEN SPACE COOLING POTENTIAL ON LAND SURFACE TEMPERATURE IN ANTALYA CITY OF TURKEY

S. Selim[1*], B. Eyileten[2], N.Karakuş[2]

1 Akdeniz University, Faculty of Science, Department of Space Science and Technologies, 07058 Antalya, Turkey - serdarselim@akdeniz.edu.tr (* corresponding author)
2 Akdeniz University, Institute of Science, Department of Remote Sensing and Geographical Information Systems, 07058 Antalya, Turkey - buketeyileten@gmail.com; nkarakus@akdeniz.edu.tr

KEY WORDS: Green Spaces, Urban Heat Island, Land Surface Temperature, Vegetation Index, Remote Sensing.

ABSTRACT:

The aim of this study is to investigate the potential cooling effect of urban green spaces on land surface temperature (LST). Two significant green areas and their surroundings in the Konyaaltı district of Antalya province were selected as the sample area. Antalya is one of the most important tourist destinations in Turkey and has experienced rapid population growth along with increasing construction. Because the sample area is located in the Mediterranean Climate Zone, the research datasets were limited to a 6-month time series covering May and October, as recommended by previous studies. In the study, cloudless Landsat 8 satellite images were utilized to obtain vegetation density and land surface temperature. After making atmospheric corrections to the satellite images, the researchers used a series of algorithms to calculate NDVI and LST values from Landsat 8's NIR, Red, and thermal bands. A linear cross-section was assigned from the maps, and statistical analysis was performed by applying the Pearson correlation test to the data obtained from the pixels in contact with the section. The analysis revealed that there is a strong opposite correlation between plant density and land surface temperature, and the land surface temperature decreases as the plant density increases. The cooling effect of green areas range from 0.13 - 1.04 °C, although it varies according to the month. The 1st sample area had an average cooling effect of 0.77 °C, while the 2nd sample area had an average of 0.28 °C cooling effect. Combining the results from both sample areas, the researchers found that urban green spaces provide a cooling effect of 0.52 °C during the hot months of the spring and summer seasons in the Mediterranean climate zone. The results suggest that green areas play an important role in cooling today's cities that have turned into concrete jungles. Therefore, it is suggested that increasing the presence of urban green areas through green infrastructure planning can not only enhance the cooling effect of green spaces in urban areas but also help combat global climate change.

1. INTRODUCTION

The growth of populations and consequent increase in urbanization has led to several undesirable environmental changes. Although urban areas account for a small fraction of global land use, industrial development tends to concentrate in urbanized areas, where half of the world's population is already concentrated. Consequently, it is widely acknowledged that the adverse effects of climate change, one of the most pressing ecological and social problems of the 21st century, will be particularly pronounced in urban areas (Moradi and Görer Tamer, 2017; Moda et al, 2019; Hobbie, and Grimm, 2020). As urbanization progresses, land cover changes gradually and natural surfaces are replaced by urban textures. The expansion of concrete surfaces exerts pressure on natural areas and causes land use changes. Furthermore, urbanization exacerbates temperature increases in cities, leading to the formation of urban heat islands, where atmospheric greenhouse gas concentrations and surface temperatures are higher compared to green spaces (Pielke et al, 2011; Zurqani et al, 2019; Orhan, 2021).

As a result of climate change, factors such as an increase in temperature and direct exposure of concrete surfaces to sunlight, as well as the retention of heat by these surfaces, lead to an increase in Land Surface Temperature (LST) in urban areas, thereby negatively impacting human health. Consequently, various strategies are being developed to reduce urban LST. Scientific studies emphasize the necessity of increasing the current potential of green areas that have both cooling capacity in combating global warming and are included in urban plans (Susca et al, 2011; Koc et al, 2018; Orhan, 2021).

Urban green spaces are anticipated to have a pivotal role in regulating urban climates due to their capacity to mitigate the adverse effects of urban warming. Through various means such as providing shade, regulating air currents, promoting evaporation, and generating favorable micro-climates, urban green spaces have the potential to enhance urban health by acting as a source of cooling. Furthermore, they can reduce land surface temperatures by impeding the sun's rays from reaching reflective surfaces. As a result, urban green spaces are viewed as an effective strategy to counter the negative effects of urban warming and land surface temperature. Consequently, it is imperative to identify urban heat islands and land surface temperatures in regions and cities with high population density and warm climate and to investigate their relationship with green spaces for developing micro-climate strategies. Research conducted by Gill et al. (2007), Bowler et al. (2010), Escobedo et al. (2011), Norton et al. (2015), Yang et al. (2019), and Aydemir et al. (2022) underscores the importance of enhancing the existing potential of green infrastructure in urban planning and development to combat global warming.

The study utilized geographical information systems and remote sensing techniques and focused on two urban green spaces in Konyaaltı, a popular tourist destination in Turkey: Hayat Park and Akdeniz Kent Parkı. The study aimed to evaluate the cooling effect of these green spaces on the urban climate and associate it with green spaces to increase the climatic comfort of individuals, particularly in Antalya. Antalya has experienced significant population growth and construction in recent years, leading to pressure on green areas. Therefore, the city is unable to benefit adequately from the ecosystem services that its green areas contribute to urban cooling. The study's findings could serve as a reference for central and local governments, urban planners, and open green space planning and evaluation to enhance urban green spaces and reduce the UHI effect in Antalya and other similar cities. By identifying the benefits of urban green spaces and their potential to mitigate the UHI effect, this study could contribute to the development of effective urban planning strategies that prioritize the preservation and creation of green spaces in urban areas.

2. MATERIAL AND METHODS

2.1 Study Area

The research focused on two significant green areas and their adjacent lands in the Konyaaltı district of Antalya province, which is one of the most significant tourist destinations in Turkey and has witnessed increasing construction in tandem with rapid population growth. In order to assess the potential cooling effect of the selected urban green areas, it was essential to collect LST data of the surrounding lands. To accomplish this, the study was performed within a 1x1 km sample area that encompassed the selected green space (Figure 1).

Hayat Park and an urban forest to its north were chosen as the first sample area, which covers an urban green area of 32.01 hectares at coordinates 36°52'40"N and 30°38'00"E. This sample area has a limited amount of green space and a high amount of land and buildings surrounding the urban green area.

The second sample area comprised Akdeniz City Park, situated in the city center near the coast, and the fairground area to the north of the park. The urban green space in this area covers 15.15 hectares and is geographically located at 36°52'50"N and 30°39'30"E. Unlike the first sample area, the surroundings of the urban green space in the second sample area have fewer land and buildings, and a higher proportion of green space.

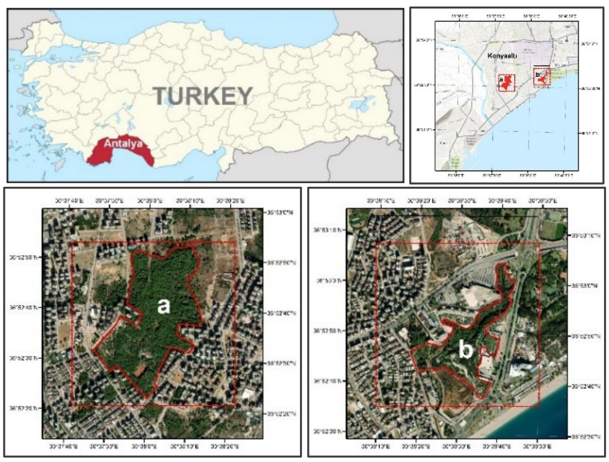

Figure 1. Study area

The decision to select the Konyaaltı district of Antalya province as the study area was influenced by several factors, including the city's population growth, climate, and importance as a prominent tourist destination in Turkey. In terms of selecting the green areas, their central location in the city, areal sizes, vegetation densities, and environmental land uses were taken into consideration.

2.2 Datasets

Olgyay (1973) suggested that thermal comfort conditions deteriorate the most from May to October due to hot stress in the Mediterranean Climate Zone (Karakuş and Selim, 2022; Cinar et al, 2023). Based on this information and previous scientific research, the study focused on the months between May and October. To obtain data on vegetation density and land surface temperature in the study area, the research used cloudless Landsat 8 satellite images, which were downloaded free of charge from the United States Geological Survey (USGS) 'Earth Explorer' website. Landsat 8 provides medium-resolution data ranging from 15 to 100 meters. Landsat 8 satellites dated 14.05.2019, 25.06.2017, 01.07.2019, 15.08.2018, 19.09.2019 and 15.10.2017 were used in the study.

2.3 Method

To investigate the cooling effect of green areas on land surface temperature, open access Landsat 8 satellite imagery was obtained and processed. Atmospheric correction operations were performed in Quantum GIS (QGIS) software, and NDVI (Normalized Difference Vegetation Index) was created using Near Infrared (NIR) and Red bands in ArcGIS software. The Land Surface Temperature was determined using Landsat 8's thermal bands with the help of a series of algorithms. The process consisted of six stages, which are as follows: 1) Calculating the spectral radiance at the top of the atmosphere (TOA), 2) Converting TOA to brightness temperature (BT), 3) Computing the Normalized Difference Vegetation Index (NDVI), 4) Determining vegetation cover (Pv), 5) Calculating emissivity (ε), and 6) Computing Land Surface Temperature (LST). Subsequently, the cooling potential was calculated by subtracting the LST of the areas outside the urban green space from the LST of the entire sample area. In addition, to determine the linear relationship between vegetation and land surface temperature, a linear cross-section was applied to both the NDVI and LST maps. This method involved comparing reflectance values of sample points taken from the images with those from the cross-section lines. Finally, statistical analysis was conducted using the Pearson correlation test on the data obtained from the pixels that intersected with the cross-section lines (Figure 2.).

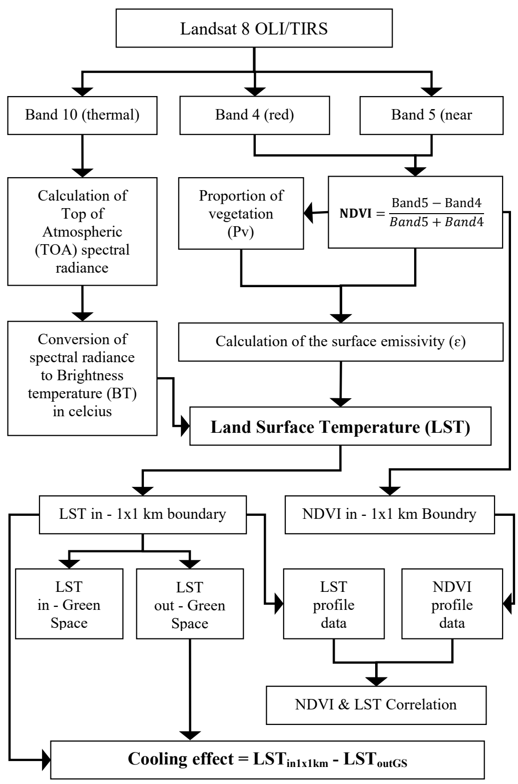

Figure 2. Flowchart

3. RESULT AND DISCUSSION

The main objective of this study was to investigate whether urban green areas have a cooling effect on land surface temperature in specific areas of the Konyaaltı district in Antalya province. To achieve this goal, the study employed Landsat 8 OLI/TIRS satellite images to generate LST and NDVI maps of the green areas and their surrounding areas. Cross-sectional analyses were conducted in a West-East direction to determine the relationship between ground surface temperature and urban green areas. Statistical analysis was then used to determine the relationship between ground surface temperature and the green area using the LST and NDVI values of the pixels in the section plane. The maps and graphics of the first sample area are presented in Figure 3, while NDVI and LST values calculated by month and correlation coefficients are presented in Table 1.

In May, the minimum NDVI value of 0.05 units was detected outside the green area, whereas the maximum NDVI value of 0.36 was observed in both inside and outside the green area in the sample area. The lowest LST value of 33.12 °C was found inside the green area, while the highest LST value of 42.10 °C was detected outside the green area. The difference in average NDVI between the inside and outside of the green area was 0.10, and the average LST difference was 3.18 °C. The results of the Pearson Correlation test applied to the NDVI and LST data in the cross-sectional plane taken in the West-East direction indicated a very strong negative correlation (R=-0.920) between NDVI and LST.

In the month of June, the minimum and maximum NDVI values in the sample area, measuring 0.06 and 0.38, respectively, were discovered to be outside the green area. Within the same area, the minimum LST value of 42.49°C was detected inside the green area, whereas the maximum LST value of 49.52°C was identified outside the green area. The average difference in NDVI between the green and non-green areas was found to be 0.08, whereas the average difference in LST was 2.20°C. The application of the Pearson Correlation test to the NDVI and LST data collected along the West-East cross-sectional plane revealed a strong negative correlation (R=-0.867) between these two variables.

In July, the minimum and maximum NDVI values in the sample area were both detected outside the green area, with values of 0.05 and 0.43, respectively. While the minimum LST value of 39.37°C was found inside the green area, the maximum LST value of 47.82°C was detected outside it. On average, the NDVI difference between inside and outside of the green area was 0.10, and the LST difference was 2.97°C. Results of the Pearson Correlation test on the NDVI and LST data in the West-East cross-sectional plane revealed a highly negative correlation (R=-0.937) between NDVI and LST.

In August, it was observed that the sample area recorded the minimum NDVI value (0.05) and the maximum NDVI value (0.38) outside of the green area. Despite the lowest LST value of 41.10°C being detected inside the green area, the highest LST value of 49.39°C was found outside it. On average, the NDVI difference between inside and outside of the green area was 0.10, while the LST difference was 2.58°C. The Pearson Correlation test conducted on the NDVI and LST data in the West-East cross-sectional plane indicated a very strong negative correlation (R=-0.935) between NDVI and LST.

The sample area in September revealed that the lowest NDVI value (0.05) and the highest NDVI value (0.36) were both detected outside the green area. The minimum LST value (33.79 °C) was found within the green area, whereas the maximum LST value (40.55 °C) was located outside of it. On average, the difference in NDVI between the inside and outside of the green area was 0.08, while the average LST difference was 2.24 °C. The Pearson Correlation test applied to the NDVI and LST data in the West–East cross-sectional plane demonstrated a very strong negative correlation (R=-0.947) between NDVI and LST.

In October, the sample area showed that the lowest NDVI value (0.03) and the highest NDVI value (0.37), along with the minimum LST value (30.24 °C) and the maximum LST value (35.24 °C), were detected outside of the green area. On average, the difference in NDVI between the inside and outside of the green area was 0.04, while the average LST difference was 0.98°C. The Pearson Correlation test, which was conducted on the NDVI and LST data in the cross-sectional plane taken in the West-East direction, indicated a very strong negative correlation (R=-0.915) between NDVI and LST.

Table 1. NDVI and LST values and NDVI & LST Correlation of Hayat Park and surrounding urban forest

Location			Time					
			May	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**
NDVI	In - Green Space Boundry	$NDVI_{min}$	0.10	0.11	0.12	0.10	0.10	0.09
		$NDVI_{max}$	0.36	0.34	0.37	0.34	0.31	0.27
		$NDVI_{ave}$	0.29	0.26	0.28	0.28	0.25	0.23
	Out - Green Space Boundry	$NDVI_{min}$	0.05	0.06	0.05	0.05	0.05	0.03
		$NDVI_{max}$	0.36	0.38	0.43	0.38	0.36	0.37
		$NDVI_{ave}$	0.19	0.18	0.18	0.18	0.17	0.14
	In - 1x1 km Boundry	$NDVI_{min}$	0.05	0.06	0.05	0.05	0.05	0.03
		$NDVI_{max}$	0.36	0.38	0.43	0.38	0.36	0.37
		$NDVI_{ave}$	0.22	0.21	0.22	0.21	0.19	0.17
LST	In - Green Space Boundry	LST_{min}	33.12	42.49	39.37	41.10	33.79	30.71
		LST_{max}	37.47	46.66	43.91	45.55	37.22	33.00
		LST_{ave}	34.56	43.98	41.09	42.55	34.95	31.35
	Out - Green Space Boundry	LST_{min}	33.81	42.89	40.24	41.42	33.92	30.24
		LST_{max}	42.10	49.52	47.82	49.39	40.55	35.24
		LST_{ave}	37.74	46.18	44.06	45.13	37.19	32.33
	In - 1x1 km Boundry	LST_{min}	33.12	42.49	39.37	41.10	33.79	30.24
		LST_{max}	42.10	49.52	47.82	49.39	40.55	35.24
		LST_{ave}	36.70	45.46	43.09	44.28	36.46	32.01
NDVI & LST Correlation		R	**-0.920**	**-0.867**	**-0.937**	**-0.935**	**-0.947**	**-0.915**

In the first study area, the mean variation of NDVI differs depending on the month and is usually 0.09, whereas the average difference in LST is 2.36 °C. The most significant temperature difference of 3.18 °C is observed in May, and the smallest temperature difference of 0.98 °C is recorded in October.

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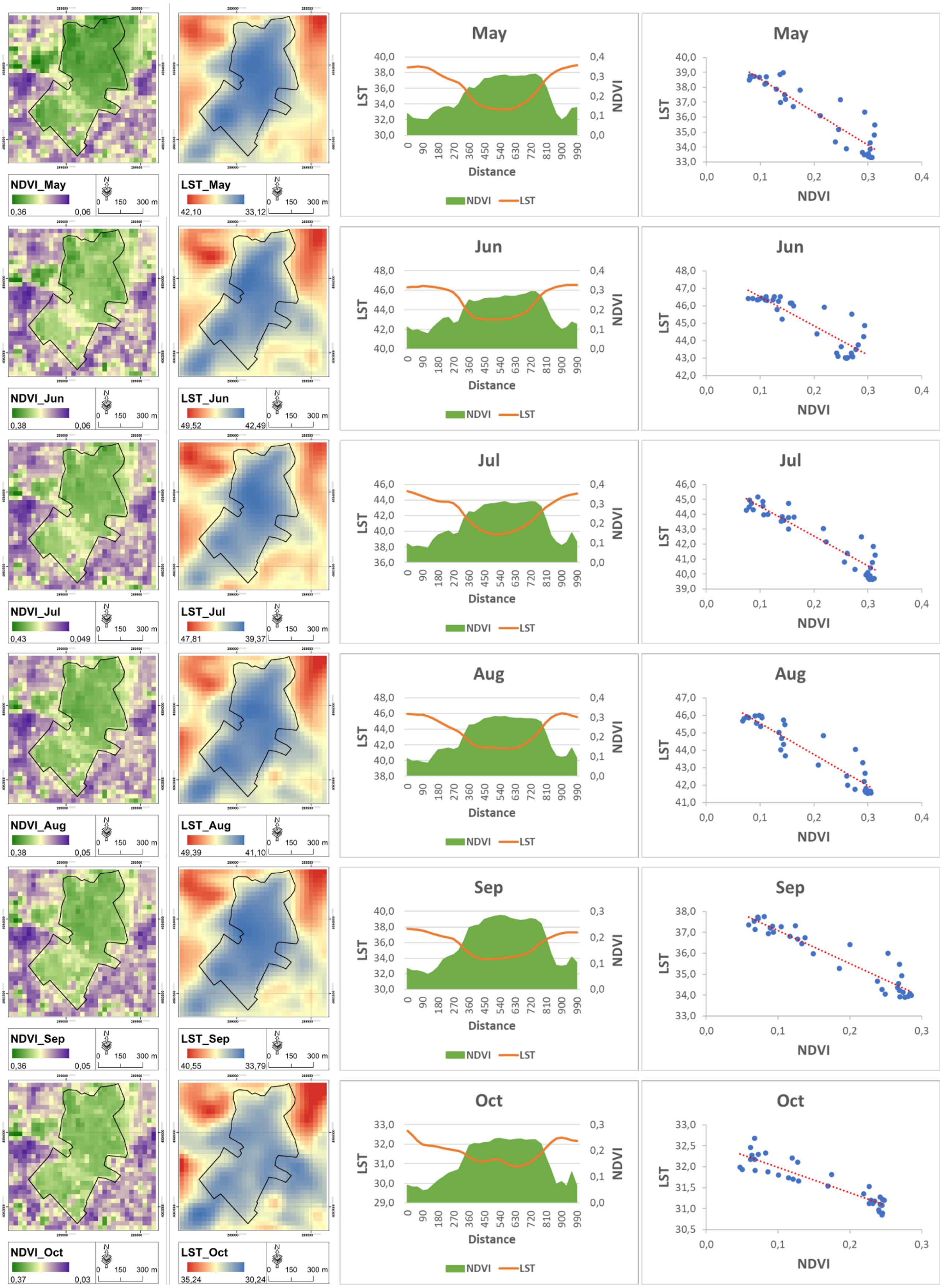

Figure 3. Monthly maps and graphs of the NDVI and LST for the Hayat Park and Kent Forest sample area

Figure 4 displays the maps and graphs for the second research area, and Table 2 demonstrates the NDVI and LST values for each month, including correlation coefficients.

In the month of May, the minimum NDVI value in the sample area was measured as 0.00 outside the green area, while the maximum NDVI value was detected as 0.60 inside the green area. The minimum LST value in the area was recorded as 32.88 °C and the maximum LST value was 47.40 °C outside the green area. The average NDVI difference between the inside and outside of the green area was found to be 0.19, while the average LST difference was 2.06 °C. According to the Pearson Correlation test applied to the NDVI and LST data taken in the West-East section plane, a very strong negative correlation (R=-0.921) was found between NDVI and LST.

In the month of June, the minimum NDVI value outside the green area in the sample area was found to be 0.01, while the maximum NDVI value within the green area was 0.58. The minimum and maximum LST values in the area were recorded as 40.13 °C and 52.41 °C respectively, outside the green area. The average NDVI difference between the inside and outside of the green area was calculated as 0.17, while the average LST difference was found to be 2.11 °C. Based on the Pearson Correlation test conducted on the NDVI and LST data in the West-East direction cross-sectional plane, a strong negative correlation (R=-0.846) was identified between NDVI and LST.

In July, the minimum and maximum NDVI values in the sample area were measured outside the green area, with values of -0.04 and 0.62, respectively. The minimum and maximum LST values in the area were also determined outside the green area, with values of 36.99 °C and 50.59 °C, respectively. The average NDVI difference between the inside and outside of the green area was found to be 0.19, while the average LST difference was 2.53 °C. Analysis of the NDVI and LST data obtained from the West-East direction cross-sectional plane using Pearson Correlation test revealed a strong negative correlation (R=-0.854) between the two variables.

In August, the minimum and maximum NDVI values in the sample area were detected outside the green area, with values of -0.02 and 0.5, respectively. Similarly, the minimum and maximum LST values in the area were also measured outside the green area, with values of 37.64 °C and 49.68 °C, respectively. The average NDVI difference between the inside and outside of the green area was calculated as 0.18, while the average LST difference was 2.16 °C. Analysis of the NDVI and LST data obtained from the West-East direction cross-sectional plane using Pearson Correlation test revealed a strong negative correlation (R=-0.906) between the two variables.

In the month of September, it was observed that the minimum and maximum NDVI values in the sample area were located outside the green area, with values of 0.00 and 0.51, respectively. Likewise, the minimum and maximum LST values in the area were measured outside the green area, with values of 33.28 °C and 42.65 °C, respectively. The average NDVI difference between the inside and outside of the green area was determined as 0.16, while the average LST difference was calculated to be 1.41 °C. The analysis of the NDVI and LST data from the West-East direction cross-sectional plane using Pearson Correlation test showed a very strong negative correlation (R=-0.915) between NDVI and LST.

In October, the minimum NDVI value (-0.01) was found beyond the green area in the sample region, while the highest NDVI value (0.46) was detected inside the green area. The lowest and highest LST values (29.58 °C and 37.14 °C, respectively) were both identified outside the green area. It can be observed that the average NDVI difference between inside and outside of the green area is 0.12, whereas the average LST difference is 0.87 °C. Based on the Pearson Correlation test conducted on the NDVI and LST data in the cross-sectional plane, which was taken in the West-East direction, a strong negative correlation (R=-0.844) was discovered between NDVI and LST.

Table 2. The correlation between the values of NDVI and LST with the NDVI and LST values of the Akdeniz Kent Park and the surrounding Fairground area.

Location			**Time**					
			May	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**
NDVI	In - Green Space Boundry	$NDVI_{min}$	0.12	0.10	0.09	0.08	0.12	0.07
		$NDVI_{max}$	0.60	0.58	0.62	0.54	0.51	0.46
		$NDVI_{ave}$	0.37	0.36	0.38	0.35	0.33	0.28
	Out - Green Space Boundry	$NDVI_{min}$	0.00	0.01	-0.04	-0.02	0.00	-0.01
		$NDVI_{max}$	0.47	0.51	0.54	0.44	0.45	0.40
		$NDVI_{ave}$	0.18	0.19	0.19	0.17	0.17	0.16
	In - 1x1 km Boundry	$NDVI_{min}$	0.00	0.01	-0.04	-0.02	0.00	-0.01
		$NDVI_{max}$	0.60	0.58	0.62	0.54	0.51	0.46
		$NDVI_{ave}$	0.21	0.22	0.22	0.20	0.19	0.17
LST	In - Green Space Boundry	LST_{min}	34.04	41.16	38.76	38.88	34.75	30.62
		LST_{max}	39.86	47.83	45.20	45.16	39.06	34.59
		LST_{ave}	36.04	43.81	40.97	41.68	36.01	31.87
	Out - Green Space Boundry	LST_{min}	32.88	40.13	36.99	37.64	33.28	29.58
		LST_{max}	47.40	52.41	50.59	49.68	42.65	37.14
		LST_{ave}	38.10	45.92	43.50	43.84	37.42	32.74
	In - 1x1 km Boundry	LST_{min}	32.88	40.13	36.99	37.64	33.28	29.58
		LST_{max}	47.40	52.41	50.59	49.68	42.65	37.14
		LST_{ave}	37.79	45.61	43.12	43.52	37.21	32.61
NDVI & LST Correlation		R	-**0.921**	-**0.846**	-**0.854**	-**0.906**	-**0.915**	-**0.844**

The average NDVI difference in the sample area is 0.17, while the average LST difference is 1.86 °C. The maximum temperature difference occurred in July at 2.53 °C, while the least difference was seen in October at 0.87 °C.

In the first sample area, which includes Hayat Park and the urban forest to the north, the amount of buildings and hard ground is high, but the amount of green area around these buildings is low. As a result, the average LST difference between inside and outside the green area (2.36 °C) of the first sample area is higher than the average LST difference between inside and outside the green area in the second sample area. Due to the lower amount of buildings and hard ground and the higher amount of vegetation in the periphery of the second sample area, Akdeniz city park and the fairground area in its north, the average LST difference (1.86 °C) between the inside and outside of the green area is lower than that of the first sample area. The average temperature difference between the inside and outside of the urban green space in both of the sampled areas was calculated to be 2.11 °C.

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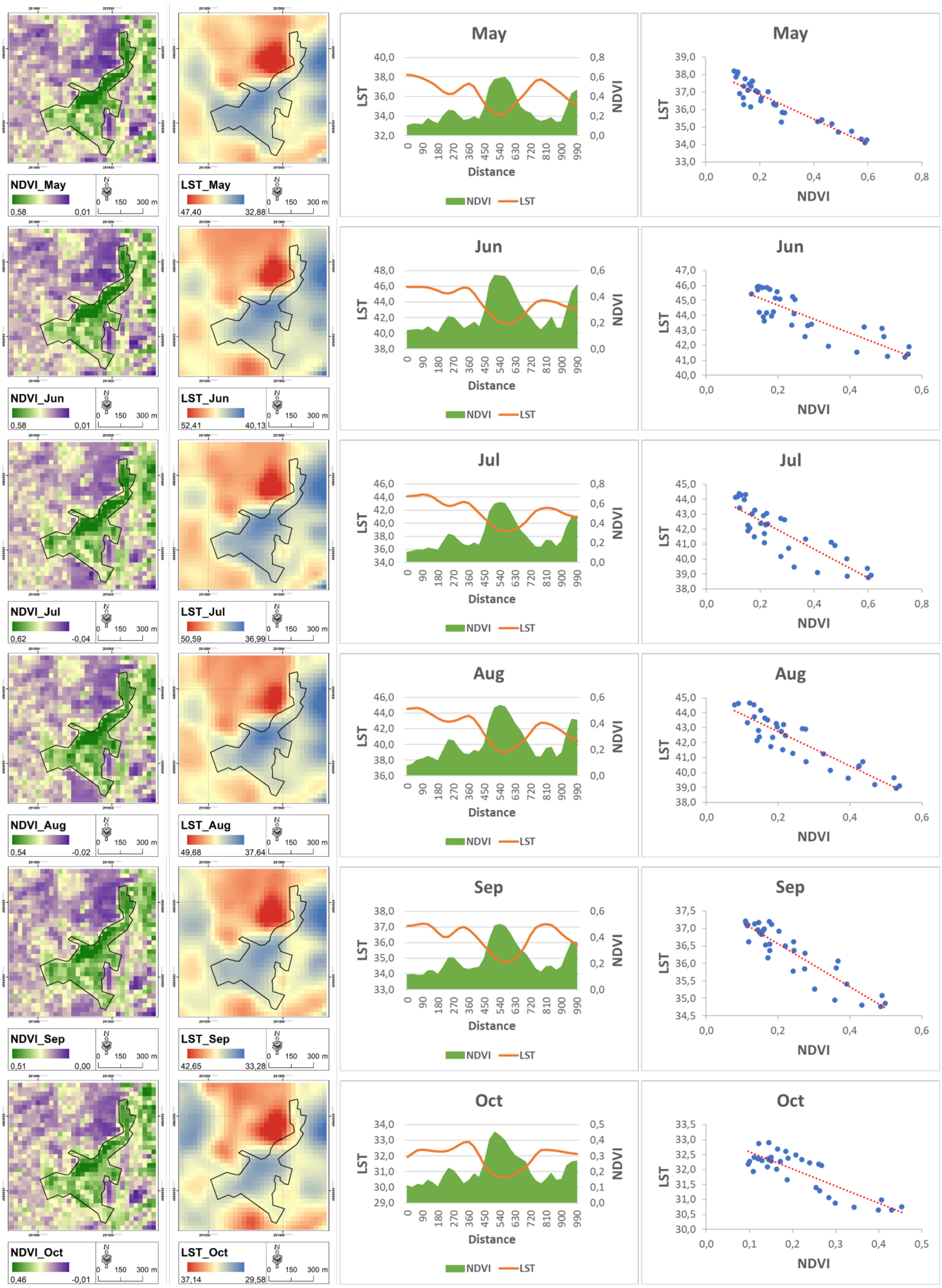

Figure 4. Monthly maps and graphs of the NDVI and LST for the Akdeniz Kent Park and Fairground sample area

In the first sample area, it was found that the plant density and surface temperature differences between green areas and the areas outside the green area border had a positive correlation (R=0.578), based on the results of the Pearson Correlation test. Similarly, a stronger positive correlation (R=0.933) was detected in the second sample area. These findings indicate that the presence of green areas has a cooling effect on land surface temperature in both sample areas. Furthermore, it was observed that as the NDVI difference between the inside and outside of the green area decreases, the LST difference also decreases, while an increase in the NDVI difference leads to an increase in the LST difference (Figure 5).

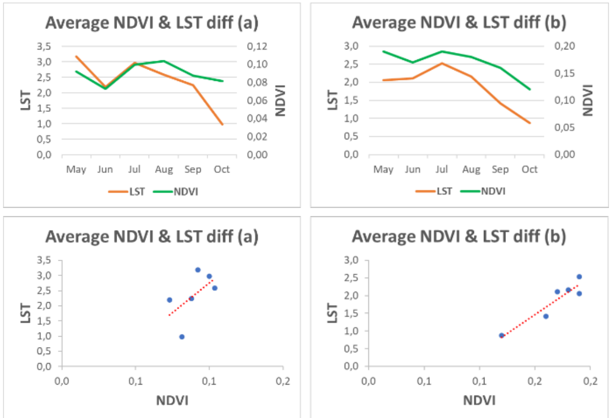

Figure 1. The average difference in NDVI and LST between inside and outside the green area for sample area 1 (a) and sample area 2 (b)

The relationship between vegetation density and land surface temperature has been extensively studied and is supported by the cross-section graphics in Figures 3 and 4 of this study. The literature also confirms that areas with low vegetation density in the land cover have higher land surface temperatures, while areas with high vegetation density have lower land surface temperatures (Leuzinger and Körner, 2007; Koc et al, 2018; Aram et al, 2019). Green areas, especially those with trees, have been shown to effectively reduce the land surface temperature of the surrounding environment (Frumkin and McMichael, 2008; Aram et al, 2019).

The aim of this study was to investigate how green areas affect the temperature in urban environments. To achieve this, temperature changes were measured in two sample areas of 1x1 km. The findings of the analysis are as follows Figure 6:

- In May, sample area 1 exhibited a cooling effect of 1.04 °C, whereas sample area 2 showed a lower cooling effect of 0.31 °C. The average cooling effect of green areas in May was calculated to be 0.67 °C.
- In June, sample area 1 had a cooling effect of 0.72 °C, whereas sample area 2 had a cooling effect of 0.32 °C. The average cooling effect of green areas in June was determined to be 0.52 °C.
- In July, sample area 1 had a higher cooling effect of 0.97 °C compared to sample area 2 which showed a cooling effect of 0.38 °C. The average cooling effect of green areas in July was found to be 0.67 °C.
- In August, sample area 1 had a higher cooling effect of 0.84 °C compared to sample area 2 which showed a cooling effect of 0.32 °C. The average cooling effect of green areas in August was determined as 0.58 °C.
- In September, sample area 1 showed a cooling effect of 0.73 °C, while the second sample area showed a cooling effect of 0.21 °C. The average cooling effect of green areas in September was determined as 0.47 °C.
- In October, sample area 1 showed a cooling effect of 0.32 °C, while the second sample area showed a cooling effect of 0.13 °C. The average cooling effect of green areas in October was determined to be 0.23 °C.

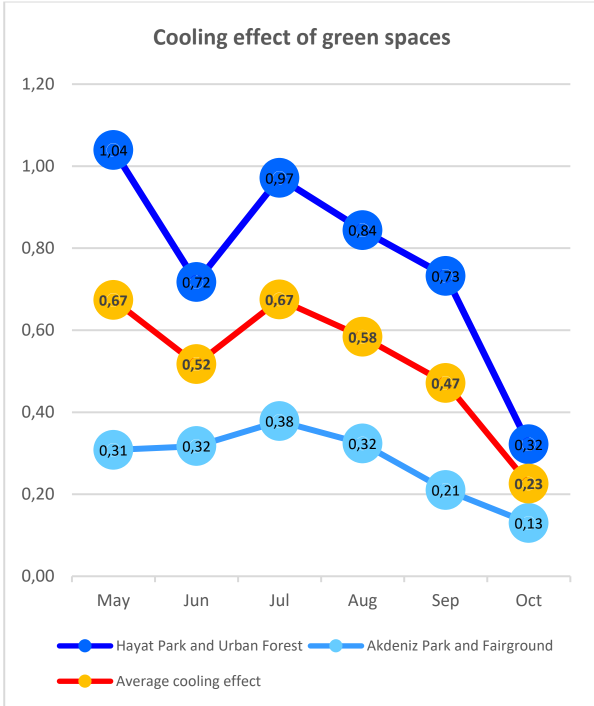

Figure 6. Cooling effect og green spaces in Konyaaltı

The results of the analysis indicated that the first sample area exhibited a greater cooling effect than the second sample area. This discrepancy is primarily attributed to the relatively larger amounts of bare soil and building area surrounding the Hayat park and urban forest, and the consequent lack of vegetation cover between buildings in the first sample area. In contrast, the high plant density in the land cover surrounding the Mediterranean city park and fairground area was the most significant factor contributing to the lower cooling effect observed in the second sample area. Additionally, the cooling effect of different plant species varied, with coniferous plants exhibiting lower surface temperatures than broad-leaved plants, as previously noted by Leuzinger and Körner (2007). Urban green areas have the potential to lower land surface temperatures by up to 5°C compared to other urban land cover types. Notably, the presence of green spaces in residential areas can lead to a cooling effect of up to 4°C on average surface temperature with an increase of 10% in coverage (Gill et al, 2007; Watkins et al, 2007; Frumkin and McMichael, 2008), thus highlighting the significant role that green areas, especially in urban environments, can play in mitigating temperature-related issues.

4. CONCLUSION

The primary objective of this investigation was to explore the cooling effects of urban green areas in the Konyaaltı district of Antalya province, using selected sample areas. The findings indicated significant variations in temperature between the surface temperatures of green areas within the sample areas and those outside the green area boundaries. The temperature discrepancies varied by month, with an average of 7.02 °C in the first sample area and 11.56 °C in the second sample area. The study observed that low plant density led to elevated land surface temperatures, while high plant density resulted in lower land surface temperatures. Additionally, a robust negative correlation between plant density and land surface temperature was established. Moreover, the investigation found that as the Normalized Difference Vegetation Index (NDVI) difference between the inside and outside of the green areas decreased, the land surface temperature difference also decreased. Conversely, the land surface temperature difference increased as the NDVI difference increased.

Through the analyses conducted to ascertain the potential cooling impact of urban green areas on land surface temperature, it has been established that the cooling effects varied between the two sample areas across the months. Upon averaging the six-month cooling effect of the sample areas, it was determined that the first sample area had an average cooling effect of 0.77 °C in its environs, while the second sample area had an average cooling effect of 0.28 °C in its environs. The observed difference is believed to be due to differences in the composition of the land, the density of green spaces within the area, and the plant species present in the area. Collectively, the evaluation of both sample areas indicates that urban green spaces have an average cooling effect of 0.52 °C in the hot months of spring and summer within the Mediterranean climate zone.

The findings of this study reveal that green areas play a crucial role in mitigating the warming effect of urban areas that are dominated by impervious surfaces. Therefore, it is recommended that urban green spaces should be expanded by implementing green infrastructure planning as a means of addressing the pressing challenge of global climate change, which is recognized as a significant ecological and social issue of the current century. This would allow for greater utilization of the cooling capacity of green spaces in urban settings.

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REFERENCES

Aram, F., García, E. H., Solgi, E., & Mansournia, S. (2019). Urban green space cooling effect in cities. *Heliyon*, *5*(4), e01339.

Aydemir, K. P. K., Altınok, G. K., & Ünsal, Ö. (2022). Determining UHI Effect by Remote Sensing Method in Bolu City Centre, Turkey. *ICONARP International Journal of Architecture and Planning*, *10*(2), 735-758.

Bowler, D. E., Buyung-Ali, L., Knight, T. M., & Pullin, A. S., 2010. Urban greening to cool towns and cities: A systematic review of the empirical evidence. Landscape and urban planning, 97(3), 147-155.

Cinar, İ., Karakus, N., & Toy, S. (2023). Analysing daytime summer thermal comfort conditions for Turkey's third largest tourism destination. *Environmental Science and Pollution Research*, 1-11.

Escobedo, F. J., Kroeger, T., & Wagner, J. E., 2011. Urban forests and pollution mitigation: Analyzing ecosystem services and disservices. *Environmental pollution, 159*(8-9), 2078-2087.

Frumkin, H., & McMichael, A. J. (2008). Climate change and public health: thinking, communicating, acting. *American journal of preventive medicine*, *35*(5), 403-410.

Gill, S. E., Handley, J. F., Ennos, A. R., & Pauleit, S. (2007). Adapting cities for climate change: the role of the green infrastructure. *Built environment*, *33*(1), 115-133.

Hobbie, S. E., & Grimm, N. B. (2020). Nature-based approaches to managing climate change impacts in cities. *Philosophical Transactions of the Royal Society B*, *375*(1794), 20190124.

Karakuş, N. and Selim, S. (2022). Temporal and spatial distribution of outdoor thermal comfort conditions: The case of Konyaaltı-Antalya, Turkey. *The Journal of Graduate School of Natural and Applied Sciences of Mehmet Akif Ersoy University, 13*(2), 259-269.

Koc, C. B., Osmond, P., & Peters, A. (2018). Evaluating the cooling effects of green infrastructure: A systematic review of methods, indicators and data sources. *Solar Energy*, *166*, 486-508.

Leuzinger, S., & Körner, C. (2007). Tree species diversity affects canopy leaf temperatures in a mature temperate forest. *Agricultural and forest meteorology*, *146*(1-2), 29-37.

Moda, H. M., Filho, W. L., & Minhas, A. (2019). Impacts of climate change on outdoor workers and their safety: some research priorities. *International journal of environmental research and public health*, *16*(18), 3458.

Moradi, M., & Görer Tamer, N. (2017). Bursa Örneğinde Kentsel Büyümenin Yerel İklim Değişikliği Üzerine Etkisi. *Planlama* 2017;27(1):26–37.

Norton, B. A., Coutts, A. M., Livesley, S. J., Harris, R. J., Hunter, A. M., & Williams, N. S., 2015. Planning for cooler cities: A framework to prioritise green infrastructure to mitigate high temperatures in urban landscapes. *Landscape and urban planning, 134*, 127-138.

Olgyay, V. (1973). Design with climate, bioclimatic approach to architectural regionalism. Princeton University Press, 190p, Princeton.

Orhan, O. (2021). Mersin ilindeki kentsel büyümenin yer yüzey sıcaklığı üzerine etkisinin araştırılması. *Geomatik*, *6*(1), 69-76.

Pielke Sr, R. A., Pitman, A., Niyogi, D., Mahmood, R., McAlpine, C., Hossain, F., ... & de Noblet, N. (2011). Land use/land cover changes and climate: modeling analysis and observational evidence. *Wiley Interdisciplinary Reviews: Climate Change*, *2*(6), 828-850.

Susca, T., Gaffin, S. R., & Dell'Osso, G. R. (2011). Positive effects of vegetation: Urban heat island and green roofs. *Environmental pollution*, *159*(8-9), 2119-2126.

Watkins, R., Palmer, J., & Kolokotroni, M. (2007). Increased temperature and intensification of the urban heat island: Implications for human comfort and urban design. *Built Environment*, *33*(1), 85-96.

Yang, J., Jin, S., Xiao, X., Jin, C., Xia, J. C., Li, X., & Wang, S. (2019). Local climate zone ventilation and urban land surface temperatures: Towards a performance-based and wind-sensitive planning proposal in megacities. *Sustainable Cities and Society*, *47*, 101487.

Zurqani, H. A., Post, C. J., Mikhailova, E. A., & Allen, J. S. (2019). Mapping urbanization trends in a forested landscape using Google Earth Engine. *Remote Sensing in Earth Systems Sciences*, *2*, 173-182.