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EFFECTS OF CEMETERY ECOSYSTEMS ON URBAN HEAT ISLANDS

Mezarlık Ekosistemlerinin Kentsel Isı Adaları Üzerindeki Etkileri

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ÖZ

Dini inanışlar gereği özel ilgi gösterilerek korunan mezarlıklar, sahip oldukları ekolojik özellikleri sebebiyle özellikle kentlerde ekosistemlerin düzenleyici servislerine katkı sağlarlar. Küresel iklim değişikliği kapsamında, bulundukları bölgenin mikro-iklimsel özelliklerini destekleyerek hava ve yüzey sıcaklıklarının dengelenmesine olanak sağlarlar. Kırsal alanlara göre daha yoğun sıcaklıkların hissedildiği kentlerde, mezarlıkların bu sıcaklık değerleri üzerindeki etkisinin sayısal değerlerle ortaya konulması çalışmanın motivasyonunu oluşturmaktadır. Bu çalışmada, Antalya'daki bazı kentsel mezarlıkların arazi yüzey sıcaklığı üzerindeki azaltıcı/arttırıcı etkisi uzaktan algılama ve coğrafi bilgi sistemleri ile somut olarak belirlenmeye çalışılmıştır. Bu amaçla, güncel ve açık erişimde olan Landsat 8 uydu görüntüleri kullanılmıştır. Görüntülere atmosferik düzeltme ön işlemleri uygulandıktan sonra ilgili mezarlıkların bitki indexi NDVI ile belirlenmiştir. Ardından arazi yüzey sıcaklığını belirlemek üzere 6 aşamalı arazi yüzey sıcaklığı (LST) algoritması uygulanmıştır. Oluşturulan NDVI ve LST görüntüleri üzerinden ArcGIS kullanılarak enine ve boyuna kesitler alınmış, bu kesit çizgisi üzerindeki her bir pixelin NDVI ve LST değerleri otomatik olarak belirlenerek karşılaştırılmış ve fark grafikleri oluşturulmuştur, doğruluk analizleri gerçekleştirilmiştir. Elde edilen sonuçlar, yoğun bitki örtüsüne sahip mezarlıkların arazi yüzey sıcaklıkları ile yakın çevresi arasında yaklaşık 3.42°C fark olduğunu, daha düşük bitki yoğunluklu mezarlıklarda ise bu farkın azaldığını göstermektedir. Ayrıca çalışmada, Andızlı Mezarlığının çevresini soğutma etkisi 0.44°C, Uncalı Mezarlığının ise 0.33°C, Kurşunlu mezarlığının ise çevresini 0.30°C ısıtma etkisi olduğu sonucuna varılmıştır.

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ABSTRACT

Cemeteries, which are protected with special attention due to religious beliefs, contribute to the regulatory services of ecosystems, especially in cities, due to their ecological characteristics. Cemeteries, within the scope of global climate change, enable the balancing of air and surface temperatures by supporting the micro-climatic characteristics of the region they are located in. In cities where temperatures are more intense than in rural areas, the motivation of the study is to reveal the effect of cemeteries on these temperature values with numerical data. In this study, the reducing/increasing effect of some urban cemeteries in Antalya on land surface temperature was tried to be determined concretely by remote sensing and geographic information systems. For this purpose, up-to-date and open access Landsat 8 satellite images were used. After atmospheric correction pre-treatment was applied to the images, the vegetation index of the relevant cemeteries was determined by NDVI. Then, a 6-stage land surface temperature (LST) algorithm was applied to determine the land surface temperature. Cross-sections were taken from the created NDVI and LST images using ArcGIS, the NDVI and LST values of each pixel on this section line were automatically determined and compared, and difference graphs were created, and accuracy analyses were performed. The results obtained show that there is a difference of approximately 3.42°C between the land surface temperatures of the cemeteries with dense vegetation and their immediate surroundings, and this difference decreases in the cemeteries with sparse vegetation. In addition, it was concluded in the study that the cooling effect of the Andızlı Cemetery was 0.44°C, the Uncalı Cemetery was 0.33°C, and Kurşunlu Cemetery was a heating effect of 0.30°C.

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RESEARCH ARTICLE / ARAŞTIRMA MAKALESİ

1. INTRODUCTION

Today, the opportunities offered by cities, such as education, health, and employment, are more accessible compared to rural areas has accelerated urbanization. As a result, cities are growing twice as fast in terms of area compared to population growth (Angel et al., 2011; Seto et al., 2011). Indeed, the fact that 80% of the Global Gross Domestic Product (GDP) is made from cities reveals the place and importance of urbanization in the welfare level of society (Grubler and Fisk, 2012). Moreover, urban sprawl threatens habitats and increases deforestation. Therefore, carbon emissions increase as a result of land use changes. In fact, according to UN Habitat (2011), 71-76% of carbon emissions and 67-76% of global energy consumption occur in cities today (Seto et al., 2014; UN Habitat, 2011).

The acceleration of industrialism, infrastructure, and human activities in urban areas and the new consumption practices are important factors contributing to greenhouse gas emissions (Mahmood et al., 2020; Liobikienė and Butkus, 2019; Liu and Bae, 2018). For instance, burning fossil fuels, such as coal, oil, and gas, increases the production of gasses such as methane, carbon dioxide, ozone, chlorofluorocarbons, and hydrofluorocarbons create an atmospheric greenhouse effect. This increase causes a rise in the annual average surface temperature and the urban heat island effect (Höök and Tang, 2013; Forster et al., 2007). This corresponds well to why climate change is felt more in cities on a regional and global scale (Levermore et al., 2018). While the vegetation decreases due to urbanization, an increase in impermeable surfaces is observed. These changes in the albedo characteristics and geometries of cities reduce the cooling rate and increase the perceived temperature since impermeable surfaces such as buildings and streets that absorb the sun's heat during the day do not return this absorbed heat energy as radiation at night. (Gill et al., 2007; Levermore et al., 2018).

Indeed, the literature indicates that the expansion of urban residential areas is spatially consistent with the expansion trend of the heat island effect. One of the most emphasized points in this literature seems to be the thermal comfort impact of urban green space (Bowler et al., 2010; Norton et al., 2015). In general, a large amount of urban green space can provide a high cooling effect and reduce the effects of urban heat island (Buyantuyev and Wu, 2010; Chen et al., 2006). Because the fact that the vegetation they contain has higher evapotranspiration and lower emissions compared to residential areas is the main factor in lower surface temperatures (Weng et al., 2004). Therefore, it can be said that urban green spaces directly impact the urban climate.

One of the essential structures among urban green spaces is urban cemeteries (Roy et al., 2012). Cemeteries, which were previously established outside the settlements but surrounded by the concentration of the city over time, are not exposed to pressures such as recreation and commercialization, unlike a typical city park (Gabriel, 2016; Rugg, 2006). In this light, it can be argued that they are well-protected and are one of the green areas best suited for daily use in the urban fabric (Nielsen et al., 2014).

Because cemeteries are cultural heritage sites and are places with complex meanings and uses that include cultural, social, and personal elements associated with community history (Barrett and Barrett, 2001; Pliberšek and Vrban, 2019; Woodthorpe, 2011). They play a critical role in the protection and support of urban biodiversity, thanks to the habitat heterogeneity they host and the habitat continuity they provide. In addition, they also contribute to regulatory ecosystem services by offering benefits such as climate regulation, rainwater retention, and cooling effect, similar to habitats containing predominantly trees (Haase et al., 2014; Kowarik et al., 2016).

Remote sensing technologies come to the fore in terms of producing data at different spatial scales and for different time periods by using high spatial-resolution images (Pu and Landry, 2012). Remote sensing and geographic information systems technologies can be used in urban green space systems and in determining and characterizing the role of cemeteries in these systems (Shojanoori and Shafri, 2016). In this context, this study aimed to demonstrate the benefits of cemeteries to ecosystem services and their contribution to the fight against the urban heat island effect. The motivation behind this research is the lack of a study on the determination of the cooling effect offered by the cemeteries in the province of Antalya, which are part of the urban green space system and which are often ignored despite the ecosystem services they provide. In this research, intensity the existing green texture of the city cemeteries of Uncalı, Andızlı, and Kurşunlu within the borders of Antalya province affects the temperature of the land surface around them was analysed.

2. MATERIAL AND METHODS

2.1. Study Area

The study covers 3 big cemeteries within the borders of Antalya province. Uncalı cemetery, located in the central district of Konyaaltı, has an area of 19.95 ha and is located at 36°53'53.30"N and 30°37'32.10"E coordinates. Andızlı City Cemetery, located in the central district of Muratpaşa, has an area of 13.00 ha and is at the coordinates of 36°53'38.09"N and 30°42'31.07"E. Kurşunlu City Cemetery in Aksu district has an area of 22.80 ha and is located at 37° 1'34.22"N and 30°49'59.03"E coordinates (Figure 1).

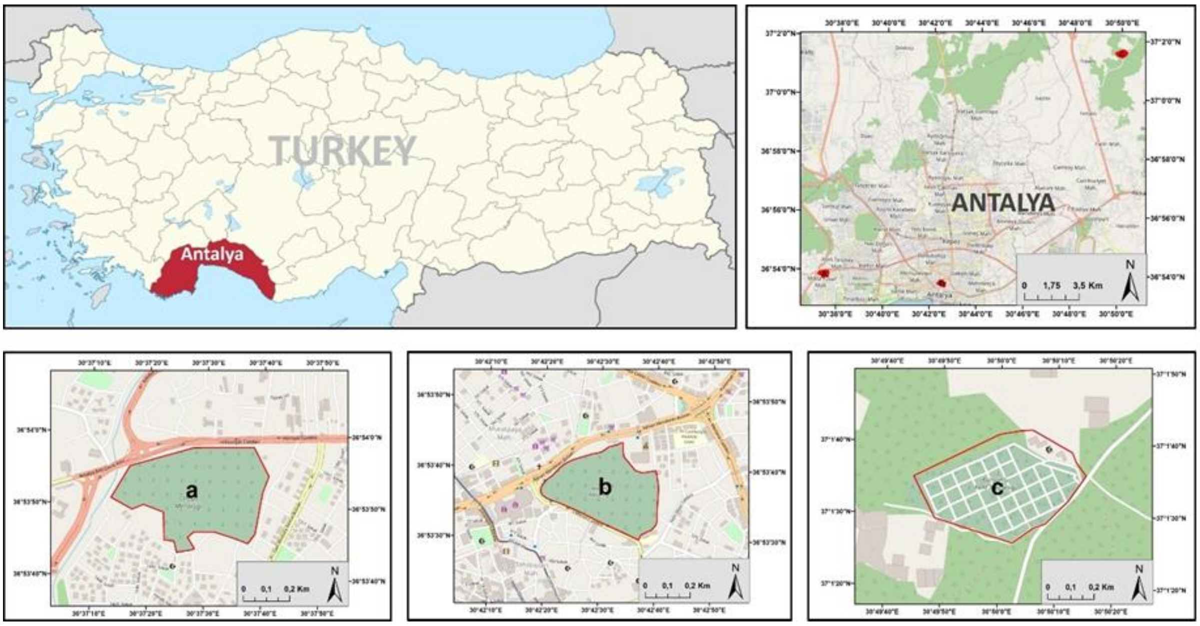

Figure 1. Locations of cemeteries (a; Uncalı Cemetery, b; Andızlı Cemetery, c; Kurşunlu Cemetery)

Şekil 1. Mezarlıkların konumları (a; Uncalı Mezarlığı, b; Andızlı Mezarlığı, c; Kurşunlu Mezarlığı)

Antalya is a vibrant touristic city and is densely populated throughout the year. The fact that it is one of the top locations in Turkey where the number of sunny days and the average temperatures are high has been significant for its selection as the study area. In addition, the size of the area, vegetation density, and environmental land uses were the key components in the selection of which cemeteries to choose. According to the data based on the measurements of the General Directorate of Meteorology between 1930 and 2021, the average temperature values in the province of Antalya in June, July, and August were 25.3°C, 28.5°C, and 28.4°C; the average lowest temperatures were 19.6°C, 22.8°C, and 22.8°C; and the average highest temperature values were 30.7°C, 34.1°C, and 34.1°C respectively. In addition, the highest temperature values measured in the city were 44.8°C for June, 45.0°C for July, and 44.8°C for August (Meteoroloji Genel Müdürlüğü, 2022).

2.2. Data Sets

The primary dataset of the study consists of related bands of Landsat 8 OLI/TIRS satellite images with 30 m spatial resolution, dated 14.06.2021 (Table 1). The Operational Land Imager

(OLI) and the Thermal Infrared Sensor make up the bulk of the data of the Landsat 8 satellite (TIRS). With a spatial resolution of 30 meters (visible, NIR, and SWIR), 100 meters (thermal), and 15 meters, these two sensors give seasonal coverage of the pieces of land on the planet (panchromatic). NASA and the U.S. Geological Survey collaborated to produce Landsat 8 (USGS). At the Earth Resources Observation and Science (EROS) center, USGS is in charge of post-launch calibration efforts, satellite operations, data creation, and archiving. QGIS 3.6.3 and ArcGIS 10.4.1 software was used to process the images.

Table 1. Characteristics of bands used in Landsat 8
Tablo 1. *Landsat 8'e ait kullanılan bandların özellikleri*

Bands	Wavelength (micrometers)	Resolution (meters)
Band 4 - Red	0.64-0.67	30
Band 5 - Near Infrared (NIR)	0.85-0.88	30
Band 10- Thermal Infrared (TIRS) 1	10.6-11.19	100

2.3. Methods

The method of the study consists of 3 stages: preprocessing satellite images, performing (Normalized Difference Vegetation Index) NDVI and (Land Surface Temperature) LST analyses, and applying accuracy analyses. In the first stage, the atmospheric correction process was applied to the provided satellite images using QGIS software. In the second stage, band 4, band 5, and band 10 were used to perform NDVI and LST analyses, and the following procedures were applied respectively (Figure 2).

Then, horizontal, and vertical section lines were applied to the produced images. The NDVI and LST values of each pixel on the raster data of the section lines were automatically extracted. Following these processes, the obtained data were carried over to the table, and various graphs were created in line with this information. Finally, in the last stage of the study, Pearson correlation (Equilibrium 1) was applied to the data to determine whether there is a linear relationship between the obtained NDVI and LST values and, if so, what the direction and severity of this relationship is.

$$r = \frac{\sum(\mathrm{x}-\bar{\mathrm{x}})\,(\mathrm{y}-\bar{\mathrm{y}})}{\sqrt{\sum(\mathrm{x}-\bar{\mathrm{x}})^2\ \sum(y-\bar{y})^2}} \quad (1)$$

Where x and y represent NDVI and LST values as example means of the two value arrays. Where x¯, mean of x variable and y¯, mean of y variable. If the resultant value r is close to +1, this indicates a strong positive correlation. If the resultant value r is close to -1, this indicates a strong negative correlation (Lee Rodgers and Nicewander, 1988).

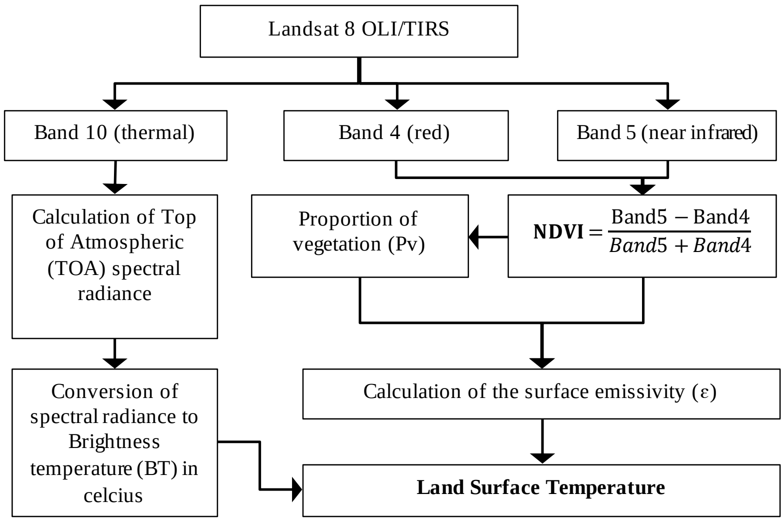

Figure 2. LST and NDVI processes
Şekil 2. LST ve NDVI süreçleri

3. RESULTS

This study was carried out to determine in which direction and to what extent the existing green texture of the city cemeteries of Uncalı, Andızlı and Kurşunlu within the borders of Antalya province affects the temperature of the ground surface around it. LST and NDVI maps of the cemeteries and their immediate surroundings were produced using the three bands of the Landsat 8 OLI/TIRS satellite image. In the immediate vicinity of the cemeteries, a 1x1 km border was created to include the cemetery. In order to determine the relationship of the ground surface temperature with the green texture and the effect of the green texture within the cemetery on its surrounding environment, sections were taken in the West-East and South-North directions in the research area. The relationship between ground surface temperature and green texture was determined by using the LST and NDVI values of the pixels in the section plane.

Maps and graphics of the Uncalı cemetery can be seen in Figure 3. Uncalı cemetery has a size of 19.95 ha. Approximately 50% of the cemetery is covered with vegetation. While there is dense vegetation in the north, northeast, and in middle parts of it, there is less vegetation in the south, southeast and southwest. The NDVI values of Uncalı cemetery were found to be a minimum of 0.14, a maximum of 0.29 and an average of 0.22. In the area around the cemetery, the NDVI was determined to be a minimum of 0.06, a maximum of 0.38, and an average of

0.20. The minimum LST value of Uncalı cemetery was 37.42 °C, the maximum was 40.88 °C and the average was 38.99 °C. In the area around the cemetery, the minimum LST value was 38.28 °C, the maximum was 43.48 °C, and the average was 40.66 °C. The average LST in the 1x1 km area within the cemetery was determined as 40.32 °C.

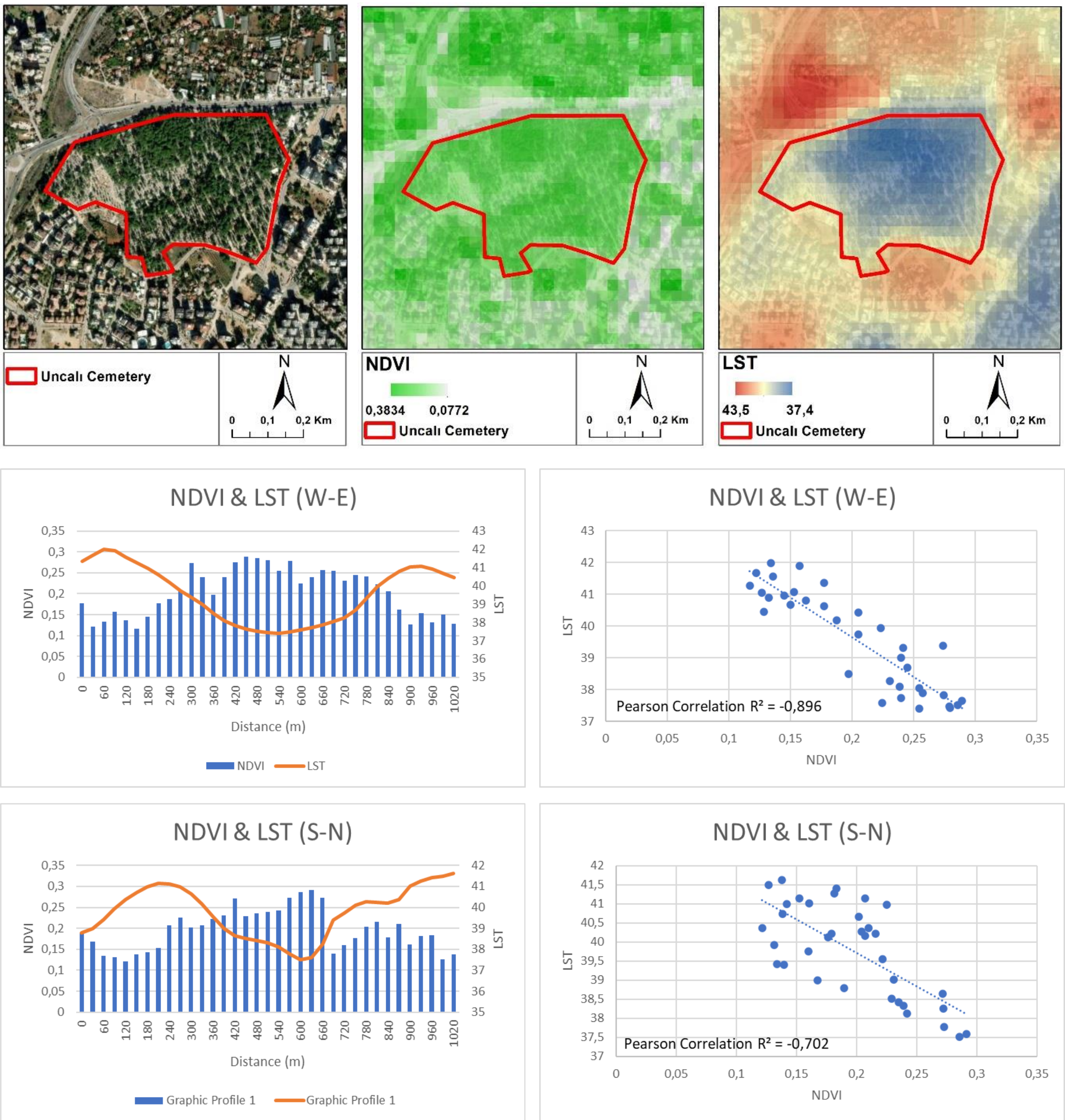

Figure 3. Uncalı Cemetery
Şekil 3.*Uncalı Mezarlığı*

According to the Pearson Correlation test applied to the NDVI and LST data in the cross-sectional plane taken in the West–East direction, a strong negative correlation (R2=-0.896) was found between NDVI and LST. The cemetery is located between 210 and 930 meters in the cross-section graph created in the West-East direction. It was observed that LST increases due to the low plant density to the west and east, outside the cemetery, and a decrease in LST due to the increase in plant density inside the cemetery borders.

According to the Pearson Correlation test applied to the NDVI and LST data in the cross-sectional plane taken in the South-North direction, a negative correlation (R2=-0.702) was found between NDVI and LST. In the section graph created in the south-north direction, the cemetery is located between 330 and 660 meters. LST values were measured low due to the high plant density of the land cover in the south of the cemetery. These values increased with the decrease in the plant density as the line scanned by the cross-sectional area was followed and decreased again with the increase in the plant density in the cemetery. Although the plant density in the north of the cemetery is higher than in the south, it was observed that there was an increase in LST due to the differentiation of the land cover.

The maps and graphics of the Andızlı cemetery can be seen in Figure 4. Andızlı cemetery has a size of 13 ha. Approximately 80% of the cemetery is covered with vegetation, but there are partial openings in the middle and south. Andızlı cemetery NDVI values were measured as a minimum of 0.11, a maximum of 0.38 and an average of 0.26. The NDVI values in the area around the cemetery were determined as a minimum of 0.02, a maximum of 0.38 and an average of 0.13. The minimum LST value of the Andızlı cemetery is 35.92 °C, the maximum LST value is 39.55 °C, and the average LST value is 37.35 °C. In the area around the cemetery, the minimum LST was 39.86 °C, the maximum LST 42.72 °C and the average LST 40.77 °C. The average LST in the 1x1 kilometer area where the cemetery is located was determined as 40.33 °C.

According to the Pearson correlation test applied to the cross-sectional data taken in the West–East direction, a strong negative relationship (R2=-0.897) was found between NDVI and LST. In the cross-section graph created in the west-east direction, the cemetery is located between 270 and 780 meters. It was observed that the ground surface temperature was high due to the low plant density in the western and eastern land cover in the outer part of the cemetery, and the ground surface temperature was low due to the high plant density within the confines of the cemetery.

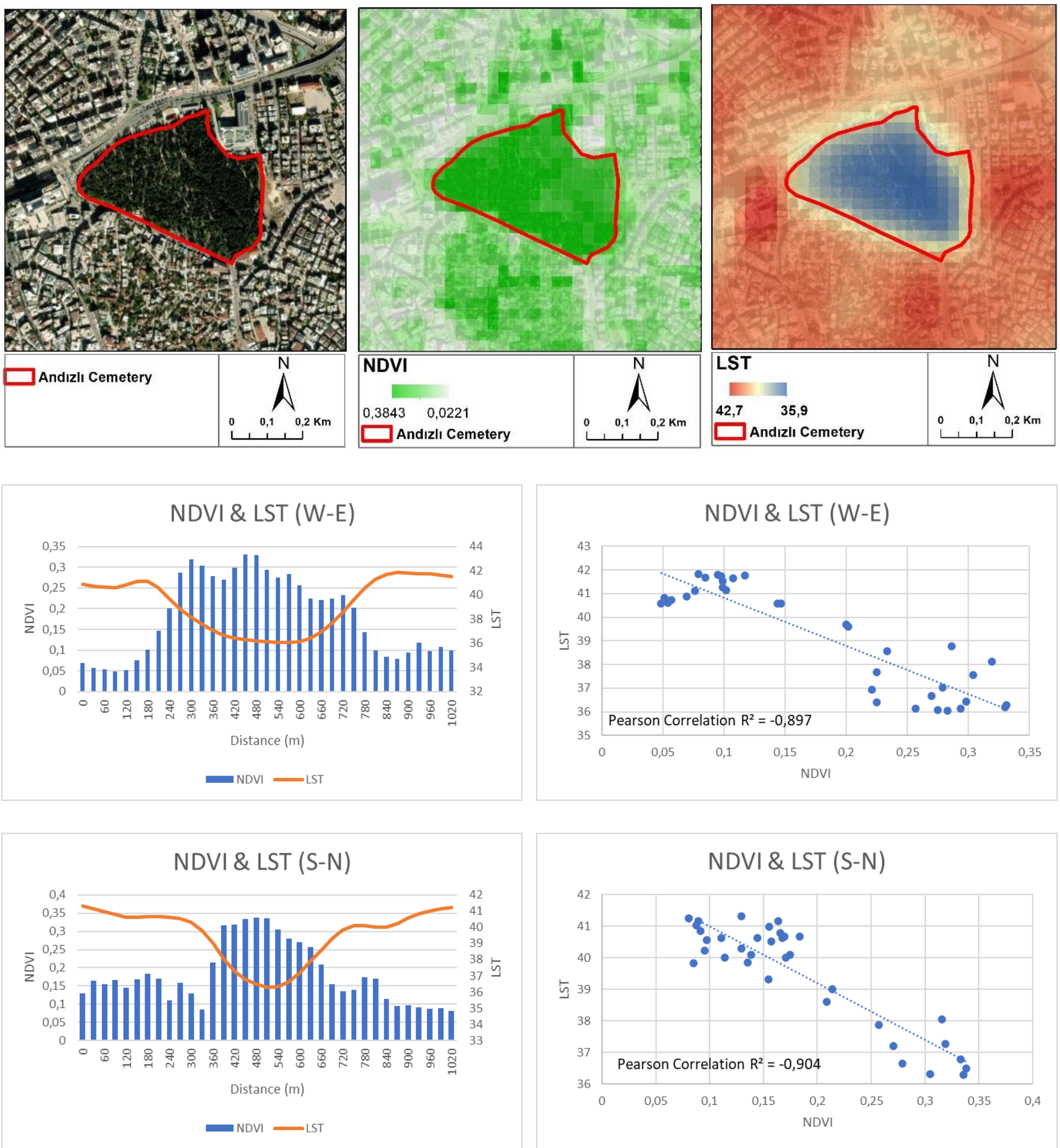

Figure 4. Andızlı Cemetery
Şekil 4.*Andızlı Mezarlığı*

According to the Pearson Correlation test applied to the data in the cross-sectional plane taken in the South–North direction, a strong negative relationship (R2=-0.904) was found between NDVI and LST. In the section graph created in the south-north direction, the cemetery boundaries fall between the 390th and 690th meters. It has been observed that the ground surface temperature is high due to the low vegetation density in the land cover to the south and north of the cemetery, while the ground surface temperature is low due to the high vegetation density in the cemetery.

Maps and graphics of Kurşunlu Cemetery can be seen in Figure 5. Kurşunlu cemetery has a size of 22.80 ha. Approximately 30% of the cemetery is covered with vegetation. While there is a relatively dense vegetation along the northeast-southwest boundary line of the cemetery, thinning of the vegetation in clusters is observed towards the middle of the cemetery. The NDVI values in Kurşunlu cemetery were measured at a minimum of 0.06, a maximum of 0.27 and an average of 0.14. In the area around the cemetery, the NDVI was determined to be 0.04 at a minimum, 0.46 at a maximum, and 0.20 on average. The minimum LST value of Kurşunlu cemetery was found to be 37.72 °C, maximum was 44.47 °C and the average was 40.49 °C. In the area around the cemetery, the minimum LST was determined as 34.66 °C, maximum 46.94 °C and an average of 39.15 °C. The average LST in the 1 km^2 area containing the cemetery was determined as 39.45 °C.

According to the Pearson correlation test applied to the cross-sectional data taken in the West–East direction, a strong negative relationship (R2=-0.841) was found between NDVI and LST. The cemetery is located between 210 and 760 meters in the cross-section graph created in the west-east direction. It was observed that the ground surface temperature increased due to the low plant density in the land cover to the west of the cemetery and within the cemetery. In addition, it was observed that the ground surface temperature decreased due to the high plant density in the east of the cemetery.

According to the Pearson correlation test applied to the data in the cross-sectional plane taken in the South–North direction, a negative correlation (R2=-0.744) was found between NDVI and LST. In the section graph created in the South-North direction, the cemetery is located between 330 and 720 meters. When this cross-sectional line is followed starting from the south, the LST values were measured low due to the high vegetation density in the land cover. When moving towards the cemetery, an increase was observed in the measurements in parallel to the decrease in the vegetation density, then temperature measurements decreased again in correlation with the increase in the vegetation density in the north of the cemetery.

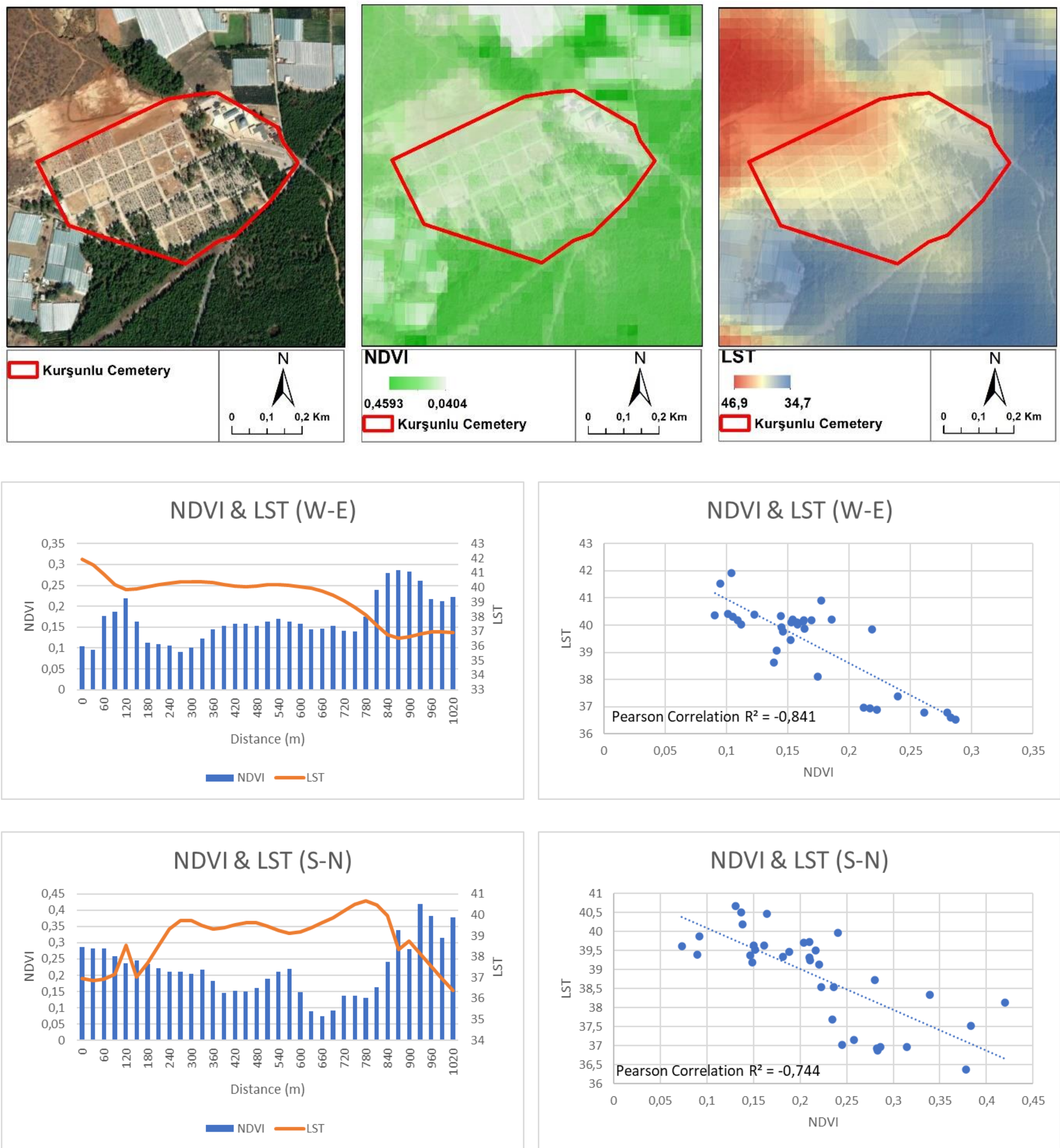

Figure 5. Kurşunlu Cemetery
Şekil 5. *Kurşunlu Mezarlığı*

4. DISCUSSION AND CONCLUSION

In this study, in what direction and how intensely the existing green texture of the city cemeteries of Uncalı, Andızlı, and Kurşunlu within the borders of Antalya province affects the surface temperature of the surrounding area was evaluated. It has been observed that there are significant temperature differences between the surface temperature inside the cemetery border and the surface temperature outside the cemetery border due to the difference in the plant density on the land cover of these two locations (Table 2).

Table 2. LST values of cemeteries and their surroundings

Tablo 2. *Mezarlıkların ve yakın çevresinin LST değerleri*

	In- Cemetery Boundry			Out- Cemetery Boundry			Average temperature difference	Cooling effect
	LST_{min}	LST_{max}	LST_{ave}	LST_{min}	LST_{max}	LST_{ave}		
Uncalı	37.42 °C	40.88 °C	38.99 °C	38.28 °C	43.48 °C	40.65 °C	1.33 °C	0.33 °C
Andızlı	35.92 °C	39.55 °C	37.35 °C	39.55 °C	42.72 °C	40.77 °C	3.42 °C	0.44 °C
Kurşunlu	37.72 °C	44.47 °C	37.35 °C	34.66 °C	46.94 °C	39.15 °C	1.80 °C	-0.30 °C

Not only that, but the differences in the land cover caused temperature differences within the cemetery boundaries themselves. The most important factor in the formation of the temperature difference both inside the cemetery and between the cemetery and the surrounding land is the land cover. It was seen that the land surface temperature is high in regions where the vegetation density in the land cover is low, and the land surface temperature is low in the regions where the vegetation density in the land cover is high (Leuzinger and Körner, 2007; Koc et al., 2018; Aram et al., 2019). Literature states that the trees help in lowering the average land surface temperature of their surroundings (Spronken-Smith and Oke, 1998; Gill et al., 2007; Watkins et al., 2007; Frumkin and McMichael, 2008; Aram et al., 2019). Coniferous plants are better than broad-leaved plants in lowering the surface temperature (Leuzinger and Körner, 2007; Zengin et al., 2019). Since residential areas have a heterogeneous land cover, such as concrete structures, open spaces, and green areas (Ardahanlıoğlu et al., 2020), they have higher land surface temperatures. Some studies show the land surface temperature of urban green areas with dense vegetation can be 5 °C cooler than the land surface temperature of other urban land cover areas. In addition, trees play a significant role in the cooling of the city. A 10% increase in green spaces in residential areas can reduce the city's average surface temperature by up to 4°C (Spronken-Smith and Oke, 1998; Akbari, 2002; Gill et al., 2007; Watkins et al., 2007; Frumkin and McMichael, 2008). As seen in Table 2, the Andızlı cemetery, which has the densest vegetation of all three, has a cooling effect of 0.44 °C, while the Uncalı cemetery, which has lower vegetation density, has a cooling effect of 0.33 °C.

In contrast, Kurşunlu Cemetery, having the lowest vegetation density, stands out by having no cooling effect but rather heating up its surroundings by 0.30 °C. Generally, cemeteries have lower land surface temperatures due to denser vegetation compared to residential areas. In addition, higher land surface temperatures are observed in cemeteries with bare ground cover compared to cemeteries with vegetation. Since the land cover is heterogeneous and each object on the land surface has different reflection and absorption properties, surface temperature differences occur both within the cemetery itself and between the cemetery and its surroundings (Çelik, 2017; Çoşlu et al., 2021).

The results show that the average temperature of the Andızlı cemetery is 3.42 °C lower than its surroundings. It should be noted that in the Andızlı example, even though the study area is densely vegetated itself, the surrounding urban texture has a minimal green cover. It was concluded that the average temperature of the Uncalı cemetery, which is located on the periphery of a settlement and has a partial green texture around it, but itself has a medium density of vegetation, is 1.33 °C lower than its surroundings. On the other hand, it has been determined that the average temperature of Kurşunlu cemetery, which is in a rural area and has forests and open areas around it, but itself is mostly dense bare soil, is 1.80 °C higher than its surroundings. Considering all this information, it can be deduced that the cemeteries located in the city center have a greater cooling effect compared to the cemeteries located in the city periphery, and also, the cemeteries in rural areas might exhibit a heating effect instead of cooling. Just like other urban green areas, cemeteries should be evaluated within the green infrastructure, as they are beneficial to the urban ecosystem (Çınar et al., 2015). It is reported in the literature that when the cemeteries are not arranged according to landscape planning and landscape design criteria, the existing structure has deteriorated over the years (Özhancı and Aklıbaşında, 2017). Therefore, it should be considered as a physical planning issue (Akten and Özkartal, 2016). With the inclusion of cemeteries as active green spaces in the urban landscape, the ecosystem services provided by these cemeteries can be supported and the planning of qualified sustainable urban open-green space systems can be ensured (Tırnakçı, 2021). Contribution to ecosystem services should be increased by rethinking the existing ecological connectivity within the green infrastructure system to encompass independent green spaces such as cemeteries (Selim and Demir, 2018; 2019). It is suggested that one of the most important ecological focal points of the green infrastructure system should be accepted as cemeteries, and they should be included in local and regional planning by providing ecological connections of them with urban green spaces.

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