Research Article

ICONARP
International Journal of Architecture and Planning
Received: 19.10.2021 Accepted: 05.10.2022
Volume 10, Issue 2/ Published: 20.12.2022
DOI: 10.15320/ICONARP.2022.223 E- ISSN:2147-9380

ICONARP

Determining UHI Effect by Remote Sensing Method in Bolu City Centre, Turkey

Kıymet Pınar Kırkık Aydemir*
Gamze Kazancı Altınok**
Ömer Ünsal***

Abstract

Urban Heat Island (UHI) has been described by authors as the UHI effect is among the most common forms of human origin (anthropogenic) local climate change. The increasing UHI effect with the differences in land use and landscape pattern varies depending on surface soil, watery field presence and vegetation. In this study, using Landsat 5 TM of 1994 and Landsat 7 ETM+ images of 2019, the ArcGIS 10.6.1 program and the remote sensing methods have identified surface temperature and vegetation distribution. Surface temperature values of the land-use in Bolu province of 2019, 1/5000 Urban Development Plan land uses and average temperature values were determined. The study revealed the change between urban development and the effect of land surface temperature over the course of 25 years, and discussed the UHI effect in the Bolu province. The effects of the historical process in Bolu city center on land surface temperature (with LST differences) and vegetation distribution (Normalized Difference Vegetation Index; NDVI) have been surveyed. The constraints of this study are that the spatial resolution in orthophotos of 1994 is low, and the type of land-use temperature data cannot be compared to 2019. For this reason, LST and NDVI analyzes were conducted in 1994 orthophotos, classifying all parcels with structure and related area in the form of manually constructed areas (built Environment). One of the findings of this study are surface temperatures of areas used as farmland in the year 1994 data reached higher values after they quickly began to urbanize in Bolu. The main reason for the high surface temperature in the Bolu province over the 25-year period is that agricultural areas are impurized and increasing population density and the albedo effect. It has been concluded that the lack of green space and lack of vegetation in the continuous urban area has increased the UHI effect.

Keywords:
Urban Heat Island (UHI), LST, NDVI, GIS, Bolu.

*Faculty of Architecture, Bolu Abant İzzet Baysal University, Bolu, Türkiye (*Corresponding author*)
Email: kiymetpinar.aydemir@ibu.edu.tr

**Faculty of Architecture, Istanbul Technical University, Istanbul, Türkiye
Email: kazancig17@itu.edu.tr

***Social Sciences Institute, Istanbul University, Istanbul, Türkiye
Email: oomer.unsal@gmail.com

To cite this article: Kırkık Aydemir, P., & Kazancı Altınok, G. (2022). Determining UHI Effect by Remote Sensing Method in Bolu City Center, Turkey. *ICONARP International Journal of Architecture and Planning,* 10 (2), 735-758. DOI: 10.15320/ICONARP.2022.223

INTRODUCTION

The Urban Heat Island (UHI) is defined as a condition that prevents the view of the sky during the day, resulting from the absorption of overnight wavelength radiation and the retention of sun heat in the ground surface and structure (Oke, 1973; Montávez et al., 2000). The concept of urban heat island was first identified by Luke Howard in London, England in 1820 (Streutker, 2003). From 1900 onwards, the surface temperature discussed by various researchers and defined as the UHI is based on changes in land cover in cities. The UHI effect is among the most common forms of human-origin (anthropogenic) local climate change (Oke, 1973; Montávez et al., 2000). It differs depending on the construction of the layout in each city. In particular, the increased built-up areas, the excess conductivity and heat storage of the building materials used in recent years increase the visibility of temperature differences. Therefore, the temperature in dense-residential areas is observed several degrees higher than in rural areas (due to local atmospheric aeorosol concentration rise) (Oke, 1988; Wilby, 2007; Parker, 2010; Peker & Aydın, 2019).

The increased UHI effect with the differences in land-use and landscape pattern varies depending on surface soil, water content, and vegetation (Owen et al.,1998; Jianjun et al., 2005; Wu et al., 2014; LIN & LIN, 2016). The Intergovernmental Climate Change Panel (IPCC), which was held on 2014, the fifth report states that the main reason for the rising temperature since the beginning of the 20th century is the increase in emissions and greenhouse gas concentrations from human activity, emphasizing the relationship between population growth and propagating urban understanding with energy consumption patterns (Peker & Aydın, 2019). Therefore, there are many factors in cities that increase the UHI effect. The UHI and the components that affect the urban climate as indicated by Oke (1988) can be seen below:

•Urban geometry (the geographical location of the layout, distance, street widths and areas between the building dimensions,)

• Urban cover/surface cover (structured/tiled surfaces, vegetable surfaces, soil surfaces, water surfaces, bare surfaces)

• Urban fabric/building materials (construction and natural materials)

• Urban metabolism (heat, water and contamination due to human activity).

The urban geometry, expressed in the form of occupancy-spaces, formed by the surrounding area directly influences wind corridors and energy flow in the city (Oke, 1988). For example, the proximity between uncontrolled growth and structures in a dense, built-up environment with high-rise structures increases surface temperature (UHI effect) as it reduces atmospheric heat dissipation by changing wind speed and direction due to lack of green space. In addition, anthropogenic heat as the sum of the excess energy used in the transportation service and industry in heating and cooling activities in the urban area, may vary

DOI: 10.15320/ICONARP.2022.223

depending on the city's population and local climate conditions (Munn, 2002). The geographical location of the settlement directly affects local climate, and the sun determines the heat reaching the surface in the interaction between wind and cloud cover making an impact on the UHI (Zhao et al., 2016).

In terms of urban cover/surface cover the excess of built-up areas is impermeable and the coated surface ratio is higher than rural causing more solar radiation in urban areas to accumulate more heat than the natural ground of tar-covered or asphalt surfaces and the UHI effect in cities to rise (Chatzidimitriou & Yannas, 2017; Gómez et al., 2013). Therefore, the main reason for high temperatures in urban centers compared to periphery is the specified energy flow change (Graves et al., 2001; Wilby, 2007).

The texture of urban fabric/building materials that affect the formation of UHI in cities directly affects the proportion of thermal radiation, reflection and heat capacity of the preferred materials in urban areas as well as the storage and reflection of solar energy on the surfaces (Heyer, 1992). In this case, known as the Albedo effect, surfaces ranging from 0-1 include the capacity to reflect solar energy. As the albedo value approaching 1 increases the amount of energy stored on the surfaces, the UHI effects can decrease (EPA, 2008). Therefore, surfaces with a low albedo value increase the surface temperature in urban areas.

Table 1. Factors affecting UHI

Researchers	Factors
Jianjun *et al.,* 2005; Wu *et al.,* 2014; Lin & Lin, 2016; Owen *et al.,* 1998	Soil, slope, water sources, vegetation
Oke (1988)	Urban geometry, urban cover, urban metabolism
Oke, 1973; Montávez *et al.,* 2000	Land-use change
Liu *et al.,* 2015; Ullah *et al.,* 2022	Urban landscape
Kohl, 1999; Hais & Kucera, 2009; Beltrami, 2005; Luhar, 2006; Yılmaz *et al.,* 2016; Yıldız *et al.,* 2019	Industrial development, population density, topography and meteorology
IPCC, 2014; Peker & Aydın, 2019	Anthropogenic factors, population growth, urban growth

The urban canyon, which is created a morphology of the city, affects heat loss by reducing the view factor of the sky in it. Some researches shows that long structures and narrow canyons reduce the sky aspect factor creating high hot concentrations due to cool day and energy storage at night (McPherson et al., 1994; Bosselmann et al., 1995, Yang et al., 2016; Tonyaloğlu, 2019). Due to low evaporation rate, the UHI effect is increasing as the temperature concentration of cities and regional temperature is affected (Parry et al., 2007). Further research highlights that there is a versatile link between landscape pattern and UHI from the ground to the global scale (Liu et al., 2015; Ullah et al., 2022). Built-up areas and barren terrain increase the UHI effect while green areas and water surfaces reduce the UHI effect (Zhong et al., 2017; Sannigrahi et al., 2017; Ullah et al., 2022). Therefore, the industrial development of a city, population size, topographic status, meteorological conditions and physical macroform have a significant impact on the UHI effect (Kohl, 1999; Hais & Kucera, 2009; Beltrami, 2005; Luhar, 2006; Yılmaz et al., 2016; Yıldız et al., 2019). The factors affecting the UHI are covered by many researchers (Table 1).

As stated in Table 1, the physical structure of cities (such as soil, slope, water sources, vegetation), urban geometry, urban cover/land-use, population density and human activity are key factors that increase the UHI impact. The concepts such as urban climate, urban ecology, urban geography, landscaping and planning are also the focus of research due to the unfavorable effects of cities on urban ecosystems (Amberber et al., 2019). The UHI effect is directly related to the urban temperature and the perceived temperature, affecting urban life as well. The use of energy sources due to the need for additional heating and cooling systems causes the UHI effect to increase (Tomlinson et al., 2011). This also prepares the environment for the formation of high radiation fields, described as "concrete forests". The low wind speed in these areas also increases the temperature differences between urban and rural (Landsberg, 1981; Wilby, 2007). This is the main reason that the temperature felt during the summer months is above the seasonal values (Parry et al., 2007). Due to the high temperatures felt, the city's thermal comfort is deteriorating and poses serious threats to the health of the urban population (Frumkin & McMichael., 2008). The UHI also has negative effects on vegetation development, air and water quality (Zhao et al., 2016). There are many environmental problems in cities that are caused by the UHI effect (Table 2).

Table 2. UHI effects in urban areas

Researchers	UHI impacts
Parry et al., 2007; Landsberg, 1981; Wilby, 2007; Guoxiang vd., 2010; Zhao et al., 2016	Increasing temperatures
Landsberg, 1981; Wilby, 2007	The temperatures differences between urban and rural areas
Tomlinson et al., 2011	Increasing energy consumption
Guoxiang et al., 2010; Zhao et al., 2016	Negative impacts on vegetation, air and water quality
Frumkin and McMichael, 2008	Public health deterioration

As can be seen in Table 2, the rise in temperature leads to temperature differences in urban and rural areas increased energy use and demand, reduced environmental quality and deterioration of public health. Clean energy and zero carbon applications are essential in the energy-intensive workplace (industry, manufacturing, etc.) for reducing the UHI impact (Hunt et al., 2007). The presence of trees and vegetation

DOI: 10.15320/ICONARP.2022.223

in the urban areas helps reduce surface temperatures with the ability to create shadows and reduce the amount of sunlight felt (Gallo et al., 1999; Akbari, 2002).

There are different methods for measuring the UHI effect based on observations grouped as atmospheric and surface heat islands. In the urban cover layer and heat layer, thermometers and air temperature measurements (fixed air stations/mobile stations) are performed, while in the determination of surface heat islands, surface temperature measurements (thermal images) take place using remote sensing methods and thermal images (EPA, 2008). The UHI measurement on the top layer is made from fixed meteorology and mobile stations 2 meters above the ground, heat islands on the boundary layer measured at more than 2 meters, and through measuring towers and balloons instead of mobile stations (Voogt & Oke, 2003). The remote sensing technique, which is learned about lands and sea surfaces covers images from an aerial perspective using beam in one or more areas of the electromagnetic spectrum, in addition to radiated or reflected rays from the earth's surface. This method allows the computational data for the UHI effect resulting in a large number of thermal data at a time (Campbell & Wynne, 2011).

This study identified the change between urban development and the effect of land surface temperature over the course of 25 years by using Landsat 5 TM and Landsat 7 ETM+ images from 1994 and Landsat 2019 to deduct the UHI effect in the Bolu province. The effect of the historical process in Bolu city center on land surface temperature (with LST differences) and vegetation distribution (with Normalized Difference Vegetation Index (NDVI)) has been determined. Accordingly, the objectives of the research are to evaluate the surface temperature and to reveal the relationship between urban development and surface temperature using the remote sensing method.

MATERIAL

Bolu is located 262 km from Istanbul and 191 km from Ankara on the side of the D-100 (E-80) highway connecting Istanbul to Ankara in Turkey. Bolu’s border neighbors are Düzce and Sakarya in the western direction, Çankırı in the east and in the north of Zonguldak and Karabük. Geographically, Bolu is located between the 30°32' and 32°36' east longitude and the 40°06' and 41°01' north latitude (Kaya, 2019). The city center is set up in the Bolu plain, and is limited to two major mountain lanes in the north and south (DPT, 2002).

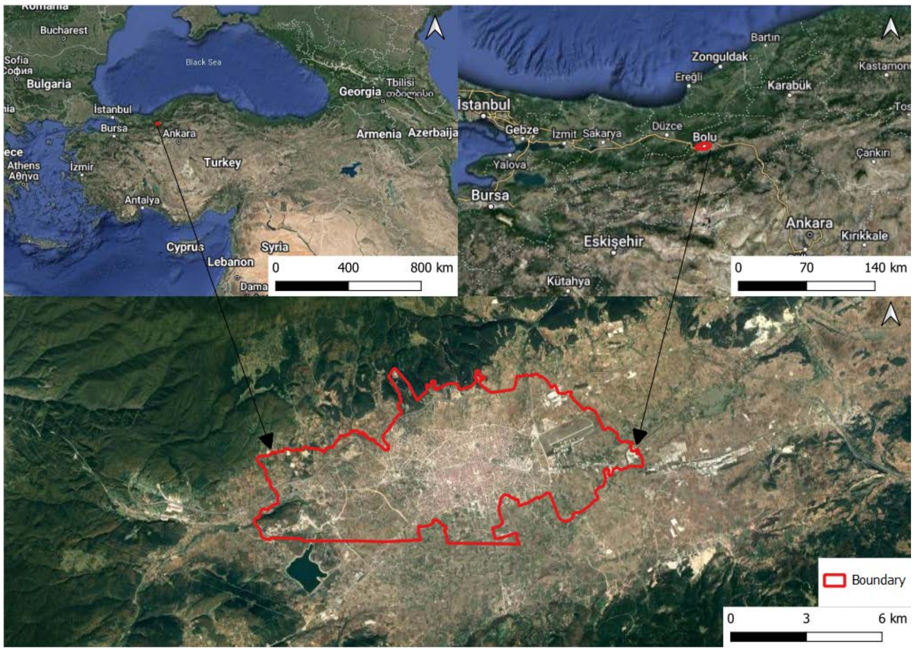

Figure 1. The Case study border and the geographical location of Bolu.

Topographically, the rise in rural settlement is 1460m and falls to 690m in the city center (Figure 2).

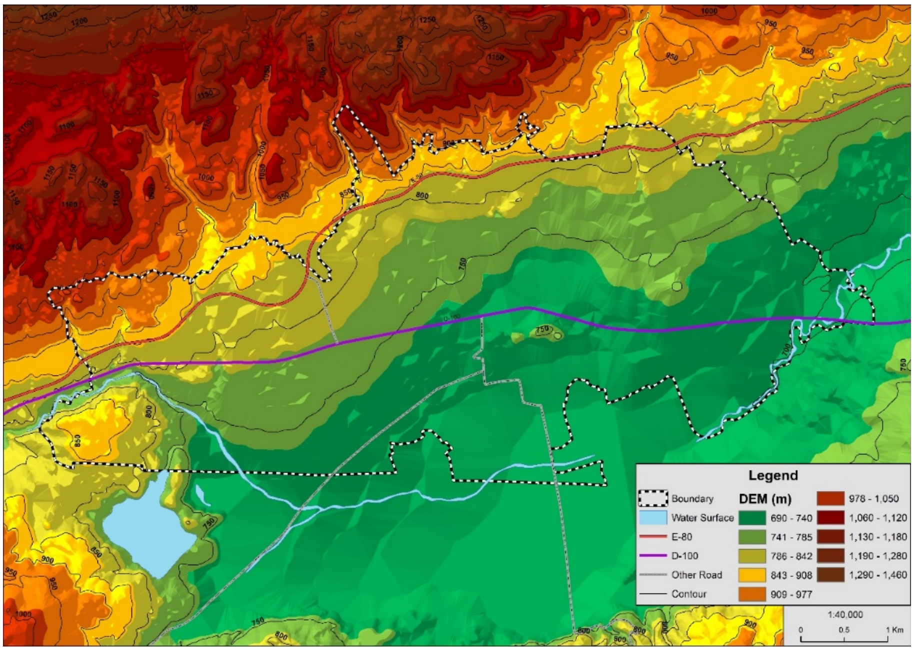

Figure 2. Topographical map of Bolu.

Between 1929 and 2019, the annual temperature in the Bolu city center is known to be the highest 39.8°C in summer and the lowest -31.5°C (Çağlak et al., 2019). In the Bolu province which characteristically reflects the Black Sea climate transitions are seen with the Central Anatolian continental climate. The spring and autumn months are cool and the summer months are under warm stress in Bolu, which has been precipitation almost every year. Between 1929 and 2019, the average temperature in the city was 10.5°C and the wind speed measured in meteorological data was 1.3 m/h (Çağlak et al., 2019). After these general topographic and climatic information about

DOI: 10.15320/ICONARP.2022.223

Bolu, some figures and maps were prepared to understand the relationship between surface temperature and urban development. When preparing these figures and maps, base maps were used. The sources of base maps have indicated here. Figure 1, base maps are obtained from Google. Figure 2, the contours are obtained from General Directorate of Mapping, Ministry of National Defence, Republic of Turkey. From Figure 3 to Figure 11, the satelite images are obtained from Landsat and aerial imagery are obtained from General Directorate of Mapping, Ministry of National Defence, Republic of Turkey.

METHODOLOGY

Firstly, the images of Landsat 5 TM in 1994 (28.07.1994) and Landsat 7 ETM+ from 2019 (10.08.2019) were downloaded in the study. Urbanization process of Bolu, the effects of land surface temperature and vegetation distribution have been determined. To determine surface temperature, the calculation was performed in three stages, expressed in digital values (DN) or brightness values for satellite images by using ArcGIS 10.6.1 and its spatial analyst extension have used to all LST extraction, mapping and analysis processes (Gerçek et al., 2014; Alkan et al., 2017).

*Digital values (DN) are converted to spectral radiance (Lλ) values measured by the satellite. The equation set up for converting pixel values for satellite images to spectral radians is given below.

L λ='gain'*DN+'bias'

That is; Lλ = MLQcal + AL

Lλ= Spectral radians (Watts/(m2 * srad * μm))

ML= Band specific scaling multiplier factor

AL= Band specific scaling summation factor

Qcal = Quantize and calibrated standard pixel values (DN). In order to use the equation, it must be formulated as specified in the equation below.

"Lλ= (LMAXλ - LMINλ Lλ/ Qcal max - Qcal min)*Qcal max - Qcal min + LMINλ"

*In the second phase, after calculating the Spectral radiance value, these values must be converted to the brightness temperature (Kelvin). The equation required for this conversion is given below (Gerçek et al., 2014; Alkan et al., 2017).

"C=K -273.15"

Using the above equation, the LST difference between 2019 and 1994 was revealed. Data containing LST differences is classified in 10 classes according to the Natural Breaks (Jenks) method. Accordingly, hot zones (3.7 to 12.8°C), as the top class have been detected.

The Normalized Difference Vegetation Index (NDVI) maps for both two years were produced for the difference in vegetation in the study. The NDVI index has been developed using the high reflections of vegetations for the energy form of the near infrared wavelength and the high absorption of energy at the red wavelength in the visible region (Doğan et al., 2014). Therefore, NDVI analysis is a proportional expression of the linear relationship between close infrared and red spectral bands. IN the LANDSAT-7 ETM+ satellite, BAND 3 refers to visible red while BAND 4 refers to close infrared. The vegetation gives high reflectance in the close infrared band and low reflectance in the red band. The formula which is given below is used for NDVI value of Landsat TM images (Bonneau et al., 1999; Edwards et al., 1999; ERDAS 2003).

NDVI = (Band 4 - Band 3) / (Band 4 + Band 3)

In the scope of the study, urban and rural/periphery areas were observed using satellite images from both two periods to explain the land-use change between urban development and the effect of land surface temperature during the 25-year period between 1994 and 2019. In this context, orthophotos of two years were provided by the Ministry of National Defense Map General Directorate (2022) including the earliest 1994 years before the 1999 earthquake, which is a breaking point for shaping Bolu city center macroform. Because the 1994 orthophotos was taken with an analogue camera there are no RGB bands and the spatial resolution is lower. Image classification tools were not available due to the resolution difference. After the current cadastral maps of the working boundary are provided as a solution, all parcels with the built environment in 1994-2019 are classified by manually. The rest of the unstructured areas are classified as "Agriculture & Forest, Other" and the types of land, such as agricultural parcels and forests, are mapped. Thus, land use changes have been identified over the last 25 years (Figure 3).

The average temperatures of the land-use classification have been determined by the LST difference data in 2019-1994 and the Urban Atlas classes (Table 2). For this operation, the LST difference map is divided into one degree (such as 22-23 degrees). The data (raster) has been converted to raster data with a decimal value and a raster integer value. The decimal point range values (such as 22.5 degrees) are printed instead of the code values. The re-classification LST difference layer is converted to vector data format via raster to polygon. At the final stage, the Urban Atlas and vector LST differential layer are colliding through union.

DOI: 10.15320/ICONARP.2022.223

FINDINGS AND RESULTS

In order to understand the UHI effect, it is necessary to examine the topographic and morphological structure and spatial formation of Bolu city center as a case study area. The city center is located in the plain between the two mountains and the north and south of the Bolu plain (see Figure 2). Moreover, that the city is located in plain and peripheries are completely surrounded by built-up areas, causing the cooling air in the valley peaks to descend to the center over the slopes. In the city, where wind speed is insufficient, polluted air is accumulated above the city (Bolu ÇŞİM, 2020; Çağlak et al., 2021). The temperature differences between the city center and the periphery also seen in the Bolu city (Çalışkan & Türkoğlu, 2014; Tonyaloğlu, 2019; Toy et al., 2019). The temperature in the city in August, the hottest month in summer, is 30°C, although the temperature in the country is 19°C, the average of 10 years of data from the 17070- Bolu Central meteorological station (at 763 m altitude) and the 17637-Bolu Mountain meteorological station (at 948 m altitude). The temperature difference between the urban and rural areas is also measured at 11°C (Çağlak et al., 2021).

The land surface temperature in the city center varies between 21.5 and 43.3°C as indicated in satellite images (Figure 3) in 1994.

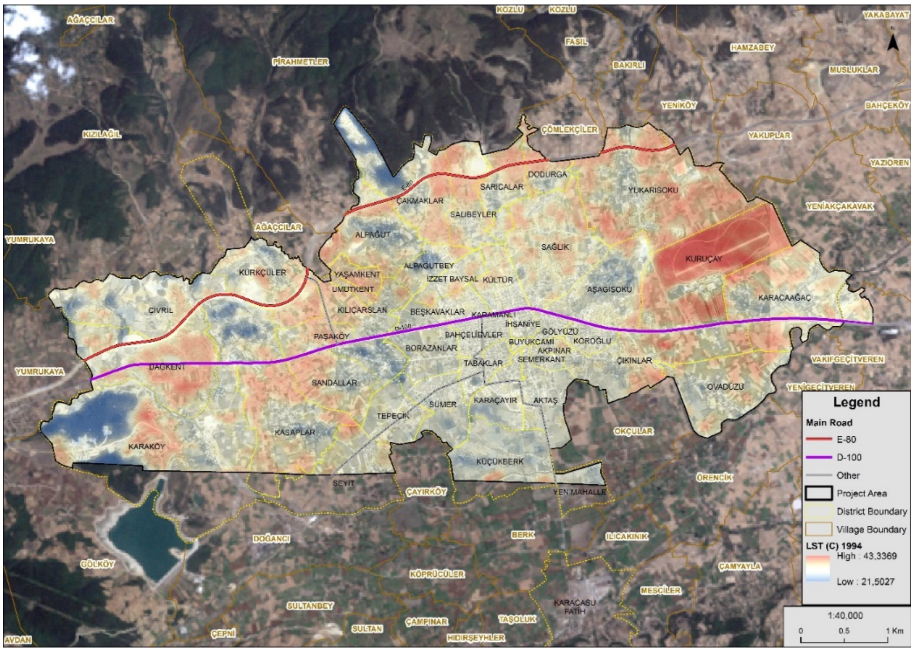

Figure 3. LST map in 1994.

In the 1994 LST MAP, the temperature varies between 22-30 °C in Büyükcami, Gölyüzü, Akpınar, Semerkant, Karamanlı, Karaçayır, Tabaklar, İhsaniye and Aktaş neighborhood forming in the Kuruçay neighborhood, east of the city, the surface temperature reaches 43°C due to agricultural areas and military airports. In the neighborhood of Karaköy, where Bolu Abant İzzet Baysal University was located in 1994, it is seen that the surface temperature is low due to the presence of forestry areas. The temperature rises above 30°C in some places due to increased farmland in the periphery. The surface temperature effect is

ICONARP – Volume 10, Issue 2 / Published: 20.12.2022

reduced by the rise in the northwest and south parts of the city, as the green forest cover increases there. Therefore, the LST effect has increased in agricultural areas in 1994. On the other hand, when looking at surface temperature in 2019, it is seen that temperatures rise above 30°C in the Büyükcami, Gölyüzü, Akpınar, Semerkant, Karamanlı Aktaş neighborhood and their peripheries, but surface temperatures change between 25 and 30°C in the Tabaklar, İhsaniye, Karaçayır neighborhoods (Figure 4).

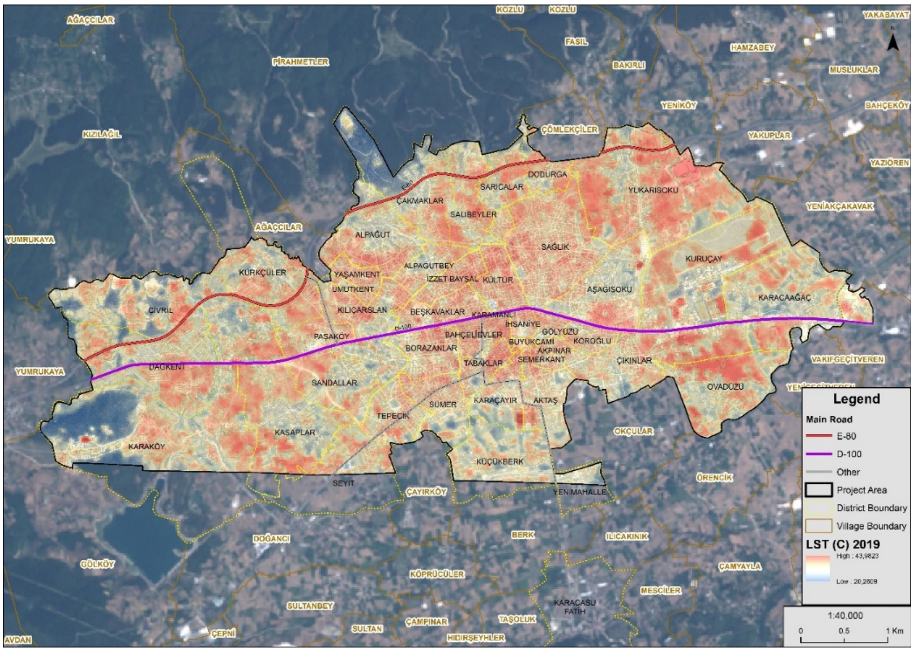

Figure 4. LST map in 2019.

Compared to 1994, the surface temperature in the city center tends to increase. The effect of surface temperature is generally between 25-32°C in the city, given the type of land-use in 2019. In the city, the industrial zone is 32°C, sports and entertainment areas are 31.5°C with the highest surface temperature. In addition, the temperature ranges from 29 to 30°C in agricultural areas south and west of the city. Compared to orthophotos in 1994, forestation and surface temperature at the military airport east of the city tend to decrease. The maximum surface temperature is 29.7°C at the military airport in 2019. The land has been forested in the last 25 years.

In order to track urban development and dense construction in Bolu, and to better understand their impact on urban warming, there is a need for comparison between the past and the present period. The development plan, which is important and effective in the city's spatial development, is dated 1985 (Taner, 2014). According to this plan, the city maintained its agricultural growth until 1990 and expanded with the opening of Abant Izzet Baysal University in 1992 and the construction of housing areas following the 1999 Gölcük-Düzce earthquakes (Taner, 2014). It is emphasized that two major earthquakes -- 1944 and 1999 -- were found in the south, and that they did not show a spread in accordance with the conditions of safe-resilient construction

DOI: 10.15320/ICONARP.2022.223

(Bayar et al., 2017). The most important factor for developing Bolu's macroform is the 1999 earthquake (Bayar et al., 2017). In addition, low-density housing areas increased with construction of Bolu Tunnel on D100 roads and E80 Anatolian Highway in transportation, so the city expanded north, causing urban sprawl (Bayar et al., 2017). The built-environment areas in 1994 are shown in below (Figure 5).

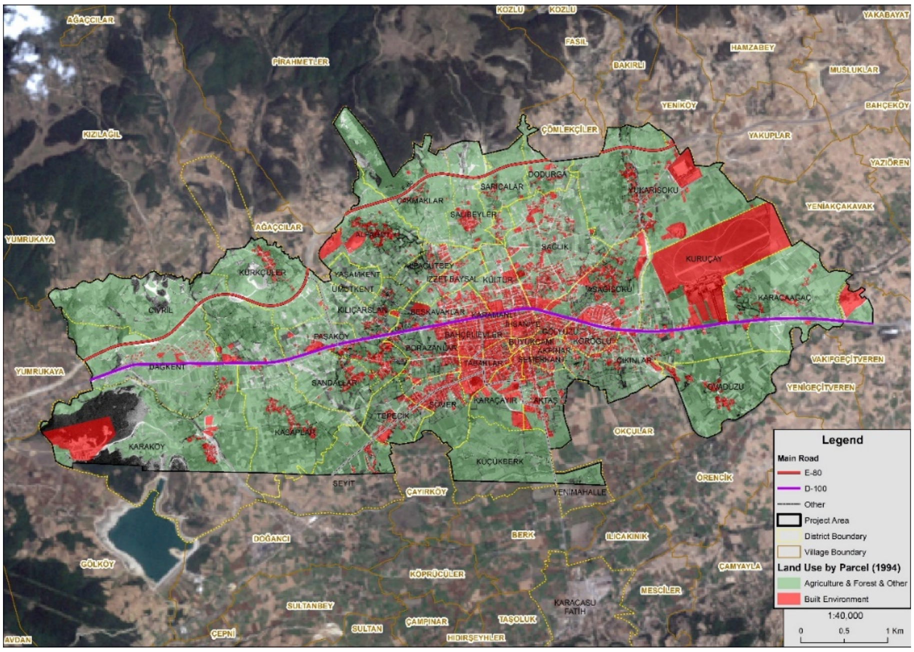

Figure 5. Built environment in 1994.

According to the TUREF TM33 (EPSG 5255) system, the areas that have been constructed for 1994 are 10.96 km2 Figure 5). when the orthophotos of 2019 is examined, the built-up areas have taken up 19.61 km2 areas in total. The built-up areas cover a 30.45% area within the city of Bolu (Figure 6).

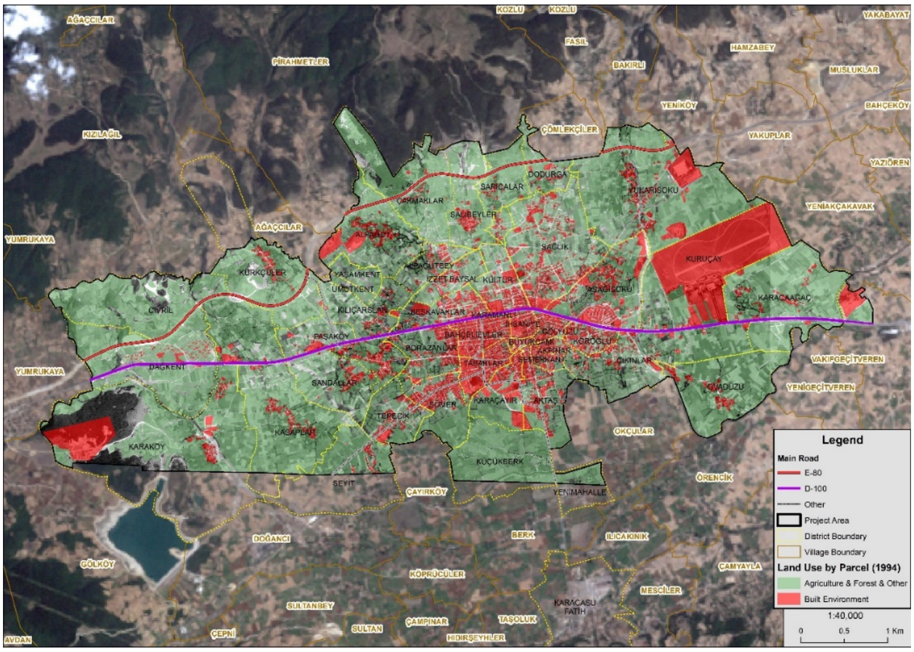

Figure 6. Built environment in 2019.

Areas of built-up expanded during the 25-year growth process are north and west, as seen in Figure 7.

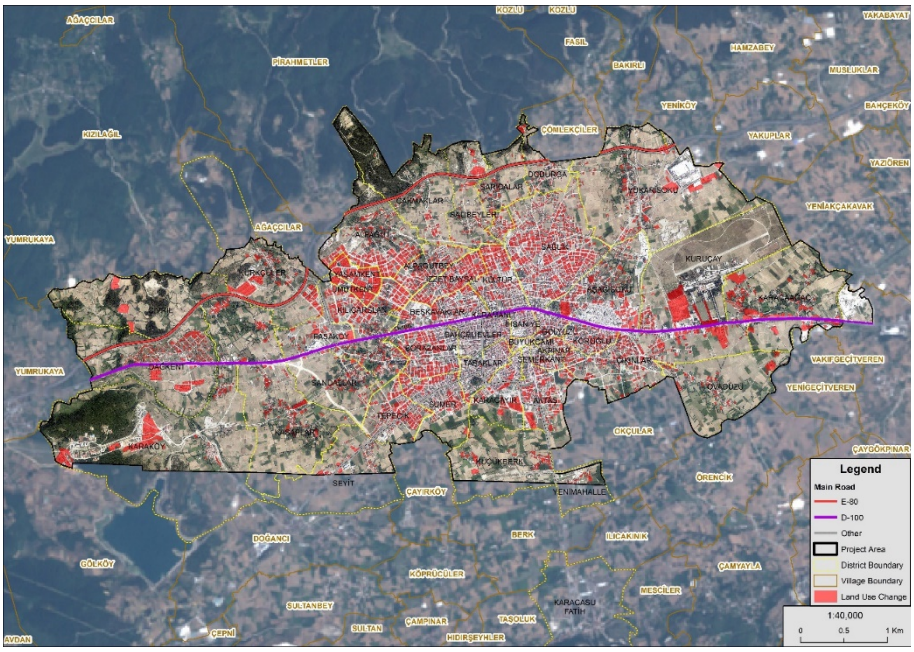

Figure 7. Built up are changes between 1994 and 2019.

The 1/5000 Urban Development Plan and the data obtained by the Ministry of Environment, Urbanization and Climate change were evaluated together and prepared the urban land-use map (Figure 8) of 2019, provided by the Bolu Municipality to highlight the urban growth between 1994-2019.

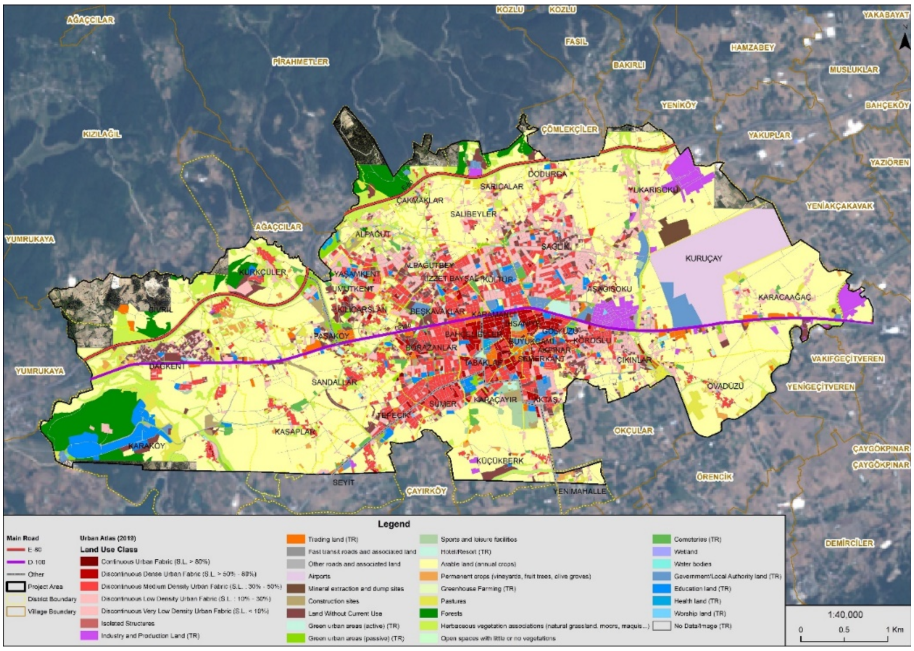

Figure 8. Urban land-use map (Urban Atlas, 2019).

Continuous urban area; 38,243m2, high density discontinuous urban area; 1,006,152 m2, discontinuous urban area in medium density; 4,700,654m2, discontinuous urban area at low density; 472.0743.4m2; very low density urban area; 256.092m2 in orthophotos used to

DOI: 10.15320/ICONARP.2022.223

determine the surface temperature effect. Passive green areas within the city are 947,362 m2, farmable outdoor areas; 25,248 m2, forest; 2,274,856 m2. The green spaces in Bolu are 960,000m2 (Bolu Municipality Park and Gardens Directorate, 2021), which are active green areas.

Table 3. Average temperatures related with the land-use functions in 2019, Bolu

Land-use functions	Average temperatures °C
Industry and production area	32.0
Sports and entertainments area	31.4
Continuous urban area (> 80%)	31.2
Discontinuous urban areas (high density) (50% - 80%)	31.2
Mine and Discharge Areas	31.1
Construction area	30.9
Hotels	30.9
Commercial area	30.8
Urban green area (passive)	30.5
Health Facilities	30.5
Discontinuous urban areas (medium density) (30% - 50%)	30.4
Religious Facilities	30.3
Fast transit roads and related fields	30.3
Discontinuous urban areas (very low- density) (< 10%)	30.3
Urban green area (active)	30.2
İdle space	30.2
Public Administrations	30.2
Roads	30.1
Discontinuous urban areas (low- density) (10% - 30%)	29.9
Graveyard areas	29.8
Airports (Military)	29.7
Arable land	29.7
Education facilities	29.4
Pastures	29.3
Isolated buildings	28.8
Water Surfaces	28.6
Herbaceous plant	28.6
Greenhouses	28.0
Unknown area (No image)	27.9
Forest	26.3

In terms of urban land use in discontinuous urban areas with a high-density surface temperature (having a base floor area between 50% to 80%) is 31°C, while the in discontinuous areas with medium-density (having a base floor area between 30% to50%) surface temperature of

ICONARP – Volume 10, Issue 2 / Published: 20.12.2022

30°C. On the other hand surface temperature is 29.9 °C in discontinuous low density urban areas (having base floor area between 10% to 30%). As the building storey heights increase and as decreases gap between the buılding and space surface temperature is increased in Bolu. The lowest surface temperature has seen forests area and water surfaces. İndustry and production areas has the highest surface temperature. İn active green spaces the surface temperature is 30.2°C. This is due to the small crown diameter of the tree. The surface temperature values according to the type of land-use for 2019 are discussed in detail in Table 3.

Compared to 1994, the surface temperature in the Kuruçay neighborhood located east of the city has decreased although surface temperature has also increased in peripheries like Yukarı soku, Sağlık, İzzet Baysal and Kültür neighborhoods located in the north of the city, and Dağkent, Karaköy in the west of the city. When comparing the urban density and surface temperature values in the city center, it can be seen temperature differences such as 0.1- 0.5 °C. Surface temperature in densely populated areas is 31.2°C while medium and low density residential areas is 29.7°C. The areas with the most heat reflections are the urban center with a temperature of 32.9°C, industrial areas with 32.6°C, technical infrastructure areas with 32°C, bus stops with 32°C, city-region trade center with 31°C and city center with 30.3°C. Surface temperature in urban parking areas is 30°C. The lowest surface temperature reflections are located on the campus of Bolu Abant Izzet Baysal University, with a surface temperature effect of 28.7°C covered by forest. The surface temperature values for land-use under the 1/5000 Urban Development Plan (Figure 9) are as specified in Table 4.

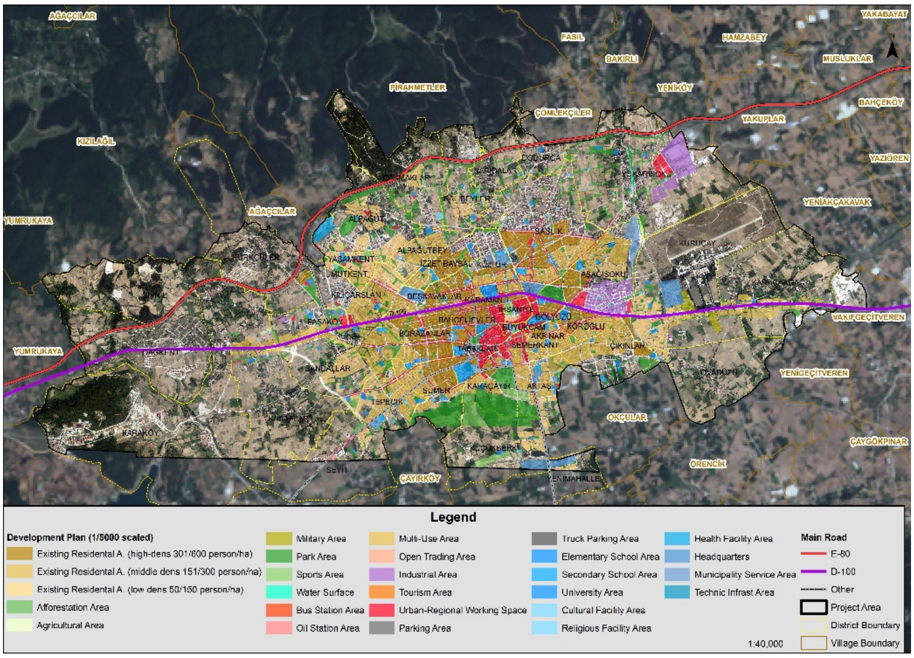

Figure 9. 1/5000 Urban development plan.

DOI: 10.15320/ICONARP.2022.223

Table 4. Land-use functions and average temperatures in 1/5000 urban development plan

Land-use functions in urban development plan	Average temperatures °C
No intersection with plan	29.3
Afforestation area	29.3
Agricultural Area	32.9
Bus Station Area	32
Cultural Facility Area	29.7
Elementary School Area	30.1
Existing Residential Area (high-density/ 301-600)	31.2
Existing Residential Area (low-density/ 50-150 p/ha)	29.7
Existing Residential Area (middle-density/ 151-300 p/ha)	29.7
Headquarters	30.3
Health Facility Area	30.4
Industrial Area	32.6
Military area	29.3
Multi-Use Area	30.4
Municipality Service Area	30.96
Oil Station Area	30.6
Open Trading Area	30
Park	30.1
Parking Area	30.5
Religious Facility Area	30.7
Secondary School Area	29.6
Sports Area	29.2
Technical Infrastructural Area	32
Tourism Area	31.1
Truck Parking Area	27.8
University Area	28.7
Urban-Regional Working Space	31
Water Surface	29.8

Figure 9 and Table 4 shows various land-use functions. When calculating the existing residential population (low-medium-high), gross population was used. As with many studies, the surface temperature map is evaluated in this study with the normalized difference vegetation index (NDVI) (Yüksel and Yılmaz, 2008; Şimşek and Şengezer, 2012; Alkan et al., 2017; Balçık and Ergene, 2017; Mercan, 2020; Polat, 2020). NDVI analysis uses range -1, +1 for vegetation density. Areas where the vegetation is dense are observed as pixel values close to +1, depending on the biomass, and in places where the vegetation decreases in the form of a pixel value close to the range -1. When the surface of the field is covered with rare vegetation, NDVI values are covered in dense vegetation in the range 0.2 to 0.5, and in the range 0,5-1, it is approximately 0 on rock, concrete and asphalt surfaces (Gerçek et al.,

ICONARP – Volume 10, Issue 2 / Published: 20.12.2022

2014; Alkan et al., 2017). Buildings, roads, etc. in the urban area the albedo value measured in areas covered with non-permeable surfaces, tar coated or asphalt surfaces accumulate more heat than the natural ground, increasing the surface temperature effect. In addition, agricultural areas are also exposed as surfaces with a high surface temperature effect because there are no trees and vegetation around them.

In the NDVI map of 1994, the values range from -0.3 to +0.7, showing a rare and moderate variation. In 2019, NDVI values range from -0.4 to +0.5. There has been a reduction in vegetation-cover density over the past 25 years. İf the areas where the NDVI difference is high is shown in green, the areas where the NDVI difference is low is shown in red (Figure 10).

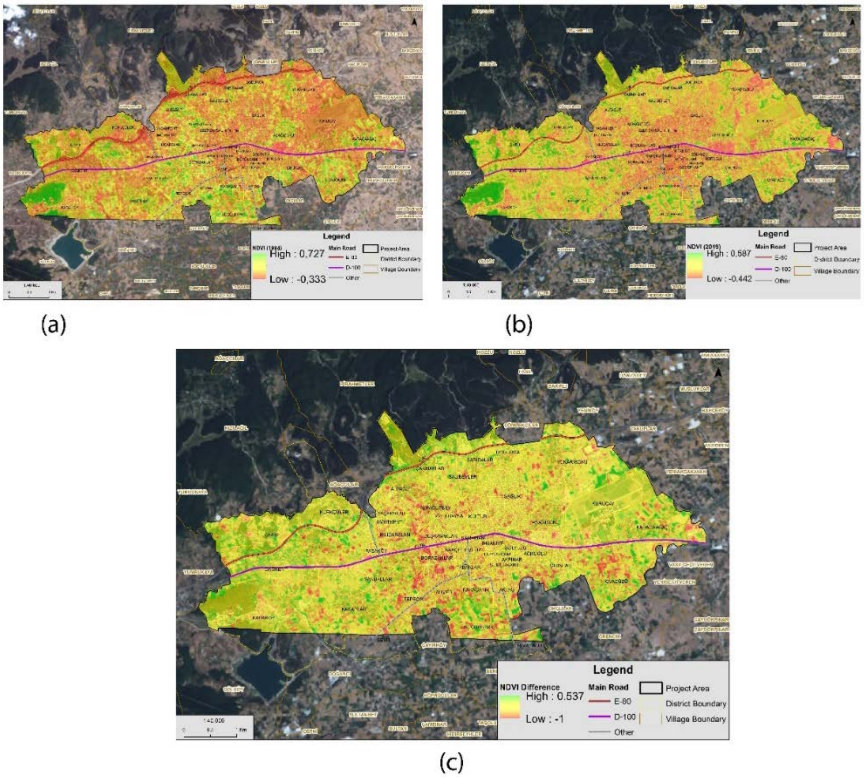

Figure 10. a) 1994-NDVI values b) 2019-NDVI values c) Between 1994 and 2019- NDVI differences values.

As it can be seen Figure 10, there were decreased vegetation density between 1994-2019. The NDVI map has dropped by -1, with the increase in construction in the neighborhoods of Beşkavaklar, Borazanlar, Bahçelievler, Tepecik and Alpagutbey. In the map of 1994, the green vegetation is dense, in Yaşamkent, Umutkent, Kılıçaslan, Çakmaklar, Sarıcalar, Kürkçüler, Dağkent, Küçükberk, Tepecik, Aktaş, Sağlık neighborhood, which have been a decrease in vegetation density between -0.5 and -1 due to urban growth that has expanded from center to peripheries. However, periphery areas with decreased NDVI values in the range of 0 -0.5 have increased vegetation density between 0 and 0.5 especially after the forestation of the military area, which is the Eşref Bitlis Komando Brigade around Kuruçay and around it.

DOI: 10.15320/ICONARP.2022.223

When examining the orthophoto images from 1994-2019, it was observed that in 1994, the agricultural sites around the city were exposed to high temperature effects due to their opening to urban development. Agricultural areas are opened to urban growth/ new developing area in Sağlık, Salıbeyler, Sarıcalar, Çakmaklar, Alpagutbey neighborhoods located in the north side. In the southern part, it is seen that construction in the Sümer and Tepecik neighborhoods has increased and surface temperature increases. NDVI flora density values have been significantly reduced since Borazanlar neighborhood has also been converted from agricultural areas to residential areas. The urban land-use map shows that the Eşref Bitlis Komando Brigade area, used as a military airfield in the east of the city, has increased its NDVI vegetation density over time with forestry.

In the LST difference map between 1994-2019, it is observed that the forestry in the military field, which is the Eşref Bitlis Komando Brigade in the east of the city, have a cooling effect on the surface between -7 and -16°C. The lowest surface temperature values in the city are forest areas covered with trees, parking spaces, university campus area, fields with green vegetation and military areas (Figure 11). It is known that the northern part of the city has risen around +2°C in the Alpagutbey, Alpagut, Izzet Baysal neighborhoods. There have been cooling on the surface of -1 or -2.4°C due to parks in the neighborhoods of Kültür, Sağlık, Yaşamkent and Umutkent. However, the ground has been heated between 0.1 and 3.7°C in Kasaplar, Sandallar, Kürkçüler neighborhoods. During the 25-year period, temperatures increased from 3.7 to 12.8°C due to agricultural areas in Küçükberk neighborhood in the south of the city. Surface temperatures can be seen at high temperatures due to the absence of green space around the area of agricultural areas, which are partly guarded in the northwest and south of the city.

Figure 11. Bolu city center a) 1994- LST values b) 2019- LST values c) between 1994 and 2019 LST differences values.

The surface temperature of the Gölköy campus of Bolu Abant Izzet Baysal University, located in the west of the city, has increased between 0 °C and +2°C. Similarly, it is noted that the surface temperature rises between 1.5 and 3.7°C in Bahçelievler, Borazanlar, Semerkant, İhsaniye, Karamanlı, Sümer and Aktaş neighborhoods which are located near the city center. Increasing particularly non-permeable surfaces in the center has increased the LST effect. When both LST and NDVI maps are reviewed, surface temperature decreases as vegetation density increases in the Bolu city. Therefore, the negative correlation observed between surface temperature and vegetation density in Bolu which is known for its green identity.

CONCLUSION AND DISCUSSION

The measurement of land surface temperature (LST) is an important assessment tool for global climate change studies, urban land use, urban land cover change, urban heat island and urban climate. In this study, Landsat 5 TM of 1994 and Landsat 7 ETM satellite images and orthophotos of 2019 were intended to assess the change of the urban heat island in Bolu city center during the spatial development process.

The geographical location of cities, morphology, land-use changes, cultural and socio-economic structure etc. are factors that affect the UHI. In the study, the average temperatures of the land-use classes were determined by evaluating the Urban Atlas classes together with the 2019-1994 LST difference data to associate the land-use cover with the surface temperature. The distribution of surface temperature values for each land-use has been determined via the existing 1/5000 Urban Development Plan. NDVI maps are also prepared to define vegetation density. After the 1999 earthquake in Bolu, the changes in land usage structure due to the rapid urbanization of the city with the north and west axes have increased the surface temperature. In Bolu, it is observed that a 38.39% field has been constructed when 2019-year-structured areas are proportional to the total parcel area. The built-up area presence has increased by 78.9% between 1994-2019.

1994 orthophoto images show that surface temperatures reach higher values after the transformation of agricultural land to urban areas. Air circulation is blocked in central neighborhoods due to the valley structure of the city center, surrounded by mountains and located on the flat plateau. Compared to 1994-2019 orthophotos, it is now seen that agricultural areas are used for transportation and residential usage. It can be agreed that urban growth has increased vehicle use by spreading uncontrolled from the center to the periphery areas, causing carbon emissions and the albedo effect raising the reflection temperature on the surface. In the last 25 years, the NDVI difference has resulted in a reduction in NDVI values in the Borazanlar and Beşkavaklar neighborhoods within walking distance of the urban center. As it expanded from the center to the periphery, the NDVI value has also decreased in Alpagutbey, Kılıçarslan and İzzet Baysal neighborhoods in the north of the city and Tepecik, Sümer, Karaçayır, Küçükberk, Ovadüzü in the south of the city.

In addition, forest/green areas increased in Bolu during the 25-year period and surface temperature has decreased at the military airport, the Esref Bitlis Comando Brigade in the east of the city. Therefore, the effect of the green surfaces seen in many studies about cooling the urban climate (Şimşek and Şengezer, 2012; Yüksel and Yılmaz, 2008; Emecen et al., 2019; Shishegar, 2013) also seen in Bolu. The process of sweating and evaporation of plants is known to have a cooling effect in urban areas. In Bolu, the Gölköy campus and surrounding forests and the Gölköy dam have a reduced reflectance temperature effect. Land-use

DOI: 10.15320/ICONARP.2022.223

types in 1/5000 scale urban development plan are evaluated with 2019 urban atlas data, the 101.818m2 parking space in low-density discontinuous urban area (area with a 10% to 30% build-up ratio), the 45.514m2 parks in the medium-density discontinuous urban area (area with a build-up ratio of 30% to 50%), 2207 m2 areas in a sustained urban area, there are 7553 m2 parks in the high density, non-continuous urban area (area with a built-up ratio of 50% and 80%), 10,687 m2 parks with very low intensity, non-continuous urban area (area with a built-up ratio of 10%). Bolu Municipality has also stated that they are working to increase green space in the city.

However, the main reason for the high surface temperature rise in Bolu province is the opening of agricultural areas for development and increase in population density. The choice of materials on large asphalt and flooring surfaces in new development areas with building forms and textures reduces evaporation and stores heat under the surface. In addition, the lack of green space in the continuous in urban settlement and high-density discontinuous urban settlement has caused an increase in the city's surface temperature. In the Conference of Livable Cities (2016), it has been emphasized that the global temperature has increased by approximately 1°C in the last 150 years. In addition, the increase in global temperatures between 1951 and 2010 along with the rise in average surface temperatures of 2°C and the impact of urbanization on the UHI are explained (Kurnaz, 2016).

Accordingly, in order to reduce the existing urban heat island effect in Bolu and to prevent urban heat island effect in the urban development areas solutions should be produced by taking some precautions such as promoting ecological material selection, walkability and bicycle use, creating wind corridors, supporting green roofs and green building applications, using smart mapping systems. In particular, when planning in new development areas, creating spatial decisions in such a way that it does not create barriers to dominant wind direction, wind corridors and speed, taking into account built-up area-green field ratios will have an impact on reducing the UHI effect. In addition to the important metropolitan area today (such as London, Paris, Madrid, Sydney, Tokyo and New York), it is known that the Local Climate Change Action Plans were prepared in Turkey, which reflected climate action from region scale to architectural scale in large-medium-sized cities such as Gaziantep, İstanbul, İzmir (Peker et al., 2019). In Bolu, increasing efforts to produce and implement plan decisions that address the overall green infrastructure will be an important step toward protecting the green identity and to decrease UHI effect or to decrease surface temperatures.

REFERENCES

Akbari, H. (2002). Shade Trees Reduce Building Energy Use and CO2 Emissions from Power Plants. *Environmental Pollution, 116*, 119-126. http://dx.doi.org/10.1016/S0269-7491(01)00264-0.

Alkan, A., Adıgüzel, F., & Kaya, E. (2017). Batman Kentinde Kentsel Isınmanın Azaltılmasında Yeşil Alanların Önemi (The Importance of Green Places in Decreasing the Urban Temperature in Batman). *Coğrafya Dergisi*, *34,* 62-76.

Amberber, M., Argaw, M., Feyisa, G. L., & Degefa, S. (2020). Status, approaches, and challenges of ecosystem services exploration in Ethiopia: A systematic review. *Chinese Journal of Population, Resources and Environment*, *18*(3), 201-213.

Balçık F. B. and Ergene E. M., (2017), Yer yüzey Sıcaklığının Termal Uzaktan Algılama Verileri ile Belirlenmesi: İstanbul örneği, Türkiye Ulusal Fotogrametri ve Uzaktan Algılama Birliği 9. Teknik Sempozyumu Bildiri Özetleri Kitabı (Turgut B. vd., Ed), Afyonkarahisar, Türkiye, ss 21.

Bayar, R. & Doğandor, E. (2017). Arazi Örtüsü İçerisinde Bolu Kentsel Değişiminin İzlenmesi(1987-2016) (Monitoring of Bolu Urban Change in a Land Cover (1987-2016). International Congress on the 75th Anniversary of TGS, 494-504. Retrieved September 9, 2021 from: https://www.researchgate.net/profile/Rueya-Bayar/publication/323185623_Arazi_Ortusu_Icerisinde_Bolu_Kentsel_Degisiminin_Izlenmesi1987-2016/links/5a852d0aa6fdcc201b9f1ed2/Arazi-Oertuesue-Icerisinde-Bolu-Kentsel-Degisiminin-Izlenmesi1987-2016.pdf.

Bolu Belediyesi Park ve Bahçeler Müdürlüğü, 2021.

Bonneau, L. R., Shields, K. S., & Civco, D. L. (1999). Using satellite images to classify and analyze the health of hemlock forests infested by the hemlock woolly adelgid. *Biological Invasions*, *1*(2), 255-267.

Bosselmann, P., Arens, E., Dunker, K., & Wright, R. (1995). Urban form and climate: case study, Toronto. *Journal of the American Planning Association*, *61*(2), 226-239.

Beltrami, H., Ferguson, G., & Harris, R. N. (2005). Long-term tracking of climate change by underground temperatures. *Geophysical Research Letters*, *32*(19).

Campbell, J.B. and Wynne, R.H. (2011) *Introduction to Remote Sensing Fifth Edition*. The Guilford Press, New York.

Chatzidimitriou, A. and Yannas, S. (2017). Street canyon design and improvement potential for urban open spaces; the influence of canyon aspect ratio and orientation on microclimate and outdoor comfort, *Sustainable cities and society, 33,* 85-101.

Çağlak S., Aydemir KPK. & Kazancı G. (2021). Effects of urbanization on bioclimatic comfort conditions; Bolu example. *City Health Journal, 2*(2), 47-55.

Çalışkan, O., & Türkoğlu, N. (2015). Ankara'da termal konfor koşulların eğilimi ve şehirleşmenin termal konfor koşulları üzerine etkisi. *Coğrafi Bilimler Dergisi*, *12*(2), 119-132.

Doğan, H. M., Kılıç, O. M., & Yılmaz, D. S. (2014). Tokat ili bitki yoğunluk sınıflarının LANDSAT-7 ETM+ uydu görüntüleri ve Coğrafi Bilgi Sistemleri ile araştırılması. *Gaziosmanpaşa Üniversitesi Ziraat Fakültesi Dergisi*, *2014*(1), 46-53.

Edwards M.C., Wellens J., Al-Eisawi, D. (1999). Monitoring the grazing resources of the Badia region, Jordan, using remote sensing. *Applied Geography, 19,* 385–398.

Emecen, Y., & Erdem, N. (2019). Kent İklimi Üzerinde Yeşil Alanların Etkileri. *Peyzaj Araştırmaları ve Uygulamaları Dergisi*, *1*(2), 24-30.

EPA. (2008). Reducing Urban Heat Islands: Compendium of Strategies, Draft, *Climate Protection Partnership Division in the U.S.* Retrieved August 15, 2021 from https://www.epa.gov/heat-islands/ heat-island-compendium

DOI: 10.15320/ICONARP.2022.223

ERDAS (2003). Erdas Field Guide, 7th Edn. Leica Geosystems, GIS and Mapping LLC: Atlanta, Georgia.

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

Gallo, K.P., Owen, T.W., Easterling, D.R. and Jamason, P.F. (1999) Temperature trends of the U.S. Historical Climatology Network based on satellite-designated land use/land cover. *Journal of Climate, 12*, 1344-1348.

Graves, H., Watkins, R., Westbury, P. & Littlefair, P. (2001). *Cooling Buildings in London: Overcoming the Heat Island*. London: BRE and DETR.

Gerçek, D., & Türkmenoğlu Bayraktar, N. (2014). Kentsel Isı Adası Etkisinin Uzaktan Algılama İle Tespiti ve Değerlendirilmesi: İzmit Kenti Örneği (Remote Sensing Detection and Evaluation of the Urban Heat Island Effect: The Example of Izmit City). 5. *Uzaktan Algılama-CBS Sempozyumu (14-17 Ekim 2014),* İstanbul https://www. kongresistemi. com/root/dosyalar/uzalcbs2014/360. pdf.

Hais M. and Kučera T. (2009). The influence of topography on the forest surface temperature retrieved from Landsat TM, ETM and ASTER thermal channels, *ISPRS Journal of Photogrammetry and Remote Sensing,64*(6):585-591.

Heyer, W. (1992). *Witterung und Klima (Weather and climate).* Bauverlag GMBH, 274 s. Stuttgart.

Hunt, A., & Watkiss, P. (2007). *Literature Review on Climate Change Impacts on Urban City Centres: Initial Findings; ENV/EPOC/GSP (2007) 10/Final*. OECD.

Jianjun, J., Jie, Z., Hong'an, W., Li, A., Hailong, Z., Li, Z., & Jun, X. (2005). Land cover changes in the rural-urban interaction of Xi'an region using Landsat TM/ETM data. *Journal of Geographical Sciences*, *15*(4), 423-430.

Kaya, D.S. (2019). 21. Yüzyılda Bolu Şehri'nin Tarihi Coğrafyası (Historical Geography of Bolu City in the 21th Century), *İstanbul Üniversitesi Sosyal Bilimler Enstitüsü*, İstanbul.

Kohl, T. (1999). Transient thermal effects below complex topographies, *Tectonophysics, 306*(3–4), 311-324.

Kurnaz, L. (2016). Küresel İklim Hedeflerine Ulaşmak – İklim Değişikliği Eylem Planları. *Yaşanabilir Şehirler Sempozyumu*, 26 Ekim 2016, Sapanca.

Landsberg H.E.,1981: *The Urban Climate.* New York: Academic Press.

Lin, B. S., & Lin, C. T. (2016). Preliminary study of the influence of the spatial arrangement of urban parks on local temperature reduction. *Urban Forestry & Urban Greening*, *20*, 348-357.

Liu, K., Su, H., Zhang, L., Yang, H., Zhang, R., & Li, X. (2015). Analysis of the urban heat island effect in Shijiazhuang, China using satellite and airborne data. *Remote Sensing*, *7*(4), 4804-4833.

Luhar, A. K., Venkatram, A., & Lee, S. M. (2006). On relationships between urban and rural near-surface meteorology for diffusion applications. *Atmospheric Environment*, *40*(34), 6541-6553.

McPherson, E. G. (1994). Cooling urban heat islands with sustainable landscapes. *In: Platt, Rutherford H.; Rowntree, Rowan A.; Muick, Pamela C.; eds. The ecological city: preserving and restoring urban biodiversity. Amherst, MA: University of Massachusetts Press: 151-171*, 151-171.

Mercan, Ç. (2020). Yer yüzey sıcaklığının termal uzaktan algılama görüntüleri ile araştırılması: Muş ili örneği. *Türkiye Uzaktan Algılama Dergisi*, *2*(2), 42-49.

Montávez, J. P., Rodríguez, A., & Jiménez, J. I. (2000). A study of the urban heat island of Granada. *International Journal of Climatology: A Journal of the Royal Meteorological Society*, *20*(8), 899-911.

Munn, R. E. (Ed.). (2002). *Encyclopedia of global environmental change*. Chichester: Wiley.

Oke, T. R. (1973). City size and the urban heat island. *Atmospheric Environment, 7*(8), 769-779.

Oke, T. R. (1988). Street design and urban canopy layer climate. *Energy and Buildings, 11*, 103–113.

Owen, T. W., Carlson, T. N., & Gillies, R. R. (1998). An assessment of satellite remotely-sensed land cover parameters in quantitatively describing the climatic effect of urbanization. *International Journal of Remote Sensing, 19*, 1663–1681.

Parker, D. E. (2010). Urban heat island effects on estimates of observed climate change. *Wiley Interdisciplinary Reviews: Climate Change*, *1*(1), 123-133.

Parry, M. L., Canziani, O., Palutikof, J., Van der Linden, P., & Hanson, C. (Eds.). (2007). *Climate change 2007-impacts, adaptation and vulnerability: Working group II contribution to the fourth assessment report of the IPCC* (Vol. 4). Cambridge University Press.

Peker, E. & Aydın, C.E. (2019). Değişen İklimde Kentler: Yerel Yönetimler İçin Azaltım ve Uyum Politikaları (Cities in Climate Change: Mitigation and Adaptation Policies for Local Governments). *İPM Sabancı Üniversitesi* Retrieved September 2, 2021 from http://www.troyacevre.org/wpcontent/uploads/2019/09/DegisenIklimde Kentler.pdf

Polat, N. (2020). Mardin ilinde uzun yıllar yer yüzey sıcaklığı değişiminin incelenmesi. *Türkiye Uzaktan Algılama Dergisi, 2* (1), 10-15.

Sannigrahi, S., Bhatt, S., Rahmat, S., Uniyal, B., Banerjee, S., Chakraborti, S., ... & Bhatt, A. (2018). Analyzing the role of biophysical compositions in minimizing urban land surface temperature and urban heating. *Urban climate*, *24*, 803-819.

Shishegar, N. (2013). Street design and urban microclimate: analyzing the effects of street geometryand orientation on airflow and solar access in urban canyons. *Journal of clean energy technologies*, *1*(1).

Streutker, D. R. (2003). *A study of the urban heat island of Houston, Texas* (Doctoral dissertation, Rice University.

Şimşek, Ç. K., & Şengezer, B. (2012). İstanbul metropoliten alanında kentsel ısınmanın azaltılmasında yeşil alanların önemi. *Megaron,* 7 (2), 116-128.

Taner, İ. (2014). Bolu Kentinin Mekansal Gelişimi (Spatial development of Bolu City). *AİBÜ Sosyal Bilimler Enstitüsü Dergisi,* 14(1), 377-411.

T.C. Başbakanlık Devlet Planlama Teşkilatı (DPT). (2002). Bolu İli Raporu (Bolu Province Report). Retrieved September 4, 2021 from (https://sbb.gov.tr/wp-content/uploads/2018/11/Bolu-Ili_Raporu%E2%80%8B.pdf

Tomlinson, C. J., Chapman, L., Thornes, J. E., & Baker, C. J. (2011). Including the urban heat island in spatial heat health risk assessment strategies: a case study for Birmingham, UK. *International journal of health geographics*, *10*(1), 1-14.

Tonyaloğlu, E. E. (2019). Kentleşmenin kentsel termal çevre üzerindeki etkisinin değerlendirilmesi, efeler ve İncirliova (Aydın) örneği. *Türkiye Peyzaj Araştırmaları Dergisi*, *2*(1), 1-13.

DOI: 10.15320/ICONARP.2022.223

Toy, S., Kayıp, D.B. & Çağlak, S. (2019). Eskişehir'de (biyo) İklime Duyarlı Kentsel Tasarım Örneği (Example of (bio)Climate Sensitive Urban Design in Eskişehir). *GÜFBED/GUSTIJ*, 9(2), 353-361.

Ullah, N., Siddique, M. A., Ding, M., Grigoryan, S., Zhang, T., & Hu, Y. (2022). Spatiotemporal Impact of Urbanization on Urban Heat Island and Urban Thermal Field Variance Index of Tianjin City, China. *Buildings*, *12*(4), 399.

Voogt, J.A. and Oke, T.R. (2003). Thermal Remote Sensing of Urban Areas. *Remote Sensing of Environment, 86,* 370-384.

Yang, L., Qian, F., Song, D. X., & Zheng, K. J. (2016). Research on urban heat-island effect. *Procedia engineering*, *169*, 11-18.

Yılmaz, H., Yılmaz, S., Yavaş, M., Mutlu, E., & Koç, A. (2016). Climate-sensitive pavement modelling for pedestrian ways. *Procedia Engineering*, *169*, 408-415.

Yıldız, N.D., Avdan, U., Avdan, Z. (2019). Kentsel Mekân Farklılıklarının Isı Adası Oluşumuna Etkisinin Belirlenmesi: Erzurum Kenti Örneği, SETSCI Conference Proceedings, *4 (3):* 220-224.

Yüksel, Ü. D., & Yılmaz, O. (2008). Ankara kentinde kentsel ısı adası etkisinin yaz aylarında uzaktan algılama ve meteorolojik gözlemlere dayalı olarak saptanması ve değerlendirilmesi (Determination and evaluation of urban heat island effect in Ankara city in summer based on remote sensing and meteorological observations). *Gazi Üniversitesi Mühendislik Mimarlık Fakültesi Dergisi*, 23(4), 937-952.

Wilby, R. L. (2007). A review of climate change impacts on the built environment. *Built environment*, *33*(1), 31-45.

Wu, H., Ye, L. P., Shi, W. Z., & Clarke, K. C. (2014). Assessing the effects of land use spatial structure on urban heat islands using HJ-1B remote sensing imagery in Wuhan, China. *International Journal of Applied Earth Observation and Geoinformation*, *32*, 67-78.

Zhao, W., Li, A. N., & Zheng, J. (2016). A study on land surface temperature terrain effect over mountainous area based on Landsat 8 thermal infrared data. *Remote Sensing Technology and Application, 31*(1), 63-73.

Zhong, S., Qian, Y., Zhao, C., Leung, R., Wang, H., Yang, B., ... & Liu, D. (2017). Urbanization-induced urban heat island and aerosol effects on climate extremes in the Yangtze River Delta region of China. *Atmospheric Chemistry and Physics*, *17*(8), 5439-5457.

Resume

Kıymet Pınar Kırkık Aydemir received MSc degree in Urban Design from İstanbul Kültür University in 2010. She received her Ph.D. degree in Landcape Architecture from Bartın University in 2018. She currently works at Bolu Abant İzzet Baysal University, Department of Urban and Regional Planning, as an Associate Prof. She has worked livability space/cities.

Gamze Kazancı Altınok is graduated from Middle East Technical University as an honor bachelor degree of City and Regional Planning Department in 2017. After graduation, she did her master's education in Istanbul Technical University (ITU), Urban Planning the years between 2017-2019, and she has been working at ITU as a research assistant since 2018. Now, she has been doing her Ph.D in Urban and Regional Planning Department. Moreover, she is a Ph.D Erasmus student at University of Lisbon, Department of Urbanism for one year (2022-2023).

Ömer ÜNSAL received bachelor's degree at Geography and MSc degree at Remote Sensing and GIS. He has worked smart city, geodatabase model, maturity

assessment models in Istanbul University, Department of Geography PhD program.

DOI: 10.15320/ICONARP.2022.223