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Research Article

CALCULATING SURFACE TEMPERATURE OF IZMIR, TURKEY

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Abstract

As well known, Land Surface Temperature (LST) is one of the essential parameters in evapotranspiration estimation, urban climate, vegetation monitoring and climate change. The main objective of this study was to retrieve spatial distribution of LST for the province of İzmir, Turkey using Landsat 8 satellite imagery which was acquired on August 23, 2019. The new generation of Landsat 8 has a new instrument called Thermal Infrared Sensor (TIRS) that captures the temperature of the earth's surface in two bands. In this particular study, one of the most popular methods, Radiative Transfer Equation (RTE) method, was employed. According to the results, the low temperatures were retrieved in İzmir Bird Paradise and Tahtali Dam around 10 °C while high temperatures were found in bare land with temperatures around 34 °C. It was also determined that temperatures in forest areas were ranging from 17 °C to 25 °C according to tree density.

Keywords: ArcGIS; Emissivity; GIS; Landsat 8; LST; Model Builder.

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Arastirma Makalesi

İZMİR'İN YÜZEY SICAKLIĞININ HESAPLANMASI

Özet

Bilindiği gibi, Yer Yüzey Sıcaklığı (YYS) evapotranspirasyon tahmini, kentsel iklim, bitki örtüsü izleme ve iklim değişikliğinde rol oynayan temel parametrelerden biridir. Bu çalışmanın ana amacı, 23 Ağustos 2019 tarihli Landsat 8 uydu görüntüsünü kullanarak Türkiye'nin İzmir ili için YYS'nin konumsal dağılımının hesaplanmasıdır. Yeni nesil Landsat 8'in termal kızılötesi sensörü (TIRS) iki bant halinde dünya yüzey sıcaklığını ölçmektedir. Bu özel çalışmada, İzmir ili için YYS hesaplanması amacıyla en popüler yöntemlerden biri olan Radyasyon Transferi Denklemi (RTD) yöntemi kullanılmıştır. Bu çalışmanın sonucunda en yüksek sıcaklık 34 °C civarında ve çıplak alanlarda tespit edilmiş, en düşük sıcaklık ise 10 °C civarında İzmir Kuş Cenneti ve Tahtalı Barajı'nda bulunmuştur. Ayrıca ormanlık alanların sıcaklığının ise 17 °C ile 25 °C arasında ağaç yoğunluğuna göre değiştiği tespit edilmiştir.

Anahtar Kelimeler: ArcGIS; Yayınırlık; CBS; Landsat 8; YYS; Model Builder.

1. INTRODUCTION

Land Surface Temperature (LST) can be described shortly as the temperature of the earth's skin. As well know, LST is one of the important parameters in climate change, evapotranspiration, urban climate, vegetation monitoring and environmental studies from local to global scales. Nowadays, with the help of remote sensing technology, It is possible to retrieve land surface temperature especially for large areas at sufficient temporal and spatial resolution rather than point data (Li et al. 2013). So far, several methods have been developed in order to retrieve LST from satellite imageries but following three methods; single-channel (SC), split-window (SW) and radiative transfer equation (RTE) are the most popular ones among them. Over the past few decades, many studies have been carried out on thermal analysis using MODIS, ASTER, Landsat TM, Landsat ETM, and Landsat 8 data because of the popularity of the subject (Li et al., 2003; Barsi et al., 2003; Cristobal et al., 2009; Jimenez Munoz and Sobrino, 2008; Jimenez Munoz et al., 2009; Oguz, 2013; Yu et al., 2014; Oguz, 2015).

The main objective of this study was to retrieve LST from Landsat 8 satellite imagery for the province of Izmir, Turkey. In this particular study, LST Calculator tool developed by Oguz (2016) was used to retrieve LST and the tool employs only band4, band5, and band10 of Landsat 8 imagery for the LST retrieval.

2. MATERIALS AND METHODS

2.1. Input Data

In this study, Landsat 8 satellite imagery acquired on August 23, 2019 (with path/row: 181/33) was used as input data. Landsat 8 captures images of the earth every 16 day and can be downloaded free of change from USGS webpage (USGS, 2019). Landsat 8 has two sensors on board: the operational land imager sensor (OLI) and thermal infrared sensor (TIRS). OLI has 9 bands with 30m spatial resolution (except for panchromatic band) while the TIRS has two thermal bands with 100m spatial resolution as illustrated in Table 1 below

(EOS, 2019). Having two thermal bands in Landsat 8 is the main improvement compare to previous versions of Landsat.

Table 1 Landsat 8 OLI and TIRS bands

Band Number	Band Width	Description	Resolution (m)
Band 1	0.435 - 0.451	Coastal/Aerosol	30
Band 2	0.452 - 0.512	Blue	30
Band 3	0.533 - 0.590	Green	30
Band 4	0.636 - 0.673	Red	30
Band 5	0.851 - 0.879	NIR	30
Band 6	1.566 - 1.651	SWIR-1	30
Band 7	2.107 - 2.294	SWIR-2	30
Band 8	0.503 - 0.676	Pan	15
Band 9	1.363 - 1.384	Cirrus	30
Band 10	10.60 - 11.19	TIR-1	100
Band 11	11.50 - 12.51	TIR-2	100

2.2. Study Area

Izmir is a metropolitan city in the western extremity of Anatolia as illustrated in Figure 1 below. It is the third most populous city in Turkey, after Istanbul and Ankara, and the second largest metropolitan area on the Aegean Sea after Athens, Greece (Wikipedia, 2019). In 2018, the city of İzmir had a population of 2,947,000, while İzmir Province had a total population of 4,320,519 (TSI, 2019). İzmir's metropolitan area extends along the outlying waters of the Gulf of İzmir and inland to the north across the Gediz River delta; to the east along an alluvial plain created by several small streams; and to slightly more rugged terrain in the south (Encyclopedia Britannica, 2019).

The city of İzmir is composed of several metropolitan districts. Of these, the district of Konak corresponds to historical İzmir, with this district's area having constituted the city's central "İzmir Municipality" until 1984. With the formation of the "İzmir Metropolitan Municipality", the city of İzmir grouped together its eleven (initially nine) urban districts – namely Balçova, Bayraklı, Bornova, Buca, Çiğli, Gaziemir, Güzelbahçe, Karabağlar, Karşıyaka, Konak, and Narlıdere – and consolidated them with the province's additional districts outside the city proper, extending from Bergama in the north to Selçuk in the south, bringing the total number of districts considered part of İzmir's metropolitan area to thirty (Vikipedia, 2019).

İzmir has more than 3000 years of recorded urban history and up to 8500 years of history as a human settlement since the Neolithic period. Set in an advantageous location at the head of a gulf in a deep indentation midway along the western Anatolian coast, the city has been one of the principal mercantile cities of the Mediterranean Sea for much of its history. Modern İzmir also incorporates the nearby ancient cities of Ephesus, Pergamon, Sardis and Klazomenai, and centers of international tourism such as Kuşadası, Çeşme, Mordoğan and Foça. When the Ottomans took over İzmir in the 15th century, they did not inherit compelling historical memories, unlike the two other key points of the trade network, namely Istanbul and Aleppo. Izmir's port is Turkey's primary port for exports in terms of the freight handled and its free

zone, a Turkish-U.S. joint-venture established in 1990, is the leader among the twenty in Turkey (Wikipedia, 2019).

According to the Köppen–Geiger classification system, İzmir has a Mediterranean climate, which is characterized by long, hot, and dry summers, and mild to cool, rainy winters. The total precipitation for İzmir averages 695.4 mm per year; however, the vast majority of the city's rainfall occurs from November through March. The rest of the precipitation generally falls during April through May and September through October. There is very little to no rainfall from June through August. Maximum temperatures during the winter months are usually between 10 and 16 °C. Although it is rare, snow can fall in İzmir from December to February over a period of hours rather than a whole day or more, with a record of 32 cm of snowfall recorded on January 31, 1945. During summer, the air temperature can climb as high as 40 °C from June to September; however, the high temperatures are usually between 30 and 36 °C (Wikipedia, 2019).

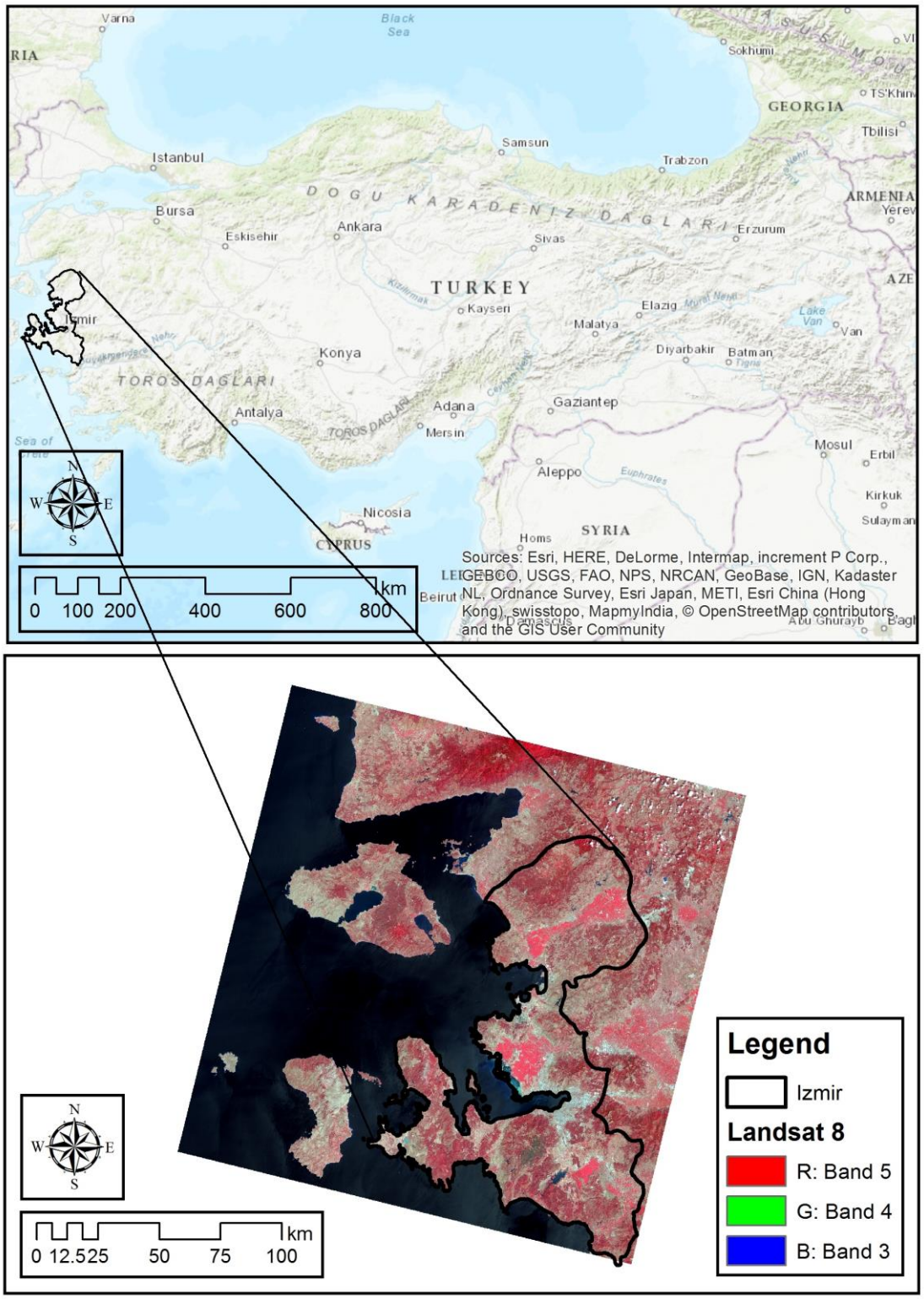

Figure 1. Location map of the study area

The flow diagram of the methodology is given in Figure 2 below. The more detailed information can be obtained from the articles published by Jimenez-Munoz et al. (2014), Yu et al. (2014) and Oguz (2016).

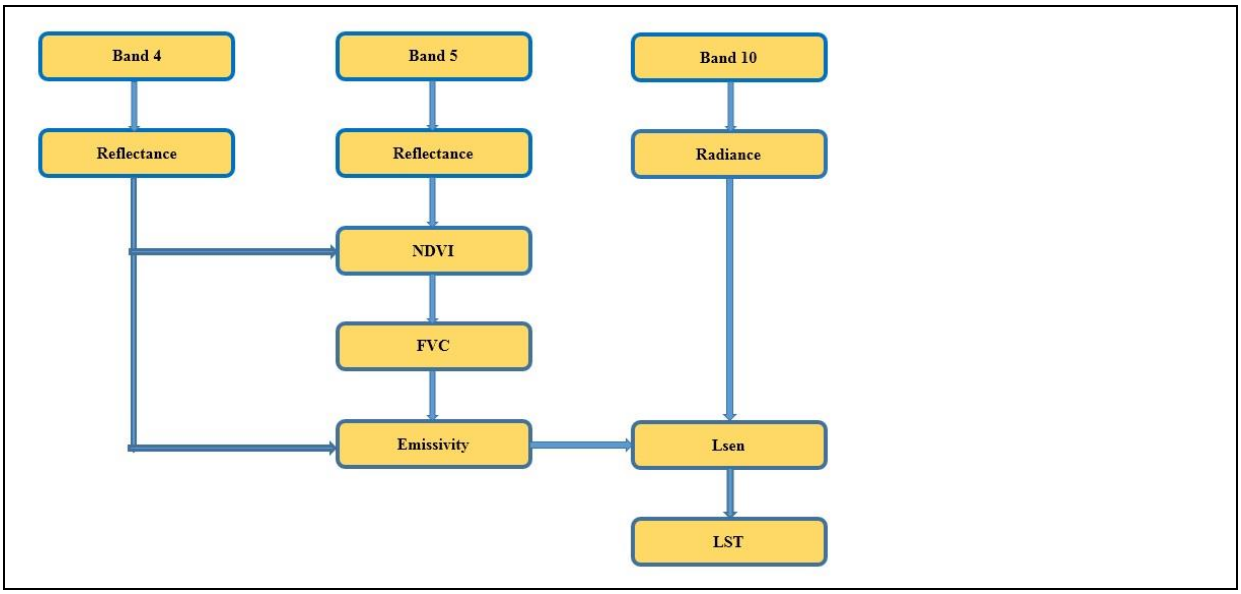

Figure 2. Flow diagram of the study

In this study, a python tool, LST Calculator, developed by Oguz (2016) was employed in order to retrieve land surface temperature from Landsat 8 imagery.

3. RESULTS AND DISCUSSION

LST Calculator accepts Landsat 8 imagery as an input for the LST retrieval. Specifically, bands 4,5 and 10 were used in this process. The python tool outputs a single band that stores LST values in each pixel. Figure 3 below illustrates the final LST distribution map of whole scene.

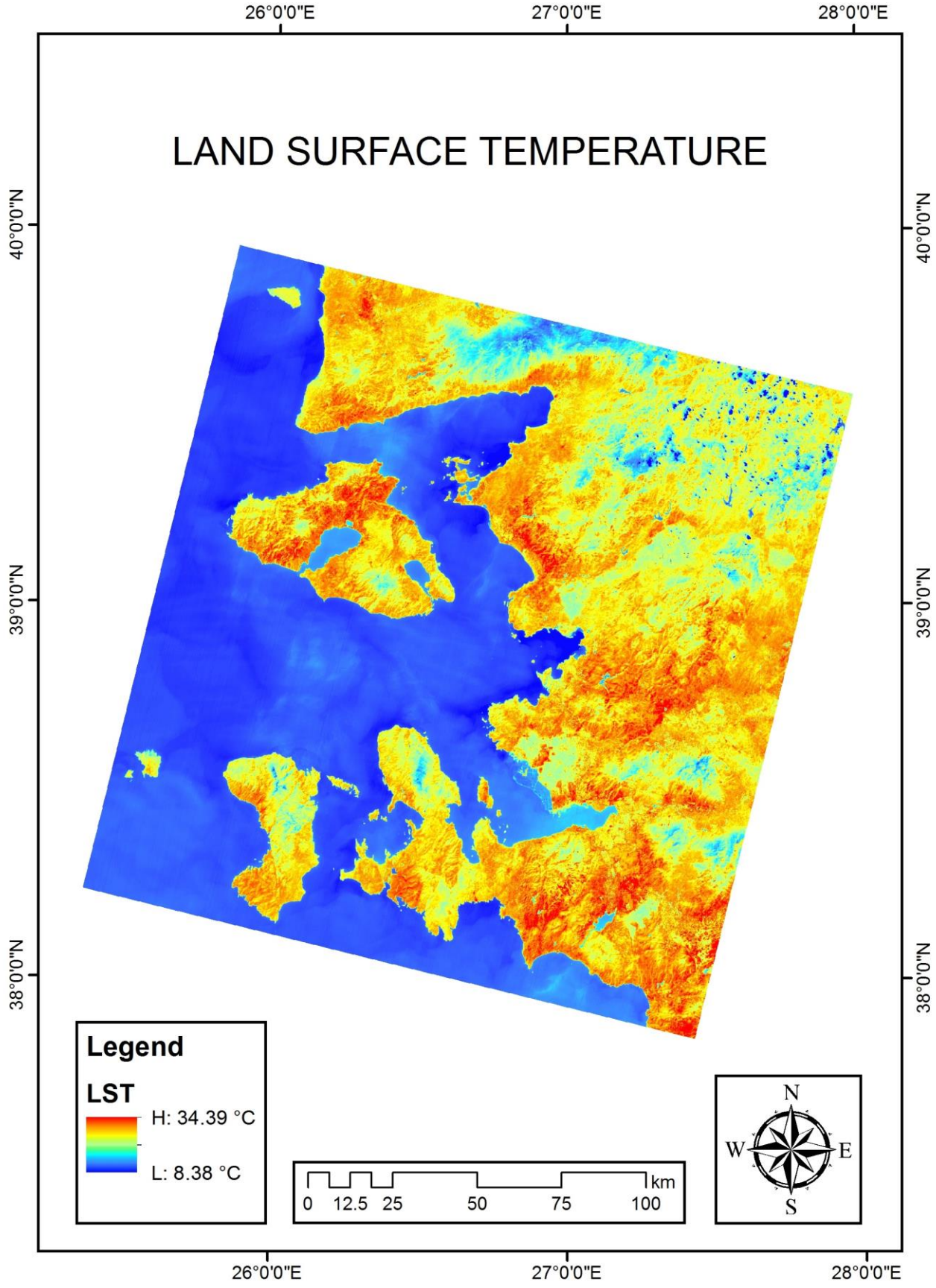

Figure 3. LST distriburion map of Landsat 8 scene

As illustrated in the figure above, the lowest temperatures were found in the sea area starting from 8 °C approximately and the highest temperatures were located in bare land with a maximum value of 34 °C.

The study area of Izmir was extracted from the whole scene and the new LST distribution map of Izmir was given in Figure 4 below.

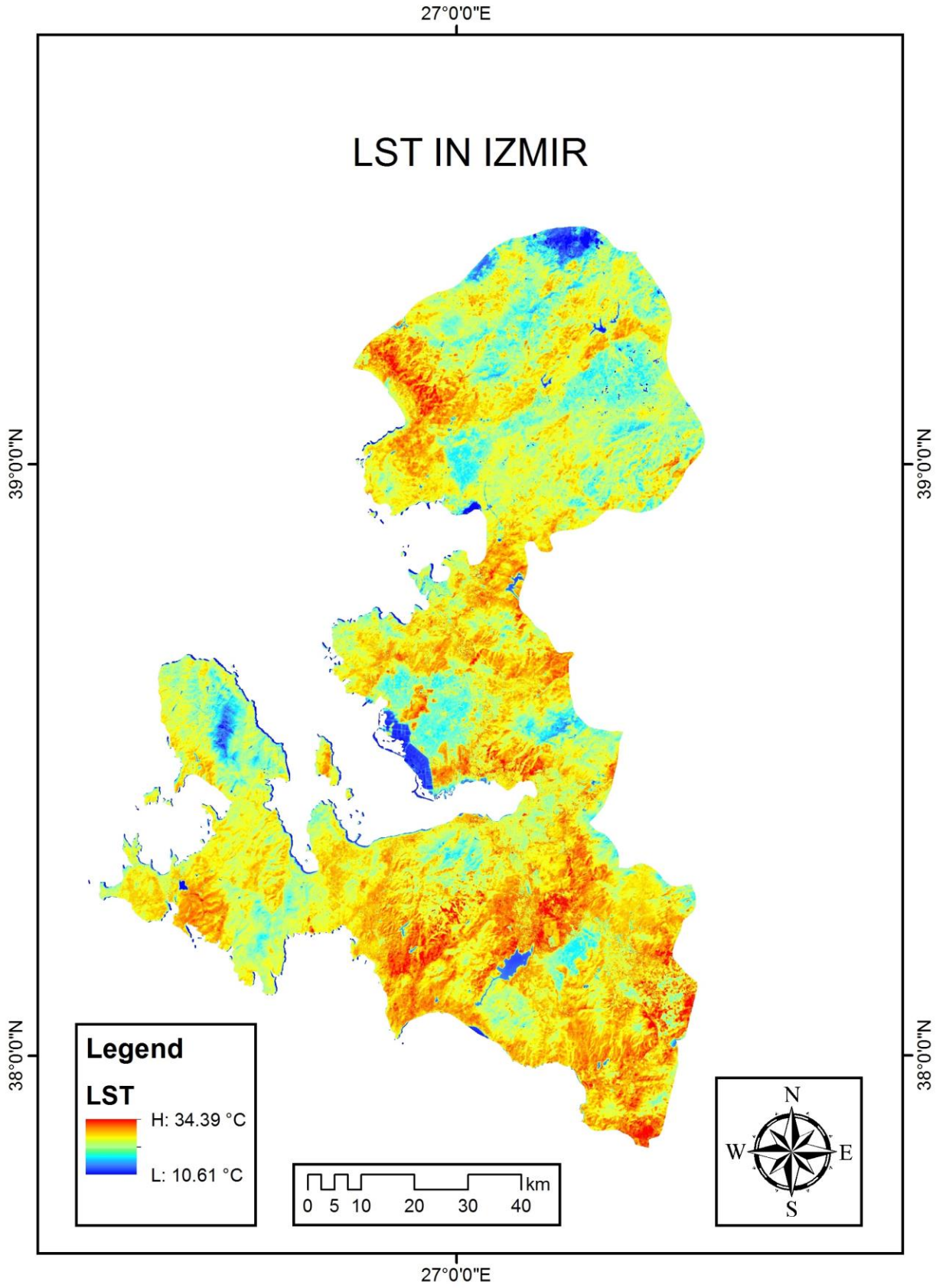

Figure 4. Spatial Distribution of LST in Izmir

According to the results, the low temperatures were retrieved in İzmir Bird Paradise and Tahtali Dam around 10 °C while high temperatures were found in bare land with

temperatures around 34 °C. It was also determined that temperatures in forest areas were ranging from 17 °C to 25 °C according to vegetation density.

4. CONCLUSIONS AND RECOMMENDATIONS

LST is an important parameter in thermal analysis because LST calculated from satellite imagery can be used to monitor urban climate in order to better understand the environmental conditions necessary to sustain human life.

It is not quite easy though to retrieve accurate LST for large regions in thermal studies. Therefore, the RTE method has been employed in this study due to accuracy of the model as indicated in article published by Yu et al. (2014). This final LST distribution map can be used by local managers to determine hot areas of Izmir. Afforestation of these areas may help lower the mean LST of Izmir.

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CONFLICTS OF INTEREST

The authors declare no conflict of interest.

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