LONG TERM MONITORING OF LAND USE - LAND COVER CHANGE AND ITS EFFECT ON SURFACE TEMPERATURE BY USE OF LANDSAT IMAGES AND GOOGLE EARTH ENGINE PLATFORM

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Abstract

The harmful impacts of fast urbanization and population growth on nature are becoming more pronounced every day. Human demands are growing in tandem with population growth, and the most common solutions advocated to address these needs are agricultural development and urbanization. The increase in urban areas causes a decrease in forest and green areas that contribute to the occurrence of urban heat islands and an increase in surface temperature. This study, choosing the city of Istanbul, the largest metropolis of Europe, as the study area, investigates the land cover - land use (LCLU) changes and their effects on the surface temperature covering the years 2001, 2011, and 2020. To produce an urban heat island, LST data from Level 2 Collection 2 data of Landsat satellite images were used. The urban thermal field variance index (UTFVI) was calculated form the LST data, which can be considered as an indicator of urban heat islands (UHI). When the heat islands in urban regions were compared to those in rural areas, it was discovered that the heat islands in urban areas were much observable with higher surface temperature. When the UTFVI index maps of different years were compared, it is determined that UHI is increased about 21 percent between 2001 – and 2011 and by 5 percent between 2011 and 2020. These findings are also comparable with the increased amount of urban areas through these dates.

Keywords: UHI, LST, Landsat 5 TM, Landsat 7 Enhanced Thematic Mapper (ETM+), Landsat 8 OLI/TIRS, GEE, Remote Sensing

INTRODUCTION

Uncontrolled and continuous urbanization is becoming an essential problem day by day in the metropolitan cities of developing countries like Turkey (Alganci, 2019). Meeting the needs of this population causes urban areas. In other words, this increase in concrete and asphalt areas, which we define as impermeable surfaces, means that green and forest areas are destroyed and reduced (Çelik, 2019). In addition, rapid urbanization and increasing population density have negative effects on climate, nature, and human health. (Liu & Huang, 2018). One of the impacts is dramatically increasing urban heat island (UHI) (Tan et al., 2010).

Simply put, the UHI is described for higher temperatures in urban areas than in rural areas nearby, and monitoring the effects of urban heat islands is extremely vital in terms of urban planning and sustainability (Li et al., 2011). Jin, (2012) proposed a new index to calculate the UHI density also this index shows that the difference between UHI occurring in the

daytime and summer months is very large when compared to those formed during the night and winter months. To examine the UHI effect, Çelik, (2019) used the Urban Thermal Field Variance Index(UTFVI) developed by Yong et al., (2006) article In this index, it is stated that LST is calculated only with the help of thermal bands and there are 6 ecological evaluation criteria.

The aim of this study is an investigation of UHI depending on the land cover in the province of Istanbul. To see the land cover change, maps were produced in decades periods. In this study, the UTFVI index was used to determine the UHI impact areas in addition LCLU maps including the years 2001, 2011, 2020 were derived and compared with UHI maps.

METHOD

Study Area and Satellite Images

Istanbul, one of the most important metropolitan cities in the world and the most populous city of Turkey, has been chosen as the study area. Istanbul has been facing rapid urbanization due to migration from other cities of Turkey and industrial developments that result in significant changes in LCLU.

Moreover, new transportation infrastructures, which are the Yavuz Sultan Selim Bridge, the Black Sea Highway, and the Istanbul International Airport contributed to the degradation of natural surfaces.

In this study, Landsat 5 TM, Landsat 7 Enhanced Thematic Mapper (ETM+), and Landsat 8 OLI/TIRS satellites images belonging to 2001, 2011, and 2020 were used. Since Level 2 Collection 2 data is used, image pre-processing steps such as atmospheric correction and orthorectification are not required. The above-mentioned satellite sensors produce surface temperature and surface reflection data.

LC/LU CLASSIFICATION

In this study, the Level 1 classification schema defined in CORINE standards was used for determining the LCLU from satellite images. These are forest, water, urban areas, bare land, and agricultural areas. The minimum distance and random forest supervised classification algorithms were applied to satellite images by use of the GEE platform. The following table shows the polygons per class for training the algorithms.

Table 1. Train data sets.

Classification names	Number of training samples			Number of test samples		
	2001	2011	2020	2001	2011	2020
Forest	103	158	60	38	24	21
Water	36	18	22	15	10	17
Urban	107	167	137	51	64	46
Bare land	91	107	101	25	37	33
Agriculture	103	160	85	15	21	19

The number of decision trees was chosen as 100 for the random forest algorithm, and the Mahalanobis measurement metric was used for the minimum distance algorithm.

In the next step, accuracy was assessed using the random number of points by year as shown in Table 1. The class distribution of the control points is provided in Table 1. It has been observed that the random forest algorithm gives more accurate classification results than the minimum distance algorithm for all dates.

Accuracy assessment results of LC/LU maps are shown in Table 2.

Table 2. Accuracy Assessment Results.

	2001		**2011**		**2020**	
	P.A	**U.A**	**P.A**	**U.A**	**P.A**	**U.A**
Forest	0.99	0.97	0.99	0.99	0.99	1.00
Water	0.96	1.00	1.00	0.99	0.99	0.99
Urban	0.99	0.95	0.97	0.98	0.95	0.99
Bare land	0.95	0.97	0.98	0.98	0.89	0.92
Agriculture	0.86	0.95	0.95	0.90	0.98	0.90
Kappa	0.97		0.97		0.96	
Overall Acc.	0.97		0.97		0.96	

UTFVI Retrieval

To reveal UHI-affected areas, urban thermal field variance index (UTFVI) was proposed by Zhang et al., (2006). UTFVI formula is shown in equation 1.

$$\text{UTFVI} = \frac{LST - LST_m}{LST} \quad (1)$$

LST represents land surface temperature and LST_m represents mean land surface temperature for the study area.

Considering the UTFVI index values;

- UHI is not effective below 0 index values.
- UHI is affecting poorly between 0- 0.005.
- UHI is affecting moderately between 0.005-0.01.
- UHI is affecting highly between 0.01-0.015.
- UHI is affecting very highly between 0.015-0.02.
- Above 0.02 UHI is affecting extremely (Çelik, 2019).

RESULTS AND DISCUSSION

In the study, when UTFVI maps are compared with the LCLU maps obtained as a result of classification, it has been observed that urban areas are warmer than the surrounding rural areas as an expected result.

According to the areal statistics provided in Table 3, it is observed that urban areas have

increased their surface area that resulting in a decrease in forested and green areas. The replacement of forest areas with barren and urban land also causes an increase in the urban heat island, as seen in Figure 1.

According to evaluations, the UTFVI increased by %21 between 2001 – and 2011 and by 5 percent between 2011 and 2020. The results are supported by the transition of forests, barren lands and agricultural lands into urban areas as statistically provided in Table 3 and Table 4. According to Table 3 and Table 4, forest land cover decreased as a percent of %7.51 between 2001 to 2011 and %10.05 between 2011 to 2020. In addition, land use for urban areas increased to a percent of %33.84 between 2001 to 2011 and %28.66 between 2011 to 2020.

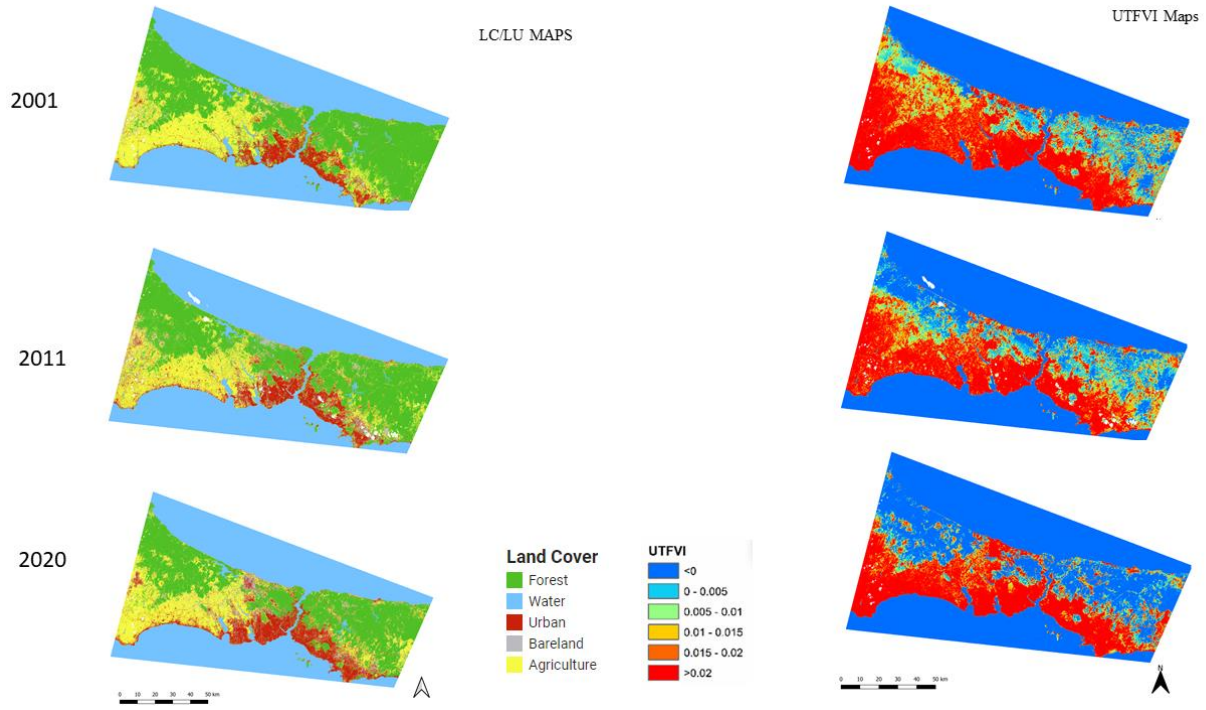

Fig. 1. LC/LU maps and UTFVI index maps

Table 3. 2001-2011 Changed areas by classes (km^2).

	Forest	Water	Urban	Bareland	Agriculture
Forest	**3366.87**	3.35	91.02	106.41	405.46
Water	16.55	**5415.80**	0.30	7.78	2.46
Urban	9.82	0.70	**509.32**	104.61	55.99
Bareland	15.53	4.82	66.27	**110.87**	70.73
Agriculture	265.90	3.51	243.80	195.57	**1276.08**

Table 4. 2011-2020 Changed areas by classes (km^2).

	Forest	Water	Urban	Bareland	Agriculture
Forest	**3074.53**	8.43	99.74	127.72	364.24
Water	5.70	**5393.53**	3.75	19.50	5.66
Urban	18.53	0.21	**663.92**	76.80	151.23
Bareland	35.42	3.85	185.91	**139.01**	161.05
Agriculture	171.27	0.95	218.39	158.61	**1261.49**

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