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IMPACT OF LAND USE/LAND COVER ON URBAN HEAT ISLAND (UHI) WITHIN BUCHAREST AREA

IMPACTUL UTILIZĂRII TERENULUI/ACOPERIRII TERENULUI ASUPRA INSULEI DE CĂLDURĂ DIN ZONA BUCUREȘTIULUI

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Abstract: Environmental issues, in the context of climate change attracted the attention of researchers, government organizations and NGOs, which cooperate to find solutions on the greenhouse effect and decrease carbon dioxide in urban areas. Urban planning could play a key role in minimizing climate risks for the human environment. Bucharest is a very dynamic capital-city in terms of economy and demography and thus its urban extension, along new built-up areas and changes of land use/land cover, has a direct influence on many environmental issues, for example the variation of spatial distribution of temperatures. Over the past 30 years, the urban landscape in Bucharest has been changing as new elements were newly constructed or transformed: numerous residential neighbourhoods in the city and mostly in its peripheral areas, vast commercial areas, business centres, etc. The main objective of this research is to demonstrate the relationship between land cover/land use classes and temperature variations, identified by satellite imagery. Therefore, satellite imagery provided by Landsat 5 TM, Landsat 8 OLI/TIR, Sentinel 1 scenes acquired from the years 1990, 2000, 2007, 2015, 2016, 2017, 2018 were selected for this study. The spatial resolution is 30 m for Landsat images in order to demonstrate the correlation between land use/land cover changes and LST estimation. A multi-temporal analysis was also conducted. Nowadays, high-resolution satellite imagery may contribute greatly to the monitoring of green spaces, saving time and money.

Key-words: *land use/land cover, urban heat island, remote sensing, Bucharest*
Cuvinte-cheie: *utilizarea terenului/acoperirea terenului, insulă de căldură, teledetectie, București*

I. INTRODUCTION

It has been proven that urbanization leads to heat island occurrence and cities in Romania are no exception (Zoran et al, 2012). The main causes include the change of land use. The high density of urban fabrics contributes with a proportion

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of 20% to the formation of urban heat island (Sirodoev et al., 2015). Currently, there are numerous data sources based on which the urban area can be studied. These sources can be grouped into: ground-based data and remote sensing, while the ancillary data can be classified in air quality, land cover/land use, and urban topography (Cheval et al., 2020).

The study area consists of the Municipality of Bucharest, one of the most developed cities in Romania, as well as the localities around it, divided into four concentric zones (Fig. 1). This delimitation was aimed at observing the effect of land changes and topoclimatic conditions in Bucharest and its surroundings.

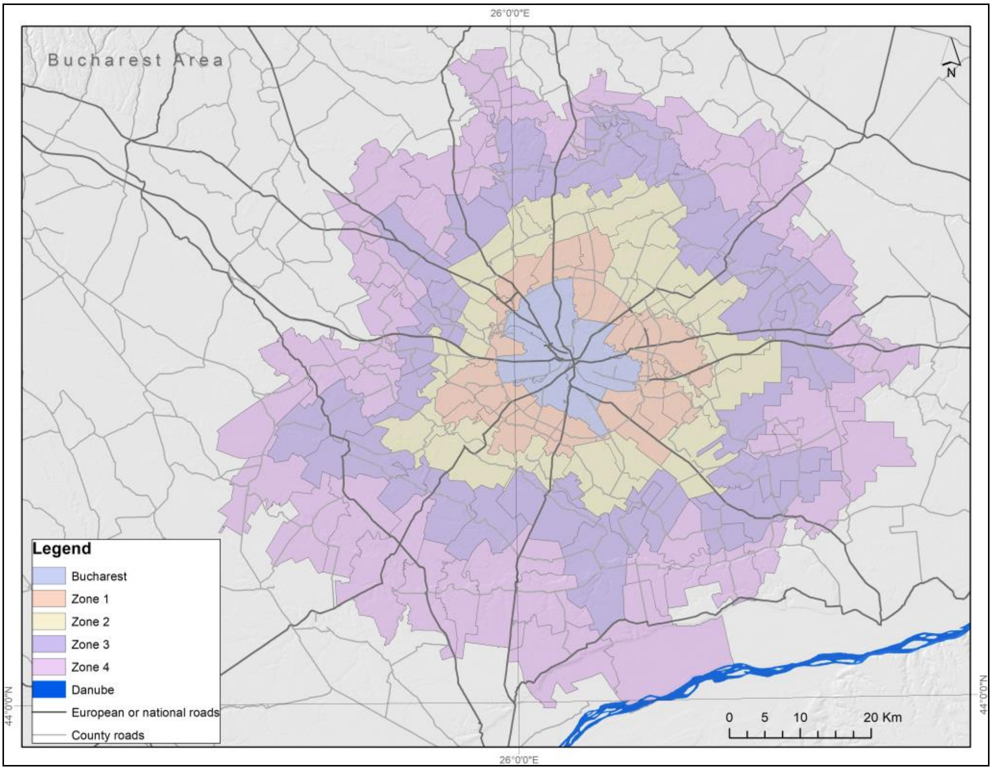

Fig. 1. Location of the study area

II. DATA AND METHODS

For this study, it is used Corine Land Cover (1990, 2000, 2006, 2012, and 2018) having 100 m resolution, Sentinel 1 (Nov 2015, 2016, 2017 and 2018) at 30 m resolution, Sentinel 1 (august 2018) 10 m resolution, Landsat TM (august 1990, 2000, 2007), Landsat OLI (august 2015, 2016, 2017, 2018) 30 m resolution, and also Sentinel 2 (august 2018) at 10 m resolution.

The used data are Sentinel 1 Ground Range Detected (GRD) scenes, acquired in the instrument Interferometric Wide Swath (IW) mode. They are processed using the Sentinel-1 Toolbox, such as Radiometric Calibration, Multilooking with number of range looks: 3, Speckle Filtering (Single Product Speckle Filtering, Relined Lee) and geometric correction using Range Doppler Terrain Correction. For Landsat TM data (august 1990, 2000, 2007), it was applied FLAASH atmospheric correction, then the Normalized Difference Vegetation Index (NDVI) was computed. Land Surface Temperature calculation was performed in ArcGIS using ModelBuilder (Fig. 2).

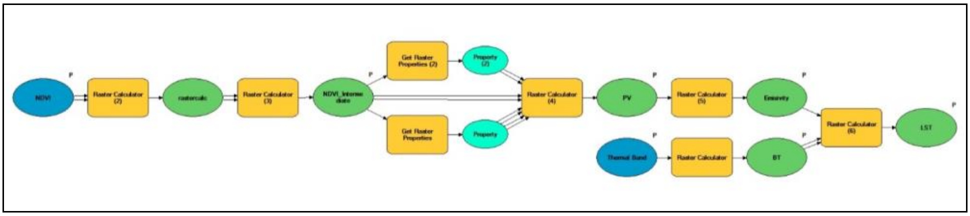

Fig. 2. Land Surface Temperature processing using ModelBuilder

The Normalized Difference Vegetation Index (NDVI) was introduced by Rouse et al. (1974) to differentiate green vegetation from soil brightness. It is the most common index used for highlighting the vegetation health. Areas of barren rock, sand and snow produce NDVI values of <0.1, while shrub and grassland typically generate NDVI values of 0.2–0.3, and temperate and tropical rainforests produce values in the 0.6–0.8 range (https://earthobservatory.nasa.gov).

The thermal infrared band (Band 6 for Landsat 5 and Bands 10 and 11 for Landsat 8) is particularly useful for assessing the spatial distribution of temperatures and studying the urban heat island phenomenon. In accordance with blackbody theory, the thermal emittance from an object can be expressed as Planck's radiance function. Using this expression, data is converted from spectral radiance to brightness temperature (Sobrino et al., 2004, Jimenez-Munoz&Sobrino, 2010).

$$\mathbf{BT = K2/ \ln (K1 +1)\ L\lambda} \quad (1),\ \text{where:}$$

BT = At-satellite brightness temperature (K)

$L\lambda$ = TOA spectral radiance (Watts/ (m2 * srad * μm))

K1 = Band-specific thermal conversion constant from the metadata (K1_CONSTANT_BAND_x, where x is the thermal band number)

K2 = Band-specific thermal conversion constant from the metadata (K2_CONSTANT_BAND_x, where x is the thermal band number)

$$\mathbf{L\lambda = MLQcal + AL} \quad (2),\ \text{where:}$$

$L\lambda$ = TOA spectral radiance (Watts/ (m2 * srad * μm))

ML = Band-specific multiplicative rescaling factor from the metadata (RADIANCE_MULT_BAND_x, where x is the band number)

AL = Band-specific additive rescaling factor from the metadata (RADIANCE_ADD_BAND_x, where x is the band number)

Qcal = Quantized and calibrated standard product pixel values (DN)

$$\mathbf{LST = T/ (1 + (w * T / 14380) * ln(e))} \quad (3),$$ where:

T = At-satellite brightness temperature (K)
W = Center wavelength (μm)
e = Emissivity
In this study, NDVI was used for estimation of land surface emissivity.

$$\mathbf{e = 0.004*Pv+0.986} \quad (4),$$ where:

Pv = Proportion of vegetation
Pv = ((NDVI-NDVImin)/(NDVImax-NDVImin))2

II. RESULTS AND DISCUSSIONS

3.1. Land use/land cover in Bucharest area

Starting with the 90s and until 2018, there has been a series of changes regarding the coverage of the land, as a result of the development of some sectors of activity to the detriment of the others. Thus, the area built in 2018 has expanded, compared to 1990, the natural grasslands, fruit tree plantations, vines, as well as forests have reduced (Fig. 3).

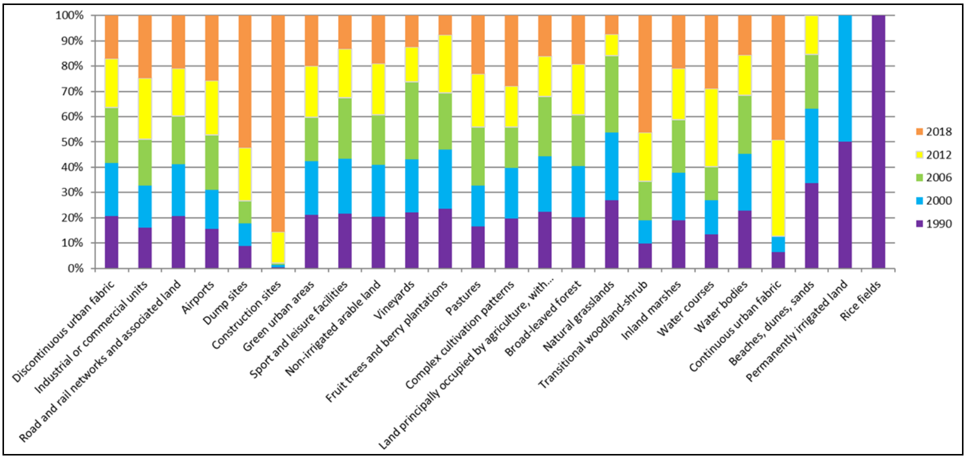

Fig. 3. Change of land cover area between 1990 and 2018 according to Corine Land Cover products

From the processing of SAR images, during the period 2015-2018, five land use classes were extracted: agricultural areas/ grassland areas, artificial surface, forest and seminatural areas, water bodies and wetlands. Thus, following the classification of images from 2018, it turned out that the largest area is occupied by the agricultural areas/ grassland areas (69%), followed by the forest area (21%) wetlands (5%), artificial surface (3%) and water bodies (2%) (Fig. 4). The agricultural area has over 386,000 ha, the forest area has over 119,000 ha, while the built area has 15,500 ha (Fig. 5).

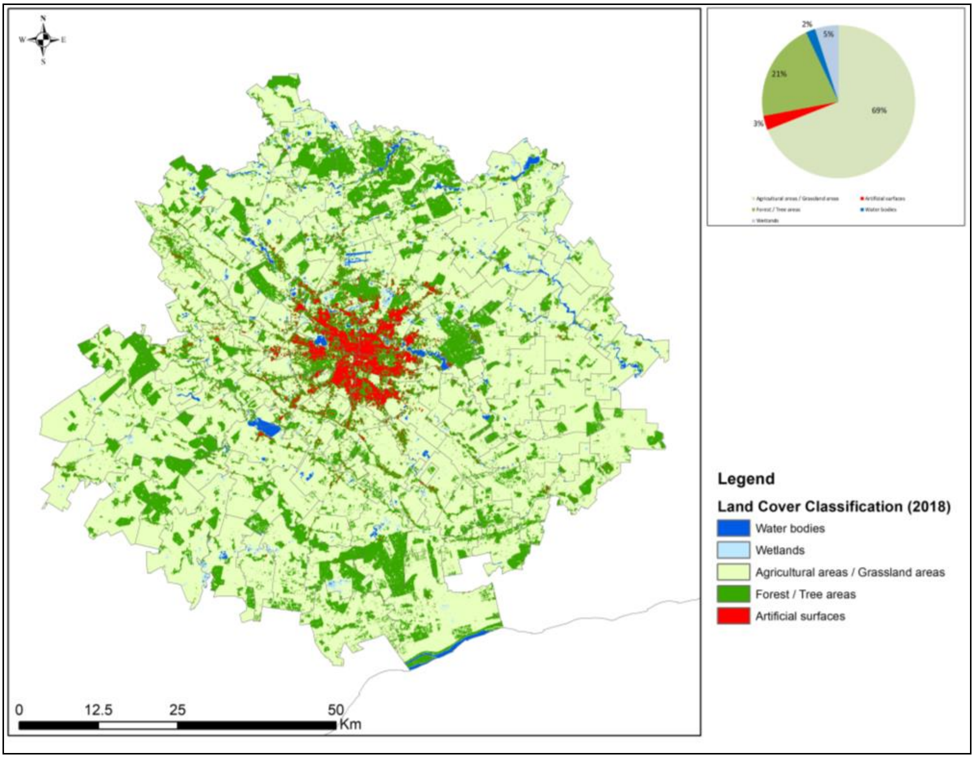

Fig. 4. Land Cover Classification from Bucharest area (2018) from Sentinel 1 (SAR)

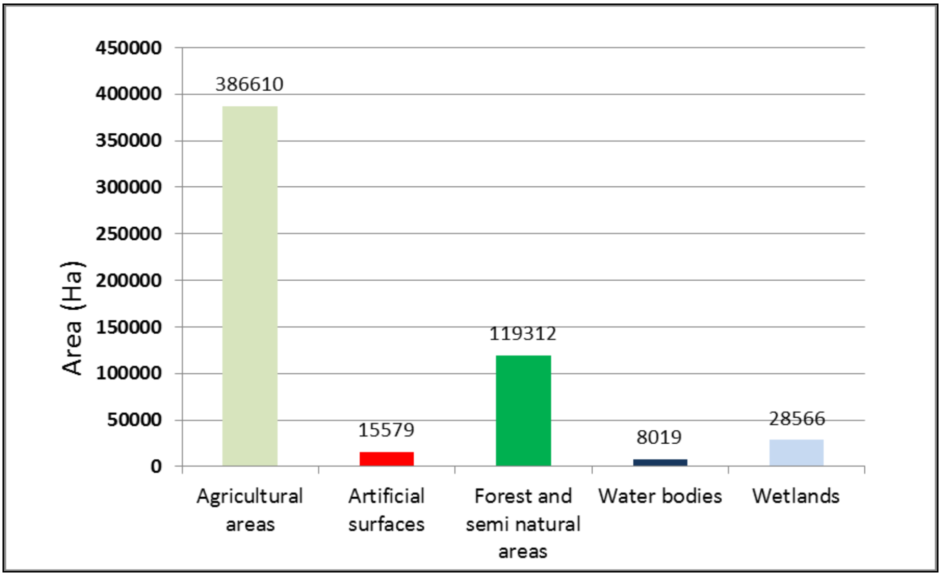

Fig. 5. Land Cover Area (2018) from Sentinel 1 (SAR)

3.2. Land Surface Temperature

Based on the comparative analysis of LST at the level of TAU for the years 1990 and 2017, lower values can be observed in 1990 (Fig. 6) compared to those of 2017. At the same time, it can be observed that in both years the average value of LST in Bucharest is higher than in the other localities. Of the six sectors of Bucharest in 1990, the highest average value is registered in sector 5, and the smallest in sector 1. In 2017, all six sectors have higher values compared to the other TAUs.

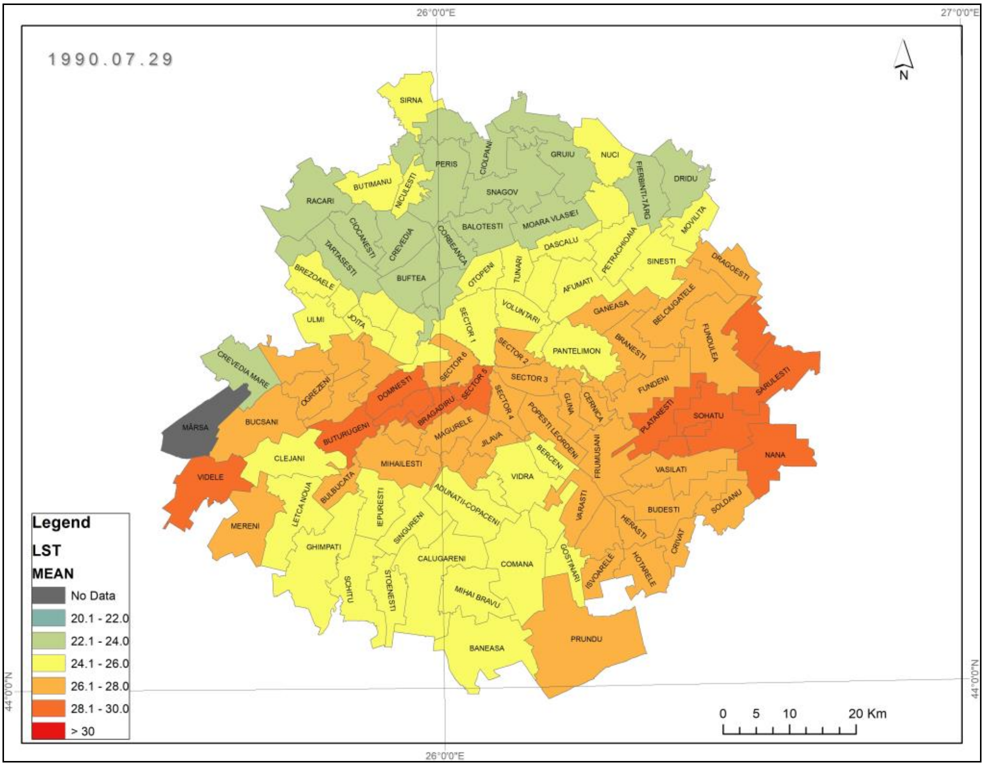

Fig. 6. Average of LST at Territorial Administrative Unit (29.07.1990)

IV. CONCLUSIONS

In conclusion, the analysis of the impact of land use on the heat island can be performed based on satellite images, which are an alternative to ground measurements (Fig. 7). However, a multitemporal analysis of the satellite images available from the point of view of the land use/land cover and also from point of view of the temperature on the ground surface is necessary. Since the only available satellite images that cover a long range of data and have a temperature sensor are Landsat images, it is difficult to find images that meet all the conditions of their selection, such as cloud cover.

It is recommended to select satellite images based on the temperature of the air from the weather stations, so that in all the days where there are images to be the same average daily temperature.

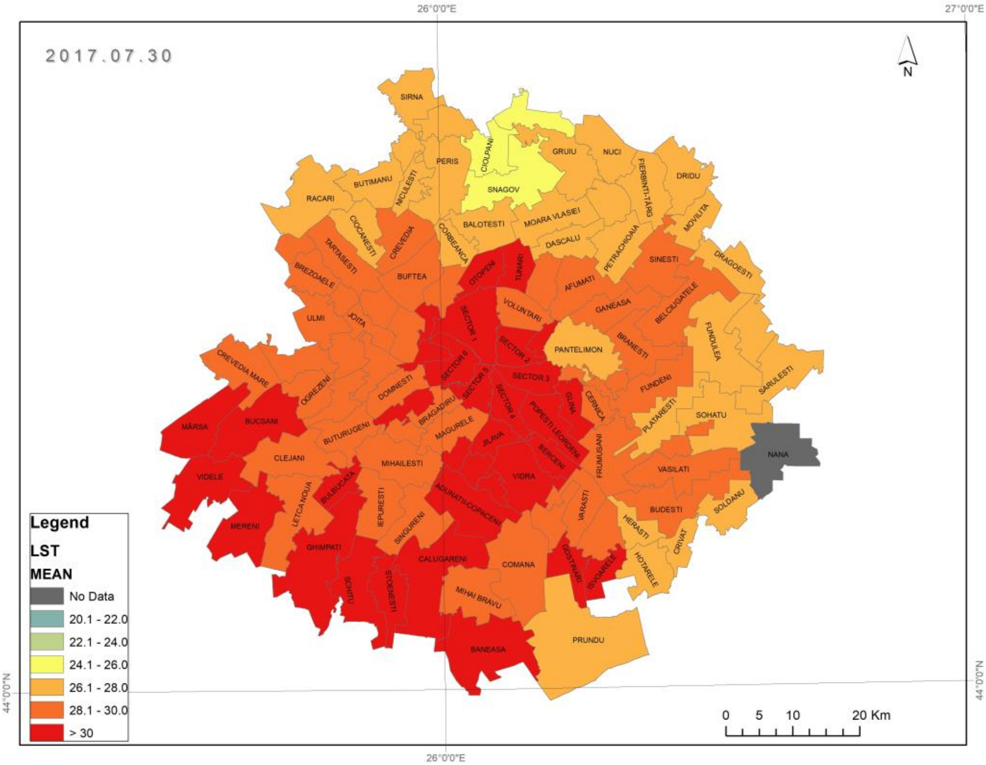

Fig. 7. Average of LST at Territorial Administrative Unit (30.07.2017)

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