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ANALYSIS OF LAND SURFACE TEMPERATURE IN THE TIMIŞOARA CITY USING LANDSAT 8 SATELLITE IMAGES

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Abstract

The monitoring of large areas by using satellite technique is very useful in the context of sustainable development and efficient and secure management. Satellite methods and techniques are increasingly used in studying and monitoring land and vegetation. There is very useful spectral information with great precision in characterizing large areas of land. This study is used for analyzing and determining how one of the most important parameters that could be obtained based on satellite images and the spectral frequency spectrum of the thermal surface in the thermal area, which is named the surface temperature of the ground. The studied area was Timisoara, and the LST parameter was determined using a specialized GIS software based on images from Landsat 8. Landsat 8 is an American Earth Observation Observatory launched on February 11, 2013 and an infrared thermal sensor TIRS) with two thermal bands. Starting from Landsat 8 satellite images and bands 10 and 11, the information spectrum describing the studied area was extracted and mathematical algorithms were processed, the LST parameter was determined to characterize the studied area. This study is also used to analyse how the soil surface temperature is determined based on Landsat 8 satellite imagery and a terrain surface response spectrum. To detect certain temperature categories of a surface or object, the radiation emitted by this electromagnetic spectrum is measured with thermal infrared.

***Keywords**: Indices, LST, NDVI, NDBI, Timisoara.*

INTRODUCTION

Remote sensing is the science and technology of obtaining information (Tentu, 2018) on the Earth's surface from a distance (without coming into contact with it) by using electromagnetic radiation.

Remote sensing could be defined in more detailed form as “a field technique” that deals with the detection, measurement, recording and visualization in the form of images of electromagnetic radiation emitted by objects and phenomena from Earth or the Universe from a distance.

Remote sensing is an activity of detecting, measuring, recording and viewing in the form of electromagnetic images of radiation emitted by objects and phenomena from Earth or the Universe from a distance without having direct contact with them (Barsi et al., 2007).

Remote sensing, regardless of the nature of the applications, whether passive or active, uses electromagnetic radiation to obtain body images at a certain altitude (airplane, satellite, balloon, helicopter) because in this way the image could be used as maps and plans (Moscovici et al., 2015), the interpretation of objects is optimal and easy (Moldovan et al., 2017).

The electromagnetic spectrum is a physical model that shows us known and measured electromagnetic radiation, depending on their wavelength and specific energy level, representing the total electromagnetic radiation of the universe. The spectrum presents a number of areas where electromagnetism radiation is delineated based on wavelength. Remote sensing applications are limited to producing images, impossible to obtain spectral areas.

The present investigations aimed mainly at the study of the NDVI and NDBI indices, as well as a LST parameter for the Timisoara City area during 2013-2018.

Starting from the Landsat 8 satellite images (Herbei et al., 2016), spectral information which characterizing the studied area was extracted. Spectral information was expressed using spectral bands based on which the NDVI and NDBI vegetal cover characterization indices were calculated (Herbei, 2015).

The aim of the present paper is to highlight the efficiency of remote sensing and satellite technologies, rather than the acquisition of terrestrial surface data and their interpretation, so that the results obtained serve as many fields of activity (Preoțescu and Nedea, 2017).

MATERIAL AND METHOD

Timişoara is the municipality of Timiş County, Banat, Romania. It is located in the west of Romania, close to the borders with Hungary and Serbia, on the Bega River, geographically at approximately equal distances to Bucharest (541 km), Vienna (549 km) and Sofia (509km).

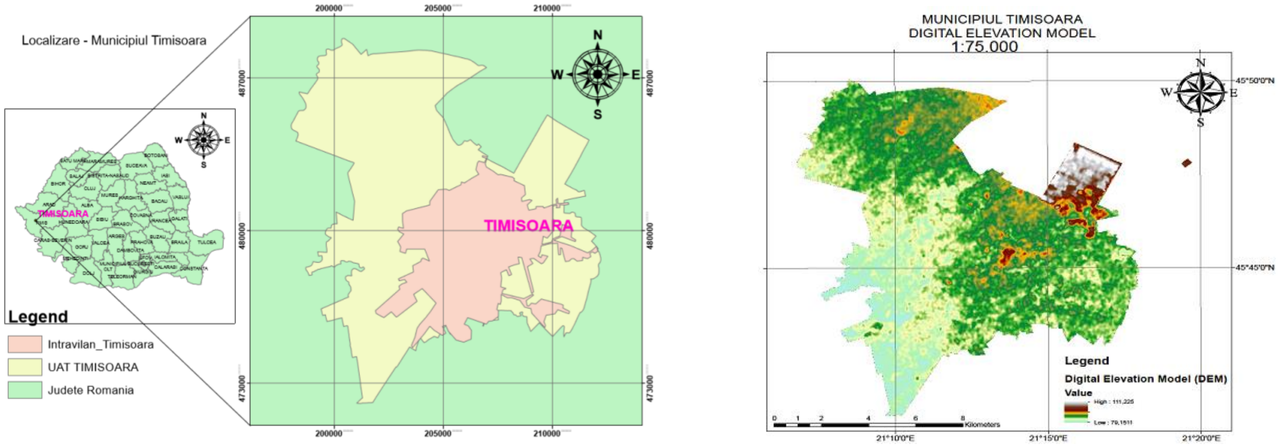

Figure 1.The Study Area – The city of Timisoara

The LANDSAT program offers repetitive multi-spectral data acquisition of the Earth's surface on a global basis.

The information of Landsat is the longest record of the continental surfaces of the Earth, as seen from space.

LANDSAT 8 was lunched on February 11, 2013 (former Landsat Data Continuity Mission - formerly Landsat Data Continuity Mission, LDCM). Landsat 8 collects data and images uses in agriculture, education, business, science and geography. Landsat 8 system has two important tools: Operator Land Imager (OLI) Operational Terrestrial Device, Infrared Thermal Sensor - Infrared Thermal Sensor (TIRS). The TIRS instrument collects two wavelength spectral bands covered by a single TM sensor and previous ETM + sensor bands.

These performance factors improve signal-to-noise (SNR) over a 12-bit dynamic range (this translates to 4096 grey levels in the image, compared to only 256 grey levels in the previous 8-bit tools).Signal-to- allows a better characterization of the state and the conditions of the land cover. The products are delivered as 16-bit images (55,000-grays scale) (Pantea and Lacusteanu, 2017).

The Landsat 8 remote-sensing images that were used in this study were downloaded free of charge from the https://earthexplorer.usgs.gov/ portal. These images have a spatial resolution of 30 m and a temporal resolution of 16 days (Herbei, 2018).

The spectral bands, the wave length of the Landsat 8 bands and the resolutions of them are shown in Table 1.

Table 1. Spectral Band Descriptions - LANDSAT 8

Bands	The wavelength (micrometers)	Resolution
Band 1 Ultra Blue (coast / aerosol)	0.435 - 0.451	30
Band 2 - Blue	0.452 - 0.512	30
Band 3 - Green	0.533 - 0.590	30
Band 4 - Red	0.636 - 0.673	30
Band 5 - Near Infrared (NIR)	0.851 - 0.879	30
Band 6 - Shortwave Infrared (SWIR) 1	1.566 - 1.651	30

Band 7 - Shortwave Infrared (SWIR) 2	2.107 - 2.294	30
Band 8 - Panchromatic	0.503 - 0.676	15
Band 9 - Cirrus	1.363 - 1.384	30
Band 10 - Thermal Infrared (TIRS) 1	10.60 - 11.19	30
Band 11 - Thermal Infrared (TIRS) 2	11.50 - 12.51	30

Landsat 8 scenes were processed using ERDAS Image software, which haspre-processing and post-processing tools for remote sensing images(https://landsat.usgs.gov/using-usgs-landsat-8-product).
ERDAS Image allowed the calculation of the vegetation indices used in this study: NDVI and NDBI, as well as the LST parameter calculation based on TIR thermal bands 10 and 11.For calculating the LST parameter, we developed an automated calculation model in ERDAS.
Landsat 8 provides band metadata, such as thermal constant rescaling factor value, etc., which can be used to calculate LST.

From the file containing the Landsat scene information that is used with the MTL extension we will extract the following information that we will need in the LST calculation:
Example: Landsat Scene 8 on August 7,2018
LANDSAT_SCENE_ID="LC81860282018219LGN00"
WRS_PATH = 186,   WRS_ROW = 28
DATE_ACQUIRED = 2018-08-07
SCENE_CENTER_TIME="09:20:38.6343750Z"

Figure 2. Landsat 8MTL scene

Table 2. Metadata file description

	Existing name in Metadata file (*.mtl)	**Band 10**	**Band 11**
Radiance Multiplier the radiance rescaling factors Band-specific multiplicative rescaling factor	RADIANCE_MULT_BAND_10 RADIANCE_MULT_BAND_11	3.3420E-04	3.3420E-04
Radiance Add the radiance rescaling factors Band-specific additive rescaling factor	RADIANCE_ADD_BAND_10 RADIANCE_ADD_BAND_11	0.10000	0.10000
K1 the thermal constants needed to convert thermal band data to TOA brightness temperature	K1_CONSTANT_BAND_10 K1_CONSTANT_BAND_11	774.8853	480.8883
K2 the thermal constants needed to convert thermal band data to TOA brightness temperature	K2_CONSTANT_BAND_10 K2_CONSTANT_BAND_11	1321.0789	1201.1442
θ_{SE} Local sun elevation angle. The scene centre sun elevation angle in degrees is provided in the metadata	SUN_ELEVATION	56.01538947	

- **LST**

One of the most important parameters that could be obtained based on satellite imagery are based on the spectral spectrum of thermal surfaces. There are several procedures developed for extracting temperature information from satellite imagery; differences are dictated by the specificity of each type of image (Valor and Caeselles, 2005).
Most methods of obtaining LST involves transforming the value of the digital number (DN) into reflectance values, applying the necessary corrections (atmospheric) and finally achieving the temperature of the reflector one (Weng et al., 2004).
LST (Surface Temperature) is the surface temperature of the earth that is in directly contact with the measuring instrument (usually measured in Kelvin). LST is the surface temperature of the earth crust where the heat and sunlight are absorbed, reflected and reframed. LST is changing once with the change of climatic conditions and other human activities where exact prediction becomes a challenge (Sobrino et al., 2008).
Average spatial resolution data, such as LANDSAT and SPOT data, is suitable for terrestrial coverage or regional scale mapping. LANDSAT 8 carries two sensors, namely the Imager Operator Terminal (OLI) and Thermal Thermocouple (TIRS). OLI collects the data at a 30m spatial resolution with eight bands visible in infrared and near infrared and short infrared, with short frequency electromagnetic spectrum and a panchromatic resolution of additional 15m (Sobrino and Raissouni, 2000).
Below are the steps you need to take to determine the LST parameter (Sobrino et al., 2004).

- ***Conversion from Digital Number in Top Of Atmosphere [Lλ]***

The conversion of DN in TOA can be achieved using the following formula

$$L_\lambda = \text{GAIN} \times \text{DN} + \text{BIAS}$$

where:
Lλ - Top Of Atmosphere spectral radiance $[\text{Watts}/(\text{m}^2 \times \text{srad} \times \mu\text{m})]$
DN – Digital Number - Quantized and calibrated standard product pixel values
GAIN is the gain value for a specific band (RADIANCE_MULT_BAND_x, where x is the band number)
BIAS is the bias value for a specific band (RADIANCE_ADD_BAND_x, where x is the band number)

- ***Conversion to TOA Reflectance***

Converting the data of thermal bands OLI and TIRS in Digital Number DN in Top Of Atmosphere reflectance using the parameters of radiance rescaling that are found in the meta-data file of the product Landsat 8. For the Band 10 and 11, in order to convert DN to TOA, is used the following formula:

$$\rho'_\lambda = M_\rho \times \text{DN} + A_\rho,$$

where:
ρ'_λ- TOA planetary reflectance, without correction for solar angle. Note that ρλ' does not contain a correction for the sun angle;
M_ρ - Band-specific multiplicative rescaling factor from the metadata (REFLECTANCE_MULT_BAND_x, where x is the band number);
DN - Quantized and calibrated standard product pixel values (DN);
A_ρ - Band-specific additive rescaling factor from the metadata (REFLECTANCE_ADD_BAND_x, where x is the band number).

$$L_{10} = 0.0003342 \times \text{DN}_{\text{band}_{10}} + 0.1$$
$$L_{11} = 0.0003342 \times \text{DN}_{\text{band}_{11}} + 0.1$$

TOA reflectance with a correction for the sun angle is:

$$\rho_\lambda = \frac{\rho'_\lambda}{\cos(\theta_{SZ})} = \frac{\rho'_\lambda}{\sin(\theta_{SE})}$$

where:
ρ_λ- TOA planetary reflectance
θ_{SE} - Local sun elevation angle.The scene center sun elevation angle in degrees is provided in the metadata (SUN_ELEVATION);
θ_{SZ} - Local solar zenith angle: $\theta_{SZ} = 90 - \theta_{SE}$.

- ***Conversion to Apparent Brightness Temperature – AT [T]***

This conversion is made based on Planck's law. Data from TIRS band are converted from spectral radiance to brightness temperature by using thermal constants that are found in metadata file downloaded from portal http://earthexplorer.usgs.gov.

A simplified formula was used by Schott and Volchok,1985; Markham & Barker,1986; Irish, 2003.

$$T = \frac{K_2}{\ln(\frac{K_1}{L_\lambda} + 1)}$$

where:

T - Apparent Brightness Temperature [GRADE KELVIN];

Lλ (L10 or L11) - Top Of Atmosphere spectral radiance[Watts ÷ (m2 × srad × µm)

K1 - Band-specific thermal conversion constant - calibration constants - from the metadata (K1_CONSTANT_BAND_10 or K1_CONSTANT_BAND_11)

K2 - Band-specific thermal conversion constant - calibration constants - from the metadata (K2_CONSTANT_BAND_10 or K2_CONSTANT_BAND_11)

For this study, Apparent Brightness Temperature was calculated for the Band 10 and 11, thus the result was converted from degrees Kelvin to Celsius:

$$T_{10} = \frac{1321.08}{\ln(\frac{774.89}{L_{10}} + 1)}$$

$$T_{10}[K] = T_{10} - 273.15[C]$$

$$T_{11} = \frac{1201.14}{\ln(\frac{480.89}{L_{11}} + 1)}$$

$$T_{11}[K] = T_{11} - 273.15[C]$$

- ***Calculating the Normalized Differential Vegetation Index (NDVI)***

The Normalized Differential Vegetation Index (NDVI) is a standardized vegetation index that is calculated using Near Infra-Red (Band 5) and Red (Band 4).

$$NDVI = \frac{NIR - R}{NIR + R} = \frac{B5 - B4}{B5 + B4}$$

where:

RED = DN values in the RED band

NIR = DN in the Near-Infrared band

- ***Calculation of Land Surface Emissivity (LSE) – ε***

Land Soil Emissivity (LSE) is the mean emissivity of an element of the Earth's surface calculated from NDVI values.

$$P_V = \left[\frac{NDVI - NDVI_{MIN}}{NDVI_{MAX} - NDVI_{MIN}}\right]$$

where:

PV = Proportion of vegetation

NDVI = The DN value in the NDVI image

NDVI min = The minimum DN value in the NDVI image

NDVI max = Maximum DN value in the NDVI image

In practice, due to the choice of a typical soil value, it is a more critical issue due to the higher variations in soil emissivity compared to vegetation, LSE is calculated as follows:

$$\varepsilon = m \times P_V + n = 0.004 \times P_V + 0.986$$

where:

E = emissivity of the isoleucine surface

PV = Proportion of vegetation

- ***Calculation of Land Surface TEMP – LST***

Soil surface temperature (LST) is the radiation temperature that has been calculated using atmospheric surface brightness, temperature, wavelength of light emission, soil surface emissivity.

$$LST = T/\left[1 + (w * \frac{T}{p}) \ln e\right]$$

where:

T - the apparent brightness temperature,T10 or T11, w - the radiation wavelength emitted [mm], $p = h \times c/s[1{,}438 \times 10^{-2}]mK$

h -Planck’s constant ($6{,}626 \times 10^{-34}$Js)

s - Boltzmann constant ($1{,}38 \times 10^{-23}$J/K)

c - velocity of light ($2{,}998 \times 10^{8}$m/s)

ε - Land Surface Emissivity (LSE)

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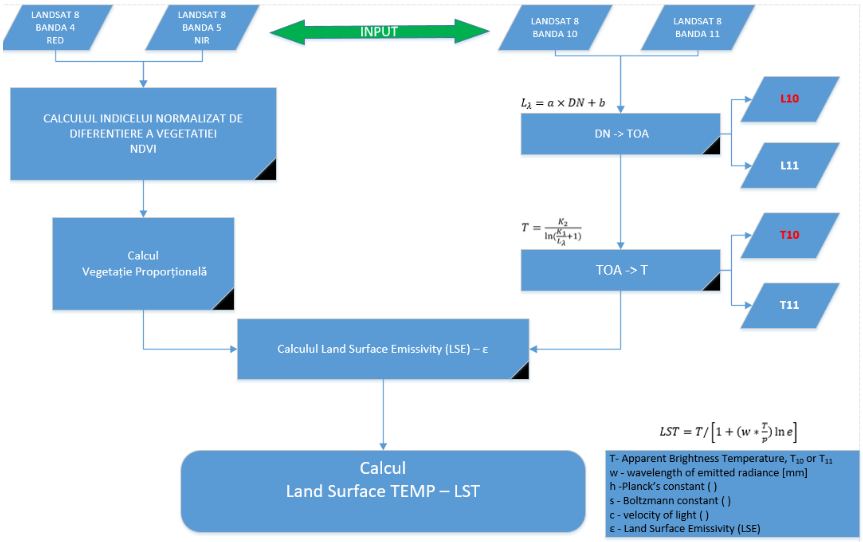

Figure 3. Logical Scheme of Calculating –LST

- ***Normalized Difference Vegetation Index (NDVI)***

The Normalized Difference Vegetation Index (NDVI) is a non-linear transformation of the Visible (RED) and Near Infrared (NIR) bands being defined as the dividend distribution difference divided by their amount.

NDVI is a unit of measurement of vegetation density and density and is associated with biophysical parameters such as biomass, foliar surface index (LAI), used very often in crop growth patterns, percentage of vegetation coverage, photosynthetic activity of vegetation. Generally, NDVI values are between -1.0 and 1.0, negative values indicating clouds or water, and positive values close to 0 indicating uncovered soil, high positive NDVIs indicate rare vegetation (0.1-0, 5) to dense vegetation (> 0.6).

Indirectly, NDVI is used to estimate the effects of precipitation over a certain period of time, to estimate the vegetation status of different cultures and to the quality of the habitat as a habitat for different pests, pests and diseases.

- ***Normalized Difference Built Index(NDBI)***

The NDBI values varies depending on the spectral signals in the middle infrared band (high reflectance of soil moisture, vegetation, rocks, including building materials) and the near infrared band (Reflectance Sea and chlorophyll).

The values are between -1 and +1.

The NDBI is calculated using the formulas:

$$NDBI=\frac{IR-NIR}{IR+NIR}$$

where:

NDBI - Normalized Difference Built Index

NIR-Near infrared band

IR –Infrared band

RESULTS AND DISCUSSIONS

In order to calculate vegetation indices and to extract spectral information, ERDAS Image v. 11 software and ArcGIS v.10.5 software were used.

To calculate the LST parameter, we developed an automated calculation model in ERDAS Image using the Afferent Toolbox analysis tools

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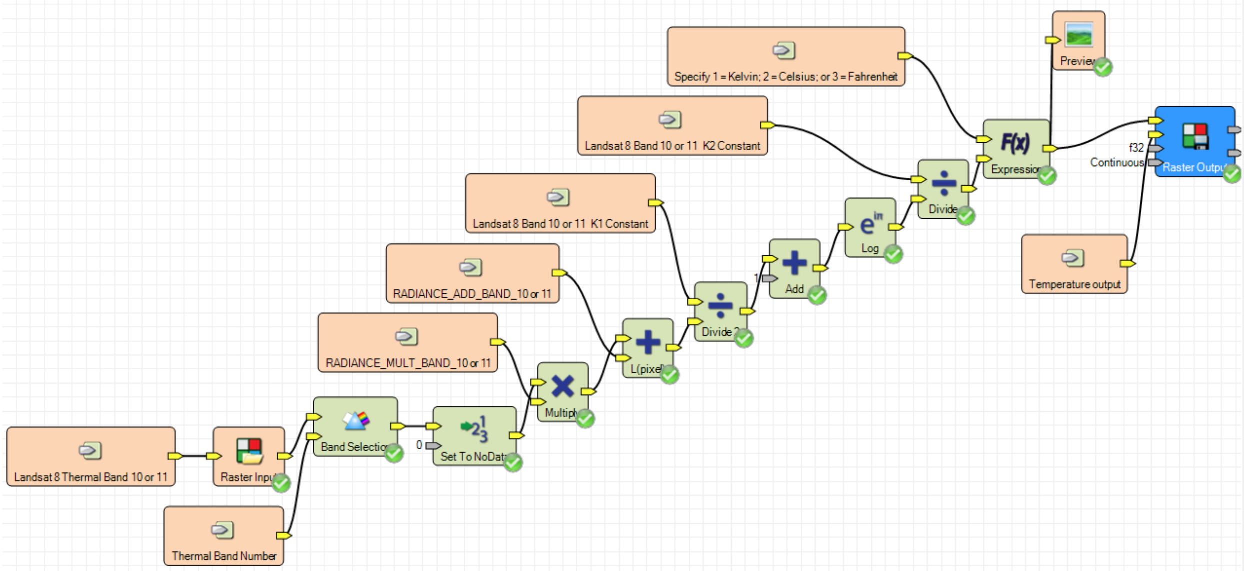

Figure 4. LST Spatial Model

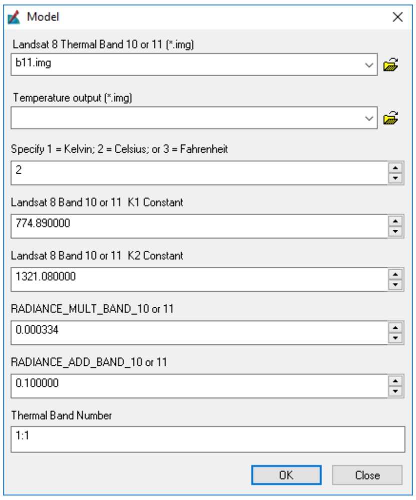

Figure 5. The Model Interface

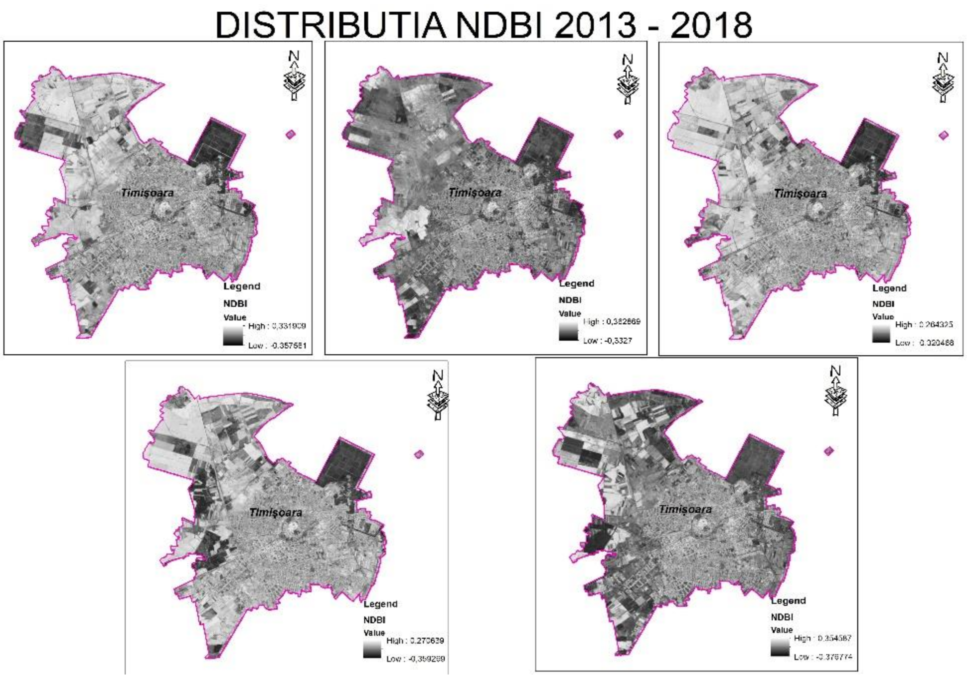

Figure 6. NDBI Distribution

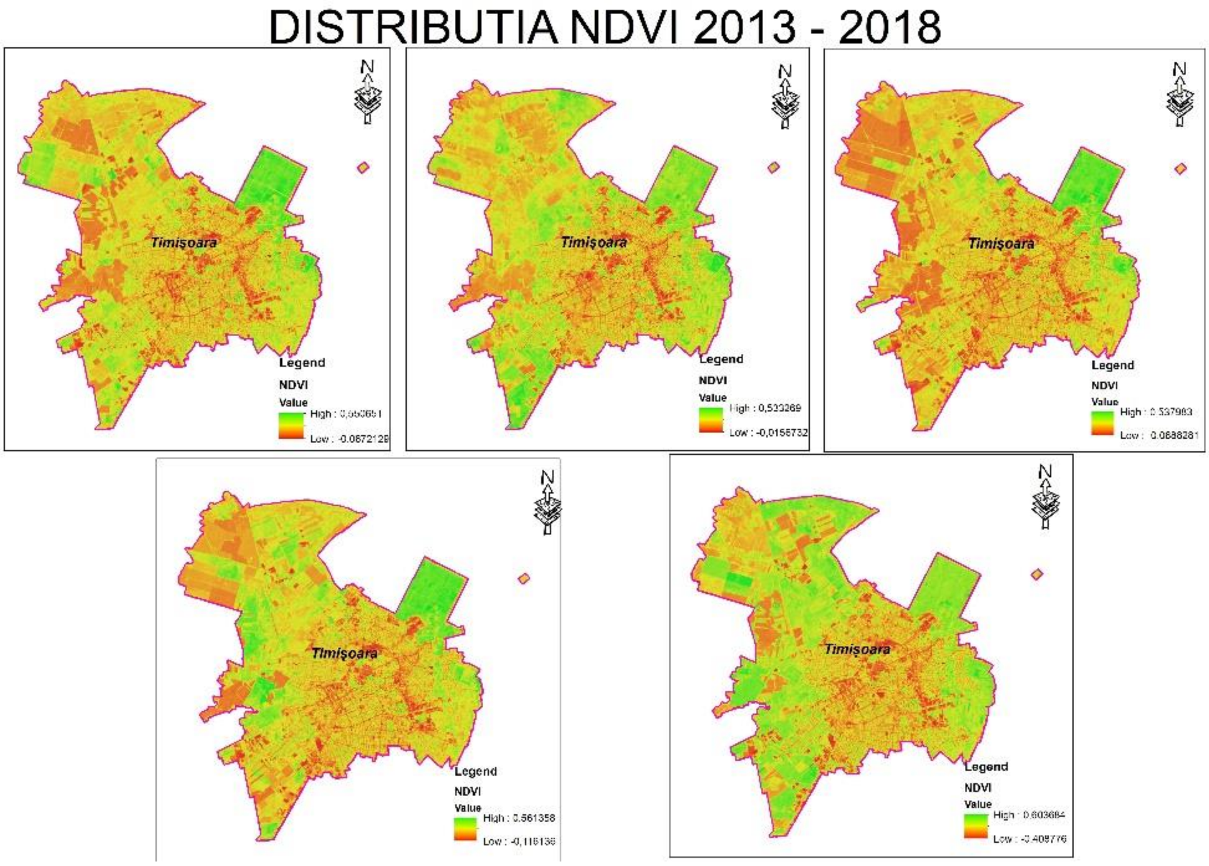

Figure 7. NDVI Distribution

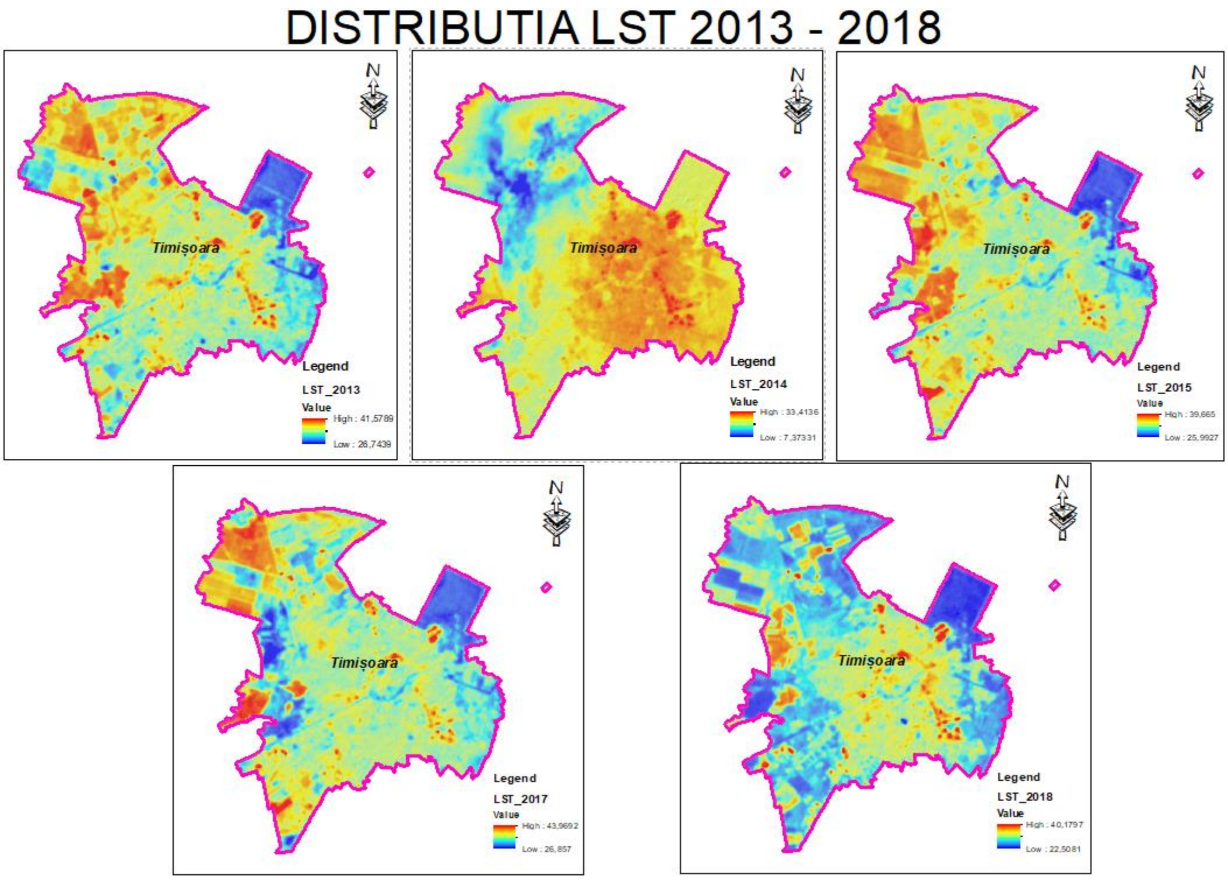

Figure 8. LSTDistribution

The highest temperature in 2013 was:41,57890 and the lowest was:26,74390.
The highest temperature in 2014 was:33,41360, and the lowest was:7,373310.
The highest temperature in 2015 was:39,6650, and the lowest was:25,9920.
The highest temperature in 2017 was:40,7790, and the lowest was:24,5630.
The highest temperature in 2018 was:37,2220, and the lowest was:20,4800.

The average values obtained for the 5 years of the studied we are shown in the following table:

Table 3. Average values from 2013 - 2018

	2013	2014	2015	2017	2018
LST	33,171	21,478	32,060	33,958	28,002
NDVI	0,242	0,271	0,214	0,250	0,315
NDBI	-0,055	-0,102	-0,033	-0,058	-0,116

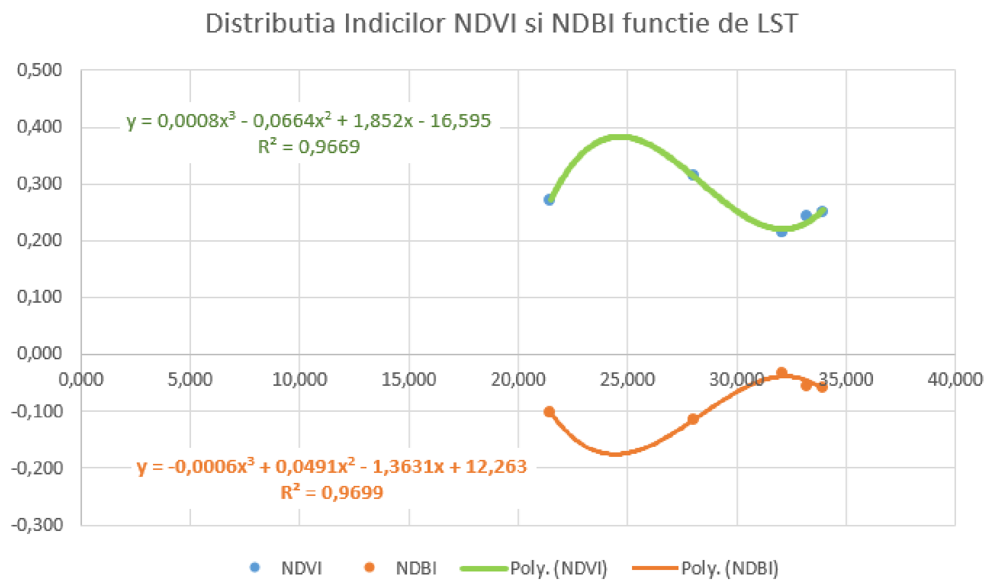

Figure 9. The distribution of NDVI and NDBI

CONCLUSIONS

Satellite images contain many information due to spectral bands in the visible and near-infrared areas, but also to the multispectral, panchromatic or stereo imagery. The analysis of this information is essential in interpreting the patterns and analysis of vegetation indices. It is also very important to analyse the changes that exist over a long period of time.

This theme was chosen on the basis of discovering and using new software and technologies in the field of land surveying and cadastre. The importance of the subject is given by the efficiency of these methods of collecting information on the Earth's surface from a large distance, without coming in contact with the intended objectives. Also, the results obtained from these processes are more promising both in terms of quantity and quality in terms of the generated information.

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