

LAND SURFACE TEMPERATURE MONITORING THROUGH GIS TECHNOLOGY USING SATELLITE LANDSAT IMAGES

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Abstract

Global warming is a factor that has widened over the last period of time, so monitoring ground temperature is needed to take measures to prevent this phenomenon. In the hope of preserving life on earth and bring balance in our life, as we use to have it, it is up to our civic duty to share the essentials of the scientific research done, for the doctoral thesis and came with some ideas and suggestion, to help our community to reach our goal. The objective of the study will describe a methodology used for estimating the terrestrial surface temperature by means of the geographic information systems technology, using the two Landsat thermal bands, acquired by the Thermal Infrared Sensor (TIRS) installed on the Landsat 8 satellite platform. A case study on the administrative area of Cristuru Secuiesc, located in the South-West part of Harghita County, will be approached in the paper. The primary data base consists of thermal bands (band 10 and band 11) and multispectral bands (2, 3, 4, 5) from the Landsat 8 mission, taken with OLI (Operational Land Imager) and TIRS (Thermal Infrared Sensor) sensors. To carry out the study, the NDVI index will be calculated using the multispectral bands, while the thermal bands will be converted to several physical quantities in order to obtain the desired result. The paper describes the process of collecting data and processing it, to obtain valuable information on the surface temperature experienced by a computer, without the need for field measurements.

Key words: GIS (Geographic Information System), Global warming, Landsat, NDVI, surface temperature.

INTRODUCTION

The purpose of this study is to develop image capture methodologies to determine terrestrial surface temperature using satellite imagery from the Landsat 8 mission taken with the Thermal Infrared Sensor (TIRS) and the OLI (Operational Land Imager) multispectral sensor via system technology geographic information. The article brings novelty elements both for the field of satellite remote sensing and for the field of geographic information systems. This study presents also theoretical and experimental information for the implementation of a geographic information system in order to provide standard products (Ferencz Z. et al., 2017).

The most important goal of this article is not the carrying out of a quantitative analysis, much being structured in the form of a seminar, addressing in particular those who are attracted by the wonderful field of remote sensing and geographical information systems.

The geographical information systems allow the user not only to obtain some information about the Earth but also help to correlate this

information with ground aspect (Maracineanu F. et al., 2013).

MATERIALS AND METHODS

The graphics software used for spatial raster spatial data geoprocessing is the ArcMap 10.1 program.

Primary digital remote sensing data are obtained free of charge from the USGS official website (earthexplorer.usgs.gov), where the area of interest is selected first, after which the type of data is selected and after filtering the results, can be downloaded online. The spatial resolution of these images is desirable, but they can be used successfully for general research.

First of all, Landsat satellite images must be purchased/downloaded using the above mentioned website.

GIS technologies have pronounced methods to analyse the relationship between several geographical and environmental data (Artun O. et al., 2017).

The study was carried out through two steps that are linked to each other, namely the first step is the calculation of the NDVI

(Normalized Difference Vegetation Index) index, while the second step is represented by a methodology/step sequence, for actual estimation of the surface temperature, and in the following, we will briefly describe the method used.

By downloading the desired Landsat scene, we will find an archive containing several files named with the spectral band number. To achieve such a study, we will need 6 spectral bands, namely bands B2 (blue), B3 (green), B4 (red), B5 (infrared) taken by the OLI (Operational Land Imager) sensor to produce the NDVI (Normalized Difference Vegetation Index) and thermal bands B10 and B11 taken over by the TIRS (Thermal Infrared Sensor) sensor installed on the Landsat satellite platform for the proper estimation of ground surface temperature.

For this article, we chose as a study area the 3rd administrative district of Cristuru Secuiesc in Harghita County, purchased in vector format *.shp from the website geoportal.ancpi.ro, maintained by the National Agency of Cadastre and Real Estate Publicity of Romania (ANCPPI).

In this case study, all Landsat images were imported into the ArcMap window and clipped out using the 3rd order administrative limit of Cristuru Secuiesc through working toolbox in the Arc Toolbox window, where we select Data Management Tools > Raster > Raster Processing > Clip. The screen capture with the Clip function window is represented in the figure below (Figure 1), where there are two input data, namely the image to be cut and the clipping contour in vector format.

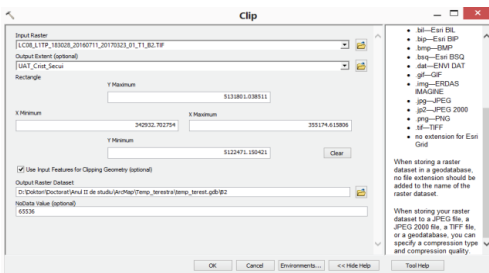


Figure 1. Clip Raster function window

Using the Image Analysis window (Figure 2), we create the RGB (Red Green Blue) color

composite (Figure 3) and select all the 4 spectral bands, then press the Composite bands button under the Processing submenu.

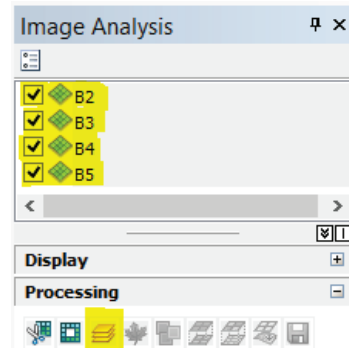


Figure 2. Image Analysis window



Figure 3. RGB composite color fake using infrared, red and green strips

Note that images that were obtained through the Image Analysis window have an on-the-fly character, and to make it a permanent layer, it is necessary to select the provisional image in the current start-up table by right-clicking save, using Data > Export Data (ESRI, ArcGIS Help, 2012). After we have obtained the colour composite, we move to creating the NDVI (Normalized Difference Vegetation Index) image. Creating the NDVI (Normalized Difference Vegetation Index) colour is greatly facilitated by using the Image Analysis window, where we select the colour composite obtained in the previous step and using the button that takes the form of a leaf under the Processing submenu (Figure 4) NDVI (Normalized Difference Vegetation Index).

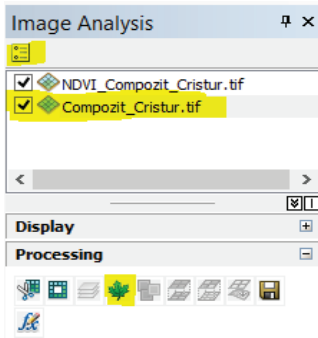


Figure 4. Creating NDVI (Normalized Difference Vegetation Index) using Image Analysis function

The calculation formula used to determine the Normalized Difference Vegetation Index (NDVI) is given by the ratio between the infrared and red band differences, respectively the sum of the infrared and red bands. The image obtained shows us the areas of land covered with healthy and dense vegetation (Figure 5).

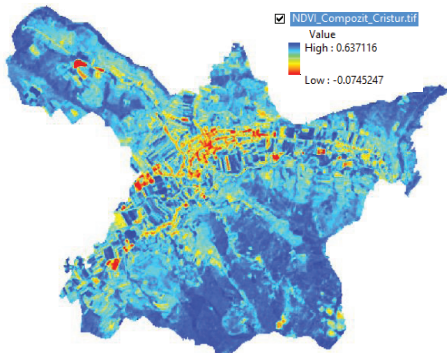


Figure 5. NDVI (Normalized Difference Vegetation Index)

Once we have the Normalized Difference Vegetation Index (NDVI), we can pass the ground surface temperature estimation by concatenating the two thermal bands (with different wavelengths) with the Normalized Difference Vegetation Index (NDVI). The first step is to convert the digital numbers into radiance, followed by the conversion of the radiance into the temperature measured by the satellite, and the last step is the actual calculation of the surface temperature. In the following we will describe the steps taken. Note that all processes/transformations will be

done using the Raster Calculator function, located between ArcToolbox work tools, in the Spatial Analyst Tools class, the Map Algebra submenu. In the following, we will briefly describe the steps to be taken to conduct the study.

1) *Converting digital numbers into radiance* is done according to the official USGS page (landsat.usgs.gov/using-usgs-landsat-8-product), where we find that the data acquired with the TIRS (Thermal Infrared Sensor) can be converted into radiance Spectral TOA (Top Of Atmosphere) by the formula:

$$L\lambda = M_L \times Qcal + A_L \quad (1)$$

where:

$L\lambda$ - TOA (Top Of Atmosphere) spectral radiance ($\text{Watts}/(\text{m}^2 \times \text{srad} \times \mu\text{m})$);

M_L - the rescaling factor specific to each spectral band described in the metadata file;

A_L - add-on factor specific to each strip in the metadata file;

$Qcal$ - Calibrated pixel values in the standard product (DN - Digital Numbers).

To apply this formula, open the Raster Calculator utility (Figure 6) and enter the formula below "0.0003342*"B10"+0.1".

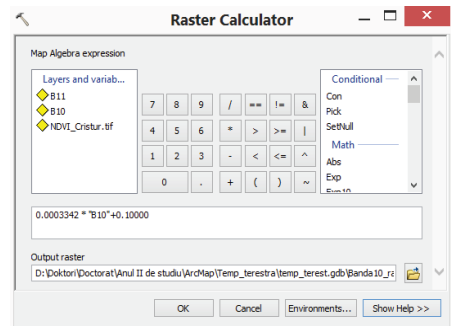


Figure 6. Raster Calculator function window

After executing this calculation we obtained the image with thermal band no. 10 in radiance, similarly to the second thermal band by replacing the phrase "B10" with "B11" in the calculation formula, thus "0.0003342*"B11"+0.1". After these steps we can move on to the next step, which is to convert the radiance to the temperature recorded at the sensor level on the Landsat satellite platform.

2) Conversion to At-Satellite Brightness Temperature, is also done according to the guidelines presented on the website (landsat.usgs.gov/using-usgs-landsat-8-product), using the formula below.

$$T = \frac{K_2}{\ln\left(\frac{K_1}{L_\gamma} + 1\right)} \quad (2)$$

where:

T - the temperature measured by the satellite (K);

Lλ - TOA (Top Of Atmosphere) spectral radiance (Watts / (m² x srad x μm));

K1 - the first transformation constant specific to each thermal strip (extracted from the metadata file);

K2 - the second transformation constant specific to each thermal strip (extracted from the metadata file).

Similar to the previous step, using the same Raster calculator function, we write the equation "1321.0789/{Ln[774.8853/"Banda10_radianta"]+1}" (where "Banda10_radianta" is the image obtained in the previous step). This formula applies exactly like the first stage of both thermal bands in part, first for the band 10, and then for the 11th band.

As mentioned above, the result obtained is expressed in Kelvin, and if we want to convert it to another unit of measurement, the Raster Calculator and transformation factor (eg: 0 K = -273.15°C, the value obtained in Kelvin degrees decreases to 273.15).

At this step, we obtained two images in (°C), and using Cell Statistics (Figure 7) we calculate the average of the two images, so we get a single image from a set of two images.

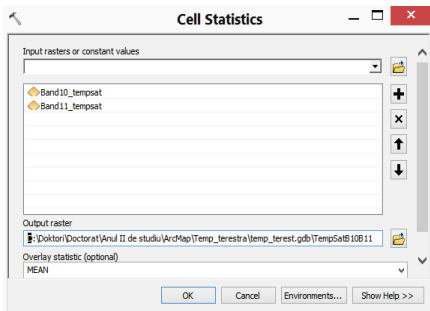


Figure 7. Cell Statistics window

3) Estimation of the ground surface temperature, is the last untreated step, where we will calculate the surface temperature using the following relationship:

$$TS = \frac{BT}{1 + (\lambda \times \frac{BT}{p}) \times \ln(\epsilon)} \quad (3)$$

where:

TS – terrestrial temperature;

BT – measured satellite temperature (obtained from the previous step);

λ – radiant wavelength emitted (11.5 μm);

p=h×c/k; p = 14380

h – Planck's constant (6.626×10⁻²³ Js);

k – Boltzmann constant (1.38×10⁻²³ J/K);

c – the speed of light (2.998×10⁸ m/s);

ε – emissivity of the land surface,

ε = (0.004×Pv+0.986)

Pv – the proportion of vegetation,

$Pv = \left(\frac{NDVI - NDVI_{min}}{NDVI_{max} - NDVI_{min}}\right)^2$.

In the ArcMap program language, the formula for calculating the terrestrial surface temperature thus appears in the Raster Calculator window "TempSatB10B11"/(1+(11.5*TempSatB10B11/14380)*Ln("0.004*(Square(("NDVI_Cristur.tif"-(-0.0745247))/(0.637116-(-0.0745247))))+0.986"))".

After running this calculation, we obtained the result below (Figure 8).

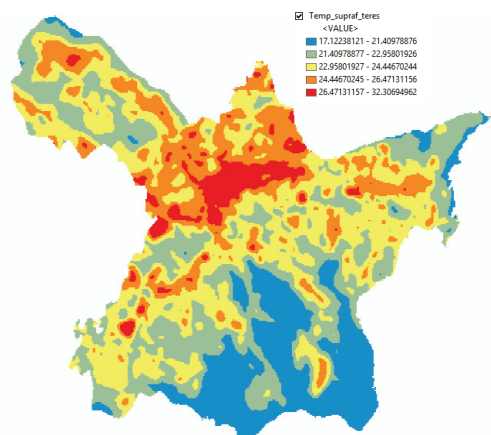


Figure 8. Land surface temperature estimation using Landsat image satellite

RESULTS AND DISCUSSIONS

As can be seen in the obtained picture of the terrestrial surface temperature of Cristuru Secuiesc, hot-stained areas are fairly high temperatures, while the cold-colored areas have a medium temperature.

Since the image was obtained on July 11, 2016, temperatures are roughly normal for that region. The red spot in the center of the image is an urban area, more specifically the city of Cristuru Secuiesc, while the orange color surrounding the red patch represents residential areas in the suburban area.

By looking at the image of the temperature (Figure 8) and the image with the fake colored infrared image (Figure 3), it can be noticed that the vegetation areas have a lower temperature than the inhabited urban areas that abound in the construction.

Analyzing the image, it can be seen that the forested area in the southern part of Cristuru Secuiesc has the lowest temperature value.

It is also worth mentioning that the two lakes located in the North-West part of the locality have temperatures close to that of the inhabited areas, being in the same class.

CONCLUSIONS

This case study presents the key to research on global warming, providing both theoretical and practical aspects, with the main purpose of education. The article has been shown how to obtain a Normalized Difference Vegetation Index (NDVI), with several image processing operations obtained by remote sensing.

Using this methodology, it is possible to estimate the temperature of the terrestrial surface anywhere on the earth globe in a very comfortable and light manner.

This method is very fast, and does not require any cost to acquire primary data. Any user can estimate the terrestrial surface temperature with a computer with normal parameters and a spatial data processing program in vector and raster format. The disadvantage of this method is the cost of the acquisition of the processing programs, but there are Open Source alternatives, with which most analyzes can be carried out, but the computing power of these programs is not at the level of the ArcMap decrypted military software, nor neither acquisition costs nor the multitude of integrated tools.

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