BULETINUL INSTITUTULUI POLITEHNIC DIN IAŞI
Publicat de
Universitatea Tehnică „Gheorghe Asachi” din Iaşi
Volumul 63 (67), Numărul 3-4, 2017
Secţia
HIDROTEHNICĂ

INVESTIGATING LAND SURFACE TEMPERATURE CHANGES USING LANDSAT DATA: A CASE STUDY OF IAŞI COUNTY

BY

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Received: April 24, 2017
Accepted for publication: May 8, 2017

Abstract. The main purpose of this paper is to investigate the change of land surface temperature between 1993 and 2016, for Iaşi county, using remotely sensed data. LST is an estimate of ground temperature and the important to identify change in environment. The advantages of using remotely sensed data are the availability, consistent and repetitive coverage and capability of measurements of earth surface environment. Among them Landsat is the most popular one. The images taken, at 1993/2003/2013/2016, by Landsat-5 TM and Landsat 8- OLI satellites were used as the basic data source. The obtained results showed, that temperature increased about 7ºC between 1993 and 2016, for Iaşi county.

Keywords: Land surface temperature; Landsat; emissivity.

1. Introduction

Thermal properties of surface, Earth’s surface energy balance and atmospheric conditions effect the land surface dramatically. Local and global

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change continues in the Earth's climate since the industrial era continues. Some of the changes occurs due to natural phenomena and anthropogenic activities such as; greenhouse gas, land cover and land use change, uncontrolled use of groundwater, deforestation, rising water demands, urbanization, and irrigation activities (Penny & Kealhofer, 2005).

Remote sensing is useful for understanding the spatiotemporal land cover change in relation to the basic physical properties in terms of the surface radiance and emissivity data (Orhan, 2016). Since the seventies of the twentieth century, satellite-derived (like Landsat-5/8) surface temperature data have been utilized for regional and local climate analyses on different scale (Carlson *et al*., 1977). Landsat having medium-resolution satellite in the only source of land surface temperature in wordwide since 1972. Therefore the Landsat-5/8 satellite images were used in paper. Many researchers showed that the surface temperature of the work confirmed from Landsat-5 and Landsat-8 (Mallick, 2012).

Nowadays LST (land surface temperature) is used to determine the temperature distribution at the change global, regional and local scale. Also it's used in climate and acclimate change models in particular. LST, calculated from remote sensing data is used in a lot of sphere of science, like: agriculture, climate change, hydrology, forestry, urban planning, oceanography etc. Obtaining surface temperatures and using them in different analysis is important to determine the problem associated with the environment (Orhan *et al*., 2014).

2. Data and Methods

2.1. Study Area

Study Area is geographically situated on latitude 46°48'N to 47°35'N and longitude 26°29'E to 28°07'E. Neighboring county are Botosani to the north, Neamt to the west, Vaslui to the south and Republic of Moldova to the east. Figure 1 represents the study area. Iaşi county is situated in easten of Romania and it has an area of 5.476 km^2.

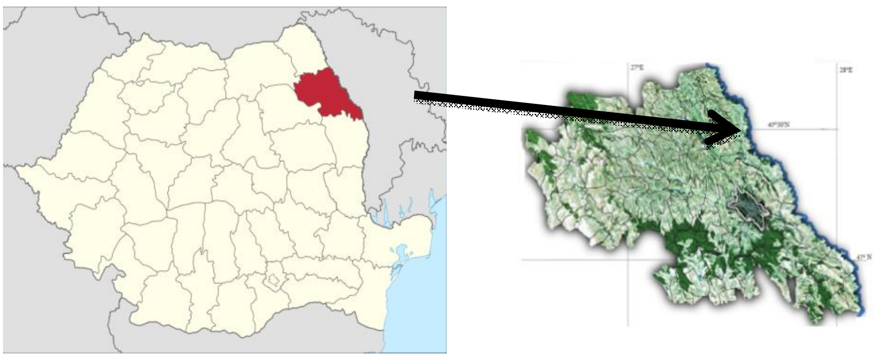

Fig. 1 – Study Area (www.wikipedia.com).

2.2. Data and Methods

In this paper is investigated multi-temporal land surface temperature (LST) change of Iaşi county using remotely sensed data. The present is focused on the thermal remote sensing application of Landsat satellite data. Landsat 5 TM and Landsat-8 OLI, all data were used in this study for modeling. Details of the used data are given in Table 1. A cloud-free Landsat-5/8 images, acquired about August, 1993, 2003, 2013 and 2016, were used for generating LST maps.

Table 1
Landsat Data

No.	Indicative		Date	Satellite
	Path	Row		
1	182	27	06.08.1993	Landsat-5
2	182	27	02.08.2003	Landsat-5
3	182	27	18.08.2013	Landsat-8
4	182	27	05.08.2016	Landsat-8

Landsat 5 TM data has seven bands including a thermal band which is used to estimate LST (land surface temperature) and other 6 visible and IR (infra-red) bands are used for emissivity and indices extraction. Landsat 8 measures different ranges of frequencies along the electromagnetic spectrum – a color, although not necessarily a color visible to the human eye. Each range is called a band, and Landsat 8 has 11 bands. Bands 10 and 11 are in the thermal infrared, or TIR – they see heat. Instead of measuring the temperature of the air, like weather stations do, they report on the ground itself, which is often much hotter (NASA Landsat Science).

2.3. Data Processing

To estimate the LST from the Landsat-5 thermal infrared band data, DN of sensors were converted to spectral radiance using equation (Chander & Groeneveld, 2009):

$$L_1 = \frac{L_{\max_\lambda} - L_{\min_\lambda}}{Q_{\text{cal}_{\max}} - Q_{\text{cal}_{\min}}} \times \left(Q_{\text{cal}} - Q_{\text{cal}_{\min}}\right) + L_{\min_\lambda}, \qquad (1)$$

where: L_λ is the cell value as radiance, (W/(m^{2}sr μm)); Q_{cal} – the quantized calibrated digital number; $Q_{\text{cal}_{\min}}$ – the minimum quantized calibrated pixel value; $Q_{\text{cal}_{\max}}$ – the maximum quantized calibrated pixel value; $L_{\min_\lambda}$ – the spectral radiance scales to $Q_{\text{cal}_{\min}}$; $L_{\max_\lambda}$ – the spectral radiance scales to $Q_{\text{cal}_{\max}}$.

To estimate the LST from the Landsat-8 thermal infrared band data, DN of sensors were converted to spectral radiance using equation (Barsi et al. 2014):

$$L_\lambda = M_L \times Q_{cal} + A_L - Q_i, \quad (2)$$

where: M_L is the band-specific multiplicative rescaling factor; Q_{cal} – the Band 10/11 image; A_L – the band-specific additive rescaling factor; O_i – the correction for Band 10/11.

Spectral radiance is converted to brightness temperature by assuming the earth of surface is a black body (Chander *et al.*, 2009; Coll *et al.*, 2010):

$$T_b = \frac{K_2}{\ln\left(\frac{K_1}{L_\lambda}+1\right)} - 273.15, \quad (3)$$

where: T_b is the brightness temperature; L_λ – the cell value as radiance; K_1 and K_2 – Calibration constant of Landsat-5/8 calibration.

Ghulam (2010) also followed the same equation. This research also illustrated radiant temperature as surface temperature. Beside these two, Chander and Markham (2003) also used kinetic temperature as a final output of thermal remote sensing data. It didn't mention any necessity or use of emissivity or any other parameters for temperature correction. This method followed by the mentioned studies just used the radiant temperature rather than estimating land surface temperature through considering any surface parameters (Saiful Azim and Ashraful Islam, 2012).

The brightness temperature was converted to land surface temperature using next equation:

$$T_S = \frac{T_b}{1+\left(\lambda \times \frac{T_b}{\rho}\right)\ln \varepsilon_\lambda} \quad (4)$$

where: λ (11.45 μm for Landsat 5; 10.895 μm for Landsat 8 band 10/12 μm for Landsat 8 band 11) is the emitted radiance wavelength; ρ (0.01438 mK) is generated from the equitation $\rho = h \times c/b$, in which h (6.626×10^{-34} Js) is the Planck's constant, c (2.998 × 108 m/s) is the velocity of light, and b (1.38×10^{-23} J/K) is the Boltzmann constant; ε_λ – the surface emissivity.

The LSE (land surface emissivity (ε)) must be known in order to estimate LST. The determination of the ground emissivity is calculated conditionally (Sobrino *et al.*, 2004):

$$e_\lambda = \varepsilon_v \mathrm{PV} + \varepsilon_s \lambda(1 - \mathrm{PV}) + C_\lambda, \quad (5)$$

where: ε_v and ε_s are the vegetation and soil emissivities; C_λ – mean surface roughness (C = 0 for a flat surface).

In this paper, land surface emissivity (ε) extracted by using NDVI considering three different condition (soil, fully vegetated and mixture of bare soil and vegetation).

A method for calculating Proportion of Vegetation (*P*V) (Wang *et al*., 2015) using the NDVI values for vegetation and soil ($NDVI_{veg}$ = 0.5 and $NDVI_{soil}$ = 0.2) to apply in global conditions using the following equation (Sobrino *et al*., 2004):

$$PV = \left[\frac{NDVI - NDVI_{soil}}{NDVI_{veg} + NDVI_{soil}} \right]^2 .$$

The Normalized Difference Vegetation Index (NDVI) is a numerical indicator that uses the visible and near-infrared bands of the electromagnetic spectrum, and is adopted to analyze remote sensing measurements and assess whether the target being observed contains live green vegetation or not (John Rouse, 1973). The NDVI algorithm subtracts the red reflectance values from the near-infrared and divides it by the sum of near-infrared and red bands:

$$NDVI = \frac{NIR - RED}{NIR + RED}.$$

Calculating LSE for Landsat 5

When NDVI values is less than 0.2 the surface is covered with soil and 0.97 is assigned as emissivity value. For NDVI values is greater than 0.5 the surface is covered with fully vegetated and 0.99 is assigned as emissivity value. Using these data (TM6 soil and vegetation emissivities of 0.97 and 0.99, respectively), the final expression for LSE is given by:

$$eTM_6 = 0.986 + 0.004PV.$$

Calculating LSE for Landsat 8

It is known the average emissivity of four representative terrestrial materials (water, building, soil, vegetation emissivities of 0.991, 0.962, 0.966 and 0.973) in Band 10 and Band 11 of Landsat 8 proposed by the authors in (Wang *et al*., 2015). Considering NDVI threshold, the emissivity value of 0.966 is assigned for soil and 0.973 is assigned for fully vegetated and equations 5 is applied to retrieve the emissivity in this study.

3.**Results and Discussions**

Fig. 2 show LST maps and Table 2 show statistical data of LST.

Table 2
Statistical Data of LST

Years	Minimum	Maximum	Variations	Mean	Standard Deviation
1993	15.6	34.9	19.3	20.4	1.66
2003	10.9	37.2	26.3	21.9	1.72
2013	17.8	39.8	22	26.7	2.63
2016	16.6	40.2	23.6	27.6	2.66

Parameter “mean” is the most important indicator for evaluate changing LST for period 1993-2016. As can be seen in 1993 the value for parameter “mean” was over 20ºC. After 23 years there was an increase in this parameter about 7 degree. In 2003 was 21.9ºC and in 2013 over 26ºC. Between 1993 and 2003 was an increase of 1.5ºC and between 2013–2016 a warming about of 1ºC. The most consistent change was between 2003 and 2013 about 5 degrees.

Another important indicator would be the maximum temperature. The difference between 2016 and 1993 is about 6 degrees.

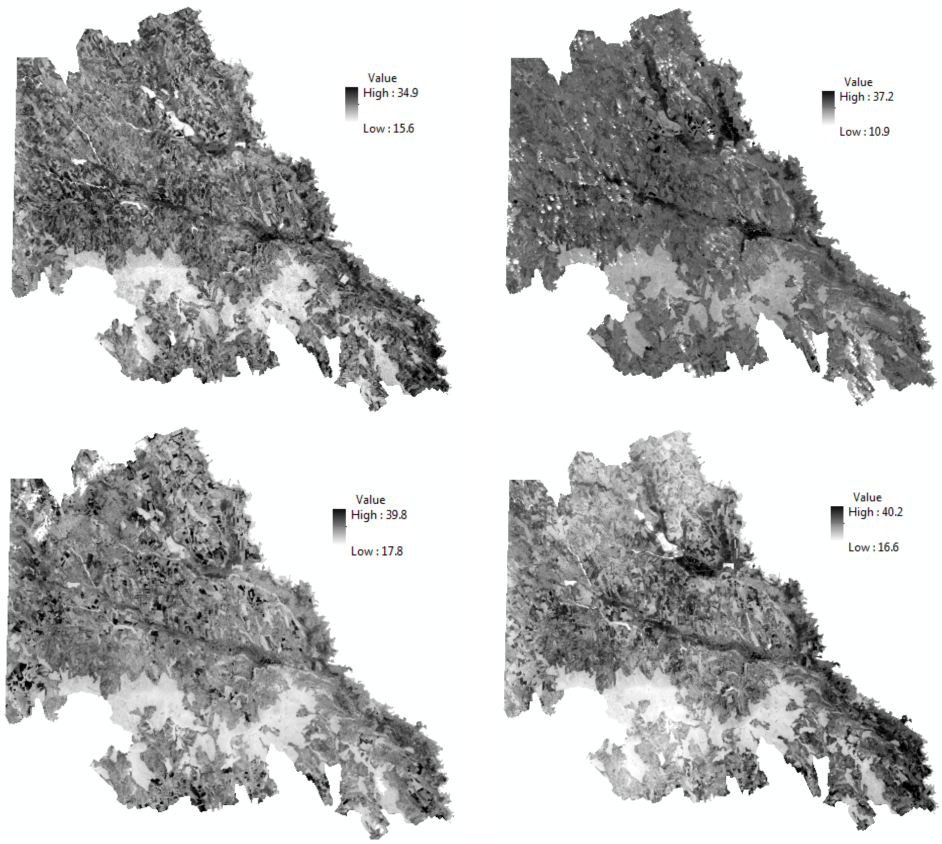

Fig. 2 – LST maps 1993/2003/2012/2016.

An analysis of LST maps reveals that minimum temperatures are found in forest areas, while maximum temperatures are in urban areas.

4.Conclusions

For environmental studies and earth, land surface temperature is now considered an important parameter. Modeling for estimating land surface temperature from Landsat thermal imagery can be a good, time saving and effective options the researchers who with this.

In this study, using Landsat data, is determined land surface temperature for Iaşi county between 1993 and 2016. For this period was an increase about 7 degree. The most consistent change was between 2003 and 2013 about 5 degrees. An analysis of LST maps reveals that minimum temperatures are found in forest areas, while maximum temperatures are in urban areas.

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* * * www.Wikipedia.com

⁎*⁎ NASA Landsat Science (https://landsat.gsfc.nasa.gov).

INVESTIGAREA SCHIMBĂRII TEMPERATURII SUPRAFEȚEI TERENULUI UTILIZÂND DATE LANDSAT: STUDIU DE CAZ PENTRU JUDEȚUL IAŞI

(Rezumat)

Scopul principal al acestei lucrări este de a investiga schimbarea temperaturii solului între anii 1993 şi 2016, pentru județul Iaşi, folosind date din teledetecție. LST este o estimare a temperaturii la sol şi are aplicativitate în identificarea schimbărilor de mediu. Avantajele utilizării datelor din teledetecție sunt disponibilitatea, ciclicitatea datelor, capacitatea efectuării măsurătorilor pentru mediu asupra suprafaței pământului. Dintre imaginile satelitare, Landsat este cel mai popular. Imaginile preluate, în 1993/2003/2013/2016, de către sateliții Landsat-5 TM şi Landsat 8-OLI au fost folosite ca sursă de date. Rezultatele obținute au arătat că temperatura, în județul Iaşi, a crescut cu circa 7°C între 1993 şi 2016.