Investigating Land Surface Temperature and Vegetation Indices Changes Using Landsat Data: A Case Study of Iaşi County

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ABSTRACT: The main purpose of this paper is to investigate the change of land surface temperature between 1994 and 2016, for Iaşi county, using remotely sensed data. Also in this research the changing of vegetation indices (VI) is investigated. LST is an estimate of ground temperature and the important to identify change in environment. Vegetation indices are quantitative measurements indicating the vigor of vegetation. 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 1994/2003/2013/2016, by Landsat-5 TM and Landsat 8- OLI satellites were used as the basic data source. The obtained results showed that temperature, for Iaşi county, increased about 7°C between 1994 and 2016. Also, during the same period, the VI (NDVI, EVI, SAVI and MSAVI) analysis shows a decrease in dense vegetation and an increase in urban areas.

KEY WORDS: Land surface temperature, Landsat, vegetation indices

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1. Introduction

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

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).
A Vegetation Indices (VI) is a spectral transformation of two or more bands designed to enhance the contribution of vegetation properties and allow reliable spatial and temporal inter-comparisons of terrestrial photosynthetic activity and canopy structural variations (Huete et al., 2000). In general, it can be observed that vegetation indices do not have a standard universal value, research having often shown different results. The atmosphere, sensor calibration, sensor viewing conditions, solar illumination geometry, soil moisture, color and brightness seriously affect vegetation indices. Moreover, in a heterogeneous environment, where there is a mixture of vegetation and other ground elements in the pixels, the study of vegetation indices becomes more complex. However, the choice of a vegetation index as opposed to another, for whatever application, is quite delicate to make. Each environment has its own characteristics and each index is an indicator of green vegetation in its own right (Bannari et al., 1995). In the field of remote sensing applications, scientists have developed vegetation indices (VI) for qualitatively and quantitatively evaluating vegetative covers using spectral measurements.

2.Data and methods

2.1. Study Area

Iaşi county is considered as study area in this research. Study Area is geographically situated on latitude 46°48'N to 47°35'N and longitude 26°29'E to 28°07'E. Neighborings Iaşi 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.

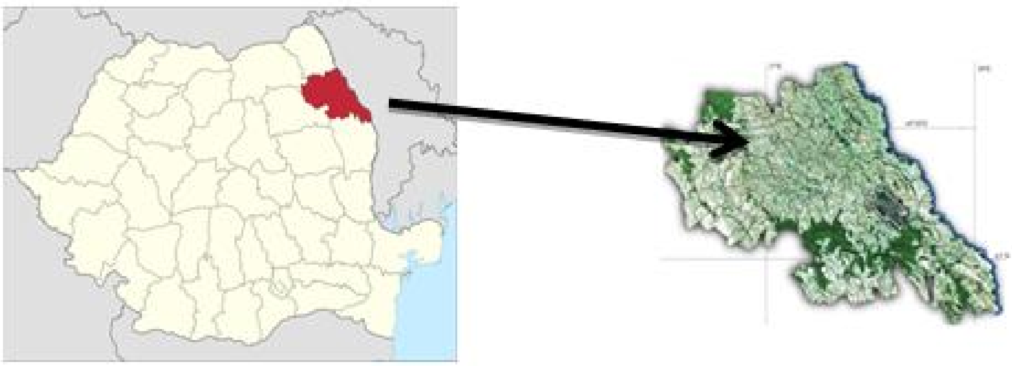

Figure 1.Study Area (www.wikipedia.com)

2.2. Landsat data

In this paper is investigated multi-temporal land surface temperature (LST) and V.I. 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, 1994, 2003, 2013 and 2016, were used for generating LST maps.
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).

Table 1. Landsat data

No.	Indicative		Date	Satellite
	Path	Row		
1	182	27	09.08.1994	Landsat-5
2	182	27	02.08.2003	Landsat-5
3	182	27	18.08.2013	Landsat-8
4	182	27	06.08.2016	Landsat-8

2.2. Landsat data

2.3.1.Method Selection for Estimating LST

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

$$L_\lambda = \frac{L\max_a - L\min_a}{Qcal_{max} - Qcal_{min}} \times (Qcal - Qcal_{min}) + Lmin_\lambda \qquad ...(1)$$

Where:

- Lλ = the cell value as radiance (W/(m2sr μm))
- Qcal = the quantized calibrated digital number
- Qcalmin = the minimum quantized calibrated pixel value
- Qcalmax = the maximum quantized calibrated pixel value
- LMINλ = the spectral radiance scales to Qcalmin
- LMAXλ = the spectral radiance scales to Qcalmax

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).

$$L_\lambda = M_L \times Qcal + A_L - Q_i \qquad ...(2)$$

Where:

- ML = the band-specific multiplicative rescaling factor
- Q cal = the Band 10/11 image
- AL = the band-specific additive rescaling factor
- Oi = 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):

$$T_b = \frac{K_2}{\ln\left(\left(\frac{K_1}{L^a}\right) + 1\right)} - 273.15 \qquad ...(3)$$

Where:

- Tb = the brightness temperature
- Lλ = the cell value as radiance
- K1 and K2 = 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).

2.3.2. Vegetation Indices (VI)

The spectral composition of the radiant flux emanating from the Earth's surface provides information about the physical properties of soil, water, and vegetation features in terrestrial environments. Remote sensing techniques, models, and indices are designed to convert this spectral information into a form that is readily interpretable. However, the fundamental interactions of radiant energy with the Earth's surface must be understood for remote sensing to be efficiently applied (Huete, 1989).

Normalized Difference Vegetation Index (NDVI)

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.

$$NDVI = \frac{(NIR - RED)}{(NIR + RED)}$$

Enhanced Vegetation Index (EVI)

EVI incorporates an "L" value to adjust for canopy background, "C" values as coefficients for atmospheric resistance, and values from the blue band (B). These enhancements allow for index calculation as a ratio between the R and NIR values, while reducing the background noise, atmospheric noise, and saturation in most cases (https://landsat.usgs.gov). The enhanced vegetation index (EVI) is an 'optimized' vegetation index designed to enhance the vegetation signal with improved sensitivity in high biomass regions and improved vegetation monitoring through a de-coupling of the canopy background signal and a reduction in atmosphere influences (Huete et al., 2002).

EVI = G * ((NIR - R) / (NIR + C1 * R – C2 * B + L))

Soil Adjusted Vegetation Index (SAVI)

SAVI is calculated as a ratio between the R and NIR values with a soil brightness correction factor (L) defined as 0.5 to accommodate most land cover types.

SAVI=((NIR - R) / (NIR + R + L)) * (1 + L)

In an attempt to improve NDVI, Huete developed a vegetation index that accounted for the differential red and near-infrared extinction through the vegetation canopy. The index is a transformation technique that minimizes soil brightness influences from spectral vegetation indices involving red and near-infrared (NIR) wavelengths (Huete, 1988).

Modified Soil Adjusted Vegetation Index (MSAVI)

MSAVI is calculated as a ratio between the R and NIR values with an inductive L function applied to maximize reduction of soil effects on the vegetation signal. The modified soil-adjusted vegetation index (MSAVI) is soil adjusted vegetation indices that seek to address some of the limitation of NDVI when applied to areas with a high degree of exposed soil surface. Qi et al. (1994a) developed the MSAVI.

MSAVI=(2 * NIR + 1 – sqrt ((2 * NIR + 1)2 – 8 * (NIR - R))) / 2

3. Results and discussions

3.1. Estimating LST

Figure 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
1994	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 1994-2016. As can be seen in 1994 the value for parameter “mean” was over 20^{o}C. After 22 years there was an increase in this parameter about 7 degree. In 2003 was 21.9^{o}C and in 2013 over 26^{o}C. Between 1994-2003 was an increase of 1.5^{o}C and between 2013-2016 a warming about of 1^{o}C. The most consistent change was between 2004 and 2013 about 5 degrees.

Another important indicator would be the maximum temperature. The difference between 2016 and 1994 is about 6 degrees.

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

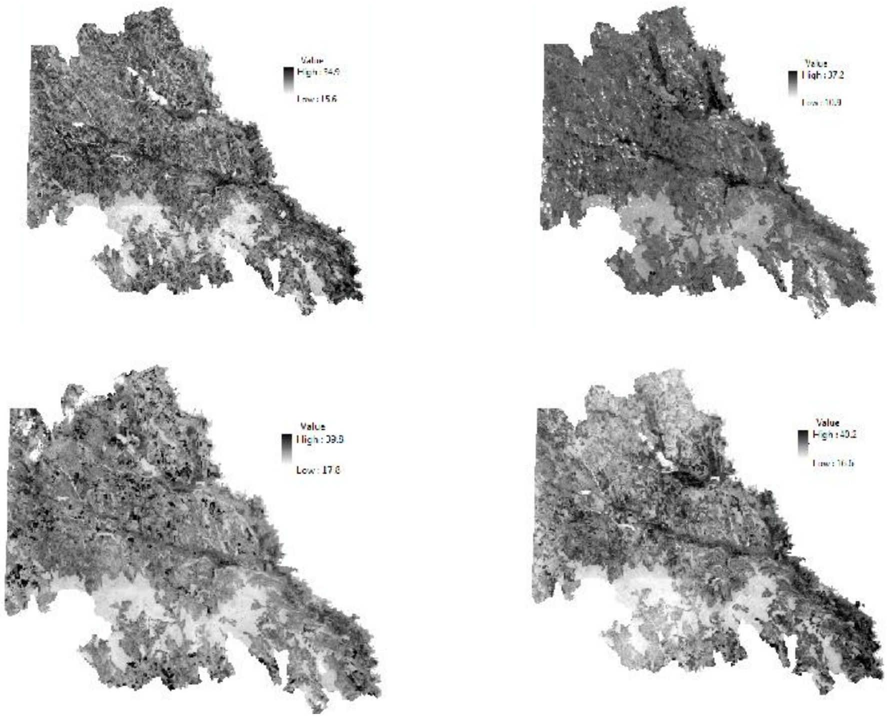

Figure 2. LST maps 1994/2003/2012/2016

3.1. Calculation of Vegetation Indices (VI)

Figure 3 show VI maps and table 3 show statistical data of VI.

Table 3. Statistical data of VI

Years	NDVI			EVI			SAVI			MSAVI		
	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean
1994	-0.48	0.77	0.40	-0.12	0.63	0.24	-0.14	0.73	0.27	-0.10	0.5	0.19
2003	-0.5	0.8	0.52	-0.17	0.87	0.32	-0.18	0.98	0.36	-0.13	0.68	0.24
2013	-0.2	0.63	0.36	-0.15	0.79	0.34	-0.29	0.96	0.53	-0.11	0.71	0.26
2016	-0.23	0.66	0.34	-0.09	0.89	0.36	-0.35	0.97	0.5	-0.09	0.72	0.29

Making an analysis of the parameters enumerated in the table can account for the fact that there is a decrease in dense vegetation. The best observation is that the mean and maximum parameters for NDVI show a significant decrease between 1994 and 2016.

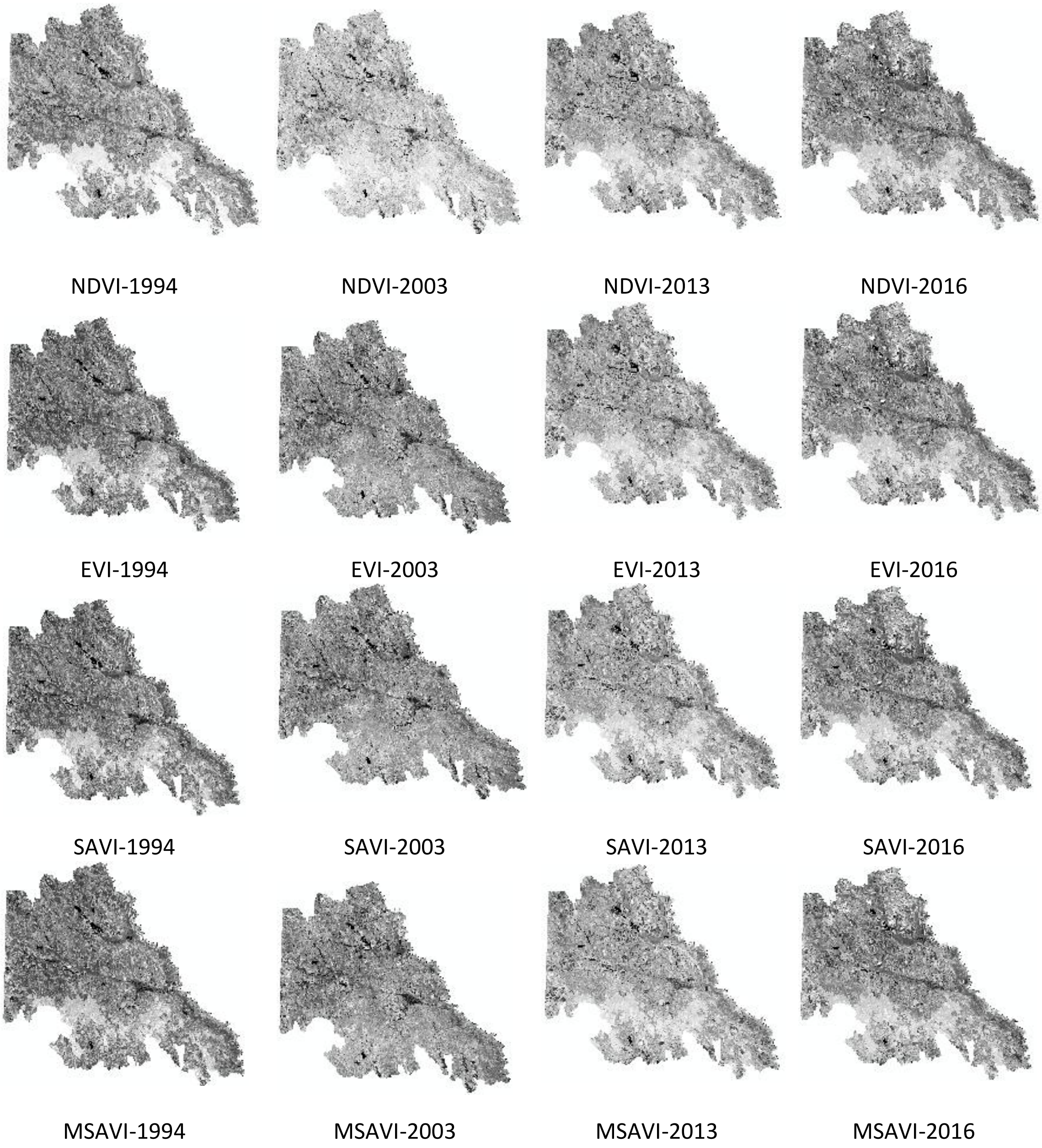

Figure 3. VI maps 1994/2003/2012/2016

4. Conclusions

In this study, using Landsat data, is determined land surface temperature for Iasi county between 1994 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.

With the increase of LST in the period under scrutiny in this paper, one can notice a decrease in the areas occupied by dense vegetation. At the same time, there has been an increase in urban areas.

These parameters may be some of the determinants of climate change, but much more detailed research is needed to draw this conclusion.

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