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INVESTIGATING THE RELATIONSHIP BETWEEN LAND SURFACE TEMPERATURE AND URBAN INDICES USING LANDSAT-8: A CASE STUDY OF IAȘI

Paul Macarof¹, Iulian Cristian Bîrlica¹, Florian Stătescu¹

Abstract. This study investigates the relationship between land surface temperature (LST) and urban indices (such as: Normalized Difference Bareness Index (NDBaI), Normalized Difference Build-up Index (NDBI) and Urban Index (UI)) using Landsat-8 OLI imagery, for Iasi municipality area. Landsat data were used to estimate the LST, NDBI, NDBaI and UI for Iasi municipality area, between 2013-2016. In that period, the mean temperature rose by about 2⁰C, so as to 2016 the mean temperature was of over 30⁰C and the maximum temperature exceeded 40⁰C. Analyzing the relationship between LST and urban indices it can be noticed that, whilst NDBI and UI indices have high a correlation with LST, the correlation between NDBaI and LST is lower. The R² fluctuates significantly from over 0.4 for NDBI and UI to about zero for NDBaI. Therefore, NDBI and UI are accurate indicators of SUHI effects, as against NDBaI and can be used as a complementary metric to the traditionally applied NDVI for analyzing surface urban heat island studies.

Keywords: Land surface temperature, urban index, Landsat-8

1. Introduction

Land surface temperature is an estimate of ground temperature and it is important to identify changes in the environment. Land surface temperature can provide important information on the surface physical properties and climate which plays a role in many environmental processes (Dousset, Gourmelon 2003; Weng, Lu, Schubring, 2004). Many studies have estimated the relative warmth of cities by measuring the air temperature, but this method can be both expensive and time consuming. Remote sensing is a better alternative to the aforesaid methods. The advantages of using remotely sensed data are the availability of high resolution, consistent and repetitive coverage and capability of measurements of earth surface conditions (Owen, Carlson & Gillies 1998). Many studies showed that the surface temperature of the work confirmed from Landsat data (TM/OLI) (Amiri et al., 2009; Mallick et al., 2012; Guo et al., 2012; Li et al. 2016; Avdan et al., 2016). LST (Land Surface Temperature), used to find the change in local, regional or global scale and the temperature distribution, used in climate change models especially. Calculated from remote sensing data, LST is used in a lot of circles of science, like: forestry, climate change, hydrology,

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oceanography, urban planning, agriculture etc. Obtaining surface temperatures, according to Orhan and using them in many analyses is important to define the problem correlated with the environment (O. Orhan et al. 2014).

It's known that between the LST and the normalized difference built-up index (NDBI) there is a strong linear relationship. The main goal of this study is to investigate the relationship between LST and the urban indices for period 2013-2016.

2. Data and methods

2.1. Study Area

The study area is geographically situated on latitude 47°12'N to 47°06'N and longitude 27°32'E to 27°40'E. The largest city in eastern Romania is the seat of Iași County. Iași is located in the historic region of Moldavia and it has traditionally been one of the leading centres of the Romanian social, cultural, academic and artistic life. It is the "legendary city of the seven hills", namely Copou, Cetățuia, Bucium, Repedea, Șorogari, Galata, and Breazu, just like so many cities around world, one like example being Rome. Some of these hills have distinct churches perched on top, each of which warrants a different view of the city. The local climate is continental with large temperature differences between the seasons and with minimal rainfall. Iași is positioned on the Bahlui River, an affluent of Jijia that flows into the Prut River. (www.wikivoyage.org).



Figure 1. Study Area (www.hih.ro, www.apavital.ro)

2.2.Data and methods

The main objective of this study was to compare the relationships of LST and urban indices using Landsat data for the period 2013-2016 using Iasi metropolitan area as a case study.

Landsat 8 measures different ranges of frequencies along the electromagnetic spectrum – a color, despite not necessarily a color visible to the human eye. Each range is called a band, and Landsat 8 has 11 bands. The last bands, the tenth and eleventh are in the thermal infrared (TIR) – they see heat. Instead of measuring the temperature of the air, these report on the ground itself, which is often much hotter (N.A.S.A. Landsat Science).

Landsat data were offered free by USGS. Table 1 shows Landsat data that was used in this research.

Table 1. Landsat data

Nr. Crt.	Path	Row	Date
1	182	27	2013-08-13
2	182	27	2014-07-31
3	182	27	2015-07-18
4	182	27	2016-08-05

2.3. Data processing

The widespread and common urban indices are shown in the Table 2. The most of these indices extract urbanization parameters related to spectral difference of visible, near infrared and short wave infrared bands of Landsat 8 Imagery.

Zhao, in 2003, utilized Landsat 7 band 6 (TIR) and band 5 (SWIR) to generate the NDBaI. This is an index used to map bare land areas. Thermal infrared bands can distinguish high and low levels of albedo in built-up objects (Zhao et al., 2003). According to Weng, in 2008, the utilization of TIR bands is very efficient for mapping built-up areas based on a low albedo, who eliminates the effect of water and shadows, while a high albedo demonstrates bare land and built-up areas clearly.

Zha et al., in 2003, proposed a NDBI (Normalized Difference Built-up Index) to map the urban built-up area. In conjunction with a traditional NDVI (Normalized Difference Vegetation Index), this index was reported to be an effective technique to map urban built-up area. NDBI had a total accuracy 92% in their study area.

Remote sensing can be used to acquire a description of the building density with a spectral transformation called urban index transformation (Kawamura et. al., 1996). Was demonstrated that high pixel value indicates built-up area intensively.

Table 2. Urban Indices

No.	Name of urban index	Formulation
1	Normalized Difference Bareness Index (NDBaI)	$NDBaI = \frac{SWIR_1 - TIRS_1}{SWIR_1 + TIRS_1}$
2	Normalized Difference Build-Up (NDBI)	$NDBI = \frac{SWIR_1 - NIR}{SWIR_1 + NIR}$
3	Urban Index (UI)	$UI = \frac{SWIR_2 - NIR}{SWIR_2 + NIR}$

3. RESLUTS AND DISCUSSION

3.1. LST and urban indices spatial patterns

Figure 2 shows LST maps for the period 2013-2016 and table 3 shows the statistical data of LST. Analyzing parameters: variation and mean show a raise of temperature for the

period 2013-2016, of about of 2°C. Parameters mean shows, just for 2015, a little decrease as against 2014, but temperature increases in 2016.

Table 3. Statistical data of LST

Years	Minimum	Maximum	Variations	Mean	Standard Deviation
2013	22.95	38.20	15.25	28.73	2.017
2014	23.80	39.98	16.18	29.53	2.142
2015	23.30	39.10	15.80	29.34	1.908
2016	24.51	40.78	16.27	30.13	1.961

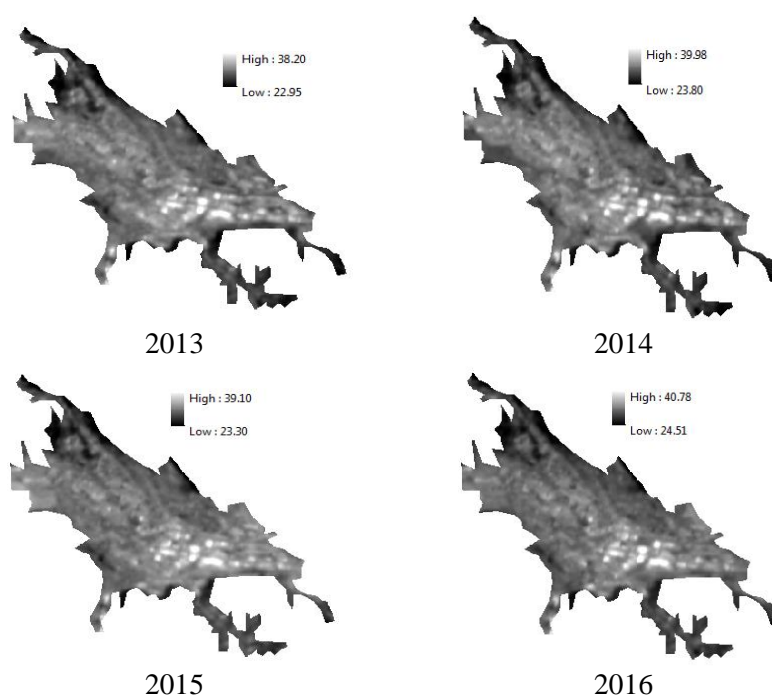


Figure 2. LST maps for period 2013-2016

3.2. LST relationships to urban indices

By analyzing the primary parameter mean, we see that the changes of the urban indices for the period 2013-2016 are minor. Parameter variations in 2015 and 2016 are determined by the emergence of new areas of construction. The value of parameter mean for UI is of about 1 in 2015 and 2016. The increasing value of the parameter mean demonstrates that the municipality of Iasi is a rapidly growing area and the emergence of new sites increases LST values. This is favored by the fact that there are few green spaces in the city of Iasi.

Figure 3 shows the urban indices maps and table 4 shows the statistical data of the indices for the period 2013-2016.

Table 4. Statistical data of urban indices

Years	2013			2014			2015			2016		
	ND BaI	NDB I	UI	ND BaI	ND BI	UI	NDBa I	ND BI	UI	NDB aI	ND BI	UI
Min.	- 0.6 5	-0.38	- 0.55	- 0.63	- 0.36	- 0.53	-0.63	- 0.37	- 0.55	-0.63	- 0.38	- 0.56
Max.	0.2	0.34	0.33	0.33	0.41	0.32	0.26	0.45	0.45	0.34	0.42	0.44
Var.	0.8 5	0.72	0.88	0.96	0.77	0.85	0.89	0.82	1	0.97	0.8	1
Mean	-0.4	-0.09	-0.2	-0.4	- 0.09	-0.2	-0.38	- 0.09	-0.2	-0.39	- 0.08	- 0.18
St. Dev.	0.0 5	0.08	0.11	0.05	0.08	0.11	0.05	0.08	0.11	0.06	0.08	0.11

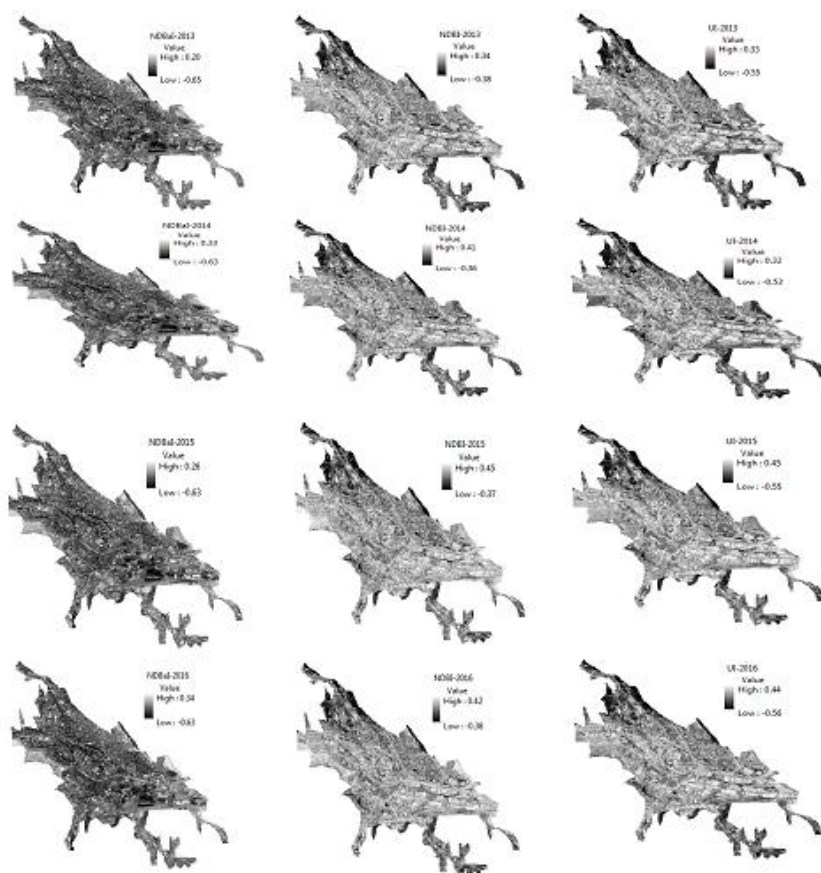


Figure 3. Urban indices maps for period 2013-2016

Figure 4 shows the relationship of LST and urban indices for period 2013-2016.

By analyzing the relationship between LST and the urban indices we notice that, whilst NDBI and UI indices have high correlation with LST, there is a lower correlation with NDBaI. The R^2 fluctuates significantly from over 0.4 for NDBI and UI to about zero for NDBaI.

We see that with the increasing “mean” parameter value of the index NDBaI, there appears a slight decrease in the value of R^2 coefficient of linear function. The strongest correlation between LST and UI is in 2013 when R^2 is about of 0.53, while the highest value of R^2 for relationship LST-NDBI is 0.49 in 2015



Figure 4. Relationship of LST and urban indices for period 2013-2016

Conclusions

This paper investigated the relationships between LST and urban indices such as: NDBaI, NDBI and UI, for period 2013-2016 for Iași municipality area. In the same period a rise of the mean temperature of about of 2°C was recorded.

The results indicate there is a strong linear relationship between LST and urban indices (UI and NDBI), whilst the correlation between LST and NDBaI is lower. The R^2 fluctuates significantly from over 0.4 for NDBI and UI to about zero for NDBaI. Therefore, NDBI and UI are accurate indicators of SUHI effects, as against NDBaI and can be used as a complementary metric to the traditionally applied NDVI for analyzing surface urban heat island studies.

While we found the variations in surface temperature can be better explained by NDBI and UI than by NDBaI, we also realize that the conclusion is based on only one area, so further are recommended other studies for other metropolitan areas.

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