

Spatiotemporal Built-up Land Density Mapping Using Various Spectral Indices in Landsat-7 ETM+ and Landsat-8 OLI/TIRS (Case Study: Surakarta City)

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Abstract. Spectral indices variations support for rapid and accurate extracting information such as built-up density. However, the exact determination of spectral waves for built-up density extraction is lacking. This study explains and compares the capabilities of 5 variations of spectral indices in spatiotemporal built-up density mapping using Landsat-7 ETM+ and Landsat-8 OLI/TIRS in Surakarta City on 2002 and 2015. The spectral indices variations used are 3 mid-infrared (MIR) based indices such as the Normalized Difference Built-up Index (NDBI), Urban Index (UI) and Built-up and 2 visible based indices such as VrNIR-BI (visible red) and VgNIR-BI (visible green). Linear regression statistics between ground value samples from Google Earth image in 2002 and 2015 and spectral indices for determining built-up land density. Ground value used amounted to 27 samples for model and 7 samples for accuracy test. The classification of built-up density mapping is divided into 9 classes: unclassified, 0-12.5%, 12.5-25%, 25-37.5%, 37.5-50%, 50-62.5%, 62.5-75%, 75-87.5% and 87.5-100 %. Accuracy of built-up land density mapping in 2002 and 2015 using VrNIR-BI (81.823% and 73.235%), VgNIR-BI (78.934% and 69.028%), NDBI (34.870% and 74.365%), UI (43.273% and 64.398%) and Built-up (59.755% and 72.664%). Based all spectral indices, Surakarta City on 2000-2015 has increased of built-up land density. VgNIR-BI has better capabilities for built-up land density mapping on Landsat-7 ETM + and Landsat-8 OLI/TIRS.

Keywords: mapping, Landsat, built-up, Surakarta

1. Introduction

The current trend in present time is the acceleration of urbanization and the expansion of urban areas that make the earth's surface turn into an impermeable layer, which is built-up land [22]. Built-up land is an area that is filled and surrounded by building[19]. The growth of built-up land in urban areas has resulted in increased built-up land density [17]. Increased built-up land density, so it is necessary for the supervision of urban development [23]. Supervision on urban development, especially built-up land density can be done through remote sensing [2]. Remote sensing has advantages such as faster, accurate, and has direct access to the earth's surface [26]. Remote sensing can also be used spatiotemporal to observe changes in built-up land density in urban areas [7]. The study of urban areas in remote sensing can be used as a means of decision-making such as urban development planning, disaster management, and urban environmental management [9][21].



Remote sensing is generally used to overcome and utilize the land. There is a way that can be used in remote sensing to produce more accurate and detailed data, ie by using various indices [9]. The built-up land indices are an indices used to extract information on rapidly constructed land through remote sensing imagery [27]. The built-up land indice generates data from the land area built on clearly observed sites. One application of land use indice is to map land constructed by [25]. Other objects that exist in urban phenomenon such as asphalt, vegetation, air, open land can be compared with other objects on curve of spectral reflection [6].

Built-up indice such as Urban Index (UI) [15], Normalized Different Built-up Index (NDBI) [28], VgNIR-BI, VrNIR-BI, and Index Based Built-up Index (IBI) [27]. The difference in each of the built-up land indice located in the band and the formula used. All land indices are built using infrared waves. However, there are several bands that are used on an indice too, but are not used on other built-up land indices. The built-up land indice, such as VgNIR-BI uses green waves, and VrNIR-BI uses red waves. This is different from the UI built-up land indice that using SWIR-2 and NDBI using SWIR-1, while the IBI uses the five waves.

A mid developments on the current assortment of built-up land indices, there is little research that examines the accuracy ratios of each of the built-up land indice. Research on comparison between indices has been done before by [12], on the indice of NDBI, NDISI, and NDII. The purpose of this research is to analyze and to compare the accuracy of built-up indices such as UI, NDBI, VgNIR-BI, VrNIR-BI, and Built-up with spatiotemporal data. Landsat-7 ETM+ representing the state of 2002 and Landsat-8 OLI/TIRS representing the state of 2015.

2. Material and Method

2.1 Study site and data specifications

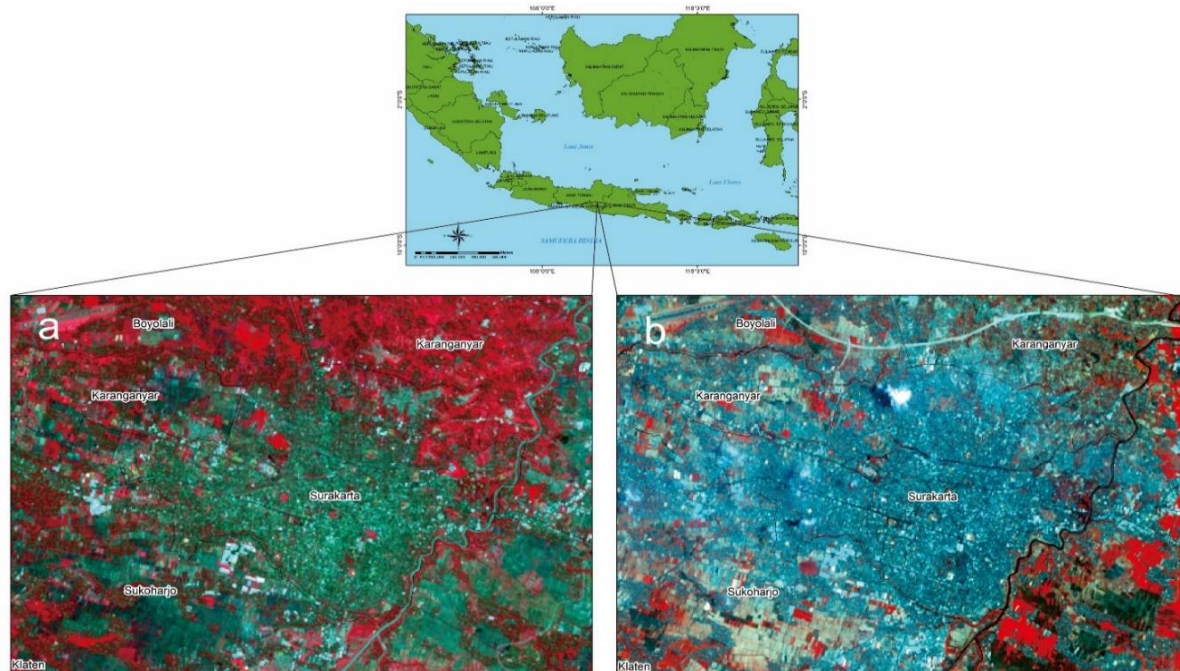


Figure 1. (a)Landsat-7 ETM+ 432 and (b)Landsat-8 OLI/TIRS 543 image of the study area: Surakarta City and its surrounding areas. Built-up land appear in dark blue or green-blue, while vegetation appears in red. Dry paddyfield appear white-red, while bodies of water appear in black. Bare land appear light blue. The black line mark the regency boundaries.

For this research, we use Surakarta City and surrounding area, Central Java Province, Indonesia. According to [13], the population density in Surakarta is 11,675 people/km², which is the highest density

in Central Java (the density of Central Java is only 1,038 people/km²), so that the development of the built-up land is quickly developed. Surakarta City with an area of 44 km², is bordered by Karanganyar and Boyolali regencies in the north, Karanganyar and Sukoharjo regencies in the east and west, and Sukoharjo regency in the south. According to population, Surakarta City is also the third largest city in the southern part of Java after Bandung and Malang [14]. The east side of the city is passed by the Bengawan Solo river.

In this research, the image used is Landsat-7 ETM+ and Landsat-8 OLI L1T (Standard Terrain Correction) image. This image can be found on path 119 and row 65 of the World Reference System (WRS). The Landsat-7 ETM+ image was acquired on May 13, 2002 and contains 8 bands, while Landsat-8 OLI is acquired on October 13, 2015 and contains 11 bands. The bands of Landsat-7 ETM+ image are stored as 8-bit digital numbers, while Landsat-8 OLI images are stored as 16-bit digital numbers [20].

Table 1. Feature of Landsat-7 ETM+ and Landsat-8 OLI/TIRS

Electromagnetic Region	Landsat-7 ETM+		Landsat-8 OLI/TIRS		Spatial Resolution
	Band	Wavelength (μm)	Band	Wavelength (μm)	
Coastal Aerosol	NA	NA	1	0.43 – 0.451	30
Blue	1	0.441 – 0.514	2	0.452 – 0.512	30
Green	2	0.519 – 0.601	3	0.533 – 0.590	30
Red	3	0.631 – 0.692	4	0.636 – 0.673	30
Near Infrared	4	0.772 – 0.898	5	0.851 – 0.879	30
Short Wave Infrared (SWIR1)	5	1.547 – 1.749	6	1.566 – 1.651	30
Short Wave Infrared (SWIR2)	7	2.064 – 2.345	7	2.107 – 2.294	30
Panchromatic	8	0.515 – 0.896	8	0.503 – 0.676	15
Cirrus	NA	NA	9	1.363 – 1.384	30
Thermal Infrared (TIR) 1	6	10.31 – 12.36	10	10.60 – 11.19	TIRS (100); ETM+ (60)
Thermal Infrared (TIR) 2	NA	NA	11	11.50 – 12.51	

Source: Landsat-7 Data User Handbook, 2003; Landsat-8 Data User Handbook, 2016

2.2 Landsat-7 ETM+ and Landsat-8 OLI/TIRS data pre-processing

Satellite imagery data should be preprocessing first before used to find the indices value. The aim of preprocessing data to make pixel value in ideal condition so that it can be used for both visual and mathematical analysis [4]. Before performing image processing into spectral indices, Landsat-7 ETM+ and Landsat-8 OLI/TIRS images should be performed radiometric calibration and atmospheric correction. The raw image value calibrated pixel value or digital number (DN) of the multispectral sensor must be converted into Top of Atmosphere (TOA) reflectance.

The TOA spectral radiance of multispectral bands of Landsat-7 ETM+ and Landsat-8 OLI imageries calculated using the formula. In this study, we used the radiometric calibration module available in the Environment for Visualizing Images (ENVI Ver. 5.2, Exelis Visual Information Solutions, Boulder, CO, USA) software to derive the TOA spectral radiance. The pixel value is processed into a TOA spectral radiance, that is:

$$L\lambda (Landsat - 7) = \left(\frac{(LMAX\lambda - LMIN\lambda)}{(QCALMAX - QCALMIN)} \right) * (QCAL - QCALMIN) + LMIN\lambda \quad (1)$$

Where $L\lambda$ is the spectral radiance at the sensor's aperture in watts/(meter²*srad*μm); the Greyscale and Brescale are respectively, the rescaled gain and rescaled bias contained in the level 1 product header or ancillary data record both expressed in watts/(meter²*srad*μm); the QCAL is the quantized calibrated pixel value in DN; the LMIN is the spectral radiance that is scale to QCALMAX; the QCALMIN is the

minimum quantized calibrated pixel value in DN. The LMIN, LMAX, QCALMAX and QCALMIN values can also be found in the metadata file.

$$L\lambda (Landsat - 8) = (ML * Qcal) + AL \quad (2)$$

Where $L\lambda$ is the TOA spectral radiance (Watts/(m²*srad*μm)), ML is the band-specific multiplication factor rescaling from metadata, AL is the band-specific additive rescaling factor from metadata, and $Qcal$ is the value of standard pixel products quantized and calibrated (DN) [24]. From TOA spectral radiance, then converted to TOA reflected value.

$$\rho\lambda (Landsat - 8) = \frac{\rho\lambda'}{\cos(\theta_{sz})} = \frac{\rho\lambda'}{\sin(\theta_{se})} \quad (3)$$

Where $\rho\lambda$ = TOA reflectance, θ_{sz} = angle of sun elevation, and θ_{se} = angle of sun zenith. TOA reflectance value converted to surface reflectance value.

The image processed into these spectral indices required atmospheric correction to the level of at-sensor reflectance. Atmospheric correction of Landsat-8 OLI/TIRS and Landsat-7 ETM+ image using histogram adjustment. The histogram evaluated is a histogram of reflected values on the sensor in the form of fractional numbers [6]. The method used in histogram adjustment is dark subtraction [28].

Radiometric corrected satellite imagery is done geometric correction process to improve geometric position accuracy and reduce distortion of earth curvature effect [6]. The first thing to do is to determine the GCP (Ground Control Points) and then done the process of geometric correction. This control point is an object visible to the image as well as visible on the reference map used in geometric correction [11]. This control point can be an object visible to the image as well as seen on the reference map used in geometric correction, such as crossing between rivers and road or crossroads and some other objects clearly visible in the image and reference map [18]. The reference map in this study is a map of the Geospatial Information Agency with a projection of the WGS 1984 Transverse Mercator 49M with a UTM grid. The points taken as much as five points for each image with RMS less than 0.5.

2.3 Spectral indices

According to [15] UI can provide actual information related to urban conditions from satellite imagery. The spectral UI indice uses near infrared and middle infrared channels such as SWIR2. The UI spectral indice is used to describe the inverse relationship between the brightness levels of urban areas in near infrared and middle infrared [15]. NDBI has an advantage over a UI that has a unique spectral response from built-up land and other types of land cover [28]. UI and NDBI are the spectral indices developed and used to explore in observation the difference between the spectral response of built-up land in near infrared and middle infrared. The difference between NDBI and UI is NDBI using SWIR1, while UI uses SWIR2. Spectral indice based on visible band to see the condition of built-up land are VrNIR-BI and VgNIR-BI. The visible band spectral indice looks to use a combination of red and green channels with near infrared. The atmospherically corrected reflectance values and brightness temperatures are derived from the built-up indices.

$$VrNIR - BI = \frac{Red - NIR}{Red + NIR} \quad (4)$$

$$VgNIR - BI = \frac{Green - NIR}{Green + NIR} \quad (5)$$

$$NDBI = \frac{SWIR1 - NIR}{SWIR2 + NIR} \quad (6)$$

$$UI = \frac{SWIR2-NIR}{SWIR2+NIR} \quad (7)$$

$$Built-up = \left(\frac{SWIR1-NIR}{SWIR2+NIR} \right) - \left(\frac{NIR-Red}{NIR+Red} \right) \quad (8)$$

Where *Green*, *Red*, *NIR*, *SWIR1*, and *SWIR2* refer to the atmospherically corrected surface reflectance values of band 2, band 3, band 4, band 5 and band 7 in Landsat-7 ETM+ image, while band 3, band 4, band 5, band 6 and band 7 in Landsat-8 OLI/TIRS image, respectively.

2.4 Extract ground value and linear regression



Figure 2. Extracting built-up land density size 45 m x 45 m using Google Earth imagery 2002 and 2015 in Surakarta City

The value of the spectral indices (VrNIR-BI, VgNIR-BI, NDBI, UI and Built-up) can not be represented as a built-up land density value, but only limited to the existence of built-up land in the image so it needs a technique to obtain built-up land density information [1]. The linear regression statistic method can predict a value using dependent and linearly independent variables [3][16]. Predicted value of built-up land density through this spectral indice value using a ground value sample in the form of built-up land density value in the field. Ground values extraction using high resolution Google Earth images of 2002 and 2015. The size of ground value extraction measures 45 m x 45 m adjusted to the spatial resolution of Landsat-8 OLI/TIRS and Landsat-7 ETM+ images. Linear regression for built-up land density using 27 ground value samples.

2.5 Accuracy assessment

To measure the accuracy and capability of the five spectral indices (VrNIR-BI, VgNIR-BI, NDBI, UI and Built-up) for mapping the developed built-up land density using the standard error of estimate. Standard error of estimate is a measure of the number of regression model errors in predicting the value of Y [10]. Standard error of estimate has a mapping accuracy (percent) using some calculation of bottom, upper, minimum error (%) and maximum error (%) based on confidence level of 95%. Detailed calculation of accuracy test methods can be found in literature [5][16].

Accuracy test of ground built-up land density mapping uses 7 ground value samples extracted from the high resolution Google Earth imagery reference of 2002 and 2015. After all ground values are verified, two ground truth images (Landsat-7 ETM+ and Landsat-8 OLI/TIRS) are generated. Finally, density of the built-up land map was built in 2002 and 2015 using various spectral indices performed comparisons.

3. Result and Discussion

3.1 Spectral Indices

Appearance of built-up land on each Landsat-7 ETM+ and Landsat-8 OLI/TIRS indices is shown in figure 3. The bright color on the image shows the existence of the built-up land. Surakarta city has the appearance of higher built-up land compared with the surrounding area. This is seen from the bright color that dominates the Surakarta city compared with the surrounding area.

Visually, Landsat-7 ETM+ has a higher sensitivity to the existence of built-up land compared to Landsat-8 OLI/TIRS. In Landsat-7 ETM+ it is clear that the difference between the built-up land that looks lighter and not built-up land that looks darker. Meanwhile, Landsat-8 OLI/TIRS has no sensitivity to the built-up land such as Landsat-7 ETM+. The existence of built-up land and not built-up land on Landsat-8 OLI/TIRS looks more vague.

The five indices that are processed in Landsat-7 ETM+ and Landsat-8 OLI/TIRS are VgNIR-BI, VrNIR-BI, NDBI, UI, and Built-up have different visual appearance. The NDBI, UI, and Built-up in Landsat-7 ETM+ and VrNIR-BI and UI in Landsat-8 OLI/TIRS show a clear distinction between built-up land and not built-up land. Not all built-up land indices are capable of representing built-up land and not built-up land in various types of imagery.

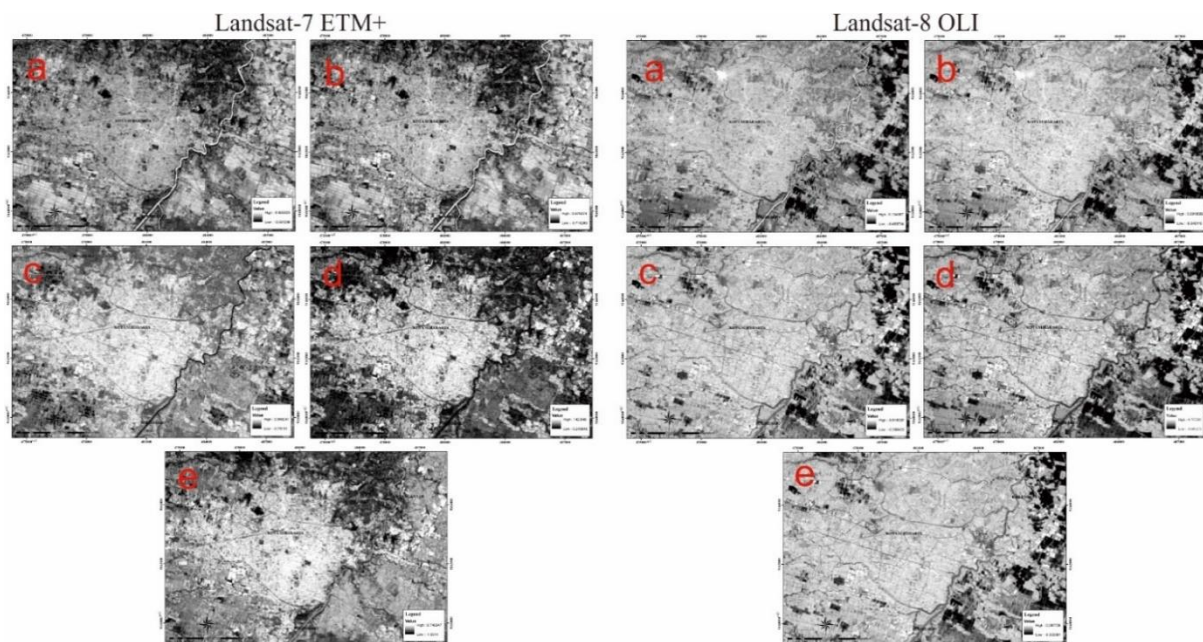


Figure 3. Spectral built-up Indices (a)VgNIR-BI, (b)VrNIR-BI, (c)NDBI, (d)UI and (e)Built-up using Landsat-7 ETM+ and Landsat-8 OLI imagery in Surakarta City and its surrounding areas. Built-up land indicated in light color.

The statistical value of built-up land indice image presented in table 2 is able to explain the appearance of the built-up land based on the image pixel value. There are four components in the image statistics that can explain the appearance of objects in the image, namely the minimum value, maximum, mean, and standard deviation. Table 2 shows the statistic values from built-up land indice imagery of the Landsat-7 ETM+ and Landsat-8 OLI/TIRS. The value in the table comes from the statistical calculation of all pixel values contained in the image.

Table 2. Spectral Indices Statistic Value

Spectral Indices	Landsat-7 ETM+ (2002)				Landsat-8 OLI/TIRS (2015)			
	Min	Max	Mean	Stdev	Min	Max	Mean	Stdev
VgNIR-BI	-0.551	0.666	-0.166	0.169	-0.489	0.134	-0.229	0.076
VrNIR-BI	-0.713	0.575	-0.286	0.206	-0.545	0.092	-0.243	0.093
NDBI	-0.781	0.556	-0.030	0.137	-0.389	0.619	-0.072	0.098
UI	0.250	142.646	52.899	17.571	-0.801	0.757	-0.314	0.189
Built-up	-1.031	0.740	-0.317	0.274	-0.333	0.388	-0.060	0.082

Source: Processing data, 2017

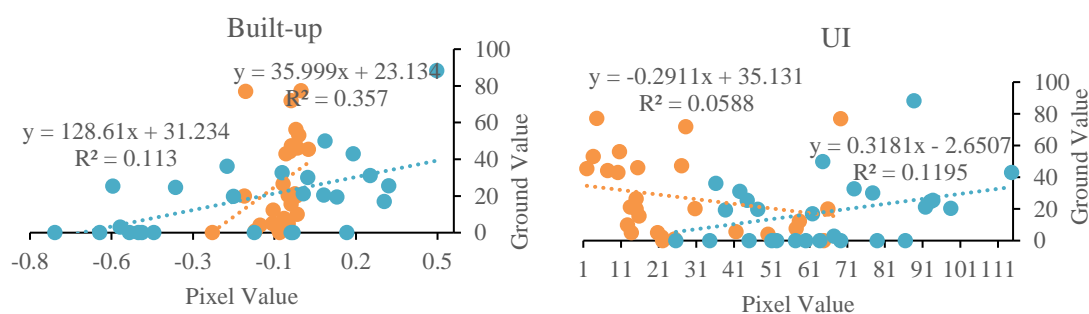
The minimum value shows the lowest pixel value in the image. The result of the minimum values of all built-up land indices imagery in Landsat-7 ETM+ and Landsat-8 OLI/TIRS, except UI indice shows a minus value. This minus value represented that there is no built-up land in the pixel. The UI indice in Landsat-7 ETM+ has a minimum value 0.250, it is different value compared to the minimum value in the other indice. The difference value with the other indices is due to the range of pixel values in the larger UI indice or the maximum value that is much greater than the value of other indicees.

The maximum value indicates the highest pixel value in the image that states the existence of built-up land. The high pixel value in the image will make the color on the image brighter. The UI indice in Landsat-7 ETM+ and Landsat-8 OLI/TIRS shows the highest maximum pixel value of 142.646 in Landsat-7 ETM+ and 0.757 in Landsat-8 OLI/TIRS. The maximum value of the UI indice in Landsat-7 ETM+ compared to other indices is due to a large range of values compared to other indices.

Mean is the average pixel value in the image obtained from the total pixel value divided by the number of pixels in the image. When the pixel value in the image has a relatively large value, the resulting value will be greater. The indice with the greatest mean is the UI in Landsat-7 ETM+ that is 52,899, while other indices of Landsat-7 ETM+ and Landsat-8 OLI/TIRS have very small and negative values. The mean value can also explain the description of built-up land in the field. The greater mean value shows that the area of built-up land recorded in the image is getting bigger.

The standard deviation (Stdev) contained in the image statistics shows the pixel value spreads in the image. The results showed that the standard deviation of all indices in Landsat-7 ETM+ and Landsat-8 OLI/TIRS, except that the UI indice in Landsat-7 ETM+ has a greater value than the mean or mean. It shows that the distribution of values within the image has a very wide spread, meaning that the pixel value in the image is very diverse and indicates that built-up land is not only concentrated in a single place, but spread in study area.

3.2 Regression between ground value and spectral indices



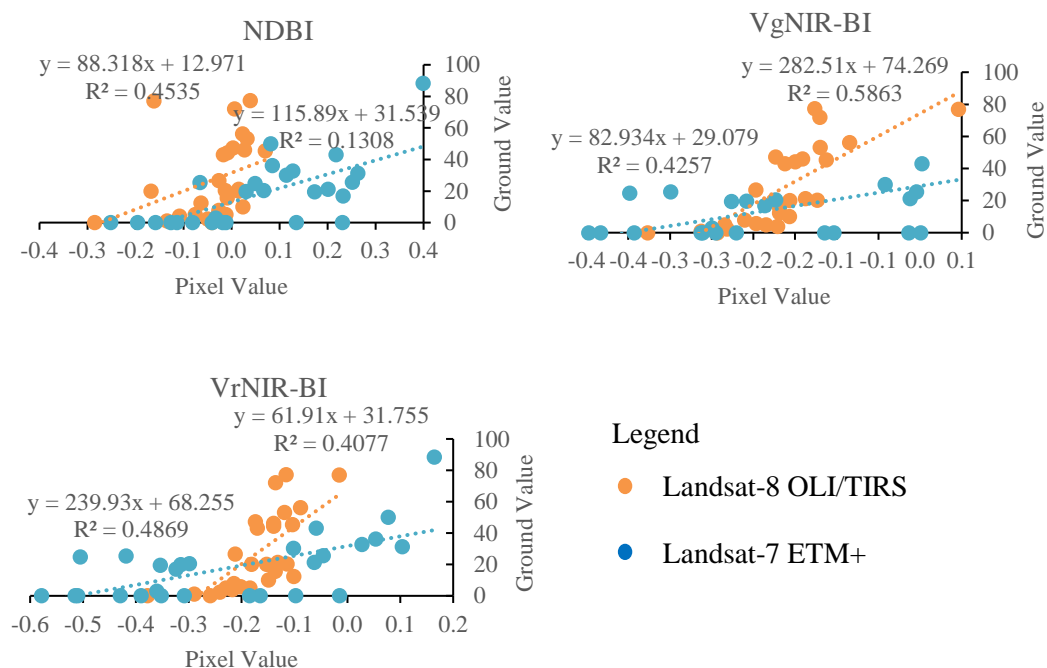


Figure 4. Regression spectral built-up indices using Landsat-7 ETM+ and Landsat-8 OLI/TIRS with built-up land density ground value

Figure 4 shows the regression graph between pixel value and field value of each indice in Landsat-7 ETM+ and Landsat-8 OLI/TIRS. The relationship between pixel value representing the built-up land density in the image with its presence in the field can be explained using the regression graph based on R^2 value. The smaller value of R^2 indicates that the relationship between image and field values is getting smaller.

VgNIR-BI has the greatest R^2 value compared to other indice which is 0.5863 in Landsat 8 OLI/TIRS. Similarly, the VrNIR-BI indice has the greatest value in Landsat-7 ETM+ that is 0.4869. This suggests that the VgNIR-BI and VrNIR-BI indices have the strongest correlation between image and field values. Therefore, the two indices are able to explain the existence of built-up land density.

The value of R^2 on the UI and Built-up indices has the lowest value compared to the values in the VrNIR-BI, VgNIR-BI, and NDBI indices. The UI indice has the lowest R^2 value in Landsat 8 OLI/TIRS of 0.0588 and the Built-up indice has the lowest R^2 value at Landsat 7 ETM+ of 0.113. Low regression value states that the existence of objects in the field can not be explained by image value well. Therefore, the UI indice is not good to explain the existence of built-up land density.

3.3 Spatiotemporal built-up land density mapping

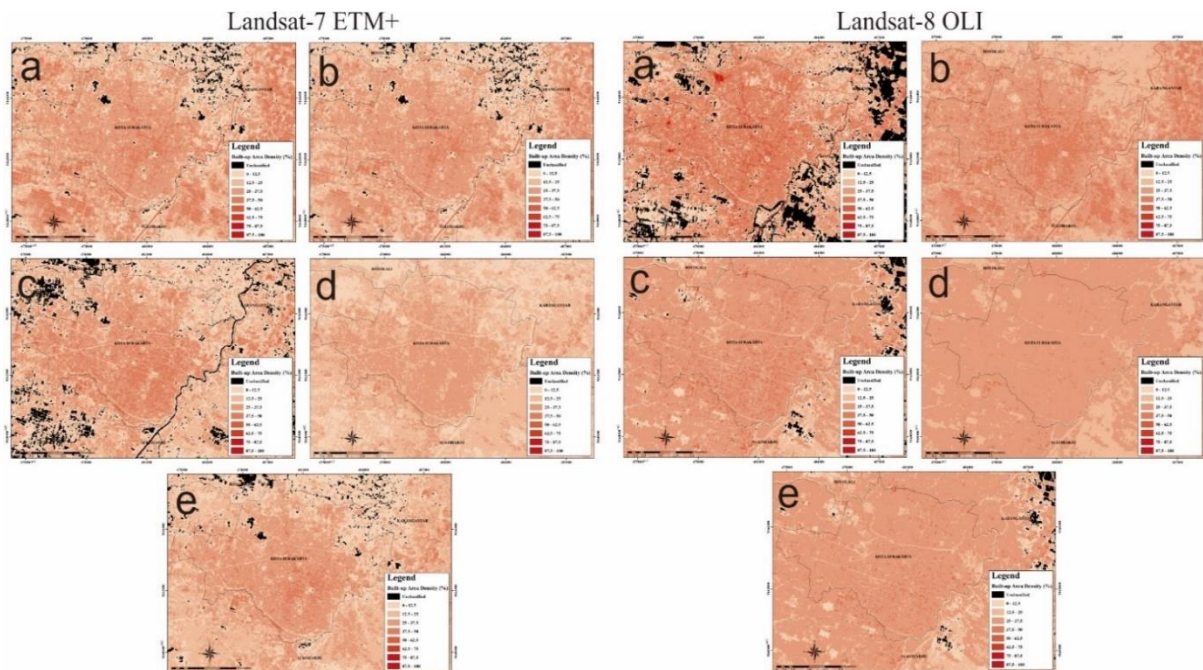


Figure 5. Built-up land density mapping (a) VgNIR-BI, (b) VrNIR-BI, (c) NDBI, (d) UI and (e) Built-up using Landsat-7 ETM+ and Landsat-8 OLI/TIRS imagery in Surakarta City and its surrounding area. The imagery are nine classes: unclassified in black, while 0-12.5%, 12.5-25%, 25-37.5%, 37.5-50%, 50-62.5%, 62.5-75%, 75-87.5% and 87.5-100 % increasingly in red.

Figure 5 is a built-up land density mapping based on each indice on Landsat-7 ETM+ and Landsat-8 OLI/TIRS. The classification of built-up land density mapping was built using VgNIR-BI, VrNIR-BI, NDBI, UI, and Built-up in Landsat-7 ETM+ and Landsat-8 OLI/TIRS, this image is divided into 9 classes that is unclassified, 0-12.5%, 12.5-25%, 25-37.5%, 37.5-50%, 50-62.5%, 62.5-75%, 75-87.5% and 87.5-100%. The increasingly red color indicates that the density of built-up land in the area has denser density. The black color on the map indicates that the area has an unclassified density value. The black color appears because the area is not built-up land, but such as surface flows, lakes, or other types of land use.

The visualization of built-up land density on Landsat-7 ETM+ varies greatly on VgNIR-BI, VrNIR-BI, NDBI, UI and Built-up. The NDBI of Landsat-7 ETM+ has the most contrasting built-up land density and shows a very striking difference between built-up and not built-up land, in contrast to the UI indice on Landsat-7 ETM+ which has a very slight difference between built-up and not built-up land. The built-up land density on VgNIR-BI and VrNIR-BI on Landsat-7 ETM+ has almost the same visual appearance.

The capabilities of VgNIR-BI, VrNIR-BI, NDBI, UI and Built-up using Landsat-8 OLI/TIRS for built-up land density mapping do not have significant visual differences such as Landsat-7 ETM+. The visual appearance showing the density of the built-up land using VrNIR-BI in Landsat-8 OLI/TIRS provides a very clear visualization of the difference between built-up land density of Surakarta City. Visually, the combination of green and red band indices in Landsat-8 OLI/TIRS has a good ability to mapping built-up land density when compared to other band.

Based on figure 5, spatiotemporal built-up land density mapping Surakarta City on 2002 and 2015 using VgNIR-BI, VrNIR-BI, NDBI, UI and Built-up in Landsat-7 ETM+ and Landsat-8 OLI/TIRS has visual visibility that explains built-up land density in Surakarta City increased on 2002-2015. The VgNIR-BI indice provide high mapping ability of spatiotemporal developed spatial density that clearly

shows the development of built-up land density in Surakarta City on 2002-2015. It is seen that the pattern of dispersion of increased built-up land density in Surakarta City leads to the north, west and south while the eastern direction does not increase. This is because a river bengawan solo in the eastern Surakarta City that inhibits the spread of increased built-up land density.

3.4 Area percentage of built-up land density in Surakarta City on 2002 and 2015

Table 3. Area Percentage of Built-up Land Density in Surakarta City 2002 and 2015

Class	Landsat-7 ETM+ 2002 (km ²)					Landsat-8 OLI 2015 (km ²)				
	Built-up	NDBI	UI	VgNIR-BI	VrNIR-BI	Built-up	NDBI	UI	VgNIR-BI	VrNIR-BI
Unclassified	100.2	163.7	0.0	111.3	111.3	30.1	45.6	0.0	265.0	519.6
0-12.5	389.0	390.9	444.8	332.1	345.5	126.2	127.9	0.0	209.5	66.5
12.5-25	317.8	234.1	401.8	230.0	240.7	235.7	232.1	345.3	218.3	62.7
25-37.5	87.9	95.1	54.8	154.4	167.3	492.4	465.9	552.1	134.0	53.0
37.5-50	6.9	17.6	0.4	68.1	34.7	15.2	27.4	4.4	58.6	48.3
50-62.5	0.0	0.4	0.0	4.3	2.3	0.4	1.1	0.0	9.9	45.1
62.5-75	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	2.5	43.4
75-87.5	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.7	38.4
87.5-100	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.4	24.6

Source: Processing data, 2017

Table 3 explains the value of area built-up land density Surakarta City on 2002 and 2015 varies on different spectral indices. This is due to VgNIR-BI, VrNIR-BI, NDBI, UI and Built-up indice in Landsat-7 ETM+ and Landsat-8 OLI/TIRS have different capabilities to estimate built-up land density. The classification of built-up land density mapping is divided into 9 classes, ie, non-classified, 0-12.5%, 12.5-25%, 25-37.5%, 37.5-50%, 50-62.5%, 62.5-75%, 75-87.5% and 87.5 -100%. The division into 9 classes on the built-up land density mapping in order to make the difference more clear in built-up land density in Surakarta City.

The built-up land density classes with not classified classes has the largest area in VgNIR-BI and VrNIR-BI indices, that are 111.3 km² in Landsat-7 ETM+ and VrNIR-BI of 519.6 km² in Landsat-8 OLI/TIRS. The built-up land density classes that is not classified with the lowest area is UI that has value 0 km² in Landsat-7 ETM+ and Landsat-8 OLI/TIRS. Spectral indice with built-up land density class of 87.5-100% is found only in VgNIR-BI area of 1.4 km² and VrNIR-BI area of 24.6 km² in Landsat-8 OLI/TIRS image. According to table five, spectral indices that have a contrasting development of built-up land density are VgNIR-BI and VrNIR-BI, while the non-contrast development of built-up land density is UI.

3.5 Accuracy assesment of built-up land density mapping

Based on table 4, the built-up land indice accuracy test values using VgNIR-BI, VrNIR-BI, NDBI, UI and Built-up in Landsat-7 ETM+ and Landsat-8 OLI/TIRS for built-up land density mapping in Surakarta City on 2002 and 2015 have different value. The different value of accuracy test value because each band in Landsat-7 ETM+ and Landsat-8 OLI/TIRS has different spectral reflectance characteristics for built-up land. To determine the capability of each spectral indice, it must analyze the statistical value of maximum error, minimum error, maximum accuracy and minimum accuracy.

Maximum error is the maximum error level on the regression result in predicting the Y value, while the minimum error is the minimum level of error in the regression result in predicting Y. The highest error is 187.84% for NDBI in Landsat-7 ETM+ and 74.517% for UI in Landsat-8 OLI/TIRS. The lowest maximum error value is 52.424% for VgNIR-BI in Landsat-7 ETM+ and 53.655% for NDBI in Landsat-

8 OLI/TIRS. The highest minimum error value is 65.129% for NDBI in Landsat-7 ETM+ and 35.602% for UI in Landsat-8 OLI/TIRS. The lowest minimum error value is 18.176% for VgNIR-BI in Landsat-7 ETM+ and 25.635% for NDBI in Landsat-8 OLI/TIRS.

Maximum accuracy is the maximum level of proximity measurement of quantity to the actual value or 100% difference with minimum error value, while minimum accuracy is the proximity level of quantity measurement to the actual value or 100% difference with maximum error value. The highest maximum accuracy score is 81.823% for VgNIR-BI in Landsat-7 ETM+ and 74.365% for NDBI in Landsat-8 OLI/TIRS. Low maximum accuracy value of 34.87% for NDBI in Landsat-7 ETM+ and 64.398% for UI in Landsat-8 OLI/TIRS. The highest minimum accuracy value is 47.575% for VgNIR-BI in Landsat-7 ETM+ and 46.345% for NDBI in Landsat-8 OLI/TIRS. The lowest minimum accuracy score is -87.84% for NDBI in Landsat-7 ETM+ and 25.483% for UI in Landsat-8 OLI/TIRS.

Table 4. Accuracy Assessment of Built-up Land Density Mapping in Surakarta City on 2002 and 2015

Spectral Indices	Landsat-7 ETM+ 2002 (%)				Landsat-8 OLI/TIRS 2015 (%)			
	Max Error	Min Error	Max Accuracy	Min Accuracy	Max Error	Min Error	Max Accuracy	Min Accuracy
VgNIR-BI	52.424	18.176	81.823	47.575	56.020	26.765	73.235	43.980
VrNIR-BI	60.754	21.065	78.934	39.245	64.825	30.972	69.028	35.175
NDBI	187.840	65.129	34.870	-87.840	53.655	25.635	74.365	46.345
UI	163.605	56.726	43.273	-63.605	74.517	35.602	64.398	25.483
Built-up	116.070	40.244	59.755	-16.070	57.216	27.336	72.664	42.784

Source: Processing data, 2017

Based on the overall statistical data in table 4, the VgNIR-BI spectral indice has the best ability for built-up land density mapping in Surakarta City on 2002 and 2015 using Landsat-7 ETM+ and Landsat-8 OLI/TIRS, while NDBI has the worst ability for Landsat-7 ETM+ and UI for Landsat-8 OLI/TIRS. VgNIR-BI has a maximum error, minimum error, maximum accuracy and minimum accuracy respectively of 52.424%, 18.176%, 81.823% and 47.545% using Landsat-7 ETM+ and 56.020%, 26.765%, 73.235% and 43.980% using Landsat -8 OLI/TIRS. The combined ability of green and red band in Landsat-7 ETM+ and Landsat-8 OLI/TIRS is the best combination of band for spatiotemporal built-up land density mapping in Surakarta City.

4. Conclusions

The observation of the built-up land in Surakarta City is done spatiotemporal using landsat-7 ETM+ representing the condition of 2002 and Landsat-8 OLI representing the state of the year 2015. The development of built-up land in the image can be observed in various ways, such as through image pixel value, visual observation, and measurement of built-up land density. Built-up land indices were attempted to find out the best indices in representing built-up land in the field through regression charts and accuracy tests with field data.

Observation of built-up land through image statistics observed with component image that is the minimum value, maximum, mean, and standard deviation. Individual built-up land indices on Landsat-7 ETM+ and Landsat-8 OLI have varying statistical values in representing built-up land. The variation in the value of the image statistics is due to different channel calculations on various indices. Values in the image statistics on the VgNIR-BI, VrNIR-BI, NDBI, and Built-up indices in Landsat-7 ETM+ and Landsat-8 OLI were normal, but found different values in the UI indice in Landsat-7 ETM+. This shows that statistically the whole indice is able to represent well-constructed land.

Visually, built-up land density changes from 2002 to 2015 are increasing. Built-up land density is higher visible from the gradation of the color of the map is getting red in 2015 in the city of Surakarta. The NDBI indice on Landsat-7 ETM+ has a clear visualization between the built-up land class, as well

as the Vr-NIR-BI indice on Landsat-8 OLI. The VgNIR-BI and VrNIR-BI indices on Landsat-7 ETM+ and Landsat-8 OLI imagery are able to represent a development of built-up land is clearly. This is evident from the value of the development of the area of built-up land.

The built-up land indice applied to Landsat-7 ETM+ and Landsat-8 OLI is not fully able to represent well on built-up land. The regression graph and accuracy test were performed to find out the best indice in mapping the density of the built-up land in Surakarta City. The VgNIR-BI indice on Landsat-8 OLI and the VrNIR-BI indice on Landsat-7 ETM+ has the greatest R^2 value, so both indices are able to explain the existence of built-up land is great. Based on the results of the accuracy test, the value of VgNIR-BI on Landsat-7 ETM+ and NDBI on Landsat-8 OLI has a high accuracy value. Therefore, the VgNIR-BI has the best ability to built-up land density mapping in Surakarta City in 2002 and 2015 using Landsat-7 ETM+ and Landsat-8 OLI from visual and statistic perspective.

Acknowledgment

We are thankful to Mrs. Prima Widayani and Departement of Geography Information Science, Faculty of Geography, Universitas Gadjah Mada whose support to this research. Many thanks are also goes to US Geological Survey (USGS) to give opportunity for the authors to access remote sensing data, such as Landsat-8 OLI/TIRS and Landsat-7 ETM+ and also to Badan Informasi Geospasial (BIG) Indonesia for map of Rupabumi Indonesia.

References

- [1] Amir Kumar, Arvind Chandra Pandey, and A T Jeyaseelan 2012 Built-up and vegetation extraction and density mapping using WorldView-II *Geocarto International* vol 27(5) pp 557-568.
- [2] Bhatta Basudeb 2010 *Advances in Geographic Information Science: Analysis of Urban Growth and Sprawl from Remote Sensing Data* (London: Springer) p 61.
- [3] Bintarto R and Hadisumarno 1991 *Geography Analysis Method 4th Ed.* (Jakarta: LP3ES) p 64.
- [4] Campbell James B and Wynne Randolph H 2011 *Introduction to Remote Sensing* (New York: The Guilford Press) p 305.
- [5] Congalton Russel G and Green Kass 2009 *Assessing the Accuracy of Remotely Sensed Data: Principles and Practices* (London: CRC Press) p 119.
- [6] Danoedoro Projo 2012 *Introduction to Digital Image Processing* (Yogyakarta: Andi Press) p 168 and 186.
- [7] Dradas Mohsen, Helmi Z M Shafri, Noordin Ahmad, Biswajeet Pradhan, and Sahabeh Safarpour 2015 Spatio-Temporal Analysis of Urban Growth from Remote Sensing Data in Bandar Abbas City, Iran *The Egyptian Journal of Remote Sensing and Space Sciences* vol 18 pp 35-52.
- [8] ENVI 2017 *Atmospheric correction: Dark subtraction* Available online: <https://www.harrisgeospatial.com/docs/AtmosphericCorrection.html> (accessed: 6 September 2017).
- [9] Estoque, Ronald C, and Yuji Muraya 2015 Classification and Change Detection of Built-up Lands from Landsat-7ETM+ and Landsat-8 OLI/TIRS Imageries: A Comparative Assessment of Various Spectral Indices *Ecological Indicators* vol 56 pp 205-217.
- [10] Freedman D A 2005 *Statistical Models: Theory and Practice* (Cambridge: Cambridge University Press) p 18.
- [11] Gao Jay 2012 *Digital Analysis of Remotely Sensed Imagery 4th ed.* (New York: McGraw-Hill) p 158.
- [12] Garg Abhisha, Divyansu Pal, Hukum Singh, and Deepak Chander Pandey 2016 A Comparative Study of NDBI, NDISI, and NDII for Extracrion of Urban Impervious Surface of Dehradun (Uttarakhand, India) Using Landsat 8 Imagery *Proc. Int. Conf. on Emerging Trends in Communication Technologies (ETCT)* pp 1-5.

- [13] Indonesian Central Bureau of Statistics (BPS) 2016 *Provinsi Jawa Tengah dalam angka 2016* Available online: https://jateng.bps.go.id/website/pdf_publicasi/Provinsi-Jawa-Tengah-Dalam-Angka-2016.pdf (accessed: 6 September 2017).
- [14] Indonesian Central Bureau of Statistics (BPS) 2017 *Kota Surakarta dalam angka 2017* Available online: https://surakartakota.bps.go.id/website/pdf_publicasi/Kota-Surakarta-Dalam-Angka-2017.pdf (accessed: 6 September 2017).
- [15] Kawamura Makoto, Sanath Jayamanna, and Yuji Tsujiko 1996 Relation Between Social and Environmental Conditions in Colombo, Sri Lanka and The Urban Indice Estimated by Satellite Remote Sensing Data *International Archives of Photogrammetry and Remote Sensing* vol 31 pp 321-326.
- [16] Kenney J and Keeping E S 1963 *Mathematics of Statistics* (van Nostrand) p 187.
- [17] Kneebone Elizabeth 2009 *Job Sprawl Revisited: The Changing Geography of Metropolitan Employment* (Washington DC: Brookings Institution) p. 15
- [18] Lillesand Thomas M, Kiefer Ralph W, and Chipman Jonathan W 2003 *Remote sensing and Image Interpretation 5th ed.* (New York: John Wiley & Sons, Inc) p 498.
- [19] Pesaresi Martino, Daniele Ehrlich, Ivano Caravaggi, Mayeul Kauffmann, and Christophe Louvrier 2011 Toward Global Automatic Built-up Area Recognition Using Optical VHR Imagery *IEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing* vol 4(4) pp 923-934.
- [20] Rashed Tarek and Jürgens Carsten 2010 *Remote Sensing and Digital Image Processing: Remote Sensing of Urban and Suburban Areas* (London: Springer) p 33.
- [21] Roy D P, Wulder M A, Loveland T R, Woodcock C E, Allen R G, Anderson, M C, *et al* 2014 Landsat-8 Science and Product Vision for Terrestrial Global Change Research *Remote Sensing Environment* vol 145 pp 154-172.
- [22] Sun Genyun *et al* 2016 Combinational Build-up Indice (CBI) for Effective Impervious Surface Mapping in Urban Areas *IEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing* vol 9(5) pp 2081-2092.
- [23] USGS 2006 *Multi-resolution Land Characteristic 2001 (MRLC2001) Image Processing Procedure* Available online: (http://landcover.usgs.gov/pdf/image_preprocessing.pdf) (accessed: 5 September 2017).
- [24] USGS 2013 *Using the USGS Landsat 8 Product* Available online: (http://landsat.usgs.gov/Landsat8_using_Product.php) (accessed: 5 September 2017).
- [25] Wang Zhaoqi, Chencheng Gang, Xueling Li, Yizhao Chen, and Jialong Li 2015 Application of a Normalized Difference Impervious Indice (NDII) to Extract Urban Impervious Surface Feature Based on Landsat TM Images *International Journal of Remote Sensing* vol 36(4) pp 1055-1069.
- [26] Wu Mengquan, Jingpu Wang, Xia Wang, and Xibing Sun 2011 Spatio-temporal Analysis of Urban Built-up Area Extension in Yantai City Based on Multi-source Remote Sensing Images *19th International Conference on Geomatics* vol pp. 1-6.
- [27] Xu H 2008 A New Indice for Delineating Built-up Land Features in Satellite Imagery *Int. Journal of Remote Sensing* vol 29(14) pp 4269-4276.
- [28] Zha Y, J Gao and S Ni 2003 Use of Normalized Difference Built-up Indice in Automatically Mapping Urban Areas from TM imagery *International Journal of Remote Sensing* vol 24(3) pp 583-594.