An Erdas Imagine Model To Extract Urban Indices Using Landsat 8 Satellite Imagery

Alihsan Sekertekin, Aycan Murat Marangoz

Abstract: Urbanization has been one of the most important issues in recent years. Expansion in urban areas may affect urban ecosystem. Thus, it is crucial to observe the variations in landscape patterns in urban areas. Satellite imagery is one of the effective ways to observe the environment. Besides, spatial distribution of urban areas can be determined using satellite images quickly and accurately. In addition, in order to distinguish urban features from non-urban areas some spectral urban indices have been developed. In this study, Landsat 8 OLI and TIRS data acquired on 7 October 2014 were utilized to retrieve urban areas by the help of spectral urban indices. Zonguldak city, a province of Turkey, was chosen as study area. The objective of this study is to create an Erdas Imagine model to retrieve urban index maps automatically. The obtained results showed that Erdas Imagine Spatial Modeler is a user friendly and effective tool for image processing. Furthermore, different kinds of spectral index maps can be retrieved easily and automatically by creating models.

Index Terms: Remote Sensing, Urban Indices, Landsat 8 OLI and TIRS, Erdas Imagine Modeler, Urbanization.

1 INTRODUCTION

Urbanization refers to as the change of rural lifestyles into urban ones [1]. Industrialization, economic opportunities or an increase in the number of people moving from rural to urban areas can cause urban development [2]. Rapid urbanization and urban expansion may have significant impact on conditions of urban ecosystems [3], [4], [5], [6]. Therefore, city planners, environmentalists, ecologists and decision makers need the distribution of urban areas as well as the expansion in urban areas in order to understand the effects of this phenomenon. Remote sensing technology uses satellite imagery to retrieve information about the changes on Earth. Nowadays, there are lots of commercial and non-commercial satellites with different specifications to map Earths and scientists utilize different kind of satellite images in terms of their application types. In this study, new generation Landsat mission satellite Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) data have been considered to obtain urban areas. Landsat data are freely distributed by National Aeronautics and Space Administration (NASA) and The United States Geological Survey (USGS). Satellite imagery is an effective way to reveal the changes on land use patterns and in order to separate urban and non-urban details lots of spectral urban indices were developed by the scientists. Normalized Difference Built-Up Index (NDBI) [7], Index-based Built-Up Index (IBI) [8], Urban Index (UI) [9] and Enhanced Built-Up and Bareness Index (EBBI) [10] are some commonly used urban indices and this study these indices have been considered so as to extract urban areas. Erdas Imagine is one of the effective image processing software and also has a user-friendly interface. In addition, users can develop their own models using modeler icon and by building models they can retrieve their results automatically.

The aforementioned urban indices were developed using previous Landsat missions namely TM and ETM+ images. However, in this study these indices will be adapted to Landsat 8 data. The objective of this study is to develop an Erdas Imagine model to extract urban indices automatically using Landsat 8 OLI and TIRS data.

2 STUDY AREA AND MATERIAL

2.1 Study Area

Zonguldak city is the study areas and it is located on the western part of Turkey's Black Sea Region (Fig. 1). The city is 3,481 km² in size and has a population of 595907. Düzce, Bolu, Karabük and Bartın provinces are the neighboring cities [11]. Zonguldak is not only major coal production center in Turkey but also it is an important industrial city. Because, it has four operational thermal power plants and one of the biggest iron steel plants in Europe. Thus, the city has great potential for the urban growth.

Fig. 1. Study area Zonguldak city; province boundary (left), municipal boundary (right).

2.2 Material

Landsat 8 OLI and TIRS data acquired on 7 October 2014 were used in this study. Landsat 8 was launched on 11 February 2013 and OLI images consist of nine spectral bands with a spatial resolution of 30 meters for Bands 1 to 7 and 9 (TABLE 1). New band 1 (ultra-blue) is useful for coastal and aerosol studies. New band 9 is useful for cirrus cloud detection. The resolution for Band 8 (panchromatic) is 15 meters. Thermal bands 10 and 11 are useful in providing more accurate surface temperatures and are collected at 100 meters and they are resampled to 30m. Approximate scene size is 170 km north-south by 183 km east-west [12].

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### TABLE 1: THE SPECIFICATIONS OF LANDSAT 8 OLI AND TIRS BANDS

<table>
<thead>
<tr>
<th>Bands</th>
<th>Wavelength (micrometers)</th>
<th>Resolution (meters)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Band 1 - Coastal aerosol</td>
<td>0.43 - 0.45</td>
<td>30</td>
</tr>
<tr>
<td>Band 2 - Blue</td>
<td>0.45 - 0.51</td>
<td>30</td>
</tr>
<tr>
<td>Band 3 - Green</td>
<td>0.53 - 0.59</td>
<td>30</td>
</tr>
<tr>
<td>Band 4 - Red</td>
<td>0.64 - 0.67</td>
<td>30</td>
</tr>
<tr>
<td>Band 5 - Near Infrared (NIR)</td>
<td>0.85 - 0.88</td>
<td>30</td>
</tr>
<tr>
<td>Band 6 - SWIR 1</td>
<td>1.57 - 1.65</td>
<td>30</td>
</tr>
<tr>
<td>Band 7 - SWIR 2</td>
<td>2.11 - 2.29</td>
<td>30</td>
</tr>
<tr>
<td>Band 8 - Panchromatic</td>
<td>0.50 - 0.68</td>
<td>15</td>
</tr>
<tr>
<td>Band 9 - Cirrus</td>
<td>1.36 - 1.38</td>
<td>30</td>
</tr>
<tr>
<td>Band 10 - Thermal Infrared (TIRS)</td>
<td>10.60 - 11.19</td>
<td>100*30</td>
</tr>
<tr>
<td>Band 11 - Thermal Infrared (TIRS)</td>
<td>11.50 - 12.51</td>
<td>100*30</td>
</tr>
</tbody>
</table>

### TABLE 2: THE FORMULATION OF THE URBAN INDICES USING LANDSAT 8 DATA

<table>
<thead>
<tr>
<th>Name of Urban Index</th>
<th>Formulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Normalized Difference Build-up Index</td>
<td>( \text{NDBI} = \frac{SWIR_1 - NIR}{SWIR_1 + NIR} )</td>
</tr>
<tr>
<td>Urban Index</td>
<td>( \text{UI} = \frac{SWIR_2 - NIR}{SWIR_2 + NIR} )</td>
</tr>
<tr>
<td>Index-based Built-Up Index</td>
<td>( \text{IBI} = \frac{2 \cdot SWIR_1 - (NIR + NIR + GREEN + SWIR_1)}{2 \cdot SWIR_1 + (NIR + RED + GREEN + SWIR_1)} )</td>
</tr>
<tr>
<td>Enhanced Built-Up and Bareness Index</td>
<td>( \text{EBBI} = \frac{SWIR_1 - NIR}{10 \cdot (SWIR_1 + TIR_1)} )</td>
</tr>
</tbody>
</table>

3 Methodology

Before using satellite imagery, preprocessing steps should be implemented. Thus, the bands which are used in the study were layerstacked and subsetted so as to include the study area. After that, Digital Numbers (DNs) of band 10 were converted to top of atmosphere (ToA) radiance using Equation (1), whereas DNs of OLI bands required for indices were converted to ToA reflectance using equation (2). These conversion formulations can be obtained from Landsat 8 handbook [13].

\[
L_\lambda = M_L Q_{\text{cal}} + A_L
\]

(1)

Where \( L_\lambda \) is TOA spectral radiance (Watts/(m\(^2\)sr\(\times\)\(\mu\)m)), \( M_L \) is band-specific multiplicative rescaling factor from the metadata (RADIANCE_MULT_BAND_x, where x is the band number), \( A_L \) is band-specific additive rescaling factor from the metadata (RADIANCE_ADD_BAND_x, where x is the band number), \( Q_{\text{cal}} \) is quantized and calibrated standard product pixel values (DN).

\[
p_\lambda = \frac{M_p Q_{\text{cal}} + A_p}{\sin(\theta_{SE})}
\]

(2)

Where \( p_\lambda \) is TOA planetary reflectance, \( M_p \) is band-specific multiplicative rescaling factor from the metadata (REFLECTANCE_MULT_BAND_x, where x is the band number), \( A_p \) is band-specific additive rescaling factor from the metadata (REFLECTANCE_ADD_BAND_x, where x is the band number), \( Q_{\text{cal}} \) is quantized and calibrated standard product pixel values (DN), \( \theta_{SE} \) is local sun elevation angle. The scene center sun elevation angle in degrees is provided in the metadata (SUN_ELEVATION). At the end of preprocessing, the data are ready for calculating urban indices. The formulations of the indices for Landsat 8 data are presented in TABLE 2.

In order to extract these urban indices automatically a model was created using Erdas Imagine Spatial Modeler icon (Fig. 2). In this model, first steps represent radiance and reflectance conversion (Fig. 3, Fig. 4). One of the important issues is that all software uses radian so it is required to convert any type of angle to radian. The output versions of the reflectance and radiance images should be in float single format so while calculating output raster “divided by zero error” will not be faced (Fig. 5). On the other hand, “divided by zero error” can also be solved using conditional statement in modeler like “EITHER 0 IF ( $raster1==0 ) OR $raster2 / $raster1 OTHERWISE”. It means that while division if the pixel value of rastere1 is 0 the output pixel will be 0 otherwise $raster2/$raster1 will be calculated. After obtaining reflectance and radiance images index formulations are implemented and urban index maps are generated. NDBI, UI and EBBI can be calculated easier than IBI. Because, as you can understand from the name of IBI it is an index based index so Soil Adjusted Vegetation Index (SAVI), the Modified Normalized Difference Water Index (MNDWI) and the Normalized Difference Built-Up Index (NDBI) are the main indices to calculate IBI. Detailed information about SAVI and MNDWI can be found in lots of scientific papers. Besides, SAVI, MNDWI and NDBI indexes should be normalized before calculating IBI.
Fig. 2. Erdas Imagine model created to extract urban indices automatically.

Fig. 3. Radiance conversion equation.
Fig. 4. Reflectance conversion equation.

Fig. 5. Saving output as float single.
4 RESULTS

The urban index maps were created using the model aforementioned above (Fig. 6). The legends of these indices can vary from site to site. In general, it ranges from -1 to +1 and in order to extract urban and non-urban areas threshold values should be determined. Threshold values can be obtained from ground data, comparison of a reference image or statistical methods. In all maps, from dark to bright areas the urban details become clearer.

Fig. 6. Urban index maps retrieved automatically by the model using Landsat 8 data.
5 CONCLUSION
In this study, a model was created to extract commonly used spectral urban indices from Landsat 8 OLI and TIRS data. These indices are obtained from previous Landsat mission images namely TM and ETM+; however, in this study these indices were adapted to Landsat 8 data. The obtained results show that these indices can be obtained efficiently using Landsat 8 data. City planners and decision makers can use these effective indices to observe the changes in urban areas. Nowadays, there are various useful software for image processing and users benefit from their opportunities. Erdas Imagine is one of the easy-to-use programs and it gives opportunity to create models to automate the image processing. For further study, it will be investigated which urban index gives the best results to present the urban areas.

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REFERENCES