The examination of geologic formations in terms of Land Cover and Land Surface Temperature (LST) by using Landsat images: A case study of Zonguldak, Turkey

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Abstract: Remote sensing technology has a great importance with regard to environmental monitoring. Satellite images present advantages to study on a large scale effectively. In this research, Landsat TMS5 satellite images acquired on 20.09.2003 and 29.09.2011 were used to retrieve Land Surface Temperature (LST) and land cover based on pixel and object based classification. Also a geological map of the study area was used to correlate the images. As a result of the research, all images were correlated each other and similarities between different regions were presented.

Keywords: Remote Sensing, Object Based Classification, Pixel Based Classification, Land Surface Temperature, Environmental Monitoring.

1. Introduction

In accordance with the recent developments in practices of remote sensing and image processing, image analyses by using satellite images have become more practical in terms of examining vast areas and obtaining data about the surface of the area like land surface temperature, land cover etc. In this context, examining geologic and geomorphologic information of the area has been possible and attractive by the use of the recent technologies mentioned above.

In this study, Zonguldak region, which is known as a mining area situated by the Black Sea has been chosen as the test area. In this region, 23 geologic formations and members have been observed which are including a geological map having a scale of 1/100000. Compared to the magmatic and metamorphic rocks, the formations containing sedimentary based rocks are much commonly noticed in the area.

The goal of this study is to investigate geological formations with regard to land cover and LST by using the visible, infrared and thermal bands of Landsat images with the acquisition dates 23.09.2003 and 29.09.2011.

2. Study Area and Data

In this research Zonguldak, the coastal city in Black Sea region, has been chosen as the study area. It has an undulating ground and rough topography. Also it has rich geologic formations.
Two Landsat TM5 images acquired on 23.09.2003 and 29.09.2011 were used in order to obtain classifications and LST maps. Also a geological map was used for analyses about land cover and LST maps. Erdas Imagine and eCognition software were used as remote sensing software to process the images.

3. Methodology

LST maps can be obtained by using thermal band of Landsat image and meteorological data. The most commonly used LST retrieval methods are split-window algorithm (Sobrino et al., 1996), temperature/emissivity separation method (Gillespie et al., 1998), mono-window algorithm (Qin et al., 2001) and single channel method (Jimenez-Munoz and Sobrino, 2003). Mono-window algorithm has been applied to the Landsat images for this research. Three main parameters, emissivity, transmittance and the average atmospheric temperature, are required for the algorithm.

Firstly the images were prepared for processing. They were resampled and clipped as including the study area. Secondly radiometric corrections like converting digital numbers to spectral radiance values and converting spectral radiance to reflectance values were conducted. Then spectral radiance values of thermal bands were converted to brightness temperature by means of Equation 1.

\[ T = \frac{K_2}{\ln \left( \frac{K_1}{L_k} + 1 \right)} \]  

where \( T \) is effective at-satellite temperature in Kelvin, \( L_k \) is the spectral radiance at the sensor's aperture, \( K_1 \) and \( K_2 \) are the calibration constants.

The other step is the estimation of Land Surface Emissivity (LSE) by using Normalized Difference Vegetation Index (NDVI). A detailed estimation of LSE from NDVI was proposed by Zhang et al. (2006).

After that the estimation of mean atmospheric temperature (\( T_a \)) via atmospheric temperature at ground (\( T_o \)) was proposed by Qin et al. (2001).

Estimation of the last parameter, atmospheric transmittance (\( \tau_i \)), could be estimated from water vapor content (\( w_i \)) as demonstrated in Table 1 (Qin et al., 2001).

<table>
<thead>
<tr>
<th>Profiles</th>
<th>Water Vapor (( w_i )) [g/cm²]</th>
<th>Transmittance estimation equation (( \tau_i ))</th>
<th>Squared correlation</th>
<th>Standard Error</th>
</tr>
</thead>
<tbody>
<tr>
<td>High Air Temperature</td>
<td>0.4-1.6</td>
<td>0.974290-0.08007×( w_i )</td>
<td>0.99611</td>
<td>0.002368</td>
</tr>
<tr>
<td></td>
<td>1.6-3.0</td>
<td>1.031412-0.11536×( w_i )</td>
<td>0.99827</td>
<td>0.002539</td>
</tr>
<tr>
<td>Low Air Temperature</td>
<td>0.4-1.6</td>
<td>0.982007-0.09611×( w_i )</td>
<td>0.99563</td>
<td>0.003340</td>
</tr>
<tr>
<td></td>
<td>1.6-3.0</td>
<td>1.053710-0.14142×( w_i )</td>
<td>0.99899</td>
<td>0.002375</td>
</tr>
</tbody>
</table>

Finally LST values could be obtained from Equation 2, the equation of mono-window algorithm.

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\[
T_s = \left[ a \cdot (1-C-D) + \left( b \cdot (1-C-D) + C + D \right) \cdot T_a \cdot T_i \right] / C
\]

(2)

\( a = -67.355351, \quad b = 0.458606, \quad C = \varepsilon_i \times \tau_i, \quad D = (1 - \tau_i) \cdot [1 + (1 - \varepsilon_i) \times \tau_i] \)

where \( T_s \) is the LST in Kelvin, \( T_i \) is the brightness temperature in Kelvin, \( T_a \) is the effective mean atmospheric temperature, \( \tau_i \) is the atmospheric transmittance value, \( \varepsilon_i \) represents land surface emissivity, \( a \) and \( b \) are the algorithm constants.

Classifications for land cover extraction based on pixel and objects were conducted by using Erdas Imagine and eCognition software (Trimble, 2013). Supervised classification was conducted for pixel based approach by using maximum likelihood method in Erdas Imagine and nearest neighborhood method was used for object based classification in eCognition (Marangoz et al., 2006).

The geological map of the study area was scanned and after that georeferencing process was applied so as to be able to conduct the analyses with other maps.

4. Results

LST maps were generated by mono-window algorithm and they were classified by using threshold method. In Figure 1 LST maps, pixel based classifications and object based classifications were presented.

Figure 1. LST and classification results, a. LST map of Landsat image acquired on 23092003, b. LST map of Landsat image acquired on 29092011, c. Pixel based classification of 2003 data, d. Pixel based classification of 2011 data, e. Object based classification of 2003 data, f. Object based classification of 2003 data.

Accuracy assessment of LST images were conducted by correlating LST values and radiance values. Correlation coefficients of LST images are respectively 91% and 92% for 2003 and
2011 images. Overall classification accuracy of pixel based classification for 2003 data is 85% with overall kappa statistics 0.8229 and overall classification accuracy of pixel based classification for 2011 data is 83% with overall kappa statistics 0.7996. Segments created for object based classification present general areas so the size of the segments are big. As a result of that, accuracy of object based classification for this research is 100%.

Geological map, object based classified images and LST maps were evaluated each other. Land cover map, LST map and geological formation have similarities in some regions (Fig. 2).

5. Conclusions

Remote sensing technology is an important science at the present. Especially environmental problems, land cover/land use changes, temporal analysis about different attributes can be obtained from satellite data and analyzed easily and properly. In this paper LST maps, land cover maps by means of pixel based and object based classifications were extracted and these maps were discussed in terms of geological formations of the region.

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