Monitoring Vegetation Conditions of Catchments Using Multispectral Remote sensing Data (Case study: Central Zab basin)

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Abstract

Monitoring vegetation of basins by remote sensing can help natural resource management. In this paper, central Zab basin, a watershed in west Azerbaijan province, Iran, was examined in a case study via two techniques of remote sensing: (1) NDVI comparison, (2) Tasseled cap. NDVI is particularly used to monitoring the presence and condition of vegetation. Tasseled cap is another index which creates three band images. The three bands represent brightness, greenness, wetness for area under consideration. The present study aims particularly at comparing high NDVI area and greenness values given by tasseled cap and low NDVI values and high brightness values.

The study clearly showed the suitability of NOAA AVHRR and Landsat 4 and 5 Thematic Mapper (TM) and Landsat-7 Enhanced Thematic Mapper (ETM*) satellite images for monitoring vegetation conditions and productivity in central Zab basin.
Key words: NDVI technique; NOAA AVHRR; Landsat TM/ETM*; DN value; Monitoring.

1. Introduction

Remote sensing data of NOAA AVHRR (Advanced Very High Resolution Radiometer) combined with ground data is used in this study as the major tool for monitoring vegetation conditions and productivity in central Zab basin.

Since the early 1980s data from NOAA AVHRR have been used extensively to monitor and to study dry land vegetation [1]. Previous studies [2,3,4,5,6, and 7] have shown the usefulness of the NOAA-AVHRR-normalized difference vegetation index (NDVI) for monitoring vegetation at different scales.

Tappan et al.(1992) found that the NDVI image data were a useful tool for monitoring growing conditions of rangeland and for making long-term productivity comparisons between the different rangeland types [8]. Furthermore, Mout et al. (1997) used the NDVI as an indicator of desertification since it related to vegetation greenness Healthy vegetation absorbs most of the red light, and reflects a large portion of the near-infrared spectrum of incident electromagnetic radiation that hits it [9]. Consequently, NDVI can be used as an index for monitoring vegetative cover in a given time period [10].

Our objectives in this research are comparing high NDVI area and greenness values given by tasseled cap and low NDVI values and high brightness values and monitoring vegetation condition compared to other methods.

2. Case study region

Zab basin occupies south-western section of West Azerbaijan and north-western part of Kurdistan. The area under present study covers parts of mountains and slopes in south-western West Azerbaijan in the central portion of Zab basin between the latitudes of (36° 8' 25") N and (36° 26' 27") N and the longitudes of (45° 21' 21") E and (45° 40' 44") E. Central Zab basin has a north-south orientation and stretches...
almost 30km in east-west direction. The study area covers some 520 km² of its total area (Fig. 1). It is one of the settled geographical basins including a city, three towns or small cities, and over 80 villages [10]. Here, a north-west extension branches off from the east-west oriented ridges of Zab valley, creating a different landscape from that of the internal sections of Azerbaijan and Kurdistan. The major part of the study area is located in the Sanandaj–Sirjan zone and its east and eastern north parts locate in the Mahabad–Khoy zone.

In aspect of tectonic since the region is located in major Zagros thrust direction and faults are the main causes of pit formation. The region morphology strongly affected by tectonic forces [11].

### 3. Methodology

Vegetation conditions can be studied at the pixel level (1 km) using the NDVI derived directly from NOAA AVHRR imagery. However, this requires the calculation of NDVI statistical distribution at the 1 km-spatial resolution from a time series of data that is not yet available.

The 1985-2009 Landsat NDVI data were compiled from Landsat 4 and 5 Thematic Mapper (TM) and Landsat-7 Enhanced Thematic Mapper Plus (ETM+) data downloaded from the United States Geological Survey (U.S.G.S.) website from (http://glovis.usgs.gov/). However, these instruments have a repeat cycle of 16 days. The time-series data comprised images for 24 years.

- Band 1, 2, 3, 4, 5 and 7 of Lansat ETM+ to 30 m in 2003.
- Band 2, 3 and 4 of Lansat TM to 60 m in 1985 (Table.1).

#### Table 1: AVHRR and Landsat TM/ETM+ scenes used in the NDVI

<table>
<thead>
<tr>
<th>Sensor</th>
<th>Period</th>
<th>Spatial resolution</th>
<th>Temporal resolution</th>
<th>Format</th>
</tr>
</thead>
<tbody>
<tr>
<td>AVHRR: Vegetation index (NDVI)</td>
<td>1978-today</td>
<td>~1km</td>
<td>Daily</td>
<td>L1B</td>
</tr>
<tr>
<td>LANDSAT-TM/ETM+1-7 (VIS, NIR, TIR)</td>
<td>1972-today</td>
<td>15/30/60m</td>
<td>16 days</td>
<td>Geo TIFF</td>
</tr>
</tbody>
</table>

Supervised Classification using Bayesian Classifier: In supervised classification, the pixel categorisation process is done by specifying the numerical descriptors of the various LC types present in a scene. Accuracy assessment: Accuracy assessments were done with field knowledge, visual interpretation and also referring Google Earth (http://earth.google.com).

In this study two techniques of remote sensing: (1) NDVI comparison, (2) Tasseled cap.

#### 3.1. NDVI

Healthy vegetation absorbs most of the red light, and reflects a large portion of the near-infrared spectrum of incident electromagnetic radiation. Consequently, NDVI can be used as an index for monitoring vegetative cover in a given time period [12]. NDVI is computed as the ratio of the measured intensities in the red (R) and near infrared (NIR) spectral bands. The more leaves a plant has, the more these wavelengths of light are affected, respectively. Since early instruments of Earth Observation, such as NOAA’s AVHRR, acquired data in visible and near-infrared, it was natural to exploit the strong differences in plant reflectance to determine their spatial distribution in these satellite images. The NDVI is calculated from these individual measurements as follows (Eq. 1):

$$NDVI = \frac{(NIR - VIS)}{(NIR + VIS)} \quad (1)$$

Where VIS and NIR stand for the spectral reflectance measurements acquired in the visible
(red) and near-infrared regions, respectively [13, 14, and 15]. For lansat TM: (Eq. 2):

$$NDVI = \frac{TM4 - TM3}{TM4 + TM3}$$  \hspace{1cm} (2)

Where Red = TM or ETM+ band 3 normalized spectral reflectance

NIR = TM or ETM+ band4 normalized spectral reflectance

Resulting index value ranges from +1 to -1 indicates sensitivity to the presence of vegetation on the land surface of the earth which can be used to address issues of vegetation type, amount, and condition. NDVI is less affected via atmospheric condition than the other indices, therefore, it is suitable for application such as change detection [16].

NDVI has been in use for many years to:

- To measure and monitor plant growth (vigor), vegetation cover, and biomass production from multispectral satellite data.
- To model the abundance of living planet material from satellite image and data.
- To simply and quickly identify vegetated areas and their condition.

The value of NDVI varies between -1 (usually water) to 1 (strongest vegetative growth) [17].

High NDVI represents an area with healthy vegetation and NDVI of an area with dense vegetation will tend to positive values (0.3 to 0.8).

3.2. Tasseled cap

Tasseled Cap transformation is one of the available methods for enhancing spectral information content of Landsat TM data. Tasseled Cap transformation especially optimizes data viewing for vegetation studies. Tasseled Cap index was calculated from data of the related six TM bands [4]. Three of the six tasseled cap transform bands are often used: band 1 (brightness, measure of soil) band 2 (greenness, measure of vegetation) band 3 (wetness, interrelationship of soil and canopy moisture). The Tasseled Cap Transformation in remote sensing is the conversion of the readings in a set of channels into composite values; i.e., the weighted sums of separate channel readings. One of these weighted sums measures roughly the brightness of each pixel in the scene [18]. The other composite values are linear combinations of the values of the separate channels, but some of the weights are negative and others positive. One of these other composite values represents the degree of greenness of the pixels and another might represent the degree of yellowness of vegetation or perhaps the wetness of the soil. Usually there are just three composite variables.

The weights used in principal component analysis are determined statistically from the data but it was soon observed that typically the first principal component typically corresponded to roughly equal weights. In other words, the data generally fall along the diagonal when channel values are plotted together [19].

If the weights used in a weighted-sum transformation are equal then the values obtained are proportional to the sum of the channel values and hence correspond to “brightness.” Principal component analysis is equivalent to transforming the data to a new coordinate system with a new set of orthogonal axes [20].

The tasseled cap transformation also corresponds to a transformation of the data to a new set of orthogonal axes. While the tasseled cap transformation was inspired by the method of principal component analysis combined with generalization from empirical observations the actual details had a more analytical basis. In the other hand, the concept of tasseled cap transformation is a useful tool for compressing spectral data into a few bands associated with physical scene characteristics. Originally constructed for understanding important phenomena of crop development in spectral space [21], the transformation has potential applications in revealing key forest attributes including species, age and structure.

3.3. Brightness – Greenness –Wetness

The Brightness, Greenness, Wetness transform was first developed for use with the Landsat MSS system and called the “Tasseled Cap” transformation. The transform is based on a set of constants applied to the image in the form of a linear algebraic formula [22]. The transform developed for the MSS consisted of coefficients that extracted brightness and greenness. This was due to the spectral resolution of
the MSS that focused primarily in the visible and near infrared. Following the launch of Landsat 4 and the inclusion of the Thematic Mapper, these coefficients were recalculated to take advantage of the increased spectral resolution of the TM [23]. This allowed for the extraction of an additional component called wetness due to the inclusion of the MIR channels that are sensitive to moisture absorption. The flowchart of project showed in figure 2.

4. Results and Conclusion

A comparison of NDVI data from Landsat-7 images with land use maps of the sample watercourses, reveals that irrigated crops have a minimum NDVI = 0.3. Hence, all pixels with a NDVI less than 0.3 are excluded from receiving canal water. Isolated areas less than 5 ha that are not connected with the main irrigation system are regarded as areas being irrigated with groundwater (Fig. 3). After excluding the areas without irrigation and areas extracting groundwater only, the remaining areas are investigated for canal water use.

The AVHRR sensor series operated by NOAA provides the longest running environmental remote sensing satellite series. The potential uses include bioclimatic indicators such as various Degree Day indicators, and Winkler and Huglin indices as commonly used in viticulture (Fig.4).
(blue), 3 (red) and 2 (green). Bright red areas indicate higher values of band 4 (near infrared). NDVI, dark green areas indicate more dense photosynthetic active tissue (Fig.5).

![NDVI Image](image)

**Fig. 5.** NDVI image extracted from Band 3 and 4 of Landsat TM to 60 m in 1985.

This case study presents encouraging results about the Monitoring. According to the tasseled cap coefficient table which is acquired from tasseled cap image, this image involves 3 bands that are called as Greenness, Brightness and Wetness. The value of each of them is calculated by this formula [24]:

\[ \text{Value} = \frac{\text{DN value of each band} \times \text{tasseled cap coefficient}}{1} \]

At the end, the summation of all values will give the brightness or wetness or greenness value of that pixel (Table 2).

### Table 2. The values and results of brightness or wetness or greenness of pixel

<table>
<thead>
<tr>
<th>Classification for ...</th>
<th>Value</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brightness</td>
<td>123.453</td>
<td>In brightness the value of band 3 is higher than other bands then it means the reflectance in band 3 is more than other bands.</td>
</tr>
<tr>
<td>Greenness</td>
<td>27.398</td>
<td>In greenness the value of band 3 is higher than bands then it means the reflectance in band 3 is more than other bands</td>
</tr>
<tr>
<td>Wetness</td>
<td>-3.654</td>
<td>In greenness the value of band 2 is higher than bands then it means the reflectance in band 2 is more than other bands</td>
</tr>
<tr>
<td>NDVI</td>
<td>0.276</td>
<td></td>
</tr>
</tbody>
</table>

- The high NDVI value represents healthy vegetated area in NDVI image.
- The tasseled cap image involves greenness, brightness and wetness bands (fig. 6). The high greenness value represents healthy vegetated area in tasseled cap image. This is confirmed by overlapping NDVI classes on TC image and it is found that high NDVI areas and areas of high Greenness overlaps.
- Similarly high wetness areas overlap the low NDVI areas and high brightness areas overlap moderate NDVI areas.
- Based on the overlapping of Tasseled Cap image and NDVI image is observed, that the most of the area of healthy vegetation is located in the west part of central Zab watershed which extended from north to south.

![Tasseled Cap Image](image)

**Fig. 6.** Tasseled cap image

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**References**


