Change detection in forest land cover type using Aster and Landsat data

Wafa Nori [1] and Abdelmoneim Elgubshawi [2]

[1]Department of Forestry and Range, Faculty of Natural Resources and Environmental studies,
University of Kordofan, Elobeid, Sudan
[2]Department of soil and water science, College of Agricultural Studies, SUST, Sudan

Abstract—The objective of this study was to evaluate the potential for monitoring forest change using Landsat ETM data and Aster data for two periods (2000 - 2003 and 2003 - 2006). This was accomplished by performing three widely used vegetation indices: Normalized Difference Vegetation Index (NDVI), Soil Adjusted Vegetation Index (SAVI), and Transformed Difference Vegetation Index (TDVI). An RGB-NDVI change detection strategy to detect major decreases or increases in forest vegetation was developed as well. These indices were applied to a case study in El Rawashda forest reserve, Gedaref State, Sudan, and their results and accuracy were discussed.

Results showed that the vegetation index maps obtained by NDVI and SAVI transformations within each computational group were similar in terms of spatial distribution pattern and statistical characteristics. As far as the degree of greenness of vegetation was concerned, the TDVI appeared to be the most sensitive. For the first period, the highest accuracy was obtained by SAVI (62.5%); however, the poorest accuracy was achieved by TDVI (59.5%). For the second period, TDVI revealed the highest accuracy (60.1%), whereas both NDVI and SAVI counted accuracy of 59.2%. Generally, the study proved that all vegetation indices produced reasonable approaches to map land cover changes over time and help to pinpoint deforestation and regrowth in the study area.

Index Terms—**change detection, NDVI, TDVI, SAVI**

I. INTRODUCTION

Forests are considered among the most important natural features in the Sudan where they form, with other varying intensities of plant cover, the base for the terrestrial ecosystems of the country. Their indirect role in supporting agriculture through ameliorating an otherwise harsh climate, combating soil erosion and conserving water is well recognized by both government circles and rural societies. In spite of this unchallenged importance, accurate information on the extent and composition of the forest cover is neither complete nor reliable [6].

Change detection is the process in which temporal differences in the state of an object or phenomenon are identified [10]. It is important in monitoring natural resources as it can quantify the spatial distribution of land cover change in the area of interest. During the past 20 years, it has become a major application in remote sensing because of increasingly consistent image quality and repetitive coverage at short intervals [5].

II. METHODOLOGY

A. Study area

El Rawashda forest reserve, Gedarif State is situated at approximately latitude 14^0 15\ N and longitude 35^0 45\ E "Fig. 1," The official gazetted area is 27290 hectares. The State boarded by Kassala state to the north, Khartoum state to the northwest, Sinnar state to the south, Gezira state to the west and Eretria to the east. Its average altitude is 600 meters above the sea level. The region under consideration is about 490 km from the capital Khartoum and 770 km from Port Sudan city, the main sea port of Sudan. Thus the region's geographical position is favorable to domestic and foreign trade [7]. El Rawashda forest reserve lies in the semi–arid zone in the part of south central clay plains near to the transition between *Acacia mellifra* and *Acacia seyal-balanites* savannah woodland.

B. Satellite Data

Landsat 7 Enhanced Thematic Mapper (ETM+) data acquired on March 29, 2000, Landsat 7 Enhanced Thematic Mapper (ETM+) data acquired on March 22, 2003 and Aster data acquired on February 26, 2006 were used for analyzing an area covering approximately 1.101.789 km² as area of interest.

C. Calculation of vegetation indices as independent variables

Normalized Difference Vegetative Index (NDVI), Soil Adjusted Vegetative Index (SAVI), and Transformed Difference Vegetative Index (TDVI) were created for each image collection date at each spatial scale, and were analyzed individually. The NDVI index was used because it is the most widely used in global vegetation studies today [4]. The SAVI index was used because it was developed to minimize the influence of the soil background on the vegetative reflectance [3]. The TDVI index was used because it does not contain the saturation concerns that NDVI has and also minimizes the influence of the soil background, similar to the SAVI index [1].

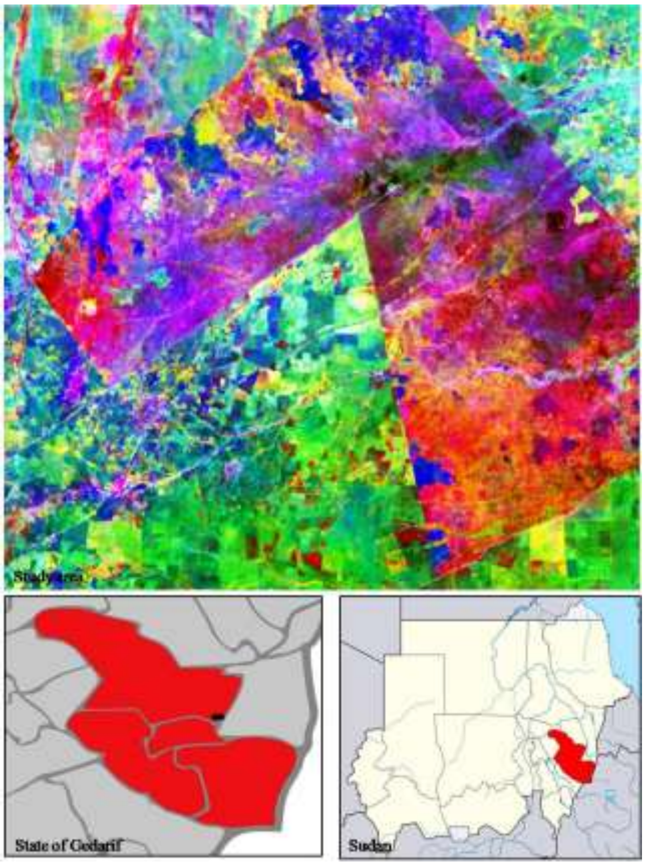

Figure 1. Location of the study area.

NDVI

The NDVI was derived from the difference between the maximum absorption of radiation in the red spectral wavelength and the maximum reflection of radiation in the near infrared spectral wavelength for each image where:

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

NDVI-RGB

Three NDVI composites for the years 2000, 2003 and 2006 were projected on a RGB axis following the RGB-NDVI change detection strategy of [9]. By simultaneously projecting each date of NDVI through the red, green, and blue (RGB) computer display write functions, major changes in NDVI (and hence vegetation cover) between dates appeared in combinations of the primary (RGB) or complimentary (yellow, magenta, cyan) colors. Knowing which date of NDVI is coupled with each display color, we visually interpreted the magnitude and direction of vegetation changes in the study area over the three dates to detect the major decreases or increases in green biomass associated with forest harvest or regeneration.

SAVI

Vegetation indices largely depend on the canopy of the forest, surface area of the green vegetation and their reflective value can be considerably affected by the reflection from the soil surface. Since the forest in the study area has a lot exposed bare ground and open forest and a sparse canopy in most areas, the SAVI index that includes a soil correction factor was used. This compensates for the relative soil effect while at the same time accounting for the amount of vegetation present. Being an open dry Acacia forest also, the effect of the soil background noise on the remotely sensed reflectance could cause giving biased strong relationship with biomass which would not be accurate. This index includes a soil adjustment factor that ranges from 0 for very high vegetation cover to 1 for very low vegetation cover. A value of L= 0.5 was used in this study and is recommended since it permits the best adjustment, by minimizing the secondary back scattering effect of the canopy transmitted soil background reflected radiation [3].

$$SAVI = \frac{(1 + L) \cdot (NIR - Red)}{(NIR + Red + L)} \quad (2)$$

TDVI

The Transformed Difference Vegetation Index (TDVI) developed by [1], was tested in this study. TDVI does not saturate like NDVI or SAVI, it shows an excellent linearity as a function of the rate of vegetation cover.

$$TDVI = 1.5 \cdot \left[(NIR - R)/\sqrt{NIR^2 + R + 0.5}\right] \quad (3)$$

D. Index Differencing

Image differencing was applied to vegetation images that were derived using three vegetation indices: NDVI, SAVI, and TDVI. In all cases, the 2000 transformed data were subtracted from 2003 transformed data and the 2003 transformed data were subtracted from 2006 transformed data, resulting in new images. A series of threshold values based on standard deviations from the mean were used on the new images to determine the changed from unchanged pixels. A visual assessment on the no-change/change pixels was performed to determine the threshold value with the highest accuracy. A process of labeling needs to occur to assign the appropriate "from" and "to" identifiers.

III. RESULTS

Vegetation index and difference images were constructed for all three vegetation indices (NDVI, SAVI and TDVI) and from all three scenes. Results showed that the vegetation index maps obtained by NDVI and SAVI transformations within each computational group were similar in terms of spatial distribution pattern and statistical characteristics. As far as the degree of greenness of vegetation was concerned, the TDVI appeared to be the most sensitive.

Change detection was performed in two ways: (I) VI differences and (ii) RGB- NDVI. The VI differences were computed from the two VI paired images, i.e., VI 2000 – VI 2003 and VI 2003 –VI 2006 and RGB-NDVI was performed using the three dates of NDVI imagery as RGB composite [9].

A. Vegetation Indices differences

Figure 2 shows vegetation index values across the study area in 2000, 2003 and 2006. As can be seen from the figure, very low index values relate to bare soil, mostly black colour that dominate in the north and in the north west of the study area, especially in the agricultural land surrounded the forest. Relatively high vegetation index values in the centre of the image represent high vegetation cover, mostly tree covers. Visual image inspection and also field checks showed that vegetation indices appear to overestimate the amount of vegetation cover in El Rawashda forest.

Changes in vegetation cover have been highlighted by subtracting 2000 vegetation index values from 2003 values and 2003 values from 2006 values "Fig. 2," Changes from 2000 to 2003 showed increased vegetation cover in the south and east south in the difference image, while changes from 2003 to 2006, showed increased vegetation cover in the centre and in the west of the differencing image. These areas provide clear evidence for management related differences in vegetation cover.

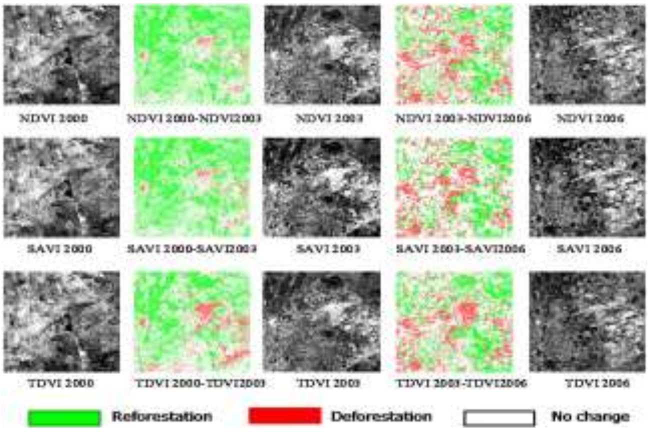

Figure 2. Resultant images of the NDVI, SAVI and TDVI transformation and image differencing.

To illustrate vegetation changes within El Rawashda forest, thresholds have been applied to the change maps to calculate the increase, decrease and no change in vegetation cover (table 5.13).

TABLE I. : THE PERCENTAGE OF INCREASE, DECREASE AND NO CHANGE IN VEGETATION COVER

VI	+ Change %	- Change %	No Change %
NDVI2000-2003	48.7	5.0	46.3
NDVI2003-2006	26.6	26.8	46.5
SAVI2000-2003	48.8	5.0	46.2
SAVI2003-2006	25.2	28.0	46.6
TDVI2000-2003	40.0	12.9	50.1
TDVI2003-2006	32.5	26.7	51.6

B. RGB-NDVI

The RGB composite based on NDVI permits to display and understand the principal environmental dynamics, distinguishing different change classes on vegetation by different colour tones "Fig. 3," Moreover it represents an important way to move across the dense forest areas allowing new clearing processes along their perimeter.

The visual comparisons of RGB-NDVI (2000-03-06) images are provided in Figure 3. Areas in red in the visual RGB-NDVI colour composites indicate forest biomass decrease between 2000 and 2006. Areas in yellow are forest biomass loss between 2003 and 2006. The cyan colour indicates the regeneration between 2000 and 2006. The magenta colour displays the reduction between 2000 and 2003 and the regeneration between 2003 and 2006. The green colour displays the reduction before 2000 and after 2006. The blue colour indicates the regeneration between 2000 and 2006. Areas in black and white indicate no change.

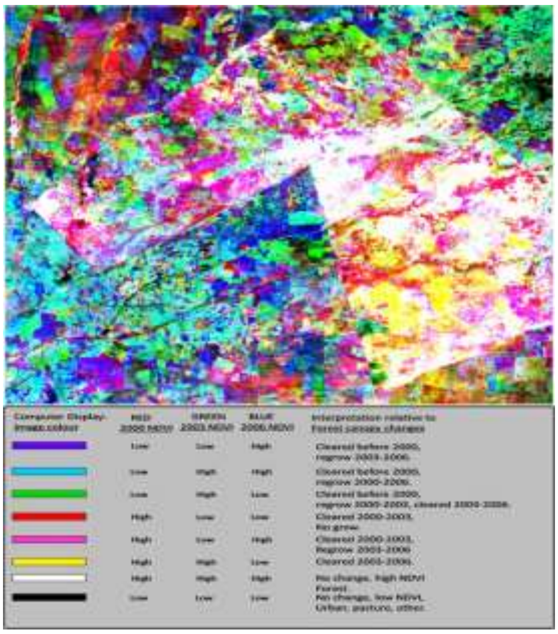

Figure 3. Simplified interpretation of three-date RGB-NDVI color composite imagery

IV Conclusions.

Within vegetation indices, NDVI and SAVI behaved similarly at detecting vegetation, whereas, TDVI showed better linearity at the function of the rate of vegetation cover, this may be attributed to the fact that TDVI does not saturate like NDVI or SAVI. Similar results have been reported in [8].

An RGB-NDVI change detection strategy to detect major decreases or increases in forest vegetation was developed as well. This method avoids the need of setting a predefined histogram threshold, but it obviates the need for a high degree of a priori knowledge and requires substantial a posterior interpretation. In this study the accuracy assessment of this method was not counted, it was only visually assessed and found to be more effective than NDVI image differencing as it distinguish different change classes on vegetation by different colour tones. The result achieved by this study corresponds to those from the literature, [2] found the RGB-NDVI method to be more accurate than NDVI image differencing and principal component analysis

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