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Change Vector Analysis for Analyzing and Mapping Desertification Processes in Arid and Semi-arid Region, North Kordofan State, Sudan

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North Kordofan is a region, characterized by a fragile ecosystem, contributes significantly to Gum Arabic production and export portfolio in the country. The region endures intensive land-use pressures and is highly sensitive to climate fluctuations. Studying desertification processes in such areas needs more and high advanced techniques. In this context, the study area endures intensive land use pressures, and the vegetation cover is more heterogeneity and highly sensitive to climate fluctuations. The overall objective of the current paper is to detect and map the desertification processes in North Kordofan region by applying remote sensing techniques. Three Landsat MSS, TM and ETM+ scenes covering the study area were selected for analysis. The images data were acquired in dry season in 1976, 1988 and 2003, respectively. In order to assess the land cover types in the region, multi-temporal satellite data and change vector analysis was adopted. The paper concluded that the change vector analysis and Landsat data appeared to be a reliable and low-cost technique for analyzing and mapping desertification processes in the arid region of Sudan.

Introduction

Arid and semi-arid regions are ones of the most active areas of environmental research [10]. A key characteristic of most arid ecosystems is that the relation between vegetation dynamics and environmental variations in climate, soils and human disturbances [11]. Remote sensing has been suggested for long time as a cost-efficient method for monitoring change in arid environments. In this capacity, there are many efforts in the development of different remotely sensed methods for monitoring and providing information on dry land degradation [2] [7]. There are several factors affecting accurate retrieval of vegetation parameters in arid regions using remote sensing. Furthermore, remote sensing of arid regions is difficult and needs innovative techniques [6] [7]. The spatial complexity of arid regions restricts the use of traditional remote sensing approaches [5] [9]. This is mainly because the changes in geographical location often do not indicate structural or functional variations. Although studies at the global scale have documented changes in ecosystem in arid lands, there has been a shortage of global ecological information on dry lands. Accordingly, many other means of mapping and monitoring the changes in arid regions have been developed [1] [4]. The nature of digital data allows for greater comparative capabilities of multi temporal analysis in comparison to traditional mapping methods. Change Vector Analysis (CVA) is an effective approach for detecting and characterizing land cover changes. CVA was introduced by [3] [8] the vector describing the direction and magnitude of change from the first to second date is a spectral change vector. This paper is aimed to combine CVA and multi-temporal Landsat analysis to detect and analysis the desertification processes in North Kordofan State.

Material and Methods

Study Site

The study site is located in arid and semi-arid zone, in North Kordofan State, (Figure. 1). It located between 13º33' and15º21' N and longitude 29º01' and 30º33' E. The study area lies mainly within a sand belt, stabilized and disturbed sand dunes are covering most of the northern and eastern part of the study area. The climate is dominantly prevailing arid and/or semi-arid – desert climate with limited and seasonal rains. The mean annual rainfall ranges from 100mm to 350mm. The vegetation cover is dominate by the common trees and shrubs are *Adansonia digitata*, *Acacia senegal*, *Acacia mellifera*, and *Acacia tortilis*.

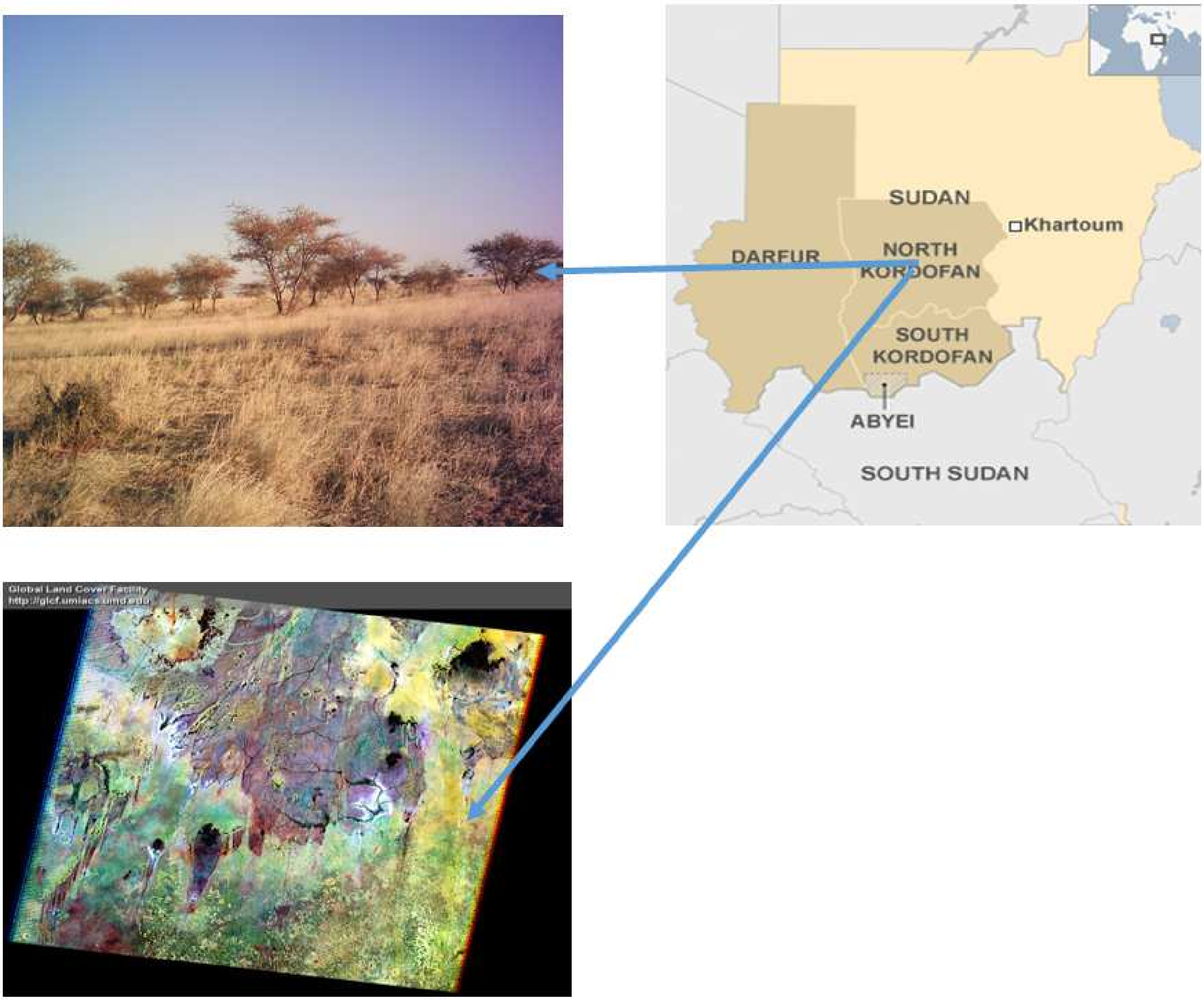

Fig. 1. *Location of study site (landsat ETM+ 2003 of study area).*

Data Acquisition and Image Processing

Three Landsat MSS, TM and ETM+ scenes covering the study area were selected for analysis. These images data were acquired in January, (dry season in the study area) in 1976, 1988 and 2003, respectively. TM and ETM+ imageries were acquired in seven and nine bands respectively, they covering the visible, near and middle infrared region of the electromagnetic spectrum. The two images, TM1988 and ETM, were geometrically corrected. Geo-referencing was provided by selecting and applying ground control points (GCPs). Nearest-neighbor re-sampling technique was used. The root mean square (RMS) error of georeferencing is approximate 0.5 pixels. Subsets of the study area were selected.

Principal Component Analysis (PCA)

Principal Component Analysis (PCA) was applied to the three images MSS1976, TM1988 and ETM+2003 to quantify the dimensionality and topology of the spectral mixing space of the images. The principal component rotation minimizes the correlations among dimensions so that the resulting principal component bands (PCs) represent orthogonal components of diminishing variance. The accompanying eigenvalue distribution provides a quantities estimate of the variance partition between the signals versus the noise dominated principal components of the image.

Change Vector Analysis (CVA)

There are many well developed techniques for land cover change detection using digital remotely sensed imagery. The nature of digital data allows for greater comparative capabilities of multi temporal analysis in comparison to traditional mapping methods. Change detection analysis approaches can be broadly divided into either post -classification change methods or pre-classification spectral change. In This paper two approaches were conducted to evaluate the variation in land use and land cover (LULC). The first approach was visual interpretation of the land cover elements in the different years by using RGB composite for displaying feature images of the three years 1976, 1988 and 2003 as blue green and red. The second approach consisted in change derived from the image (image endmember) and PCA analysis. Vector Analysis (CVA) is an effective approach for detecting and characterizing land cover change. The vector describing the direction and magnitude of change from the first to second date is a spectral change vector. Time trajectory is represented as a vector in multidimensional measurement space. In this study the magnitude of vectors was calculated among spectral changes between the endmember fractions images of dates 1976/1988 and 1988/2003 respectively. The magnitude of the vector was calculated from the Euclidean Distance and represented the difference between the pixel values of the fraction images for sand soil and vegetation cover respectively between the dates 1976/1988 and 1988/2003. It is shown in equation (1) as follows:

$$R = \sqrt{(yb-ya)^2+(xb-xa)^2+........} \qquad eq(1)$$

Where:

R Euclidean Distance

ya sand soil from date 2 xa vegetation cover from date 2

yb sand soil from date 1 xb vegetation cover from date 1

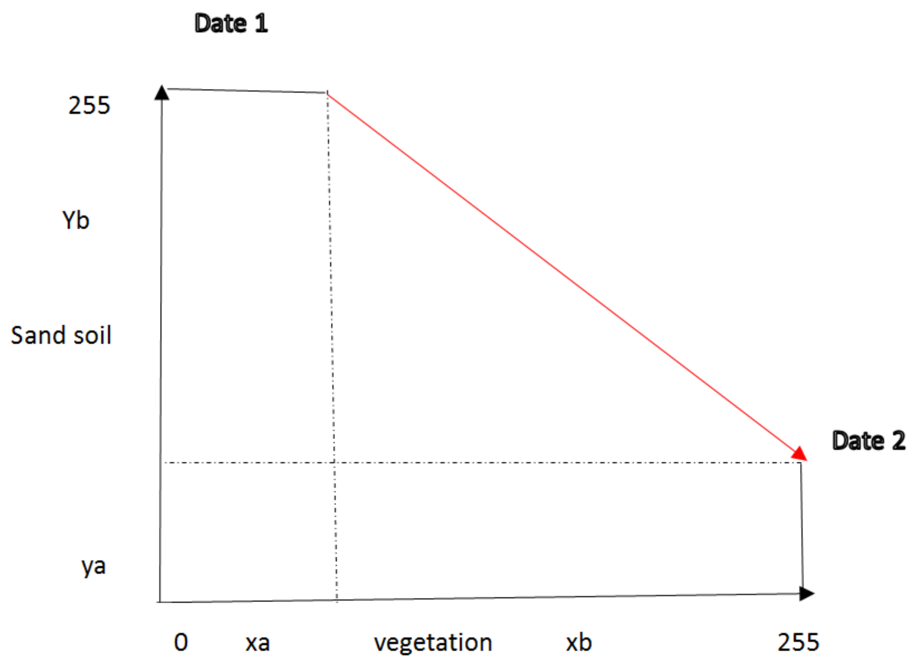

Fig. 2a. *Change vector obtained from the position variation of the same pixel in different data-takes.*

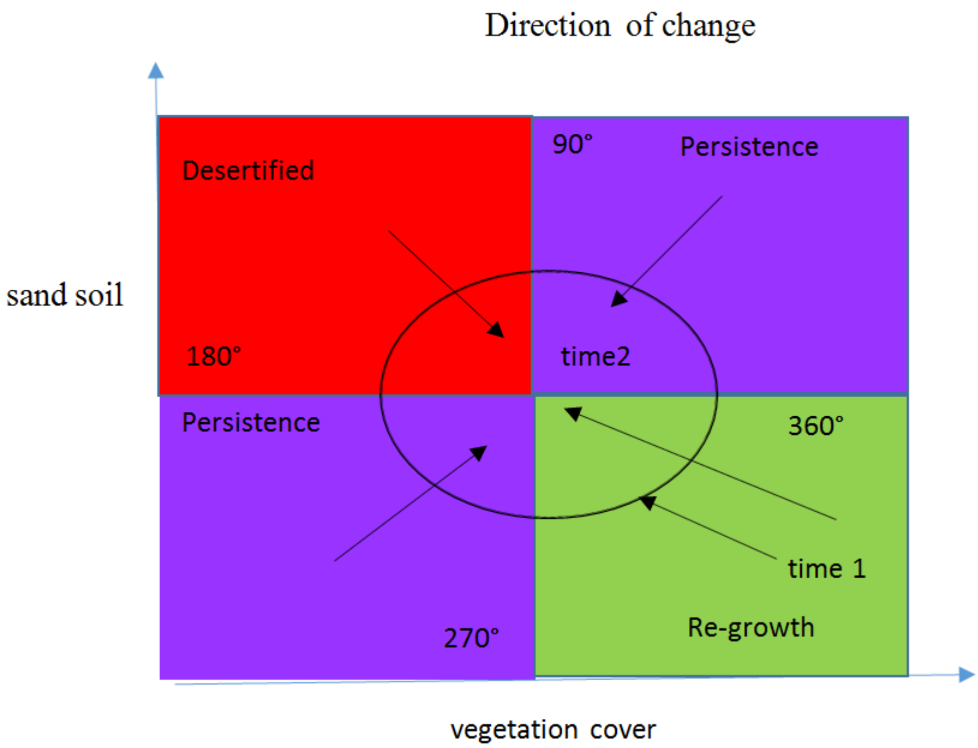

Fig. 2b. *The process for detecting the direction of change with the change vector analysis.*

Change direction is measured as the angle of the change vector from pixel measurement at time 1 to the corresponding pixel measurement at time 2 (Figure 2a & 2b). Angels measured between 90° and 180° indicated an increased in soil and decreased in vegetation cover and this means increased of desertified areas. Angels measured between 270° and 360° indicate a decreased of sand soil and increased of vegetation cover and this means re-growth of vegetation cover. Angels measured between 0° to 90° and 180° to 270° indicated either increased or decreased in both of sand soil and vegetation cover. This change is represented as persistence or stable areas, which is representative of either an increase or decrease in sand soil and vegetation in the study area.

Results and Discussion

The resulting images of CVA are an image of magnitudes and directions of the changes. The change detection image was generated from the colour composite of the magnitudes, angle of change direction in vegetation fraction. Since only sand and vegetation fractions were applied in this analysis, only three possible classes of change were being recognized. Desertified class characterised by increasing of sand fraction and decreasing in vegetation fraction, this is measured by positive angle of sand class and negative angle of vegetation class. Re-growth class was characterised by increasing of vegetation cover and decreasing of sand soil. Persistence class was indicated by simultaneous increasing or decreasing in both sand and vegetation fractions. The examples of the change classes are presented in (Figure 3) between 1976 to 1988 and 1988 to 2003 respectively. The threshold of final magnitude was defined and hybrid unsupervised/supervised classification approach was used to classify the image of change vector and angles. The classified image of magnitude and direction images with reference to the years 1976 and 1988 (Figure 3) highlights an intensive dynamics related to the different classes during this periods characterised by the increasing of sand soil and decreasing in vegetation cover in the study area. Table 2 shows that desertified class covers about 83.35% of the total area. Meanwhile, the re-growth and persistence classes cover only 12.2% and 4.4% respectively. This indicates the trend of increasing of sand encroachment in the study area during this period.

Table 1. *Distributions of classes of change image 1976 and 1988.*

Class Name	Area (ha)	Area (%)
Desertified	1979149	83.3
Re-growth	289935.5	12.2
Persistence	105944.6	4.4
Total	2375029.1	100

The change image referring to years 1988 and 2003 (Fig 3) reflects different patterns of change in desertified and re-growth classes. Desertified class appears to have very high intensity in northern part of the study area. Meanwhile re-growth class increased in the southern part of the study area. Contrasting change map of 1976 and 1988 indicates increasing in the re-growth class in the study area in addressed period. Table 2 shows re-growth class covers 17.9 % in periods of 1988 and 2003 compared to only 12.2% in period 1976 and 1988. Nevertheless, desertified class is decreased to 60.9% during the periods 1988-2003 from 83.3% during the period 1976-1988. Period 1988 to 2003 in comparison with period 1976-1988 witnessed decrease in desertified areas and increase in re-growth areas.

Table 2. *Distributions of classes of change image 1988 and 2003.*

Classes Name	Area (ha)	Area (%)
Desertified	1446212	60.9
Re-growth	426821	17.9
Persistence	499783.2	21.1
Total	2372817	100

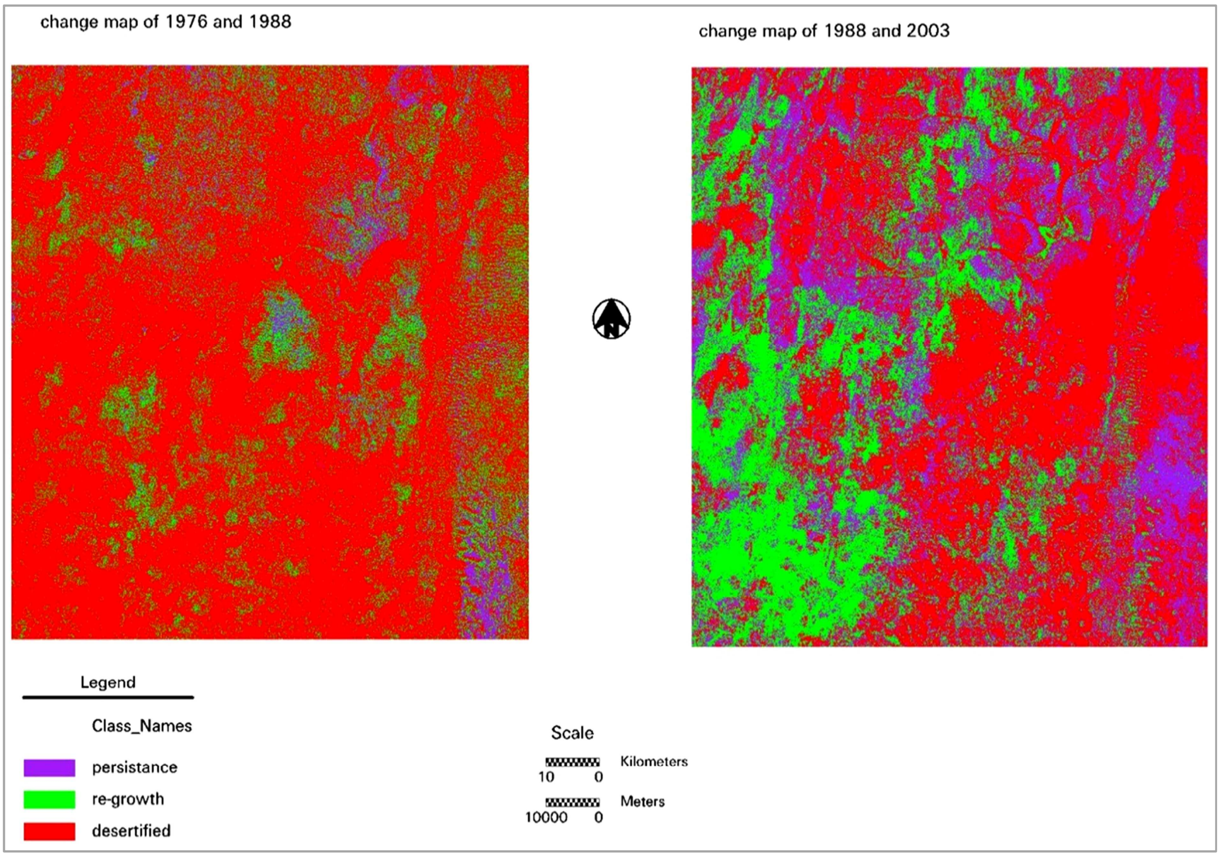

Fig. 3. *Classified image of CVA for periods 1976-1966 and 1988-2003.*

Conclusions

- Applying of change vectors analysis allowed more efficient for detection and quantification of desertification processes in the study area during the addressed periods. VCA conclude the increasing in desertified areas from 1976 to 1988, meanwhile the re-growth areas are increasing from 1988 to 2003 period.
- Application of multi-temporal remote sensing data (MSS, TM and ETM+) and VCA on this study demonstrated that it is possible to detect and map desertification processes in the study area as well as in arid and semi-arid lands at relatively low cost. ■

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