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Assessing the Impacts of Land Use Changes on Vegetation Cover in Eastern Sudan

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Abstract — **This paper an attempt has been made to investigate and monitor the Impact of Land Use and Land Cover (LULC) changes in the eastern part of Sudan (Gadarif state) by using multi-temporal Landsat data for the years 1986, 1994 and 2013. LULC grades in the classification scheme are; Forest, Mechanized Rain-fed Agriculture (MRA), Irrigated land, Rangeland, Settlement and Water. Individual classifications based on maximum likelihood of algorithm is employed. The results showed that a significant extensive change of LULC patterns has occurred during the previous years within the study area. The major trends were drasticed conversions of natural vegetation into large-scale MRA which increased from 1058241.2 ha in 1981 to 2459264.7 ha in 2013. This resulted in a progressive loss and degradation of Rangeland areas in Gadarif state; Rangeland was decreased from 4342154.2 ha in 1986 to 3473940 ha in 2013. Forest area and Rangeland are reduced due to of expansion in modern mechanized farming as a result of increasing human population to satisfy an increasing demand for food.**

Keywords — ***R*emote Sensin, Land Use and Land Cover Change, Sudan, Gadarif State**

I. Introduction

Climate Change is a global threat to natural resources and livelihoods of human societies, compounded by increase in anthropogenic activities. It was calculated that the increase of fossil fuel use will increase global warming and lead to the extinction of civilizations over the coming centuries [1]. The findings of the Intergovernmental Panel on Climate Change (IPCC) [2] reported that the climate change is already having strong impacts on human societies and the natural world, and is expected to do so for decades to come. More severe and longer droughts have been observed since the 1970s over tropical and subtropical areas according to [2], as such drying trend has been linked to higher temperatures and increased evaporation.

A plausible warmer world with longer and more severe droughts could lead to rapid collapse of tropical forest communities converting them from a net carbon sink into a large carbon source with cascading ecosystem effects affecting global climate-vegetation feedbacks [3]. Sudan is one of the driest but also the most variable countries in Africa in terms of rainfall. Extreme years (either good or bad) are more common than average years [4]. Recently, [5] defined that the climate changes as a change of climate elements which is attributed directly or indirectly to human activities (e.g. industrialization) which consequently alter the composition of the global atmosphere. Also natural climate variability has been observed over comparable time period. Noticeably, these changes in the climate have already caused many crises in natural ecosystems including Savanna arid lands of Sub-Saharan Africa.

In Gadarif State, Sudan, the Ministry of Agriculture documented that the cultivated areas were substantially increased and the productivity was dramatically decreased over the last few decades due to the effect of elevated temperature and variability and shortages in rainfall. The vegetation cover in these areas has also been affected by such harsh conditions and change in the climate. These effects included certain areas and species vulnerable to these changes, which has led to decline in their abundance and diversity. Given these agricultural expansions in forest areas and drought occurrences, it became of high priority to assess the rate of changes in vegetation cover over time in these dry lands. The findings of these assessments are very essential and useful in planning for conservation and rehabilitation efforts.

Therefore, the main objective of the present study is to evaluate the changes in LULC in Gadarif state during the last three decades using remote sensing techniques. Specific period covered and satellite images used in this study were for the years 1986, 1994 and 2013.

II. Data and Methods

A. Study area

Gadarif state, located in eastern Sudan between latitudes 12° 48' and 15° 50' N and longitudes 33° 40' and 36° 47' E, covers an area of about 6225794.91 ha, as shown in **Fig. 1**. The state is characterized by semi-arid climatic conditions with an aridity index ranging from 0.2 to 0.4, as reported by [6]. The vegetation of the study area largely depends on rainfall. According to [7] Gadarif area lies in the low rainfall woodland savannah belt on clay soil and the vegetation composed of great diversity of trees, shrubs and grasses. The average temperature of this region varies between a mean minimum of 22 °C in winter and a mean maximum of 37 °C in summer. The highest temperature in the study area is reported between April and May. Given the availability of temperature and rainfall measurements both temporally and spatially, these data are commonly used to characterize the climatic state of the territory (e.g. [8-11]).

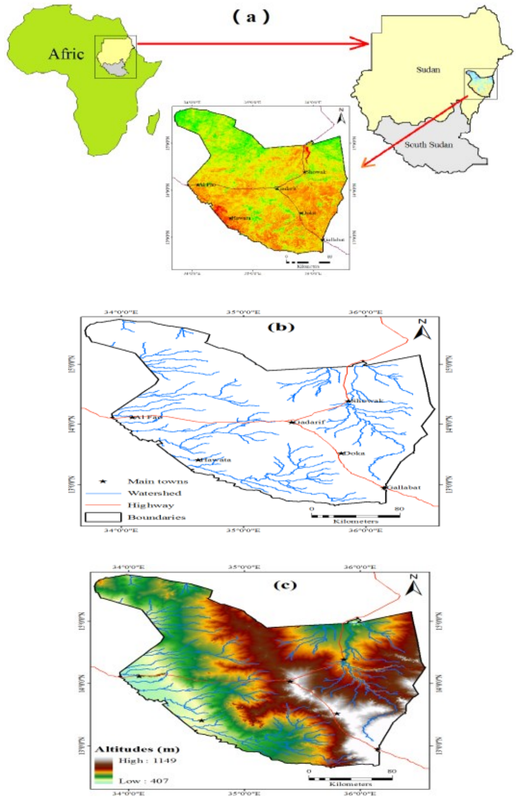

Fig. 1 location of the Study area - Gadarif state, Sudan Source of DEM data: http://srtm.csi.cgiar.org/ , resolution of 90 m * 90m

B. Satellite images

Thematic Mapper (TM) and Operational Land Imager and Thermal Infrared Sensor (OLI/TIRS) multi-spectral images are the main remote sensing data used in current study. Multi-temporal Landsat imagery for Gadarif state for the years 1986, 1994 and 2013 was used in this study. The technical details of Landsat 4-5 TM and Landsat 8 OLI/TIRS bands have been provided in **Table 1**. For other specification of Landsat satellite; refer to the official portal of Landsat (Landsat Program, NASA web). The Landsat TM and OLI/TIRS scenes of path and row of Gadarif state was downloaded from USGS web http://earthexplorer.usgs.gov/ then analyzed including classification to different land use categories. Post-classification is a term describing the comparative analysis of spectral classifications for different dates produced independently [12].

Despite criticisms focusing on accumulation of the inherent errors of each individual classification, this is the most appropriate method for comparing multi-source data, as each data layer can be generalized to a common LULC scheme before being compared [13]. In order to quantify changes of certain LULC type during certain time period, we used the following formula:

$$LULCC = \frac{LULC_b - LULC_a}{LULC_a} \times \frac{1}{T} \times 100\%$$

Where $LULCC$ is the rate of change of a certain land use and land cover ($LULC$) type for a certain time period; the subscripts a and b denote the beginning and the end of a time period for $LULC$ change investigation, respectively; and T is the time period. A positive value means that there is an increasing trend for a specific time period for an area of a certain $LULC$ type; otherwise, negative values implies deceasing trend for the area assessed.

Table 1. Properties of the data used in the study

Acquisition Date	(Satellite) Sensor	Spectral bands	Ground resolution (m)
1986	Landsat 4-5 TM	3-5	30
1994	Landsat 4-5 TM	3-5	30
2013	Landsat 8 OLI/TIRS	4-6	30

- TM= thematic mapper; OLI= Operational Land Imager and TIRS and Thermal Infrared Sensor

In this study the ERDAS IMAGINE 9.2 image and Arcgis 9.3 software's were used for overall image processing. Using the nearest neighbour method, images were resampled into a pixel size of 30 * 30 m. Amulti-date PCC based change detection algorithm is used to determine the LULC changes in four periodic intervals: 1986 to 1994, 1994 to 2013 and 1986 to 2013.

Post-classification comparison (PCC) is a quantitative method that used for independent classification of individual images for these three years for the same geographic location. It is the most commonly used method for LULC change detection mapping [18-19]. For LULC classification scheme, six level classes were adopted in **table 2**.In order to identify and quantify areas of changes, PCC procedure compares corresponding pixels (thematic labels) for each of the two times under consideration (e.g. [14-17]).

Table 2. Description of LULC classes identified in the study area

LULC classes	Descriptions
Forest	All wooded areas with (75-300 trees/ha). This class includes trees and shrubs.
MRA	Areas currently under crop or land being prepared for raising crops. Agriculture field with no such regular pattern like irrigated land.
Irrigated land	A regular pattern of land, and can be seen very clearly in the image.
Rangeland	This class includes grazing land, area with no vegetation such as bare soil, sand (excluding MRA and Irrigated land), where soil is clearly apparent
Settlement	Area with man-made structures and activities.
Water	Reservoirs and Rivers.

III. Results and Discussion

A. Classification Accuracy Assessment and LULC Mapping

In this study, the image-processing approach is found to be effective in producing compatible LULC data over time, irrespective of the differences in spatial, spectral and radiometric resolution of the satellite data. According to the produced LULC map, **Fig. 2** shows that the Forest, MRA, Irrigated land, Rangeland, Settlement and water the dominate types of LULC classes for the years 1986, 1994 and 2013.

Table 3 shows the percentages of LULC classes in the year 1986. Forest, MRA, Irrigated land, Rangeland, Settlement and water have occupied 4, 24.7, 1.2, 69.7, 0.1 and 0.2 per cent of the study area, respectively. In 1994 same types occupied 3.5, 30.4, 1.2, 64.5, 0.2 and 0.3 per cent of the study area, respectively. In 2013 occupied 2.5, 39.5, 1.4, 55.8, 0.6 and 0.3 per cent of the study area, respectively. Noticeably, there is significant increase in the area of MRA from 24.7 per cent in 1986, to 30.4 in 1994, to 39.5 in 2013. Oppositely, forest area has witnessed dramatic decline as its area reduced from 4 per cent, to 3.5 per cent to 2.5 per cent in the years 1986, 1994 and 2013, respectively.

This significant increase in the area of MRA coincidently with shrinking in forest area indicates deforestation and clear-cutting for trees for agricultural expansion, which has been a continuing trend in the study area. In addition to MRA expansions, also in fact, many people in Sudan including Gadarif state remove considerable number of trees for firewood and building materials. [20] Reported that agriculture is the main economic activity, followed by livestock raising in the traditional seasonal pattern. Also as shown in **table 3,** a large decrease in Rangeland 69.7, 64.5 and 55.8 per cent is observed, respectively in 1986, 1994 and 2013 of the study area which it may risks livestock raising in the area. On the other hand, human Settlements is observed in the study area from 0.2, 0.3 and 0.6 per cent during these three periods. Overall, during the period of the study, natural vegetation (i.e. forests and rangelands) have been significantly cleared and disadvantaged for the MRA and crop supply.

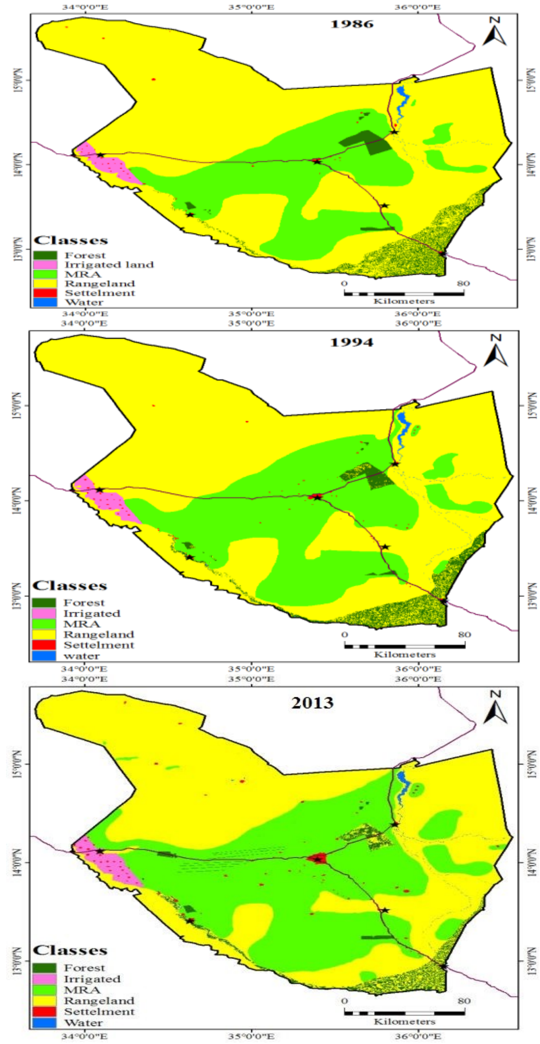

Fig. 2 LULC map in 1986, 1994 and 2013

Table 3. Areas and percentages of LULC classes for the period 1986 - 2013

	LULC classes	1986		1994		2013	
		Area (hectare)	Area (%)	Area (hectare)	Area (%)	Area (hectare)	Area (%)
1	Forest	249245	4	215689.2	3.5	154791	2.5
2	MRA	1538596.6	24.7	1890756.3	30.4	2459264.1	39.5
3	Irrigated land	72742.4	1.2	74034.7	1.2	84958.4	1.4
4	Rangeland	4342154.2	69.7	4014748.1	64.5	3473940.0	55.8
5	Settlement	8657.8	0.1	13317.5	0.2	35518.8	0.6
6	Water	14398.8	0.2	17249.1	0.3	17322.7	0.3
	Total	6225794.91	100	6225794.91	100	6225794.91	100

Table 4. Change detection (per cent) of LULC for the period 1984 to 1994

	LULC classes	Forest	MRA	Irrigated land	Rangeland	Settlement	Water
1	Forest	**50**	6	0	44	0	0
2	MRA	0	**99**	0	1	0	0
3	Irrigated land	0	1	**95**	3	1	0
4	Rangeland	2	8	0	**90**	0	0
5	Settlement	1	19	11	16	**53**	0
6	Water	0	0	0	5	0	**95**

Data in bold represent unchanged fractions of each class

Table 5. Change detection (per cent) of LULC for the period 1994 - 2013

	LULC classes	Forest	MRA	Irrigated land	Rangeland	Settlement	Water
1	Forest	**39**	10	0	50	0	0
2	MRA	1	**98**	0	0	1	0
3	Irrigated land	0	0	**96**	1	2	0
4	Rangeland	1	15	0	**84**	0	0
5	Settlement	0	12	3	7	**78**	0
6	Water	0	0	8	0	0	**91**

Data in bold represent unchanged fractions of each class

Table 6. Change detection (per cent) of LULC for the period 1986 - 2013

	LULC classes	Forest	MRA	Irrigated land	Rangeland	Settlement	Water
1	Forest	**33**	13	0	54	0	0
2	MRA	1	**97**	0	1	1	0
3	Irrigated land	0	0	**96**	1	3	0
4	Rangeland	1	21	0	**77**	0	0
5	Settlement	1	16	8	14	**61**	0
6	Water	0	0	0	8	0	**92**

Data in bold represent unchanged fractions of each class

B. LULC change analysis

There are several methods exist to study LULC change [21-22]. Using PCC method [23], images for the three years were classified separately for change detection in the study area based only on the information contained in each image. With the help of this method thematic maps of two dates are compared on pixel-by-pixel basis to extract the change that may have occurred between certain time periods. There exist four LULC classes in classified maps and every class is represented by one unique code (i.e. pixel value) range from 1 to 4. To detect the change from 1986 to 1994, the LULC 1986 map is multiplied with 10. Then both images for 1986 and 1994 added together. All other pixel values show the change that occurred in the image. Same procedure was adopted to detect the change from 1986 to 1994, 1994 to 2013 and 1986 to 2013.

In the study area, LULC classes have changed significantly. Changes are normally quantified per pixel counts, areas or percentages. Different classes are represented as different colures in each image, making it easy to identify not only where changes have taken place but also the class into which the pixels have changed. The change detection statistics for three decades of the study area is presented in **tables 4-6**.

Fig. 3 captured the post classification change analysis for 1986 to 1994, 1994 to 2013 and 1986 to 2013 image classification. The statistics in **tables 4-6** show that the MRA areas have increased significantly, covering approximately 6, 10 and 13 per cent of the Forest for the year 1986 to 1994, 1994 to 2013 and 1986 to 2013, respectively, [24] reported that the Trees class in El Rawashda forest, that is that the largest forest in Gadarif state is decreased, while MRA category is increased. Also MRA areas have increased significantly, covering approximately 8, 15 and 21 of the Rangeland for the year 1986 to 1994, 1994 to 2013 and 1986 to 2013, respectively.

[25] reported that the present natural forest in Sudan is estimated to have declined to approximately 0.8 billion m² standing crop, while it was 2.4 billion m² in mid seventies. Since the time when reservation of natural forests started in 1932, the policy was to concentrate on the management of forests reserves under government control, to organize felling program, protection, conservation, development and management. [26] mentioned over-grazing is among the causes of desertification in Sudan. Land degradation is a global problem associated with desertification, loss of biological diversity and deforestation in dry lands, which covers some 47 per cent of the Earth's surface.

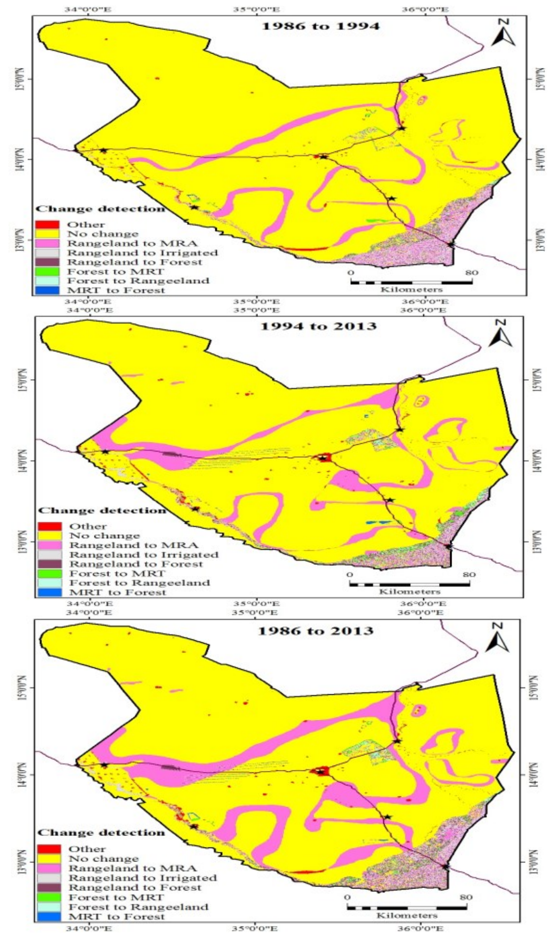

Fig. 3 Post classification change analysis for 1984 to 1994, 1994 to 2013 and 1984 to 2013 image classification.

The statistics in **table 7 and Fig. 3** showed that the percentage of Forest decreased -1.7, -1.5 and -1.4 during the 1986 to 1994, 1994 to 2013 and1986 to 2013, respectively. On the other hand the MRA has increased 2.9, 1.6 and 2.2 during the 1986 to 1994, 1994 to 2013 and1986 to 2013, respectively. According to **table 8** showed the conversion of classes of Forest to MRA is 14172, 22354 and 32393 hectare in 1986 to 1994, 1994 to 2013 and1986 to 2013, respectively. Also there is a large conversion from Rangeland to MRA as 358077, 584233 and 928991 ha in period of 1986 to 1994, 1994 to 2013 and1986 to 2013, respectively.

Table 7 LULC change rates (%) for the three study sites

	LULC classes	1986 to 1994	1994 to 2013	1986 to 2013
1	Forest	-1.7	-1.5	-1.4
2	MRA	2.9	1.6	2.2
3	Irrigated land	0.2	0.8	0.6
4	Rangeland	-0.9	-0.7	-0.7
5	Settlement	6.7	8.8	11.5
6	Water	2.5	0.0	0.8

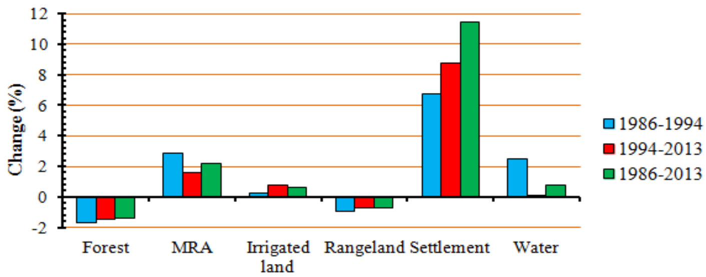

Fig. 7 Annual LULC change rates (%) for the three study sites

Table 8 Conversion of classes from one class to other one

	LULC classes	1986 to1994 (hectare)	1994 to 2013 (hectare)	1986 to 2013 (hectare)
1	Forest to Rangeland	110965	108154	135179
2	Rangeland to Forest	88059	55890	63816
3	Rangeland to MRA	358077	584233	928991
4	Forest to MRA	14172	22354	32393
5	MRA to Settlement	5145	17108	19459
6	Rangeland to Settlement	2460	5902	8340
7	Rangeland to Irrigated land	3882	10657	12776
	MRA to forest	3877	13940	9817

IV. Conclusions

Deterioration and decline rate of vegetation cover is terribly occurring throughout the last thirty years. Specifically in Gadarif state large tracts of the forests and rangeland were converted to cultivation. The overall forest area and Rangeland have reduced because of expansion in modern mechanized farming as a result of increasing human population to meet the increasing demand for food. Also trees feeling by local communities for woods and other livelihoods have contributed to this decline in forest cover.

The nomads usually have no alternatives for animal fodders except lopping trees during the dry season and feeding on young regeneration throughout the rainy season. Apparently this may have contributed to this forest cover decline as well. Current information on the status of vegetation cover and changes in its area, composition and structure is limited as well as the synergistic impacts from the observed climatic variations in the study area.

During the last four decades progressive changes within the environment occurred as a consequence of forest and grassland conversion into agricultural lands. This study recommends detailed investigations on the most affected trees species and thier diturbution by such rapid land use changes and clearance.the interactive effects of the anticipated climatic changes in the study araea should be an area of prioraty research. Also further studies on drought prediction using future climate scenarios in Gadarif state will be useful conservation and reabilitation plans.

Finally, despite there are legislations requiers farmers to cultivate 10% of the agricultural schemes with forest trees, unforteanately these laws are not effective and majority of the farmers don’t obey it. Therefore, on the light of our findings we strongly urge governmental agencies to enforce this law and closly monitor its implimentation.

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