American Journal of Environment and Sustainable Development
Vol. 5, No. 1, 2020, pp. 1-5
http://www.aiscience.org/journal/ajesd

Multi-temporal Landsat Images for Land Use Land Cover Changes in Sinnar State, Sudan

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Abstract

The current paper aims to quantify and describe the spatial and temporal patterns of Land Use Land Cover Change LULCC in Sinnar State - Sudan using Remote sensing RS and GIS technology between 2000 and 2016. Multi-temproal landsat data as well as pixel-based classification were used for analysis. The result was clearly indicated that the largest relative land cover change was the increase of Rain-fed Agriculture RfA and decreasing of forest cover. The result showed that RfA from 2000 to 2016 was increased by approximately from 256719 feddan in 2000 to 297726 feddan in 2016. Meanwhile, the Forest cover was decreased from 28253 feddan in 2000 to 12117 feddan in 2016. It well noticed that the largest relative change for the period 2000 and 2016 in the study area covered by RfA practices. This paper showed successful applications of multi-temporal landsat data and pixel based classification techniques in assessing and mapping the LULC in the study area. In addition, land cover information may also help decision-makers to understand and respond appropriately to emerging environmental risks for the inhabited people.

Keywords

Landsat Images, Pixel-based Classification, LULCC, Sinnar State-Sudan

Received: January 25, 2019 / Accepted: August 7, 2019 / Published online: January 14, 2020

1. Introduction

Sudan is a rich country such the forest resources are among them. They play a vital role in the economy and welfare of the people. Forest provides a wide range of benefits including firewood for energy, pole and sawn timber beside non-wood forest products like Gum Arabic. The forest cover in Sudan is estimated to be 12% of the total area of the country while it was 18% during early 1980 and 36% during 1950 [1]. The land use illustrates the purpose of land reserves such as recreation and agriculture. Its applications include baseline planning and subsequent monitoring where the required information provides timely knowledge of current quantity and knowledge of changes [2, 3]. The Land use Land Cover Change (LULCC) is important research to assess the changing in the Earth [4-6]. The terms LULCC used interchangeably in the study of detection and understanding of the change, but they differ in their actual meaning and are quite distinct where the ground cover shows the surface cover on the ground of various kinds and has an importance in the management of resources and planning [7]. The occurrence of changes can be caused by a number of factors such as forest, flood, soil erosion, pasture that have never been planned and much more [8]. RS is the acquisition of information about an object or phenomenon without making physical contact with the object and thus in contrast to on-site observation. Works in a number of areas, such as geography and land surveying and has applications in the military, commercial and human and many others [9]. RS works for many important purposes as well to evaluate habitat structure and LULCC in large areas [10]. There are a number of RS systems, including optical and other. The optical devices used in extracting information on the Earth's properties are Land sat-MSS, ETM +, TM [11]. The expression of “land use” and

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"land cover" are very frequent and can be easily confused. However, both definitions are important. Land cover points to the biophysical attributes of the Earth's surface whereas land use is the human purpose or intent applied to these attributes on the way the land cover is used [12].

This paper aims to quantify and describe the spatial and temporal patterns of LULCC in Sinnar locality using RS and GIS technology between 2000 and 2016. Although, Sinnar State is rich in many natural resources, but there is an overlap and miss uses of land such as agriculture, grazing and others. This has led to reducing the forest degradation and desertification processes. Assessing and mapping the accurate patterns of LULCC in such, areas can support and help can form future LULC planning as well as forest management and conservation.

2. Material and Methods

2.1. Study Area

Sinnar State is located in central-east of Sudan between longitudes 32°58 - 35°42' E and latitudes 12°5' - 14°7' N. The study area is characterized by semi-arid environments; the rainy season is confined more or less between June and October. In November, a transition period occurs towards the winter dry season that ends in February, while the summer's dry months span from March to May. The daily temperature is usually above 30°C and relative humidity more than 20% [13]. The State has a different kind of tree species; these species are able to cope in such conditions in this particular zone include short thorny trees e.g. *Acacia mellifera* (Kitir), *Acacia seyal* (Talih), *Acacia senegal* (Hashab) and *Balanites aegyptiaca* (Heglig). Together, natural forests and rangelands occupy more than 12% of the total land area of the state [14]. The soil in Sinnar state predominantly consists of dark alkaline clay soil. It is sticky during a wet season but develops wide and deep cracks once it is dry due to the high content of the expansive clay mineral montmorillonite [15]. More than 75% of who live in rural areas. Agriculture is considered as the main economic activity in the state, as the majority of people depend on it for securing their livelihoods [16].

2.2. Data Collection

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 for the years 2000 and 2016 type of GeoTiff. One Land sat satellite image located by path/row 172/51 was used; the image was downloaded a free cost from https://earthexplorer.usgs.gov (See Table 1).

Table 1. Properties of the landsat data used for analysis.

Acquisition Date	Satellite Sensor	Spectral bands	Ground resolution (m)
2000	Land sat 4-5 TM	3 to 5	30
2016	Land sat 8 OLI/TIRS	4 to 6	30

2.3. Data Analysis

The classification was divided into five land cover categories included: Bare land (Bl), Settlements (S), Forest (F), Rain-fed Agriculture (RfA), and Water (W). In this research, the Erdas imagine v 8.5 and Arcmap v 10.2 were used. Unsupervised classification (commonly referred to as clustering) is an effective method of partitioning remote sensor image data in multispectral feature space and extracting land cover information. LULC between 2000 and 2016 was detected using post-classification as it is a term describing the comparative analysis of spectral classifications for different dates. Then, in order to quantify changes of certain LULC type during a certain time, the following formula:

$$LULCC = \frac{LULC\ b - LULC\ a}{LULC\ a} * \frac{1}{T} * 100 \quad (1)$$

Where

$LULCC$ is the rate of change of a certain LULC type for a certain time; the subscripts a and b denote the beginning and the end of a time for LULCC investigation, respectively; T is the time duration between a and b. A positive value means that there is an increasing trend for a specific time for an area of a certain LULC type; otherwise, negative values implies deceasing a trend for the area assessed. To detect the change from 2000 to 2016, the LULC 2000 map was multiplied with 100. Then both images for 2000 and 2016 added together then all pixel values showed the change that occurred in the image. Post classification is a term describing the comparative analysis of spectral classifications for different dates produced independently [17].

3. Result and Discussions

3.1. LULC Analysis

Figure 1 and Table 2 Showed that the dominant types of LULC classes are Bl, S, F, RfA and W have occupied 17, 0, 7, 63, and 13% of the total area, respectively in 2000. In 2016, same types occupied 16, 2, 3, 73, and 7, respectively. There is a significant increase in the area of RfA from 63% in 2000 to

73% in 2016. F was a dramatic decline from 7% in 2000 to 3% in 2016. This significant increase in the area of RfA has a relationship to a shrinking of forest area by clear-cutting of trees for agricultural expansion.

Table 2. LULC classes for the period 2000 and 2016 in the study area.

LULC	2000		2016		Changed area (2000 - 2016)	
	Area (feddan)	Area (%)	Area (feddan)	Area (%)	Area (feddan)	Area (%)
Bl	68712	17	65776	16	-2936	-0.3
S	1357	0	7341	2	5984	5.1
F	28253	7	12117	3	-16136	-8.3
RfA	256719	63	297726	73	41007	0.9
W	55215	13	27297	7	-27918	-6.4
Total	410256	100	410256	100	0.0	-9.0

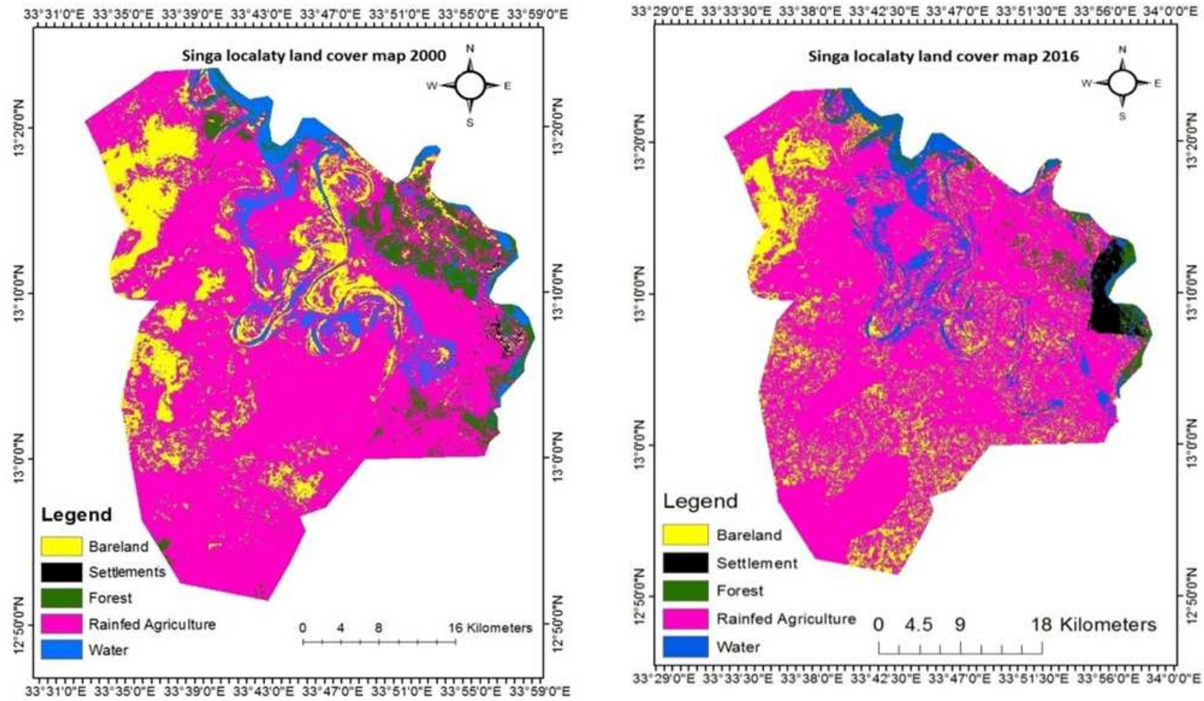

Figure 1. LULC map in 2000 and 2016.

3.2. Post-classification

Figure 2 explained the post-classification change analysis of 2000 to 2016. Table 3 showed that the change detection% of Bl and F, respectively a rate of 63.2 and 57.7 were converted to RfA. As shown in Tables 4, the post-classification comparison was used to quantify the extent of land cover changes over the 16 years. The merit of post-classification comparison is that it bypasses the difficulties associated with the analysis of the images that are obtained at different times or by different sensors and results in high change detection accuracy. Largest LULCs were converted to RfA such as Bl, and F, respectively about 43417 and 15029 feddan. Deforest for the expansion of agricultural area is one of the major sources for the degradation of renewable resources in Sudan [6, 18, 19]. Land use practices related to agriculture expansion, urbanization and deforestation affect land use and natural resource degradation [20]. Thus, [6] proposed the policy makers must consider an increase in yield per unit area by utilization of different varieties of fertilizer to enhancement the grain production, not only through the expansion of the cultivated area.

Table 3. Change detection% of LULC for the period 2000 and 2016.

	Bl	S	F	RfA	W
Bl	34.7	0.6	0.5	63.2	1
S	16.4	1.2	0.2	80.8	1.2
F	6.2	5.6	23.3	57.7	7.2
RfA	13.5	2.1	1.3	79.2	4
W	5.5	1.2	5.6	58	29.7

Table 4. The distribution of land cover classes conversion in the study area.

	LULC	Area (Feddan) 2000 - 2016
1	No change	195990
2	Bare land to Forest	354
3	Bare land to Rain-fed Agriculture	43417
4	Settlement to Forest	179
5	Settlement to Rain-fed Agriculture	58473
6	Forest to Rain-fed Agriculture	15029
7	Rain-fed Agriculture to Forest	2425
8	Water to Forest	3086
9	Other change	91303

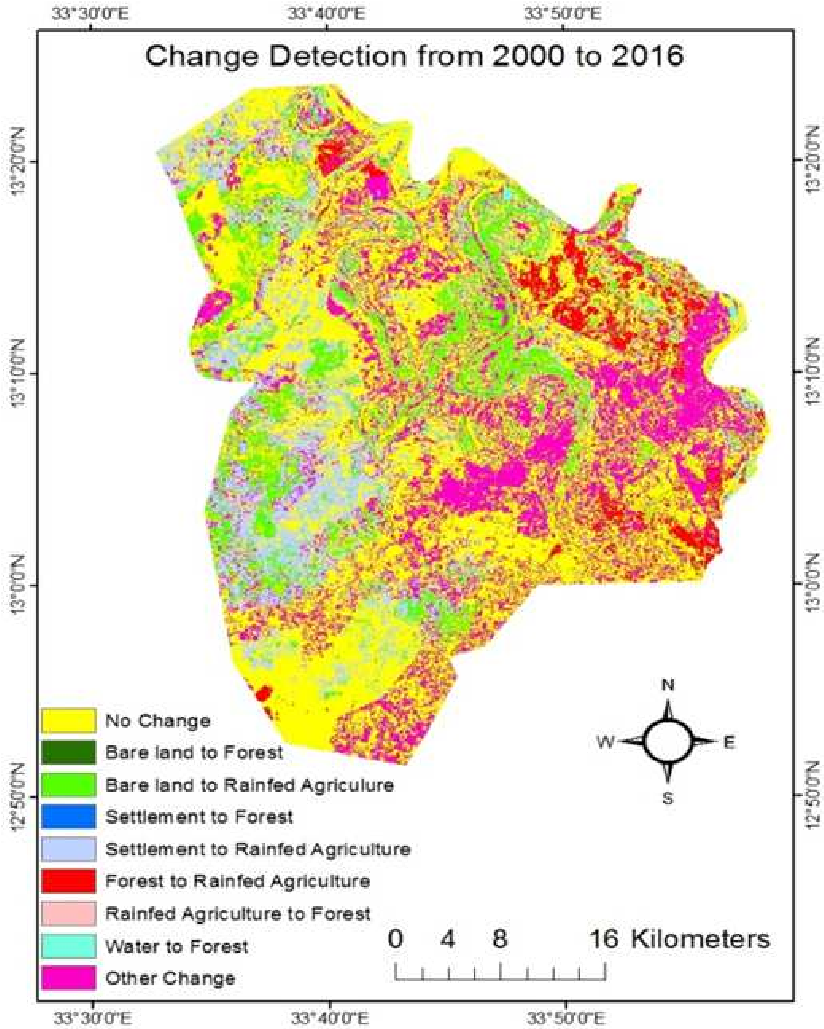

Figure 2. Change detection analysis for 2000 and 2016 image in the study area.

4. Conclusion

This paper showed the forest cover was decline; meanwhile the RfA areas were increased. It found about 15029 feddan that resulted in a high decline of forest area. A successful application of multi-temporal Landsat data and maximum likelihood algorithmic mapping of LULC classes. Comparisons between two images were made both visually and digitally to identify the LULCC and transformation that has occurred from one class to other. Analyzing and mapping trend of LULC dynamics within the study area provide basis for strategic planning, management and conservation decision-making, because changes in the LULC will have strong local, social and environmental implications, such as alterations in social stability, conflicts on natural resources, impacts on rates and types of land deforestation and thus can reduce biodiversity. This study showed that RS imagery from the different sensor could be used to monitor the LULCC over long periods.

This research recommended continues research depending on the RS to monitor the LULC. Particularly, these studies not only to improve our understanding about LULC changes and its implications in management and conservation efforts but also will provide perspectives for the planner in the sustainable development of LULC.

Acknowledgements

The research was supported by Faculty of Forestry, University of Khartoum, Sudan.

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