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Spatio-Temporal Analysis of Land Use and Land Cover Changes in Shiekan Locality-North Kordofan State-Sudan Using Remote Sensing

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Abstract: The study was conducted in Shiekan locality in North Kordofan State, Sudan and aimed to identify, assess and mapping of the land use and land cover (LULC) changes and trends in the last three decades (1989 to 2019). Satellite imageries of Landsat 5 TM (1989) and (2009), Landsat 7 ETM+ (2000), and Landsat 8 OLI (2019), covering path and row 174/51 and 175/51 were acquired in dry seasons. Image pre-proccessig, image classification (maximum likelihood) and accuracy assessment were applied. Remotely sensed data were processed and analyzed using ERDAS 9.1 and ArcGIS10.0 software. Results showed that the LULC in Sheikan locality were identified into eight classes (water, trees, shrubs, sandy soil, gardud lands, agricultural lands, rangeland and bare soil, and residential). The trees class showed an increase from 2.36% (2000) to 2.51% (2009) and decreasing in 2019 (1.87%). While, classified imageries indicated an increase of agricultural land from 69.2% in 1989 to 72.2% in 2019 as dominant class, followed by shrub lands increased from 18% in 1989 to 23.1% in 2019 in Sheikan locality. The overall obtained accuracy for classified maps was 87.50%, 89.29%, 90.20%, and 80.77% for 1989, 2000, 2009, and 2019, respectively. The study revealed that expansion of agricultural lands, climate change and illicit felling of trees are the main reseaons for natural resources degradation, mainly forest and rangelands in Shiekan locality. Use of remote sensing and GIS in assessment and monitoring of natural resources in arid and semi-arid area is highly recommended.

Keywords: GIS, Land Cover, Land Use, Remote Sensing, Sheikan Locality

1. Introduction

In Sudan, land use and land cover (LULC) changes have been an issue of concern with consequential effects on sustainable development [25]. The assessment and mapping of LULC is the technique or tools to compare the different uses and benefits that can be obtaining from the land between the past and current situation [13]. Mapping of LULC is important to extrapolate information about the distribution of natural resources and its pattern. Monitoring of vegetation change using remote sensing provides an understanding of the health and condition of vegetation as well as rates of conversion of natural vegetation to other land uses [2]. Land cover is an important component in dry lands; hence its assessment will help in understanding the changes in ecosystems [20]. Trends in LULC related to agricultural expansion and intensification are the most visible indicators of the human footprint on the biosphere [14]. Therefore, awareness on LULC changes has been increased [3, 27]. Remote sensing and GIS technology are considered an appropriate tool for observing the change in vegetation cover, as it provides cost-effective information which plays a useful role in understanding the nature of land cover changes [2, 24]. Since 1972 remote sensing technology has a good knowledge as time and cost effective tool for surveying of natural resources especially in rugged and far area for study [8]. LULC mapping is one of the most important and typical applications of remote sensing data [22].

However, there are several challenges in developing standard LULC classification. Classifying remote sensing imagery to obtain reliable and accurate LULC still remain a challenge that depends on many factors like complexity of the landscape, the remote sensing data selected, image processing and classification methods etc. Over the years, improvement has been done by classifying Landsat TM data with the most widely used parametric classifier, maximum likelihood decision rules and some ancillary data such as knowledge on locality, land use data, vegetation index and textural analysis of landsat images which can be used for detailed post-classification change detection [7, 18, 22]. Researchers, policy makers utilize LULC information to determine changes in natural resources including evaluating growth pattern [5]. A better understanding of land use dynamics is a key to various applications such as hydrology, geology, forests, agriculture, environment and ecology [4]. Studies on LULC changes have always attracted the attention of scientists across the globe including, Kenya, Ethiopia and Sudan [2]. Many studies on land degradation and desertification were carried out in drylands in Sudan for understanding the desertification issues with emphasis on remote sensing techniques [10, 17]. Also other studies conducted on LULC change, trends, transformations, and mapping in semi-arids areas in Sudan [2, 8, 17, 20, 26, 16]. These studies proved the possibility to detect and mapppng of desertification in arid and semi-arid lands in Sudan by using of multi-temporal remote sensing data. The studies also revealed that remote sensing and GIS methods are usefull for mapping and classification of LULC in Sudan.

Central and western of Sudan (Kordofan and Darfur regions) have experienced recurrent drought spells since the 1970s [20, 21]. Shiekan Locality in North Kordofan State is located in the region of arid and semi-arid area and has major natural resources and the population depends mainly on agriculture and livestock [12], also, it is considered as one of the productive areas for gum Arabic in Sudan [25]. The locality has sufferred from converion and transformation of land use and cover, desertification, drought, and other environmental problems. Therefore this study identified, assessed and mapped the LULC changes in Shiekan locality over the last three decades.

2. Materials and Methods

2.1. Study Area

The study was conducted in Shiekan Locality which lies in the center of the Kordofan between latitudes 25' 12° - 45' 13° N and longitudes 35' 29° - 30' 30° E (Figure 1). It covers an area of about 8312 Km^2 (≈2 million acres). Administratively, the locality is divided into eight administrative units. The types of soils are sandy, clay, sedimentary and gardud soils [25]. The population of Shiekan Locality according to 2008 census about 616617 persons, and about one third of the population are involved in agriculture practices. The majority of them are settlers, but the nomadic and transhumant groups are being in the area during the rainy season looking for grazing resources. The meanannual rainfall ranges between 250 – 450 mm, during periods between June and October andthe highest amount of rainfall generally occurs in August [2]. The mean annual temperature varies between 28° and 30°C but during summer the temperature can rise as high as 45°C during the daytime. The Agricultural activity is predominantly rain-fed agriculture; it considered the main economic activity in the study area, producing cash exportable crops, such as gum Arabic, groundnut, sesame, watermelon seeds and, Roselle, in addition to other food crops and mechanized agriculture which practiced in the heavy clay and gardoud soils.

2.2. Data Collection and Analysis

Remote sensing data were obtained from multi-temporal satellite imageries. The data covered three last decades (1989 to 2019) from Landsat 5 Thematic Mapper (TM) 1989, and 2009, Landsat 7 Enhanced Thematic Mapper Plus (ETM+) 2000 and Landsat 8 Operational Land Imager (OLI) 2019 (Table 1). The imageries which covered two scene (174/52 and 175/51), were downloaded freely from the United States Geological Survey (USGS) website. All imageries were geo-referenced to the (WGS84) datum and Universal Transverse Mercator (UTM) projection and spatial resolution of 30*30m was used. The image acquisition dates were selected on available of cloud free image in dry season in October as suitable periods to satellite data collection for detecting forest areas in Sudan [20]. Subset for for the Shiekan locality with an area of 836362.7 ha was created from the moasic imageries. Visual interpretation was done to satellite imageries and comparing features of the target on the lands in the study area. Ground control points (GCPs) supported the supervised classification using maximum likelihood methods were recoded by GPS [2, 20]. ERDAS version 9.2 and Arc GIS version 10.2 software were used in pre-processing, interpretation and image classification of imageries (Figure 2). The study was carried out in four stages that are data collection, image interpretation, field survey and mapping and focused on the analysis and accurassyassessment of the eight catogeries (water, trees, shrubs, *gardud* lands, sandy soil, agricultural lands, rangelands and bare soil and residential area) of land use and land cover (Table 2).

Residential areas were masked and classified.

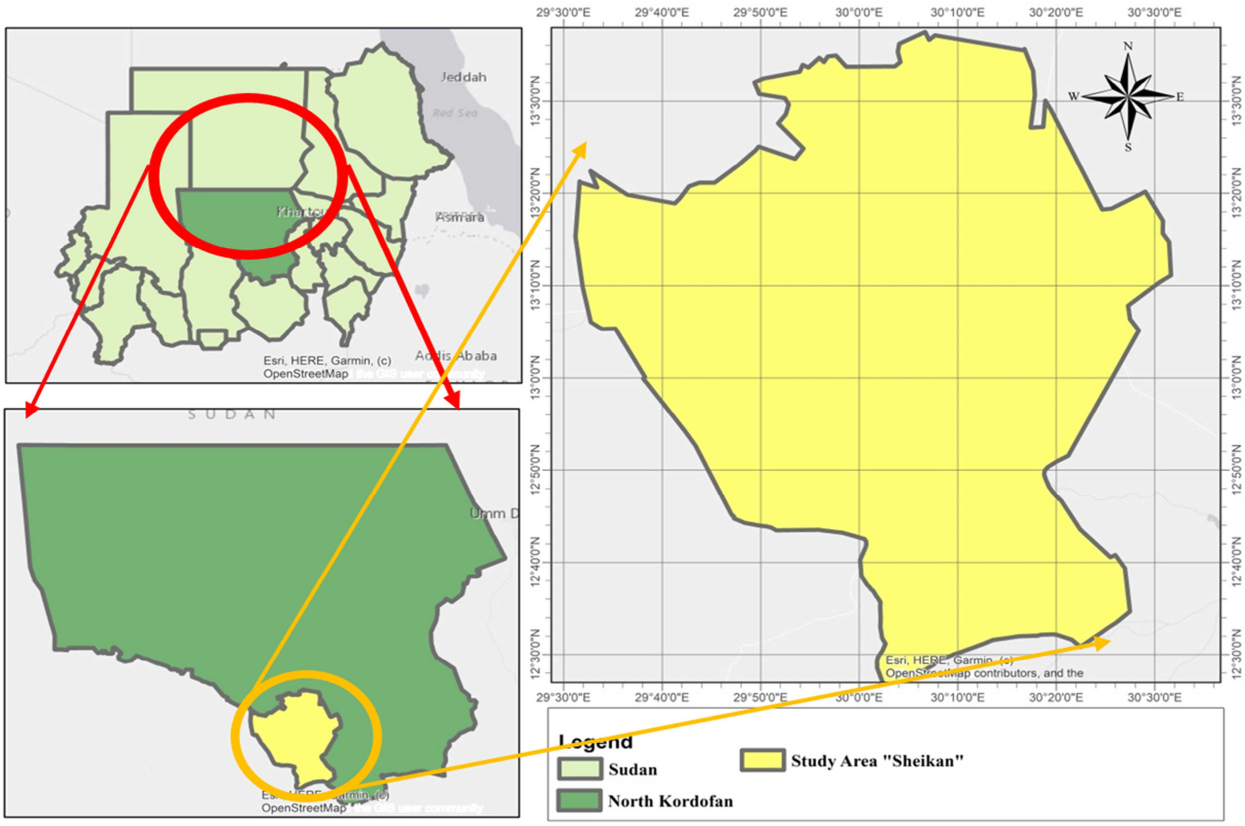

Figure 1. Map of Shiekan locality, North Kordofan, Sudan.

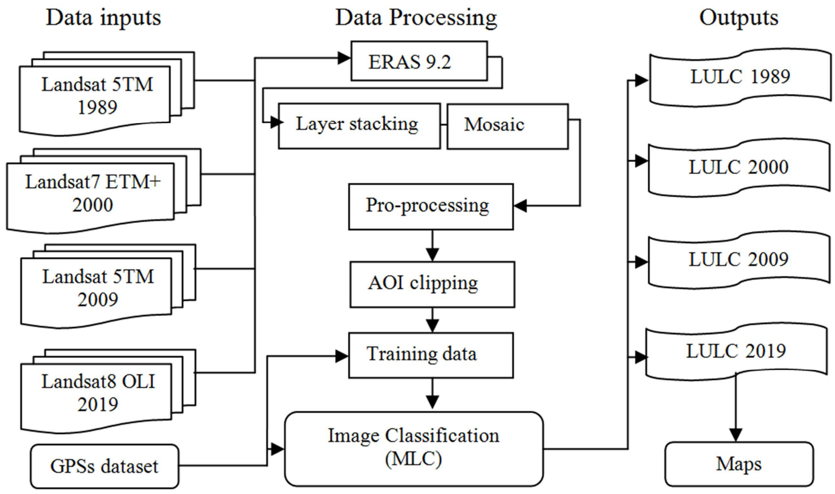

Figure 2. Flowchart of data acquisition and interpretation.

Table 1. *Charaterisics of landsat datasets used in the study, Shiekan locality, North Kordofan, Sudan.*

No.	Landsat data	Path/Row	Zone	Acquisition data	Spatial Resolution (m)	Band Combination
1	Landsat 5 TM	174/51	36	Jan 01, 1989	30*30	4-3-2 Red-Green-Blue
		175/51	36	Jan 07, 1989	30*30	4-3-2 Red-Green-Blue
2	Landsat 7 ETM+	174/51	36	Nov 19, 2000	30*30	4-3-2 Red-Green-Blue
		175/51	36	Nov 20, 2000	30*30	4-3-2 Red-Green-Blue
3	Landsat 5 TM	174/51	36	Dec 16, 2009	30*30	4-3-2 Red-Green-Blue
		175/51	36	Dec 07, 2009	30*30	4-3-2 Red-Green-Blue
4	Landsat 8 (OLI)	174/51	36	Nov 26, 2019	30*30	5-4-3 Red-Green-Blue
		175/51	36	Nov 17, 2019	30*30	5-4-3 Red-Green-Blue

Where: TM= Thematic Mapper, ETM+= Enhanced Thematic Mapper Plus, OLI= Operational Land Image

Table 2. *Description of (LULC) classes in Sheikan Locality.*

Class Name	Descriptions
Water	Areas of water bodies (Hafeir)
Trees	Pure trees include: *Acacia nilotica, Balanitesaegyptiac, Ziziphus spina-christi, Faidherbiaalbida*, and other trees particulary in near water sources and Horticulture.
Shrubs	This class cover mainly by other shrubs including: *Calatorpisprocera, Boscia sand Acacia orefota*…etc.
Gardud lands	This land mixed sandy an*enegalensis*d clay soil and it's very hard, and without any human practices.
Sandy soil	Desert areas cover by sandy dense.
Agricultural lands	Areas cultivated with crops
Rangelands /Bare soil	Bareland and grazing areas.
Residential area	Area in habit with people (Shiekan town) which weremasked out of a map and added toafter classified image

3. Results and Discussion

3.1. Land Use and Land Cover Distribution

Results showed that the LULC in Shieikan Locality were identified and classified into eight classes (water, trees, shrubs, sandy soil, gardud lands, agricultural lands, rangeland and bare soil, and residential) (Table 3). Distubution of LULC indicated that the trees class was increased by 1.65%, 2.36% and 2.51% during 1989, 2000 and 2009 respectively, while it decreased by 1.87% in 2019. These changes in trees class may be due to many factors like illicit felling, overgrazing, climate change, drought and agricultural expansion. The study also showed that agriculture was a dominant land use class (69.2%, 73.3%, 81.6% and 72.2% in 1989, 2000, 2009 and 2019, respectively) indicating that agriculture is a major activity for securing households' food and income. The expansion of agriculture was a direct result of rain fluctuation, climate change, low soil fertility and growth in the population. These findings are in line with Suliman [25] who found that increasing in traditional agriculture areas was due to increase in population that resulted in a corresponding increase in human needs (cultivable land and wood fuel). Moreover, climatic variation, low soil fertility, and use of mechanization. Rural communities in Shiekan locality practicing gum production under agroforestry systems (*Acacia senegal* (locally known as Hashab tree based systems). Results also showed that shrubs lands, the second dominant class which decreased during 1989, 2000 and 2009 by 18%, 14.4% and 9.09%, respectively an increased by 23.1% in 2019. Increasing in shrub class in the last ten years may be due to the encouragement of rural communities to work in the hashab garden cultivated for Gum arabic production and most of the local communities owned hashab gardens. The profitability of Gum arabic product led to that increase in hashab areas. This means Gum arabic is produced by the majority of small-scale farmers in the rain-fed farming contribution to the household income [11, 15, 29] and to planataions of hashab esatblished by Acacia company in the area. The findings also indicated the changes of rangeland in a decreasing trend during the last decades (Table 3). The degradation of rangelands may refer to many causes, such as expansion of agriculture, wildfires, drought, climate change and increase of livestock. Our findings are also in agreement with Mohammed *et al*. [20]. All these factors led to expansion of overgrazing on rangelands and to satisfy the needs of livestock. Dafalla *et al.* [9] mentioned that social-economic factors were a negative sign for changing trend for LULC in North Kordofan State due to overcutting of trees. The residential areas were increased from 0.24% in 1989 to 1.06% in 2019 due to increase of population over time as also mentioned by Taha *et al*. [28].

The result indicated an increase in water bodies in the area (0.02% during 1989 to 2009, and 0.04% during 2019). This was due to the establishment of new water sources (*Hafirs*) in the area to meet the needs of local communities as interpreted and observed from the classified images in 2019 (Figure 3).

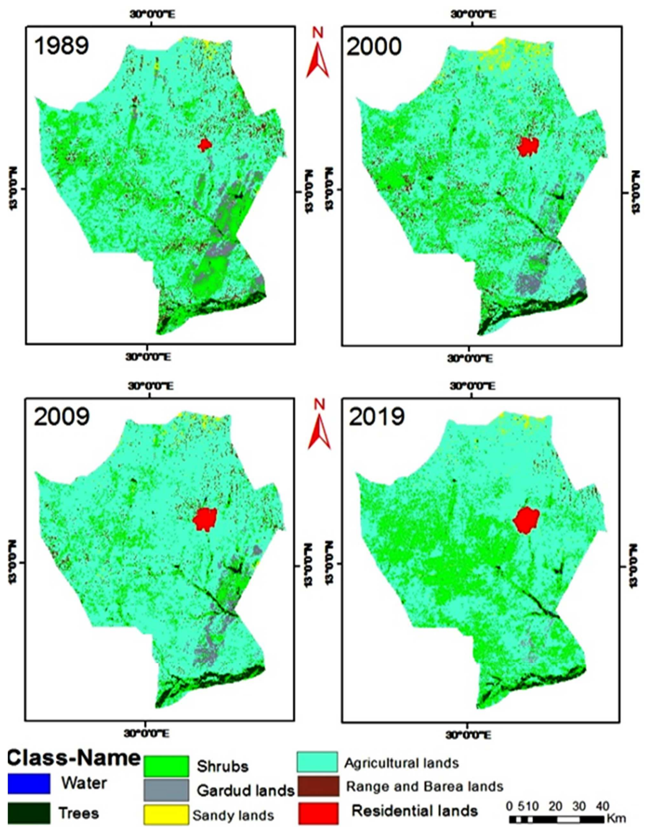

Figure 3. *Classified map of land use and cover in Shiekan locality, North Kordofan, Sudan.*

Table 3. *Classification of land use and land cover class in the study area (1989-2000-2009 and 2019).*

Years	**1989**		**2000**		**2009**		**2019**	
Class name	**Area (ha)**	**%**	**Area (ha)**	**%**	**Area (ha)**	**%**	**Area (ha)**	**%**
Water	201.33	0.02	140.04	0.02	204.12	0.02	344.25	0.04
Trees	13796.28	1.65	19720.71	2.36	20980.17	2.51	15641.28	1.87
Shrubs lands	150935.9	18	120404.7	14.4	75856.95	9.07	193246.4	23.1
Gardud lands	46055.61	5.51	30115.62	3.6	25531.74	3.05	5383.17	0.64
Sandy soil	3706.83	0.44	12302.46	1.47	3716.55	0.44	4338	0.52
Agricultural lands	578806.1	69.2	612946.1	73.3	682141.95	81.6	603873.7	72.2
Rangelands and Bare soil	40891.05	4.89	35480.52	4.24	20397.33	2.44	4638.78	0.55
Residential area	1969.56	0.24	5252.58	0.63	7533.9	0.9	8897.13	1.06
Total	836362.7	100	836362.7	100	836362.71	100	836362.7	100

3.2. Rate of Change in Land Use and Land Cover (LULC) in the Study Area

The results indicated the change of LULC during (1989-2000, 2000-2009, 2009-2019 and 1989-2019) (Table 4). The occupancy rate of trees class was found gradually increasing by 0.7%, 0.15%, and 0.22% during 1989-2000 and 2009-2019, respectively, while shrub lands class were found increasing by 5.33%, 14% and 5.06% during 2000-2009, 2009-2009 and 1989-2009, respectively. Also the agricultural lands were increased in the study area during 1989-2000 and 2000-2009 by 4.1%, 8.27%, respectively. Furthermore the results showed an increase in the residential areas in three last decades (1989, 2000. 2009 and 2019) by (0.4%, 0.27%, 0.16% and 0.83%), respectively (Table 4).

Table 4. *Rate of change (%) in land use and land cover (LULC) in Shiekan locality.*

Class name	**1989-2000**	**2000-2009**	**2009-2019**	**1989-2019**
Water	-0.01	0.01	0.02	0.02
Trees	0.7	0.15	-0.64	0.22
Shrubs	-3.65	5.33	14	5.06
Gardud lands	-1.91	-0.55	-2.41	-4.9
Sandy soil	1	-1.03	0.07	0.08
Agricultural lands	4.1	8.27	-9.36	3
Rangelands and Bare soil	-0.65	-1.80	-1.88	-4.34
Residential area	0.4	0.27	0.16	0.83

3.3. Land Use Land Cover Maps

The LULC maps were produced for each of the four imageries (1989, 2000, 2009 and 2019) for Shiekan locality (Figure 3). Comparison of the maps reflects the different changes and tranformation between the LULC classes during the 30 years (1989-2009) in Shiekan locality.

3.4. Accuracy Assessment of Classifed Imageries

The Kappa statistics and overall accuracy for the classified imagery for the year 1989, 2000, 2009 and 2019 was found to be (87.5%, 0.84), (89.29%, 0.87), (90.2, 86) and (80.77%, 77%), respectively (Table 5). According to [23], a Kappa value higher than 0.5 can be considered as satisfactory for modeling of land use change. Accuracy assessment is an important part of classification which reflects the true land cover accurately [1]. Also there are many reasons to use accuracy assessment, such as increase the quality y of information derived from remote sensing data [6].

Table 5. *Overall accuracy, and kappa statistic for land use land cover classification.*

Class name	**1989**		**2000**		**2009**		**2019**	
	P A%	**U A%**	**P A%**	**U A%**	**P A%**	**U A%**	**P A%**	**U A%**
Water	00.00	00.00	00.00	00.00	100.00	100.00	00.00	00.00
Trees	60.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
Gardud lands	90.00	100.00	75.00	75.00	50.00	50.00	66.67	100.00
Shrubs	100.00	72.00	80.00	100.00	100.00	87.50	100.00	83.33
Sandy soil	100.00	100.00	100.00	100.00	100.00	100.00	50.00	50.00
Agricultural land	85.71	85.71	88.89	80.00	88.46	92.00	71.43	71.43
Range & Bare Land	100.00	100.00	100.00	100.00	100.00	100.00	75.00	75.00
Residential area	00.00	00.00	100.00	100.00	100.00	100.00	100.00	100.00
Overall Accuracy	87.50%		89.29%		90.20%		80.77%	
Kappa Statistics	0.84		0.87		0.86		0.77	

P A = producer accuracy, UA = user accuracy.

4. Conclusion and Recommendations

Based on the remotely sensed data, the LULC in Shiekan locality indicated changes in all classes over time. However, there are some land resource components (forests and rangelands) have degraded over time due to overuse practices on the land that includes expansion of agriculture, illicit felling, overgrazing and climate change, besides inappropriate sustainable management of natural resources. Additionally, the study showed that agriculture is the dominant land use class in Shiekan locality. The residential area and water bodies were increased due to the growth of population in Shiekan locality. The study recommends that appropriate planning and sustainable natural resources management in the areas should be used to avoid degradation and hazard facing land use and land cover. Furthermore, using remote sensing and GIS for assessment and monitoring the natural resources arid and semi-arid lands is highly recommended.

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