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Assessment of Land use and land cover in *Albaja* Area in North Kordofan, Sudan Using Remote Sensing and GIS

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ABSTRACT

This study was conducted in Albaja area in North Kordofan State, Sudan, and aimed to assess, classify, and map land use and land cover changes (LULC). Remotely sensed data were based on temporal satellite imagery (TM 1985, ETM+ 1995, and Landsat8 2015). The images were enhanced and classified using a maximum likelihood approach with conduction of 200 ground control points. The accuracy assessment and Kappa statistics for all classified images were performed. Remote sensing data were analyzed using ERDAS 9.1 and ArcGIS 10.3. The LULC in Albaja area was identified into five classes: sandy soil, agricultural lands, shrub lands, woody lands, and range lands. The result indicated an increase in range lands from 30% to 46% during 1985-1995, an increase of agricultural land from 15.1% to 37.3% during 1995-2015. Results revealed an increase in sandy soil and shrub lands during 1995-2015 from 9.7% to 16.6% and from 15.5% to 17.0%, respectively. The overall accuracy of the classified images was estimated at 85.39% for TM (1985), 89% for ETM+ (1995), and 84.85% for Landsat 8 (2015). The over-grazing and the expansion of large-scale mechanized agriculture on marginal grazing lands in Albaja deteriorated the rangelands and caused changes in the vegetation composition. The study recommended the provision of extension services to the local communities to increase the role of awareness among the farmers and the pastoralists to protect the natural resources.

Keywords: *Albaja, GIS, land use land cover, rangelands, remote sensing.*

Introduction

Sudan is one of - Northeast Africa, and a vast country rich with natural resources such as agricultural land, livestock, minerals, fisheries, and forests. The majority of the population works in agriculture (about 80%) [1]. Natural resources are a primary source of wealth and often a focal point of conflict and competition among communities. Such tensions frequently arise from population growth, climate change, and the poor management of natural resources and the environment [2]. Land use and land practices have a major impact on natural resources, including water, soil, nutrients, plants, and animals [3]. The importance of studying natural resources and land use, by using modern applications such as GIS and remote sensing, is represented by automated applications that contribute and support contemporary studies, provide a mechanism to analyze spatial data and link them to non-spatial information, and give results in the management of resources, urban planning, and land use [4]. Remote sensing has become an essential tool for monitoring and assessing rangelands both globally and in Sudan. By using satellite imagery and aerial data, researchers can track changes in vegetation cover, soil degradation, and land use patterns over large and often inaccessible areas, enabling timely and cost-effective management decisions [5].

North Kordofan State is located in the region of arid and semi-arid areas in the center of Sudan and has major natural resources. The population of North Kordofan depends mainly on agriculture and livestock [6]. The State is suffering from desertification, drought, and other environmental problems, leading to the degradation of natural resources.

The *Albaja* area in North Kordofan, Sudan, is characterized by a mix of agricultural, pastoral, and forested lands [7]. Agriculture, particularly rain-fed and mechanized farming, is a primary land use, focusing on crops like sorghum, millet, and groundnuts [5]. Pastoralism is also prevalent, with significant numbers of sheep, goats, camels, and cattle grazing on communal rangelands [8]. Forests and woodlands provide resources for fuelwood, construction materials, and non-timber products, but these are increasingly under pressure from deforestation and overuse [7], [9].

Natural rangelands in Sudan, including those in the *Albaja* area, face multiple challenges that threaten their sustainability and productivity. Key problems include weak policies and planning for rangeland management, expansion of agriculture into grazing lands, recurrent droughts, rainfall variability, climatic changes, seasonal fires, overgrazing, illicit cutting of trees and shrubs, and tribal conflicts [5], [7], [8].

These pressures have led to a decline in forage biomass productivity and quality in *Albaja* since the 1980s, making effective range management and conservation critical for livestock production and environmental protection [9]. The introduction of large-scale mechanized farming has further transformed land use systems, exacerbating competition between farmers and pastoralists over rangelands and contributing to localized conflicts [7].

Understanding land cover and land use dynamics in the *Albaja* area is essential for sustainable rangeland management, as changes in vegetation cover and land use (LULC) directly influence ecosystem function, soil fertility, water availability, and biodiversity [5], [9]. Regarding the above-mentioned range problems, the rangelands of the *Albaga* area in North Kordofan have been subjected to a decline in forage biomass productivity and quality since the 1980s and till presently. The government of North Kordofan State has issued declaration no.6 for year 2014: the *Albaja* was declared as a reserved range land area and prohibited mechanized farming in the area. The study aims to identify, classify, and map land use and land cover (LULC) in the *Albaja* area in North Kordofan State.

Material and Methods

Study area

This study was conducted in *Albaja* area, which is located in North Kordofan State. It covers an area of about 5544 Km^2 and extends to cover parts of three localities; the largest area of *Albaja* is located in *Umrwaba* locality, followed by Bara locality and *Umdam Haj Ahmed* locality. The study area is situated between latitudes 13.20° and 14.05°N and longitudes 31.00° and 32.00° E (Figure 1). This area is bordered by White Nile State on the eastern side. The most dominant tribes are the *Bazaa*, *Maganin,* and *Jawamaa* as the settler tribe. *Albaja* is a major source of natural pasture for livestock in the state and for the nomadic tribes from outside the state during autumn and summer seasons.

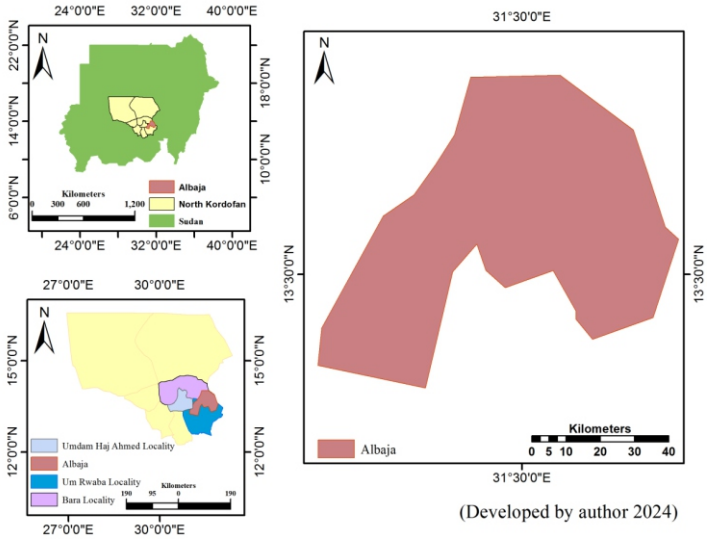

Figure 1. Location of the study area

Methodology

The study was based on three Landsat satellite images covering the paths and rows 174/50 and 174/51 in the *Albaja* area. The first image was Landsat5 (TM, 1985), which was considered as reference image, the second was Landsat7 (ETM^+, 1995), and the third image was Landsat8 (2015) (Table 1). The study area covers an area of 496691.8 ha.

Table 1. Characteristics of satellite images used in the study

Image	Path/Row	Sensor	bands	Pixel Size	Area	Date
1	174/51	TM	1-7	30*30 M	185*185	1985
2	174/51	ETM^+	1-12	30*30 M	185*185	1995
3	174/50	Landsat8	1-12	30*30 M	185*185	2015

Source: *USGS 2015*

Enhanced images were first processed by applying unsupervised classification, followed by supervised classification (maximum likelihood) with the help of 200 ground control points, which were taken by Global Positioning System (GPS). Maps of LULC were generated from supervised classification images. The images were classified and mapped by ERDAS Imagine version 9.1 Arc. GIS version 10.3.

Results and Discussion

Distribution of LULC in the *Albaja* area

The classified image in the year 2015 showed that the agricultural lands are dominant over the other classes in *Albaja* area, covering an area of 37.4% (37610.2). While the range lands are ranked as a second class with 21%. Therefore, more than 50% land in the *Albaja* area is covered by agricultural and range lands. The range lands were decreased in 2015 (21.29%) compared to 1995 (46.17%). While agricultural lands in the year 1995 and 1985 are estimated as 15.18% (75394.8 ha) and 17.69% (87870 ha), respectively. This change reflects an expansion of agricultural lands and a reduction of rangelands, which has contributed to local conflicts between farmers and pastoralists in the *Albaja* area (Table 2).

The woody vegetation in the *Albaja* area has drastically decreased from 1985 to 1995 and 2015, representing 15.20%, 13.38% and 7.57%, respectively, indicating deforestation and loss of trees. The land covered by shrubs in *Albaja* decreased by 2% from 1985 (19.5%) to 2015 (17.08%), showing a reduction in vegetation cover. The woody vegetation and shrubland classes showed a gradual decline, decreasing from 34% in 1985 to 28% in 1995 and 24% in 2015. In contrast, agricultural lands increased substantially, rising from 17.69% in 1985 to 37.3% in 2015. The sandy soil class decreased during the period 1985 - 1995 from 9.7% to 17.4%, while in 2015 it covered 16.6% (Table 2).

The woody vegetation and shrubland classes showed a gradual decline, decreasing from 34% in 1985 to 28% in 1995 and 24% in 2015. In contrast, agricultural lands increased substantially, rising from 17.69% in 1985 to 37.3% in 2015.

Table 2. Distribution of LULC in the Albaja area for 2015,1995, and 1985

Class name	2015		1995		1985	
	Area (ha)	%	Area (ha)	%	Area (ha)	%
Woody Vegetation	37610.2	7.57	66474.8	13.39	75460.3	15.20
Sandy soil	82797.4	16.67	48242.8	9.72	86507.7	17.42
Shrub lands	84786.8	17.08	77173.6	15.54	96836.7	19.50
Range lands	105713	21.29	229272	46.17	149884	30.19
Agricultural lands	185651	37.39	75394.8	15.18	87870	17.69
Total	496558.4	100	496558	100	496558.7	100

Based on the results of LULC for Landsat5 (1985), and the visual interpretation of the classified image, a heavy presence of the sandy soil with yellowish color was observed in the Southern and southwest of *Albaja,* covering 17.42% (86507.7 ha). While the range lands in cyan colored covering 30.18% (149884 ha), which was distributed homogeneously, mostly across all parts of the area. Shrub lands are proportionally covered in the central parts of the area and represent an amount of 19.5% (96836.7 ha). The agricultural lands in brown covering 17.69% (87870 ha) were found distributed between the shrub lands and range lands in a belt located in the central area and extending east to west. Worth mentioning that agriculture is practiced surrounding the villages. The green colour on the map shows the woody vegetation covering 15.19% (75460.3 ha) in the periphery area in the surrounding the east, north, and southwest area (Table 2) and (Figure 2).

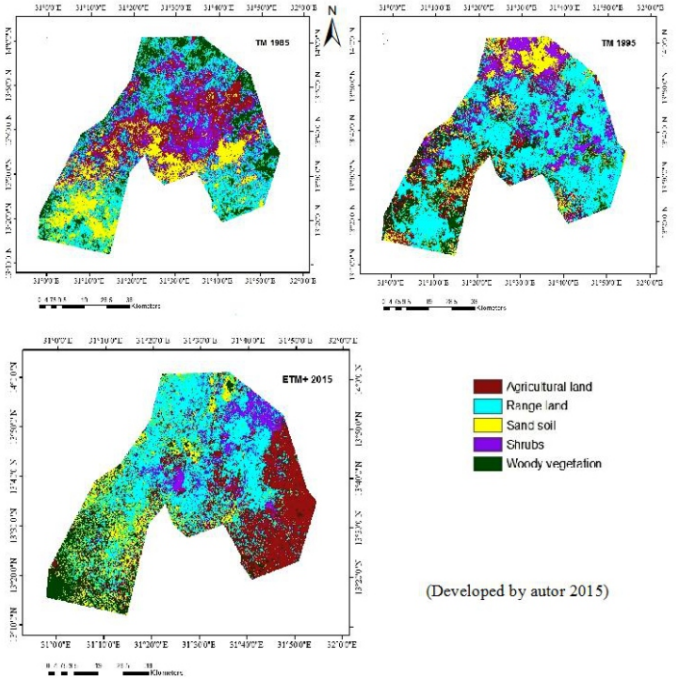

Figure 2. Maps of LULC classes in the Albaja area (2015, 1995, and 1985)

The study results of classified image 1995 showed the presence of the range lands with cyan color in vast and, covering the largest area of *Albaja* and representing 46.17% (229272 ha), while agricultural lands accounted for 17.69% (87870 ha) in brown and extended margins of the area, or around the villages and scattered with the range lands. The shrub lands and woody vegetation are found covering 15.54% (7717.6 ha), 13.38% (66474.8 ha), respectively. The shrub lands are found in the northern part, while the woody vegetation is found in the southern parts of the area.

The sandy soil is covering small patches scattered over the area with 9.7% (48242.8 ha) (Figure 2).

Trends of land use and land cover in *Albaja* area (1985–2015)

The pattern of LULC change in the *Albaja* area shows a decline in forest cover of nearly 2% between 1985 and 1995. A continued decrease is also evident in the 2015 observations, largely due to insufficient protection of trees and reduced interest in maintaining woody vegetation, coupled with the expansion of agricultural lands (Figure 3).

The range of lands is also deteriorating gradually by 46% to 21% in the year 1995-2015, which is considered a sign decrease in agricultural lands, also the study. Show that the sandy soil decreased from 17% to 9% in the year 85 to 1995 and increased again in the period from 1995 to 2015.

The results showed that shrublands increased by 2% between 1995 and 2015, but had previously declined by 4% between 1985 and 1995. Overall, both woody vegetation and shrublands exhibit a pattern of degradation, driven by factors such as tree cutting, overgrazing, agricultural expansion, conflict, and drought.

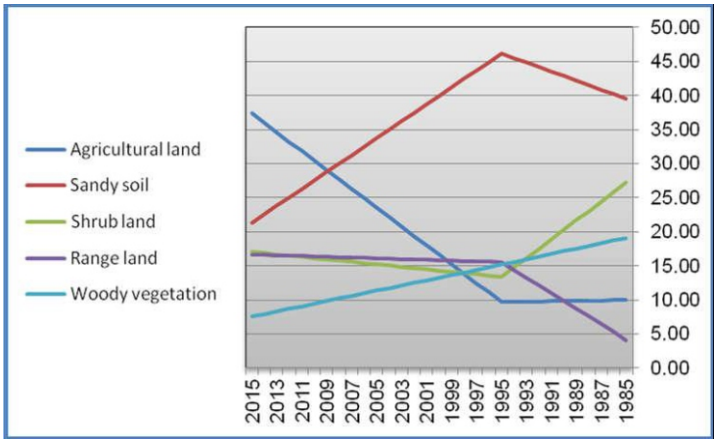

Figure 3. Trends of land use and land cover

Accuracy assessment LULC classification:

The overall accuracy of classified images (TM 1985, ETM+ 1995, and Landsat8 2015) was estimated as 85.39%, 89% and 84.85%, respectively. The user's accuracy for the woody vegetation class was found to be 100%, while the agricultural land class achieved 80%. These results are broadly consistent with the findings of [10], [11], indicating that the classification quality is good. Furthermore, analysis of Landsat 5 TM (1985) imagery produced an overall accuracy of 85.37% and a Kappa statistic of 0.8111. These results are also generally in line with those reported by [10], [11], [12] (Table 3)

Table 3. Accuracy assessment of land use and land cover classification

Class Name	Landsat5 TM 1985		Landsat7 ETM1995		Landsat8 2015	
	Producers' accuracy (%)	Users' accuracy (%)	Producers' accuracy (%)	Users' accuracy (%)	Producers' accuracy (%)	Users' accuracy (%)
1	81.82	100.00	91.67	100.00	100.00	83.33
2	92.00	100.00	92.31	92.31	90.91	90.91
3	61.11	68.75	93.75	88.24	83.33	83.33
4	96.15	92.59	95.12	88.64	75.00	85.71
5	72.73	66.67	66.67	80.00	87.80	83.72
Overall Accuracy	85.39		89.00		84.85	
Kappa Statistics	0.8111		0.8504		0.7896	

1 = Woody vegetation, 2 = sandy soil, 3 = Shrubs lands, 4 = Range lands, 5 = Agricultural lands

Conclusion

The study's results shed light on how vegetation cover in the Albaja area has changed over time, revealing patterns of both growth and decline. These insights underscore the importance of managing vegetation-related activities, as their impacts directly shape environmental conditions. Sustaining ecological balance will require improved land-use practices such as enhanced rangelands management, protection of woody vegetation, and soil restoration. Together, these measures are crucial for promoting sustainable land use and land cover development, helping ensure the long-term preservation of the Kordofan state's environment and natural resources.

Recommendations

1. Adoption of ecosystem-based rangeland management that considers site characteristics and implies interdisciplinary approaches and the need for proper land use planning and community involvement.
2. Reduction of the impact of human activities on vegetation by restoration and re-vegetation programs around the settlements, especially in the areas that are subjected to severe agricultural activities.
3. Provision of extension services to the local communities to increase the role of awareness among the farmers and the pastoralists to protect the natural resources

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