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RESEARCH ARTICLE

ENVIRONMENTAL CHANGE CHARACTERIZATION AND ANALYSIS OF RIVERS' ISLANDS: A STUDY FROM SUDAN- TUTI ISLAND DURING THE PERIOD 1975-2017: REMOTE SENSING AND GIS PERSPECTIVE

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ABSTRACT

This paper intends to study the environmental change characterization and analyses river islands with special emphasis on Tuti island area. Also, the article attempts to explore the change causes during the period 1975-2017, identifies its nature and assesses its spatial pattern, using remote sensing and GIS approaches. The main sources of data are the remote sensing images of Tuti Island (Spatial and Temporal images) for the years 1975, 1987, 2000, 2010 and 2017). The software used for data analysis is ArcGIS and Eardas Imagine. An accuracy assessment for images and results was conducted for the purpose of validation. Field survey was carried out for ground truth. Results showed that Tuti Island has witnessed an increase and decrease during the period 1975-2017,which proposed that Tuti Island has characterized by dynamic changes over time. During "1975-1987" the total area of Tuti Island increased by 11.6%, most probably due to flood events of 1988 which sediments deposited on the island surfaces area and edges. However, during 1987-2017, Tuti Island area slightly decreased by 0.83% at the minimum level and by 1.63% at the maximum level. The variation in the area is a result of the White Nile and Blue Nile deposition as well as anthropogenic factors. The results also showed that Tuti Island has a typical crescent shape with a very narrow coastal plain; these spatial attributes are an outcome of an annual deposition of silt forming a small strip of fluvial landform as a distinctive geomorphological feature of the island**.** Water erosion (Haddam) affects most of its agricultural areas on the rivers' banks of Tuti Island**.** Significant changes from agricultural area to a residential area were seen during 1975-2017; thus, indicating that many of the potential changes will not only be harmful to ecosystems and human societies, but will also be costly to deal with, both socially and economically.

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INTRODUCTION

Study and characterization of environmental change in an area by remote sensing is the process of identifying differences in that area, and observing it at different times using multi-temporal data sets (Singh, 1989). The area of application of remote sensing is almost endless**;** wherever, multi-temporal change studies are needed, remote sensing is likely a candidate for application.

However, various procedures of environmental change characterization and analysis produce different maps of change even in the same environment (Singh, 1989). Adoption of a remote sensing approach is essential to trace and compare the environmental change in Tuti Island. This includes a change in land cover, area and shape for the different selected interval.

River islands could be defined as discrete areas of woodland vegetation surrounded by either water-filled channels or exposed gravel which exhibits some stability, and remain exposed during bunk-full flows (Ward *et al*., 1999).

A river island is an outcome of sediment deposition and accumulation and it emerges above the water's surface in branching streams (Haiyun *et al.*, 2018). Main river islands across the world have experienced remarkable changes in flow, reducing their natural capability to fiddle with disturbances**.** Many researchers have studied environmental change on River Island. For instance, Patrick (1990), studied environmental changes on Pacific Islands within the last 150 years include land degradation, for which the roles of human and non-human factors are evaluated. Whereas H. Echezurı *et al.* (2002), investigated the environmental change in the Orinoco River delta. He concluded that natural and major anthropogenic factors have had an impact on environmental conditions in the delta of the Orinoco River. On the other hand, Pankaj *et al*. (2003) used remote sensing to study erosion of Majuli River-Island. Emmanuele & Stephane (2006) analyze how island in the Middle Loire River was formed and developed over different spatial and time scales**.** R. N. Sankhua *et al*. (2005), evaluated erosion activities in Majuli, the world's largest river island using remote sensing. The results showed that the total area of the island was decreased by 69% during the period1950-2002 due to incessant erosion of banks by the Brahmaputra River. L. Picco *et al*. (2012) investigated fluvial island evolution related to flood events in the Piave River using time series aerial photos of 1960, 1970, 1982, 1991, 1999, and 2006. More recently**,** Jinyan *et al*. (2018) studied temporal change of river islands in the Yangtze River using remote sensing data. In similar study Haiyun *et al*. (2018), four river islands of the Yangtze River were studied, based on Thematic Mapper (TM) and Enhanced Thematic Mapper+ (ETM+) images of the Landsat satellite series from 1985 to 2015.

Wittig *et al*. (2007), pointed out that in recent decades West Africa has witnessed foremost changes in land use, with strong impacts on runoff leading to increase in discharged for some rivers in the Sahelian zone, even with the drop in rainfall, because of considerable land use changes caused by demographic pressures (Roudier *et al*., 2014). Eltoum (2019), studies land use impact on environment of Tuti Island: changes of land use and land cover were observed using classified images of Landsat 5 in 1972, Landsat 7 in 1985 and Landsat 8 in 2018. The results indicated that several temporal changes occurred such as changed of dense tree cover land into other land use purposes. Tuti is being an agricultural region famous for its production of vegetables and all kinds of agricultural produce. These previous studies have asserted that the area of Tuti Island increases and decreases due to erosion and deposition. The change has coupled with change in land cover as an indicator of environmental change over both space and time. As such the following questions are raised:

Does *Tuti* Island undergo any environmental changes including the area, shape and geomorphic features?

Where do the erosion and deposition occur on the Island?

Does Tuti Island witness a change in Land cover?

In the light of these questions, the study aims to characterize and analyse the changes in *Tuti* Island land cover, area, and shape during 1975-2017.

The Study area: Tuti Island is located in Khartoum State at latitude 15^0 22 12 N and longitude 32^0 17 24E. It lies at the heart of the national capital of Sudan. It is bordered by Khartoum city in the South, Khartoum North in the North and Northeast and Omdurman city in the West. The Island is at the confluence of the White Nile and the Blue Nile, on the fertile flood plain known as (Gerouf) and constituted of sand and sedimentary materials (Abu sin and Davies, 1991). Tuti has a surface area of 1150 feddan (ELfaig, 2016) as shown in Figure1. The island was formed by silt depositions, which lies on sedimentary rocks. These rocks are overlaid with clay and silt. Tuti Island is a crescent shaped (Figure 1). Tuti Island has a typical tropical semi- arid climate, being a predominately hot and dry climate with maximum temperature in May and June of 40-48 °C and a short rainy season from July to September (Elfaig, 2016). Topographically Tuti Island is a flat area with a gentle slope runs from the North West towards the South east of the Island (Izzadin, 1975). Geologically**,** the deposition of silt that has been taking place through the history of the Nile has contributed positively to the formation of Tuti Island. Recently, a great change in land use and land cover has been observed in particular the change in trees area to agricultural and residential area (Ahmed and Eltoum, 2019).

The community of Tuti in terms of the population is very homogeneous (Bahreldin and Ali, 2014). They are Mahas people from Nubia in North Sudan, who arrived for cultivation (Osman, 2004). Tuti was an agricultural island, but it was also known as one of the most ancient and important centers for religious teaching in Sudan (Osman, 2004). Tuti is described as a rural settlement within an urban locality, a rural "eye" (Davis and Abusin, 1991). However, the provision of public and social services is quite enough to classify Tuti as an urban locality.

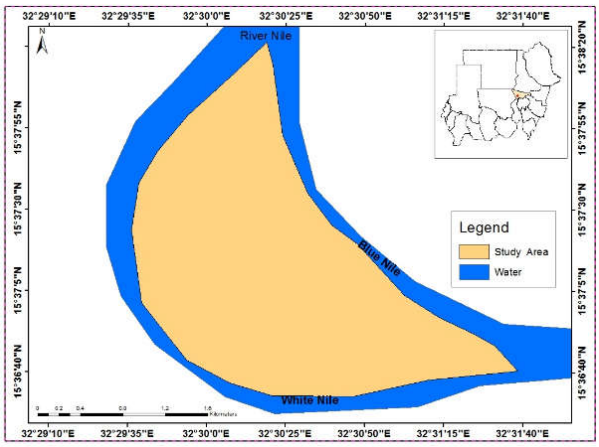

Figure 1. The location of Tuti Island

Methods of Data Collection: Collected data provides and explains characterization of environmental changes that have occurred in Tuti Island as well as the nature and extent of that change. The main sources of such data are Satellite images in addition to a field survey, textual sources "books, journals empirical studies and available official documents". Therefore, these secondary sources are reviewed and satellite images are used in this study. The images are for the years 1975, 1987, 2000, 2010, and 2017. The sources of these images are Landsat (Multispectral Scanner (MSS), Thematic Mapper (TM), Enhanced Thematic Mapper (ETM+), and the Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) as shown in Figure 2A- Figure 2D, and the characteristics of these satellite images are presented in Table 1.

The MSS image has four bands. TM and the ETM+ images have additional spectral bands in the middle and thermal infrared portions. Each satellite images covers a ground area of 28 Km²

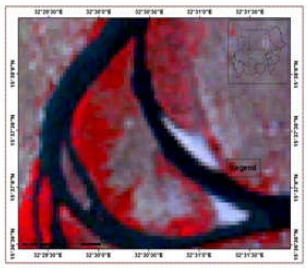

Figure 2A: The Satellite image of Tuti Island, 1975

Figure 2B: The Satellite image of Tuti Island, 1987

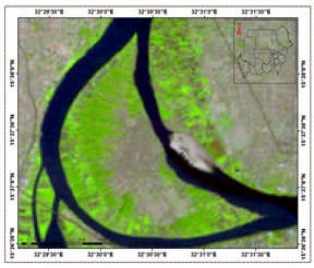

Figure 2C: The Satellite image of Tuti Island, 2000

Figure 2E: The Satellite image of Tuti Island, 2010

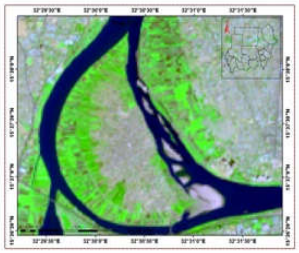

Figure2D: The Satellite image of Tuti Island, 2017

Figure 2A-2D: The Satellite Images of Tuti Island as A source of Data

Table 1. Characteristics of the satellite images used in the present study:

No.	Sensor	Path/Row	Date	Resolution (m)
1	MSS	186\49	September 1975	60
2	TM	173\49	January 1987	30
3	ETM^{+}	173\49	January 2000	30
4	ETM^{+}	173\49	January 2010	30
5	OLI_TIRS	173\49	January 2017	30

Field Survey: The field survey was conducted, to have comprehensive knowledge about the study area, and collect any ready information. During the field survey the sample sites and size for validation were chosen as presented in Table 2: This field survey helps in checking the accuracy of interpretation and make the collection between different classes of the images.

Methods of the Data Analysis: Series of steps and different types of software were used for data analysis. These include the ERDAS IMAGERY version (2014) where Layers stack and subsets were made and supported by the ARC GIS version (10.2). In this software, other tools and processes were used for identification, threshold, reclassification, conversion, and extraction and were supported by accuracy assessments for all images.

The accuracy assessments of Tuti Island maps as shown in Figure (2A-2D) have been made before conversion of the images into maps and the results were presented in Table 3. The signature and the sample taken from the images are compared with the ground truth and field survey. A descriptive statistical method was used to illustrate the change in land cover in the main classes (residential and agricultural areas)

Table 2. Sample Sites and Sizes

No.	Longitude	Latitude	Elevation (m)	Class
1	32.51181	15.61141	403.873	Residential Area
2	32.50986	15.61114	374.884	Residential Area
3	32.50853	15.61066	381.475	Agriculture Area
4	32.50599	15.61133	386.727	Residential Area
5	32.50229	15.61272	356.763	Agriculture Area
6	32.49873	15.61763	368.575	Agriculture Area
7	32.49516	15.62403	368.249	Agriculture Area
8	32.49815	15.62411	368.606	Agriculture Area
9	32.49924	15.63042	366.17	Agriculture Area
10	32.50131	15.63093	370.444	Residential Area
11	32.50396	15.62927	399.166	Residential Area
12	32.5078	15.62653	414.116	Residential Area
13	32.50825000	15.62119	385.803	Residential Area
14	32.50789	15.61887	370.411	Residential Area
15	32.51224	15.61178	372..097	Residential Area
16	32.51287	15.61039	411.235	Agriculture Area

Source: The field work, 2017.

Table 3. Accuracy Assessment for Overall Results

N0.	Year/ Image	Accuracy Assessment
1	1975	Overall Classification Accuracy 82.3%
2	1987	Overall Classification Accuracy = 90.00%
3	2000	Overall Classification Accuracy = 80.00%
4	2010	Overall Classification Accuracy = 90.00%
5	2017	Overall Classification Accuracy = 90.00%

RESULTS AND DISCUSSION

The results reveal enormous changes in Tuti Island (Surface area, Geomorphologic features, shape, and land cover that can be detailed as follows:

Change in Surface Area of Tuti Island as an indicator of environmental Change: The study shows that the surface area of Tuti Island has witnessed a continuous inconsistency, which increased and decreased during 1975-2017. The area increased by 11.6% during the period 1975-1987. A significant variation in the area during different periods is observed.

A decrease in the island area in a range of 0.83% to 1.49% during the last twenty years was reported and presented in Table 4 and Figures 3A-3E as well as Figure 4. Many changes took place in the islands Figures "3A-3D" which show the changes on the island over the period 1975 to 2017.

Table 4: Change in Tuti Island Surface Area 1975-2017

NO	Year	Area/Km^2	Percent of increased	Percent of decreased %
1	1975	4.496525	-	-
2	1987	5.019344	11.6	-
3	2000	4.977779	-	0.83
4	2010	4.896642	-	1.63
5	2017	4.823479	-	1.49

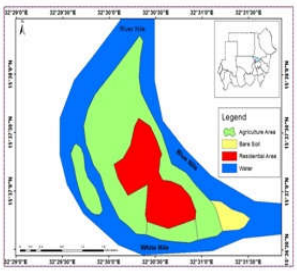

Figure 3A: The Area and shape of Tuti Island in 1975

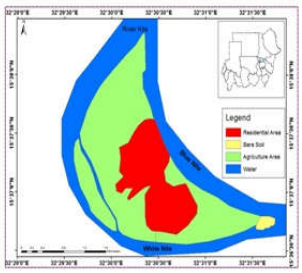

Figure 3B: The Area and shape of Tuti Island in 1987

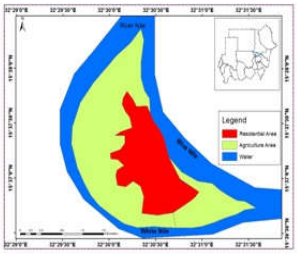

Figure 3C: The Area and shape of Tuti Island in 2000

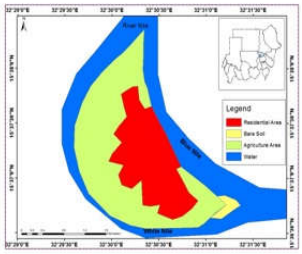

Figure 3E: The Area and shape of Tuti Island in 2010

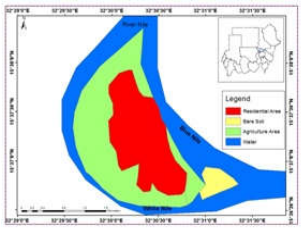

Figure 3D: The Area and shape of Tuti Island in 2017

Figure 3A-3D. Change in Tuti Island during the Period 1975-2017

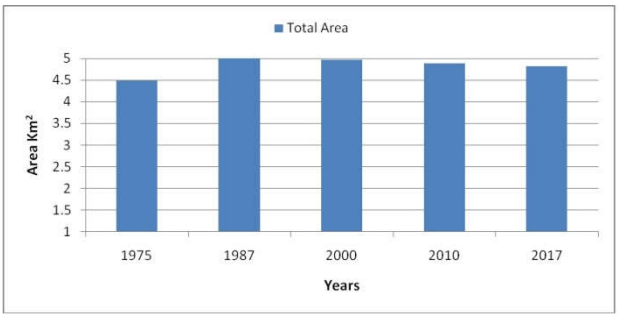

Figure 4. Change in Tuti Island Surface Area during the Period 1975-2017

The spatial change may due to the impact of hydrodynamic conditions, sediment supply, and human activities (Jinyan *et al*. 2018). Eltoum (2019), stated that Tuti Island is a case of a fragile ecosystem in Sudan where erosion, floods, and land use take place

Geomorphic Features and Shape of Tuti Island as an Indicator of Environmental Degradation (Erosion and Deposition): The study shows that Tuti Island has a typical crescent shape with a very narrow coastal plain and formation of new small islands on the east and northeast part of the island as shown in Figure 3A-3D. These features are an outcome of the annual deposition of silt, as a result of the construction of El Mek Nimir bridge on the Blue Nile (2003-2005), forming a small strip of fluvial landform as a distinctive geomorphological feature of the island. On the other hand, while the crescent shape is deepening southward, the island loses some land due to the "Haddam" phenomenon on the northern-east bank.

Change in land used Cover as an Indicator of Environmental Degradation: Land cover has been measured based on the interpretation of remote sensing images and field surveys. Two main categories and one minor category are recognized as shown in Figure 3A to 3D. The results showed that agriculture covered 68.73% and the residential area covered 27.5% of the study area in the year 1975. The situation has slightly changed during 1975-1987where agriculture covered 69.7% and the residential area covered 29.1% of the Island. A great change in land cover has occurred during the last twenty years (1987-2017) where a residential area covered more than 41.5% and the agriculture covered only 53.2% of the total areas i.e. change in the land cover of more than 50% and this variation in land cover is irregular rather than continuous. As the population increased, the residential area extended and the agricultural area expanded at the expense of vegetation cover on the north and west part of the Tuti Island and the border of the island was reshaped and extended to the south due to sand settlement and water erosion.

Table 5. Land cover in Tuti Island during "1975-2017"

	Measured variables and land cover dynamic in the study area " 1975-2017" km^2		
Years	Agricultural area	Residential Area	Bare land Area
1975	3.069109	1.23743	0.189986
1987	3.498726	1.46132	0.059298
2000	3.395049	1.58273	0.0
2010	2.98579	1.81474	0.096112
2017	2.564106	2.00091	0.258463

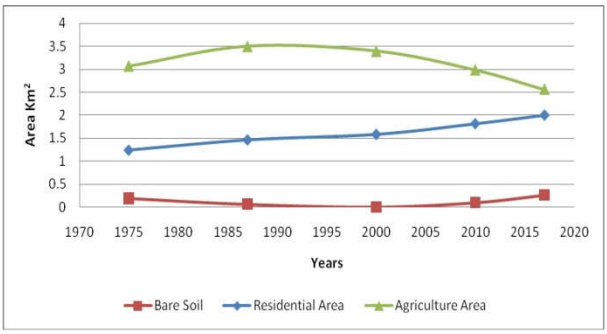

Figure 5. Land cover in Tuti Island "1975-2017"

Conclusion

The Island of Tuti has a crescent shape extending between the Blue Nile and White Nile Rivers covered with silt. The growth rate of silt was slow compared to the modern sedimentation rate. During the period1975-2017, the accumulation of silt continued and the islands increased and decreased by varying degrees . Analysis of the satellite images of 1975, 1987, 2000, 2010, and 2017 has revealed that Tuti Island has increased by 11.6% over 12 years (1975-1987), while decreased by 0.83% during 1987-2017. The precise study of the "shape, size, position, axis, land cover and geomorphic features" of Tuti Island at different dates emphasizes the complexity of Tuti Island's development during the period 1975-2017. The study recommended that it is indispensable to incessantly examine the dynamic changes of Tuti Islands to evade numerous flood disasters, which are of paramount importance for risk assessment and management.

Abbreviations:

MSS: Multispectral Scanner
TM: Thematic Mapper
ETM+: Enhanced Thematic Mapper+
TIRS: Thermal Infrared Sensor
OLI: Operational Land Imager
GIS: Geographical Information System
m: meter

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