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Mapping NDVI – based Image Differencing (2014-2024) in Sheikan Locality – Sudan

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Abstract:

NDVI image differencing stands out as a highly applicable spectral index for observing changes in the greenness of vegetation cover. The study area in Western Sudan has been highlighted in many reports, which indicate that its vegetation cover has faced severe to moderate changes since the mid-1980s. The main aim of this study is to depict changes in land surface greening using the NDVI index in Sheikan locality, Sudan, using three different periods (2014, 2018 and 2024). Landsat-8 OLI images of medium spatial resolution (30*30 m) were obtained from a USGS site (Earth explorer) to quantify NDVI values and pixel counts for the five NDVI maps reclassified classes. The pair periods analysis (2014 – 2018), (2014-2024) and (2018-2024) revealed significant variability in changes between these periods. The results concluded that a positive change occurred during 2014-2018 foe three classes and two classes showed negative changes. The same results applied for the periods 2014-2014 and 2018-2024, which presented three classes of positive NDVI changes and two classes of negative NDVI changes.

Keywords: NDVI Index, Image differencing, spectral indices, OLI, USGS.

Introduction:

Vegetation plays a vital role in the environment and biogeography, contributing to the quality of life through its essential natural processes. Vegetation is associated with various land types characterized by forests, shrubs, herbs, and grass. These elements have continuously changed due to human impacts. According to Naz et al., 2017, land cover (LC) refers to the physical characteristics of the Earth's surface, which can be either natural or artificially created. The key human activities that affect vegetation cover include deforestation (excessive cutting), shifting cultivation (intensive farming), and open grazing (over-grazing). The implementing of the NDVI index marks the beginning of a new era in the assessment and monitoring of vegetation, aided by the development of remote sensing satellite imagery and advancements in image analysis software.

Historically, the monitoring of natural resources, such as vegetation cover, was conducted through field surveys, which had limited coverage. However, the advent of remote sensing has supplanted traditional land surveying methods. The tools and data provided by remote sensing have appreciated in a revolutionary era, offering significant opportunities to assess and measure the extent and trend of changes over large areas. Changes in land cover are now utilized for inventorying past, present, and future natural resources (Pande et al., 2021).

As spatial analysis techniques continue to evolve rapidly, the domains of environmental science, ecology, geography, and climate variability, along with remote sensing (which includes satellite data and image analysis software) and Geographic Information Systems (GIS) have seen significant usage over the past two decades. Remote sensing and GIS serve various functions, such as using spectral indices like NDVI to monitor vegetation and identify changes. Before the emergence of remote sensing technology, access to vegetation data on extensive temporal and spatial scales was quite limited (Pettorelli et al., 2005). Literature has demonstrated that remote sensing supplies spatial data across different spectral resolutions, whereas GIS provides analytical tools (Ibrahim et al., 2015).

Based on today's global call for green landscapes, green cities, and green environment, which is associated with the Sustainable Development Goals (SDGs), it becomes necessary to update land surface information continuously using powerful satellite imageries and spatial analysis techniques. Mapping vegetation change helps provide information that identifies different environmental conditions. The general pattern of change due to the dynamic natural and/or human activities is associated with specific areas and over certain time series (spatiotemporal). Time series, realtime, and global satellite imagery can all provide accurate information about the surface variable (Roy et al. 2008). Current data is necessary to support decisionmakers in articulating their policies based on the impacted areas in the relationship between vegetation reviews and environmental planning. Current scientific studies in the fields of bio-ecological and natural resource management have started to prioritize the change in land use and land cover (Khan et al. 2019).

An urgent developmental need that aids in identifying the environmental issues linked to changes in vegetation cover is the evaluation of vegetation cover at the local level. After droughts adverse impacts, some areas of western Sudan experienced severe effects, and the land cover changed into patterns of degraded bare patches in both agricultural and forest areas. Over time, the use of remote sensing data has become increasingly prevalent in the spatial analysis of vegetation components, changes, and variability at local scales. Image differencing can be used to identify NDVI-based spatiotemporal variations.

This method uses image differencing to map the differences and quantify changes in vegetation cover greenness. Greenings of land surface vegetation cover monitoring became the significant standard for detection and evaluation techniques. Numerous techniques, including change detection methods, classification differencing, and vegetation indices like NDVI and VCI (Vegetation Condition Index), can be used to determine changes in vegetation cover. If the NDVI value is higher than others, it can be used to estimate the density of vegetation. The trends of the NDVI value if they to + 1 (Wen, 2020; Juergens, 2020) indicate that the vegetation coverage is better.

Throughout its operations, the NDVI index will account for the various human and physical landscape characteristics that can be found in various sub-areas within the area of interest. Analogous research has been carried out in the domains of monitoring vegetation cover and NDVI-based differencing. In order to detect changes in vegetation, Jwan et al. (2013) refined NDVI image differencing by extracting NDVI from Landsat 8 OLI imageries. The monitoring of changes in the Western Sudan cover greening based on the spatiotemporal parameters of land surface conditions has been the main focus of the NDVI core studies.

The Normalized Difference Vegetation Index was used by Bhave et al. (2008) to study the vegetation cover. The study assessed the NDVI variance as a measure of different natural factors. NDVI image differencing analysis by location as seen in earlier studies. In 2018, Zaitunah et al. used landsat-8 OLI to analyse NDVI data for various land cover types in Indonesian watersheds. A scientific paper about the spatiotemporal dynamic analysis of greenness based on the NDVI equation for change detection using time series was published in 2024 by Museied et al., in RiverNile State, Atbara City, Sudan was chosen to analyse the shift in land surface greening from 2004 to 2024. The Vegetation Density Index changes were studied by Rianti and Sari (2024) using landsat-8 OLI/TIRS satellite imagery. Regarding the type of satellite data used, Sajid et al. (2023) summarized several types of Landsat images, including thematic Mapper ™, Landsat Operational Imager (OLI), Thermal Infrared Sensor (TIRS), Enhancement Thematic Mapper Plus (ETM+), and MultiSpectral Scanning (MSS). NDVI is not limited to just one type of Landsat images. In order to detect changes in vegetation cover, the NDVI index has been studied using all of these Landsat types (Kiptala et al., 2013).

Problem identification:

Soil fertilization, biodiversity, and environmental conservation are all impacted by the ongoing shift in land cover (Putu et al., 2022). In fact, the removal of forests and the steadily declining vegetation cover have become major environmental issues in Sudan's arid and semi-arid regions. The mid-1980s, when the severe drought in western Sudan emerged, caused a decline in the quality and greenness of the vegetation. The usual situations in the study area, where forests had been turned into urban centres and agricultural lands, were transformed into bare lands, which showed significant environmental degradation that had moved the landscape greenings into bare lands. Localities in western Sudan were particularly affected by the severe drought that struck the entire region in 1984. Since then, there has been a considerable change in the vegetation cover and a degradation of more natural lands due to the increased commercial activity of firewood.

There are various types of natural environments in the research area, which is made up of four rural councils. The muddy soil in Khors and Wades, which are seasonal deposits, is what defines the Abu Haraz Rural Council. The sandy sediments along the seasonal Wades are what define Kazgiel, while the predominant sandy and dunes soils of Um Usheria rural councils have been vulnerable to severe drought since the middle of the 1980s, which has had a major effect on the agricultural lands and vegetation cover. In the eastern portion of the area, Khor Tagat is a council with a variety of natural settings, such as many Khors and sandy soil formations.

In the past, field survey visits employing various land survey techniques, including transect and quadrat systems over the study area that produced incomplete researches results, which has limited information in vegetation cover changes assessment. These were depended on the manual collection of data processed for vegetation cover investigations. This method is unquestionably time-consuming, less accurate, and has restricted coverage that makes it impossible to depict the entire spatial expanse of the area.

Study area:

The selected Sheikan locality of Sudan's North Kordofan State, was the region of attention. Geographically, it was divided into four rural councils (UM Usheria, Khor Tagat, Kazgiel, and Abu Haraz). More or less, each of these had the same geographical features but differed in their area extent. This locality was selected due to the environmental degradation that occurred in the Mid-1980s and

1990s, which must be examined in order to evaluate the three timely selected periods that were established for the 2000s. The study area was roughly 8.312 km² in size. Rain-fed shifting agriculture and multi-landscape pastures are features of the semi-arid ecosystem that includes the study area. According to Fig (1), the study area lies between latitudes 13° 12' and 14º 25' N and longitudes 29º 35' and 30º 30' E. Based on meteorological statistics from 1970 to 2018, the average annual temperature was 45 degrees Celsius with a minimum of 23 degrees, and the average rainfall was 354 millimeters.

The Sheikan locality is well-known worldwide as the world big Gum Arabic Market in El Obeid, the city capital of North Kordofan State. Several natural and economic resources, such as rain-fed agriculture, grazing, the commercialization of wood products, oil extraction, and several more locally produced goods derived from human subsidiary activities, define the area.

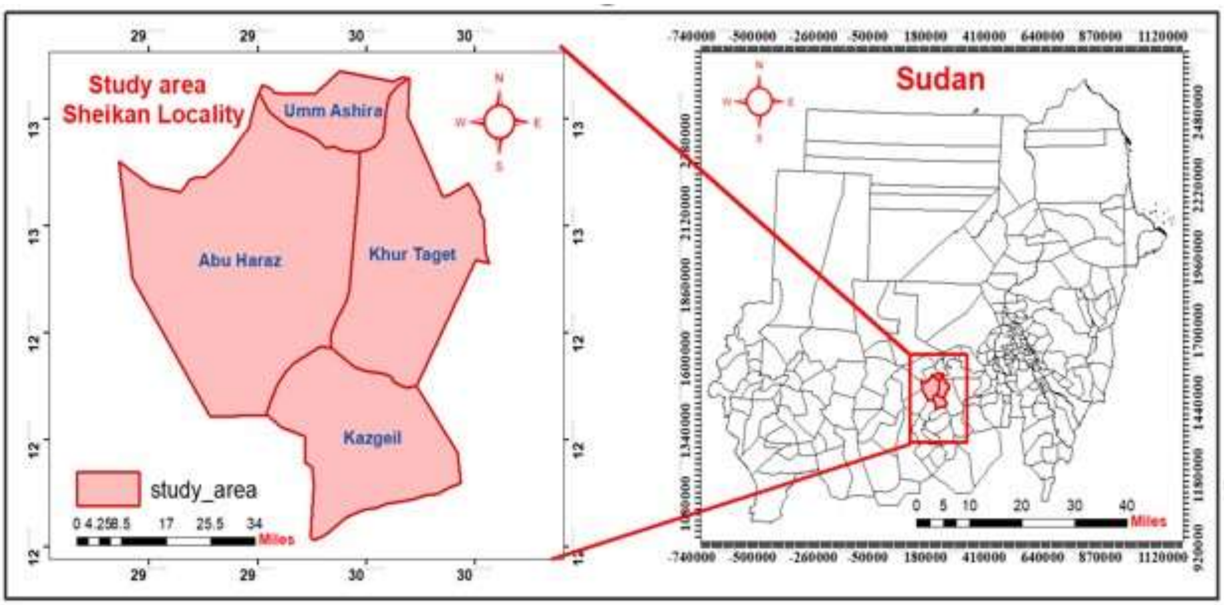
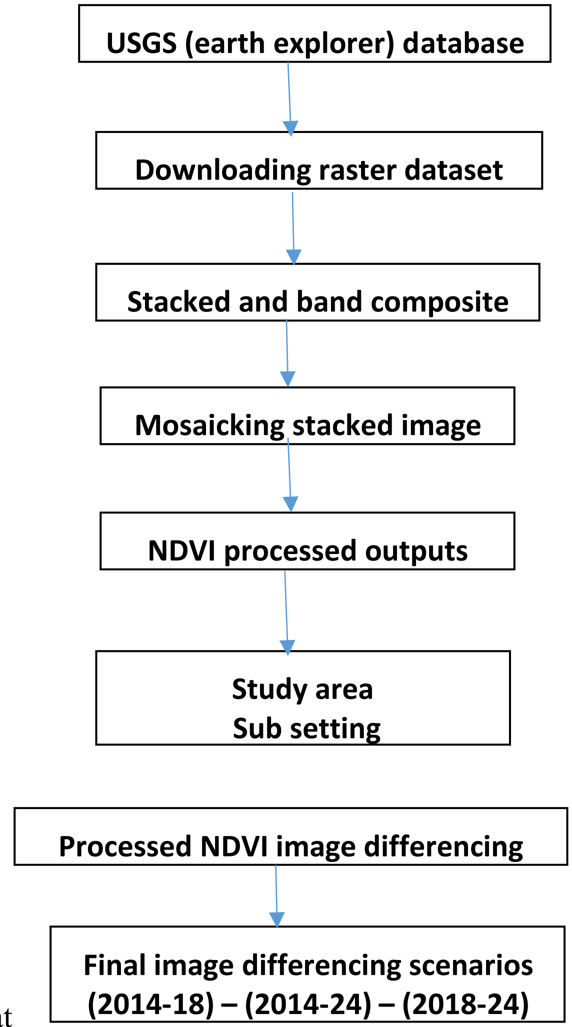


Fig (1): The study area – Sheikan Locality – Sudan

Methodology:

Based on the locality's geographical extent, NDVI image differencing was calculated by considering 4 administrative councils that consisted one Sheikan locality. This study said to be the first in its spatial coverage approach. A standard of processes to monitor land surface greenings end by creating NDVI image differencing maps, presenting NDVI image descriptive statistics parameters, calculated NDVI classified classes per area and interpreting NDVI image differencing. Five classes were identified and labeled no or less greenings, low, medium, high, and V. high greenings. The spatial extent of vegetation greenness was distributed differently across the sub-divisions of the study area. The variation of NDVI greenness over the study area is based on the density of forests and seasonal rainfall that yields different land surface greenings.

The domain of this paper is to support the fact that NDVI index is potential in assessing land cover greening focusing on Spatio-temporal analysis approach. There are sequential and logical several



operational steps that represent the methodological workflow of NDVI image differencing, Fig (2).

Fig (2): Procedural Schematic for Landsat data processing 4-1 Landsat Data preparation:

Multi-spectral Remote Sensing (RS) data are used frequently and characterized by time series data that utilize to detect successive changes, such as every 10th year, five years or year-by-year or even weekly NDVI monitoring approach, both multi-spectral and multi-temporal remote sensing data as stated by Namuqize (2018) will provide value opportunities for different disciplines involve in LULC studies. Satellite data used are downloaded from the USGS web site for land sat -8 Operational Land Imager (OLI). Landsat-8 level -2 concerning the Sheikan locality is the main source of data processed. The images were selected for the month of December, the month that reflected the land surface greenings more than the rest of the season. Path and Row for this study is identified from the spatial extent of Sudan Index shape file (174/51 and 175/51) indicated that the area is covered by two scenes. Three periodical images of Landsat 8 OLI level 2 were downloaded from the online USGS site (http//Earth explorer/usgs.gov/). The satellite land sat 8 OLI imageries were selected for analysis, each season consists of two scenes as specified in table (1) that shows the main specifications and features of the downloaded images used for NDVI analysis.

The landsat-8 OLI images used in this paper is a subset image extract from entire Landsat acquired December 2014, 2018, and 2024 over North Kordofan State. Each pixel in these OLI data presents 30×30 square meter that indicated the spatial resolution with seven multispectral bands. The data of the three seasons has good quality and directly used for processing NDVI.

In addition to image data, vector data (shape file) of the study area also used. The image and vector data are projected into the Universal Transverse Mercator projection (UTM), with standard parameters; zone (36), unit (meters), datum (WGS84), and spheroid (WGS84). Table (2) shows the landsat-8 OLI specifications. ArcGIS was first released in 1999 and originally was released as ARC/INFO, a command line-based GIS system for manipulating data (Bhave et al., 2008).

Table (2): Main landsat-8 data specifications

Bands	Spectral bands	Wavelength μm	Resolution m	Potential Information
B/1	Coastal/ Aerosol	0.43-0.45	30	Highlight shallow water Measuring change in ocean colours
B/2	Blue	0.45-0.51	30	Land cover classification change detection. monitoring urban and infrastructure, vegetation and crop monitoring
B/3	Green	0.53-0.59	30	
B/4	Red	0.64-0.67	30	
B/5	NIR	0.85-0.88	30	Monitoring plants and contrasting water bodies against the surrounding
B/6	SWIR-1	0.57-1.66	30	Infrastructure monitoring soil composition analysis and mineral detection and NBR index
B/7	SWIR-2	2.11-2.29	30	

4-2 Methods of Analysis:

The main pre-processed operations have been done to Landsat images includes images download, band combination (false color and true color combination), layer stacking (image composite), mosaicking and extraction. On the other hand, NDVI was processed and image differencing was calculated, mapped and interpreted as the main target of this study.

4-2-1 Spectral indices:

The spectral indices such as NDVI, NDWI, and NDBI are the result of radiometric measurements, which use two or more surface reflectance wavelength. In case of NDVI, combines infrared and red from visible region. By using band infrared (b/5) and Red (b/4) of Landsat 8 OLI, NDVI was derived.

4-2-2 NDVI index:

Among the many spectral indices that used for monitoring and evacuating vegetation cover, NDVI becomes the most recommended one in analysing Spatio-temporal vegetation cover changes. The Normalized Difference Vegetation Index (NDVI) has been widely used to monitor vegetation since its proposal in 1969 (Kriegler et al., 1969), and classified as an important index of vegetation widely used in research on global climate and environmental change (Gao et al., 1996). This method has a different application related to vegetation cover such as crop yield estimation, pasture quality, range lands carrying capacities and other land surface features. The NDVI map is ordinarily used for the investigation of vegetation vigour and coverage on the ground (Keiji Osaki, 2000). The development of vegetation indices from brightness values is based on the differential absorption, transmittance, and reflectance of energy by the vegetation in the red and near-infrared portions of the electromagnetic spectrum (Derring and Haas, 1980; Lyon and McCarthy, 1995; Jensen, 1996).

The use of continuous time series of global NDVI data, based on the NOAA AVHRR sensor, developed rapidly in the early 1990s. Since then, the data processing and the techniques for analyses of the data have improved significantly (Genesis et al, 2014). NDVI method has accepted by great application fields at global, national and local, but at the national level in Sudan as at the sub-division's councils or localities, there are a few studies focussed on the rural areas of the Sudan. After decades of development, several NDVI time-series datasets have been generated with various temporal and spatial resolutions (Xu et al., 2022). John et al., 1998, stated that among many vegetation indices studied, NDVI difference techniques demonstrated the best vegetation change detection.

4-2-3 NDVI calculations:

It is a numerical indicator that use NIR and Red bands of the electromagnetic spectrum. The formula is as follows:

$$NDVI = (P_{NIR} - P_{R}) / (P_{NIR} + P_{R}) \text{ ----------------------(1)}$$

$$NDVI = (P_{B5} - P_{B4}) / (P_{B5} + P_{B4}) \text{ ----------------------(2)}$$

The NDVI values rating based on the range between -1 and +1 as scale that varied based on the vegetation condition of an area. The positive values between 0 to + 1 is an indicator of greenings that classified into different classes, each class has its lower and upper limits that interpreted differently using certain scale.

4-2-4 NDVI Image Differencing:

For this current study, researchers add value method to depict changes using NDVI differencing as a potential method to depict the changes over time with specific spatial extent (Spatio-temporal) that occurring in study area (2014-2024). Considering the NDVI image differencing, we use subtract parameters for pair NDVI images as presented as an output with statistics organized in tables. Results of NDVI image differencing adjust increment and decrement in the NDVI values that indicated the variation in vegetation cover greenness. Changes can be presented and interpreted statistically indicated change and no change areas. This statistical summarization presented in table () using mean and STD for different images.

The main objective of this study was to quantify the NDVI image differencing based on class area during the selected periods. The NDVI differencing equation used is a very simple one that only based on subtracting the two different NDVI images (t_1 and t_2). The equation is as follows:

$NDVI_{diff} = (NDVI_{t2}) - (NDVI_{t1})$

Based on this, the study calculated three different NDVI image differencing scenarios, which are (2014-2018), (2014-20124) and (2018-2024).

4-2-5 Colour Ram used:

To bring the NDVI image outputs into effect, this requires a certain type of formatting includes colour specification that match the value ranges, which indicated the amount of greenness. The NDVI classes were classified and each class has its identifiable colour that suit its NDVI value ranges management based on colour ram index that gives observational values of the RGB presented in table (3). Table (3): Classification Colour Table

Classes	Class reclassified label	Colour
1	No or less NDVI greenings	Ultra blue
2	Low NDVI greenings	Ginger Penk
3	Medium NDVI greenings	Solar Yellow
4	High NDVI greenings	Medium apple
5	V. High NDVI greenings	Pecoock green

4-2-6 NDVI Interpretation:

As the NDVI values outputs interpreted by many researchers, there are different scales for evaluating NDVI values ranges. Fusami et al., 2020 stated that NDVI values range between 0.2 and 0.4 indicates sparse vegetation areas and 0.4 to 0.6 areas are variability greenings, and also 0.6 refers to the highest possible land cover greenings.

One of the main steps in the methodological plan is the reclassification of NDVI product based on ArcGIS environment. The processed NDVI images for the three periods have been reclassified using 5 classes scale, namely no or less greenings, low, medium, high and very high greenings, table (4). Each class defined by certain indicative color adjusted by color ram standard values for RGB. Table (4): NDVI interpretation scale used

Range of NDVI Value	Object Names
- 0.02 to – 0.01	No or less greenings
0 to 0.12	Low greenings
0.13 to 0.14	Medium greenings
0.15 to 0.16	High greenings
0.17 to 0.50	Very high greenings

Results and Discussion:

Interpreting NDVI image differencing requires calculating the NDVI class area based on pixel counts. High NDVI pixel count class, calculates high NDVI greenings area for that class, while less class NDVI pixels calculated low NDVI greenings area for that class. So, the NDVI class area is calculated based on cells or pixels counts depends on pixel size. Pixel counts for each class has been converted into area per hectares (pixel counts of the class multiplying by the 0.09) 5-1 NDVI statistical analysis:

Results showed that the max. NDVI value was depicted in the 2014 (0.5), with same relatively close in 2018 (0.48) and 2024 (0.49). From the NDVI value ratings, the NDVI max not exceeded 0.5 in all seasons and across the study area sub-divisions. This due to the common nature of the study area, which is affected by the drought and deforestation that caused prolong vegetation cover disturbances.

5-1-1 Pixel counts statistical analysis:

From tables (5-6-7) we can observed that the NDVI pixels counts were accounted to show different values in 2014, 2018 and 2024 across the study area. As the results of the calculations, all seasons were showed relatively similar pixels during the different periods. Abu Haraz in 2014 calculated NDVI pixels to be 47.38%, 47.34% and 47.40% in 2014, 2018 and 2024 respectively, while Kazgiel showed different pixels of NDVI in 2014, 2018 and 2024 represented by 20.82, 20.81 and 20.83 respectively. Khor Tagat NDVI pixels are 25.36, 25.35 and 25.37 in 2014, 2018 and 2024 respectively. In addition, Um Usheria showed the iminium NDVI pixels in 2014 (6.44%), in 2018 (6.50%) and in 2024 (6.40%).

5-1-2 2014 image-based NDVI statistical analysis:

Table (5): 2014 NDVI Reclassified Statistics

Councils	No. of pixels	%	Min	Max	mean	STD
Abu Haraz	4461908	47.38	- 0.31	0.38	0.133	0.019
Kazgiel	1961177	20.82	- 0.23	0.50	0.131	0.022
Khor Tagat	2388659	25.36	- 0.24	0.48	0.121	0.020
Um Usheria	606130	6.44	- 0.16	0.40	0.143	0.016
Overall Locality	9417874	100	- 0.31	0.50	0.143	0.023

5-1-2 2018 image-based NDVI statistical analysis:

Table (6): 2018 NDVI Reclassified Statistics

Councils	No. of pixels	%	Min	Max	mean	STD
Abu Haraz	4461914	47.34	- 0.34	0.41	0.145	0.025
Kazgiel	1961161	20.81	- 0.25	0.46	0.129	0.029
Khor Tagat	2388667	25.35	- 0.29	0.46	0.126	0.023
Um Usheria	612644	6.50	- 0.14	0.49	0.136	0.016
Locality	9424380	100	- 0.34	0.49	0.136	0.025

5-1-3 2024 image-based NDVI statistical analysis:

Table (7): 2024 NDVI Reclassification descriptive Statistics

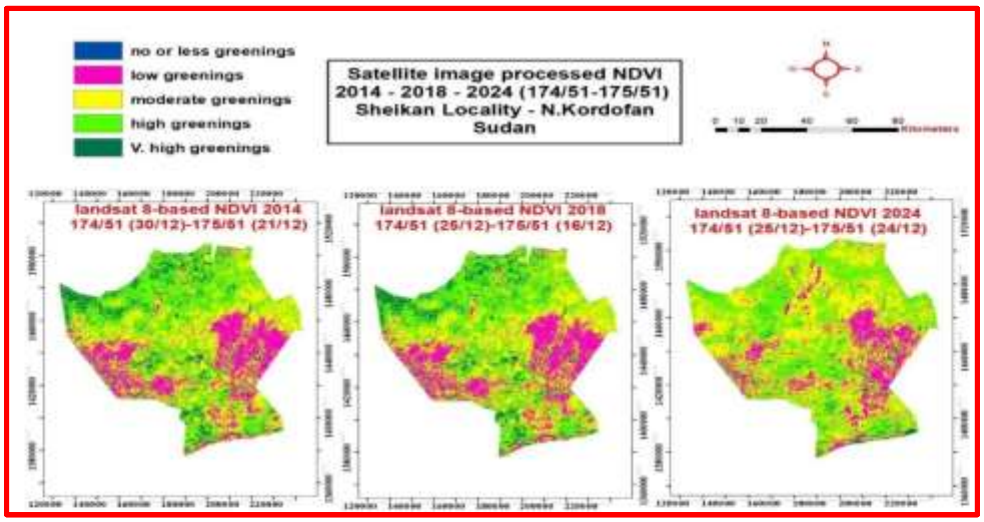
Councils	No. of pixels	%	Min	Max	mean	STD
Abu Haraz	4461895	47.40	- 0.27	0.38	0.138	0.019
Kazgiel	1961169	20.83	- 0.29	0.48	0.135	0.028
Khor Tagat	2388675	25.37	- 0.31	0.45	0.128	0.025
Um Usheria	602129	6.40	- 0.12	0.38	0.141	0.013
Locality	9413868	100	- 0.31	0.48	0.135	0.023

Image-based NDVI surface area analysis:

In this part, landscape greenness will be calculated using the Normalized Difference Vegetation index and converting reclassified classes into areas. The counts of cells (pixels) for each class were used to convert it to area in hectares by multiplying the number of cells by 0.09. Later this was used to extract change rates between 2014, 2018, and 2024.

6-1 Overall NDVI surface area analysis:

Fig (3) and tables (8 –a-b-c), represented the three seasons variation in area covered by greenings as calculated from the reclassified NDVI images. The first class showed the less area covered by greenings 421.92, 466.83 and 469.89 hectares in 2014, 2018 and 2024 respectively. In 2018 and 2024 the area covered by greenings correspond to the first class is nearly similar, while in 2014 is lesser by about 421.92 and 47.97 hectares from that in 2018 and 2024 respectively. The large area covered by greenings in 2014 is class 3 (medium greenings) 300072.6 (35%), while in 2018 it's also class 3 has an area of 332225.46 hectares (39%) and in 2024 is also class 3 383758.11



hectares (45%). This
indicated that class 3 (medium greenings) is dominant area.

Fig (3): NDVI seasonal variability (2014-18-24)

Table (8- a): Sheikan Locality NDVI Surface area statistics (dec-2014)

class	number of pixels	AREAM^2	AREA_HA	PERCENT
1	4688	4219200	421.92	0
2	1854238	1668814200	166881.42	20
3	3334140	3000726000	300072.6	35
4	3203141	2882826900	288282.69	34
5	1021667	919500300	91950.03	11

Table (8 -b): Sheikan Locality NDVI Surface area statistics (dec-2018)

classes	No. of pixels	AREAM^2	AREAHA	PERCENT
1	5187	4668300	466.83	0
2	2010403	1809362700	180936.27	21
3	3691394	3322254600	332225.46	39
4	2930203	2637182700	263718.27	31
5	787199	708479100	70847.91	8

Table (8-c): Sheikan Locality NDVI Surface area statistics (dec-2024)

Classes	No of pixels	AREAM^2	AREAHA	PERCENT
1	5221	4698900	469.89	0
2	1515808	1364227200	136422.72	16
3	4263979	3837581100	383758.11	45
4	3286610	2957949000	295794.9	35
5	342250	308025000	30802.5	4

NDVI images differencing:

The changing of surface greenings over the selected periods for this study can be interpreted using pair wise analysis. First, the change during 2014 to 2018 has been interpreted and then the change over the period 2014 to 2024 and change that occurred during 2018 to 2024. Fig (4) presents the overall NDVI classified classes area per hectares that showed the land surface greenings during the period 2014, 2018 and 2024.

Class 1 ‘no or less greenings’, depicted lesser NDVI areas all through theses seasons, with closely similar areas 469.89, 421.92 and 466.63 hectares in 2014, 2018 and 2024 respectively. Class 2 ‘low NDVI greenings’, calculated varied NDVI areas. The high land surface covered by greenings is in 2018 (180936.27) hectares, and low in 2024 (36422.72) hectares. Class 3 was depicted large areas classified as ‘medium NDVI greenings’ in all seasons with the larger coverage in 2024. Class 4 ‘high NDVI greenings’, showed good coverage, but lesser than the class 3. Class 5 classified as ‘very high NDVI greenings’ gives the real change trend of NDVI areas differencing.

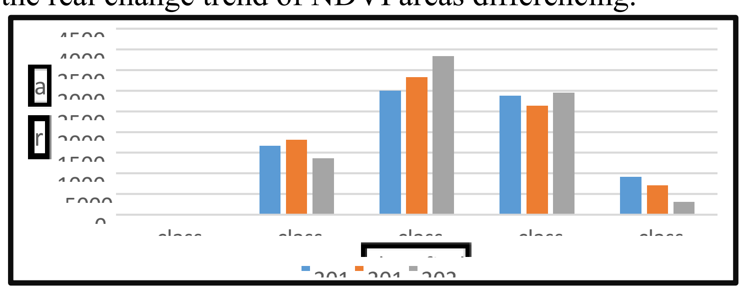


Fig (4): Overall NDVI classified classes' area (hectares)

7-1 2014-2018 NDVI image differencing:

The class 4 the very high NDVI, greenings has reduced by (24564.42) hectares during these four years, while class 5 of very high greenings, also showed decreasing trend from 91950.03 ha in 2014 to 70847.91 ha in 2018. The medium class 3 was increased by 32152.86 hectares in 2018. The NDVI area calculated in class one (no or less greenings) showed slight decreased by (-44.91) hectares, table (9) and Fig (5- a-

Table (9): Surface greenings cover changes (2014 to 2018)

NDVI value class	2014 NDVI class area			2018 NDVI class area			Change 2014-18	
	No of pixels	ha	%	No of pixels	ha	%	ha	%
1	4688	421.92	0.05	5187	466.83	0.06	44.91	11%
2	1854238	166881.42	19.69	2010403	180936.27	21.33	14054.85	8%
3	3334140	300072.6	35.40	3691394	332225.46	39.17	32152.86	11%
4	3203141	288282.69	34.01	2930203	263718.27	31.09	-24564.42	-9%
5	1021667	91950.03	10.85	787199	70847.91	8.35	-21102.12	-23%
total	9417874	847608.66	100.00	9424386	848194.74	100.00		

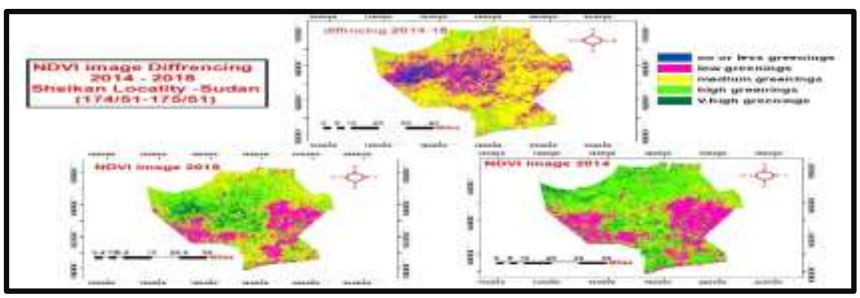


Fig (5 –a): NDVI image differencing 2014-2018 – (ArcGIS-image analysis)

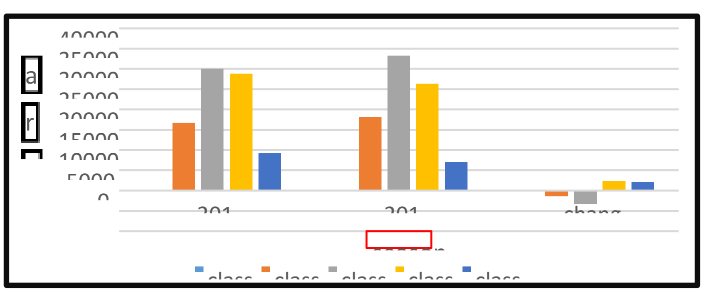


Fig (5 - b): NDVI images differencing area per hectares (2014-2018)

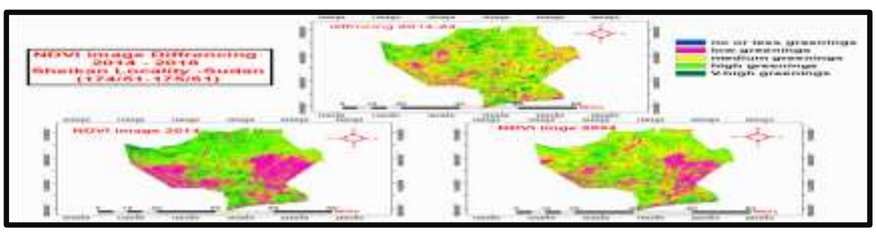
7-2 2014-2024 NDVI image differencing:

During this period 2014 -2024 (10 years), there are clear changes in NDVI classified class's area. Class 1 showed increasing in area classified as 'no or less greenings' by (-47.97) hectares, while class 2 showed increased in the area classified as 'low NDVI greenings by (30458.7) hectares. Class 3 'medium NDVI greenings', increased from 300072.6 to 388758.11 by a value (- 83685.51) hectares. Class 4 also increased by (7512.21) hectares in season 2024, while class 5 'very high NDVI greenings', was calculated the significant drop from 91950.03 in 2014 to 30802.5 hectares in 2024, table (10) and Fig (6 – a -b).

Table (10): Surface greenings cover changes (2014 to 2024)

Fig (6 - a): NDVI

NDVI value class	2014 NDVI class area			2024 NDVI class area			Change 2014-24	
	No of pixels	ha	%	No of pixels	ha	%	ha	%
1	4688	421.92	0.05	5221	469.89	0%	47.97	11%
2	1854238	166881.42	19.69	1515808	136422.72	16%	-30458.7	-18%
3	3334140	300072.6	35.40	4263979	383758.11	45%	83685.51	28%
4	3203141	288282.69	34.01	3286610	295794.9	35%	7512.21	3%
5	1021667	91950.03	10.85	342250	30802.5	4%	-61147.53	-67%
total	9417874	847608.66	100.00	9413868	847248.12	100%		



images differencing area per hectares (2014-2018)

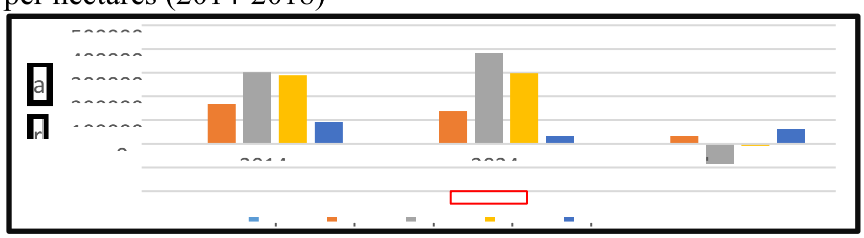


Fig (6 - b): NDVI images differencing area per hectares (2014-2024)

7-3 2018-2024 NDVI image differencing:

The NDVI image differencing during the period 2018 – 2024 (6 years) was showed varied changes based on the classified classes. Class 1 'no or less NDVI greenings', showed slight change (-3.06) indicated staple conditions during these six years. Class 2 'low NDVI greenings', calculated decrement from 180936.27 to 136422.72 hectares by changing value (44513.53) hectares. This interpreted positive change to decrease the areas of low greenings may at expense of high or very high NDVI greening areas.

Class 3 ‘medium NDVI greenings’, was depicted the decrement of about (-51532.62) hectares. Class 4 ‘high NDVI greenings’, indicated positive increment by (32076.63) hectares, while class 5, showed sharp decreasing (40045.41) hectares in area covered by very high NDVI greenings from 70847.91 to 30802.5 hectares, table (11) and Fig (7 –a -b).

Table (11): Surface greenings cover changes (2018 to 2024)

NDVI value class	2018 NDVI class area			2024 NDVI class area			Change 2018-24	
	No of pixels	ha	%	No of pixels	ha	%	ha	%
1	5187	466.83	0.05	5221	469.89	0%	3.06	1%
2	2010403	180936.27	19.69	1515808	136422.72	16%	-44513.55	-25%
3	3691394	332225.46	35.4	4263979	383758.11	45%	51532.65	16%
4	2930203	263718.27	34.01	3286610	295794.9	35%	32076.63	12%
5	787199	70847.91	10.85	342250	30802.5	4%	-40045.41	-57%
total	9424386	848194.74	100	9413868	847248.12	100%		

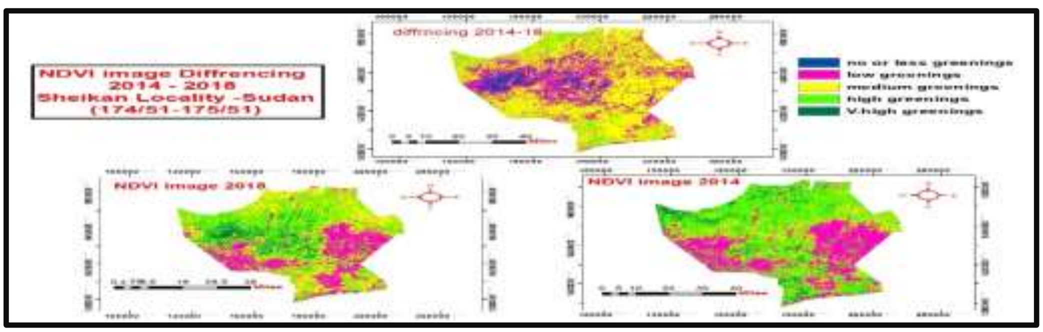


Fig (7 - a): NDVI images differencing area per hectares (2014-2018)

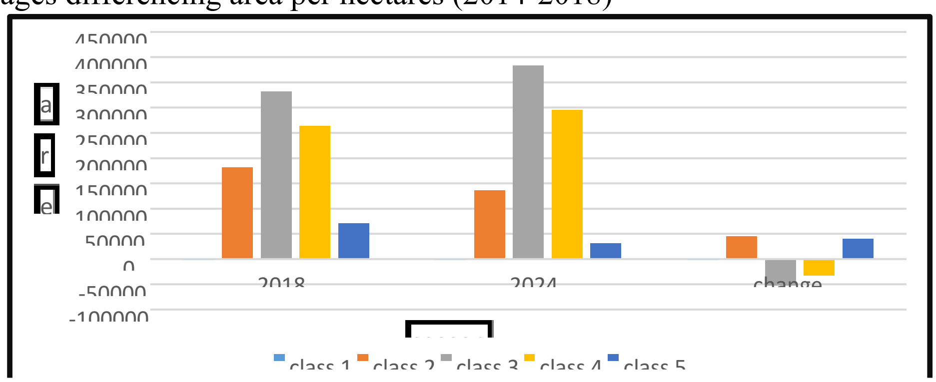


Fig (7 - b): NDVI images differencingarea per hectares(2018-2024)

Fig (8) presented the conclusion of the NDVI image differencing during the seasons (2014-2018-2024). Class 2 showed the positive change during the periods (2014-2024) and (2018-2024) and negative change during (2014-2018). Class 3 depicted that during all calculated periods, there were negative changes with sharp indicator during 20142024. Class 4 was indicated that the positive change during (2014-2018), and negative during the periods (2018-2024) and (2018-2024). The class that has no negative change during these periods is class 5 that classified as a very high NDVI greenings that indicated good land surface greenings.

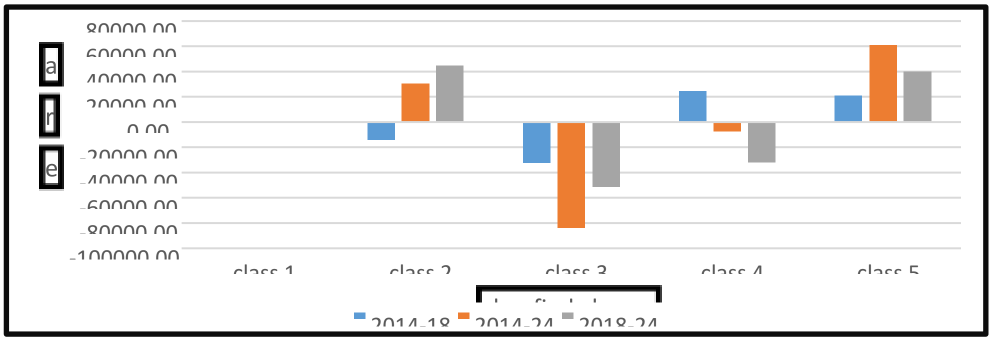


Fig (8): NDVI image differencing (2014 – 2018 – 2024) 8- Discussion:

The diversity and variability of the NDVI index values that calculated-based areas as reclassified into 5 classes are basically caused by different factors. Considering the natural factors related to climate variability, the effect of the human activities is significantly considerable with higher weight that the climate factors. The three different scenarios studied in this research (2014, 2018 and 2024) will have altered that based on the changing rainfall characteristics such as amount and distributions.

The Normalized Difference Vegetation Index (NDVI) utilizes for many different fields, such as to monitor vegetation change, drought, agricultural prediction, hazardous fire belts and movement of desert margins. The usefulness of the NDVI method is its potential capabilities to differentiate between vegetated lands and lesser lands with no vegetation cover. Heavy cultivated areas, high tree cutting areas, and degraded pasture areas indicated low NDVI values. The stocked and conserved forest lands gives an optimal condition of high NDVI value representing dense and healthier vegetation cover. This NDVI image differencing is explained Normalized Difference Vegetation Index (NDVI), as an indicator of the change occurred over an area of the existing land surface greenings conditions.

The western Sudan, including the study area, since 1980s characterized by rainfall variability and successive draughts since 1984. Sheikan locality has identified a significant variability in NDVI value ratings based on its 4 sub-divisions councils (Abu Haraz, kazgiel, Khor Tagat and Um Usheria. North-east Sheikan is located Um Usheria Rural council a sandy and dunes area, affecting much by the drought and erratic rainfall. It is the lesser council in vegetation cover due to overcutting and over cultivation. Image differencing depicted that changes occurred during 2014 to 2018, were basically from the land transformation caused by cutting and shifting cultivation activities.

The greenness of land surfaces exclusively depend on vegetation growth in healthy conditions that basically depend on the seasonal rainfall amount and efficiency. Change in seasonal rainfall caused directly change in vegetation cover density mainly during drought periods as the rainfall below the normal average. The study area was affected severely by the 1980s droughts. over the study area, the most significant land surface greenings change have occurred during the seasonal rainfall that affected the perennial plants that sustain the soil moisture and supporting the intensity of vegetation cover.

The classified high and very high greenings classes increased dramatically from 2018 to 2024, compared to change from 2014 to 2018 for the same classes. The significant no or less land surface greenings occurred surrounding the junction of the rural councils where the ElObeid city built up area continuously growing.

The result summary is that the significant greenings areas have the highest NDVI values, are found in vegetated and forest areas. On the other hand, the lower NDVI values over the study area, indicated the less vegetation coverage and barren areas as well as buildings and water bodies.

Conclusion:

This study was initiated to assess one of the environmental problems in neglected rural areas of western Sudan. The study aimed to assess land surface cover greenings based on the NDVI index estimation of pixel counts in the periods 2014, 2018 and 2024 in one of the North Kordofan Localities. Satellite data, Landsat 8 Operational Land Imager (OLI) were captured with the available spatial resolution of 30*30 meters. Year by year over the western Sudan, the quality and quantity of vegetation cover have been decreasing progressively left a severe environmental degradation. During the last 30 years, the urban new extensions caused the removal of thousands of hectares of forests surrounding main towns such as ElObeid and Um-Rwaba. Shrinkage in vegetation cover all over the locality leads to change in land surface greenness that will have adverse impacts upon the local vegetation cover and soil properties.

Based on the spectral reflectance measurements, Normalized Difference Vegetation Index (NDVI) is one of the standard spectral indices used as the potential method and data source for vegetation assessment. The study initiated to give wide spectrum for land surface greenness in Sheikan locality, Sudan.

As recommended by many studies, NDVI is a potential and effective method that provides a real conclusion of the vegetation status over time. NDVI image differencing is a powerful operation that monitor the vegetation over change generating accuracy results that help in evaluating related environmental phenomena such as drought, deforestation and desertification.

The present study has generated comparative satellite image data, which provided the basis for assessing the land surface vegetation greenness change via Spatio-temporal approach. We calculated different NDVI images for the periods 2014, 2018 and 2024 in Arc map 10.8 environment using Map Algebra-Raster calculator. The image differencing method NDVI used to depict the land surface greenings and showing changes that occurred over times.

Day-by-day, we urgently need to develop more advanced indices that monitoring and quantifying the vegetation cover changes due to the alarming call about increasing deforestation and land mismanagement. Information extracted from remote sensing raster-based data represent the key solution for the vegetation changes recover.

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