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RESEARCH ARTICLE

NDVI AND REMOTE SENSING SPECTRAL INDEX FOR MONITORING LAND SURFACE GREENINGS. ASSESSMENT CASE - UMM RUWABAH, NORTH KORDOFAN-SUDAN

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ABSTRACT

Vegetation cover condition is a dynamic natural event associated with the characteristics of seasonal rainfall. Based on its occurrence, the greenings can indicate the level of wetness and dryness as the soil moisture is highly related to its intensity. The impact of climate variability in North Sudan is likely to be greatest since the 1984 severe drought that left its continuous stresses. Most parts of North Sudan are experiencing dramatic changes in land cover at different scales spatially and temporally. Historical field survey methods for assessing and monitoring land cover conditions are no longer used since the emergence of spatial and digital techniques such as remote sensing and GIS. Remote sensing (RS) has a massive utility for applications, including assessing and monitoring land surface cover conditions. This paper aims to apply one of the potentially widely used spectral indices (NDVI) calculated by using NIR and Red bands. Landsat-8 data will be accessible from USGS Explorer free image download, which will constitute the primary inputs. The area of interest is a part of North Kordofan State in the Western Sudan zone (175/50-175/51-176/50-176/51) to a spatial extent. The expected results will be a set of NDVI maps that shows the NDVI values variability between (-1 and +1) concerning land surface greening conditions and reclassified maps (five classes) depending on values lower and upper limits.

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INTRODUCTION

The arid and semiarid ecosystems are very fragile and subject to drought cycles that consistently diminish their vegetation cover. Due to a number of natural, anthropogenic, and socioeconomic factors land use/land cover (LULC) patterns are being changed over a long period of time, i.e., decades (Coppin *et al.* .2004). The arid and semi-arid regions cover about 41% of the Earth's surface, and according to the present global warming trend, their extent will further increase during the 21st century about 38% of the world's population lives in these areas (El-Beltagy and Madkour, 2012; Zhang *et al.* 2020). Vegetation dynamics are the most representative indicator for the states of the regional climate and environment (Jong *et al.* 2011). The high variability in vegetation conditions, together with the patchy landscape structure, the open vegetation canopy, and the heterogeneous soil conditions, are all factors that pose challenges for "RS" of vegetation in the Sudano-Sahelian zone (Franklin 1991; Kammerud 1996; Leprieur *et al.* 2000). Water is the main limiting factor for vegetation growth throughout the SSZ, which means that photosynthesis mainly takes place during the wet season (Philippon *et al*. 2005). Therefore, monitoring vegetation dynamics and evaluating its driving factors contribute to a better understanding of the potential relationship between vegetation and environmental changes and are very important for formulating optimal strategies for eco-environmental restoration and protection (Gillespie *et al.* 2018; Myers-Smith *et al.* 2020).

Over the past half-century, although global ecosystems have reportedly exhibited varying degrees of degradation due to climate change and human activities (Millennium Ecosystem Assessment (MA), 2005), The common changes trend in regions related to biomass production increasing and correlated with parameters of warming and precipitation increasing especially in winter time (Elsakov *et al.* 2013). The change in Land Surface Temperatures is a sign of increased drought (Shiran, *et al.* 2021; Mustafa, *et al.* 2021). Drought is defined as a natural event that negatively affects land and water resources, and hydrological equilibrium is disrupted due to precipitations falling below normal levels (Benson *et al.* 1997, Mishra, *et al.* 2010). In terms of agriculture, the periods in which the amount of water to meet the needs of plants in the soil is not present are defined as arid (IPCC 2014, Chang 2011, Riebsame 1991, and Zhang, A. *et al.* 2022).

Remote sensing imagery can be used to detect ecological status in various ranges because it measures reflected radiation of the Earth's surface and can detect different components of an ecosystem such as soil, vegetation, and open water.Therefore, remote sensing technology has been frequently utilized in ecosystem investigations (Kwok 2018 and Xu, *et al.* 2018). NDVI is an important vegetation index, widely applied in research on global environmental and climatic change. NDVI is calculated as a ratio difference between measured canopy reflectance in the red and near infrared bands respectively (Yang Y et.al2010, Lan *et al.* 2009,). NDVI has been used widely to examine the relationship between Spectral variability and the changes in vegetation growth rate. Hence it is also useful for determining the production of green vegetation as well as detecting vegetation changes. Hoffer (1978) defined Change detection as temporal effects variation in spectral response involving situations where the spectral characteristics of the vegetation or other cover type in a given location change over time Singh (1989).Change detection applies multi-temporal datasets to quantitatively analyse the temporal effects of the phenomenon (Ajadi, *et al.* 2016, Cao, *et al.* 2016, and Kwok, R. (2018). In Sudan, in terms of severity, drought characteristics varied spatially and temporally. The precipitation pattern regulated drought intensity in Sudan, which in turn was governed by the overall regional climate system and was the result of climate change phenomenon. On the other hand, NDVI values likely reflected vegetation responses to drought conditions. In Sudan, the relationship between precipitation and NDVI has also been reported to be strong in numerous studies (Mohamed 2016). Remote sensing is significant for evaluating the effects of climate change and monitoring changes in the biophysical characteristics of land cover because it interacts with basic chemical, physical, and biological processes in the soil and controls soil moisture and vegetation properties (Zhang *et al.* 2020).

Statement of the Problem

The primary goals and purpose of this study are to use the NDVI detection method based on Remotely Sensed data (RS) and GIS to classify the temporal variation of vegetation structure, such as related factors, and the gradual decrease of green plant coverage in a temporal scale of view on the Umm Ruwaba area. Change in land use and land cover has become a serious environmental problem faced the arid and semi-arid ecosystems. Since the 1980s, the land forest in north Kordofan has continuously degraded, which is why the study has been to monitor the surface greening of these parts of it.

Significance of the Study: The significance of this work is to evaluate the effects of environmental change and monitor changes in the biophysical characteristics of land cover and surface greening. The main aim of this research is to use Remote sensing data and techniques to assess the vegetation cover conditions using a spatiotemporal. And to show the efficiency of the NDVI in assessing surfaces greening.

STUDY AREA

The study area is located between 12° 54' 21" N and 31° 12' 56" E in North Kordofan in Sudan and is the capital of the Umm Ruwabah District., it is located 147 kilometers southeast of El Obeid West Sudan shown in Figure (1). The study area has a total area of 21.000 square kilometers and has 55,700 population. The elevation is about 457 meters (1,499 feet) above mean sea level. The climatic zone is identified Semi-arid climate (Köppen climate classification: BSh) the rainfall increases in amount and duration southward. It ranges from 200 mm/y in the north to 450 mm/y in the south. The mean temperature is 27° C with 10° C and 46° C temperature extremes. During the rainy season, a south wind dominates the area whereas, the north wind dominates during the winter. The former is associated with a high mean relative humidity averaging about 55%, while the latter is characterized by a low average humidity of about 21 %. (IFAD2002). Four seasons are recognized; the rainy season (Kharif) from May to October, the Harvest season (Darat) follows early December with low humidity and night temperature, the cold dry season (Shita) from December to mid-February, and the hot dry season (Seif) with prevalent north –easterly winds, from March to May (ElTom 1975). Soil cover in North Kordofan consists mainly of coarse detritus derived from prolonged weathering of the underlying bedrock as well as some active sand dunes covering most of the Northern parts of the province. Sandy soils cover the most of two localities and support rain-fed arable agriculture, the main crops grown are millet, karkadeh, and watermelon. Gradoud soils cover about 20% of the study area. Vertisols are heavy cracking clay soil dominating the Abu Habil basins, west and east Jebel El Dayir extending to south clay plains, they are fertile with good water holding capacity, Nevertheless, the area suffers from acute shortages of fresh water supply for both human and animal consumption (Zeinelabdein *et al.* 2015). The main crops grown are sesame, sorghum, and cotton in the El Seimeih Scheme, and Gum Arabic production and forestay products (Hamad *et al.* 2018). The study area lies within the Gum Arabic Belt. The vegetation covers dominantly by a number of acacia species mainly Hashab (Acacia Senegal), Kitir (Acacia melifra), Taleh (Acacia seyal), Mikheit (Bosciasenegalensis), and different types of grosses, Abu asabi (Dactylacteniumaegyptium), Banu (Eragrostisaspera), etc, and wide range of Herbs e.g. Bighail (Blephanislinarifolia) and Sena (Cassia acutifolia), etc. (Harison 1958). The central zone of the area is subjected to additional grazing pressure during the rainy season due to the presence of the cattle of nomadic Baggara tribes and large herbs of camels coming from the north in the early wet season. Farming systems include traditional rain-fed farming in sandy soils, and semi-mechanical farming where tractors are used for land preparation for the production of sorghum and sesame under the condition of ground and vertisols.

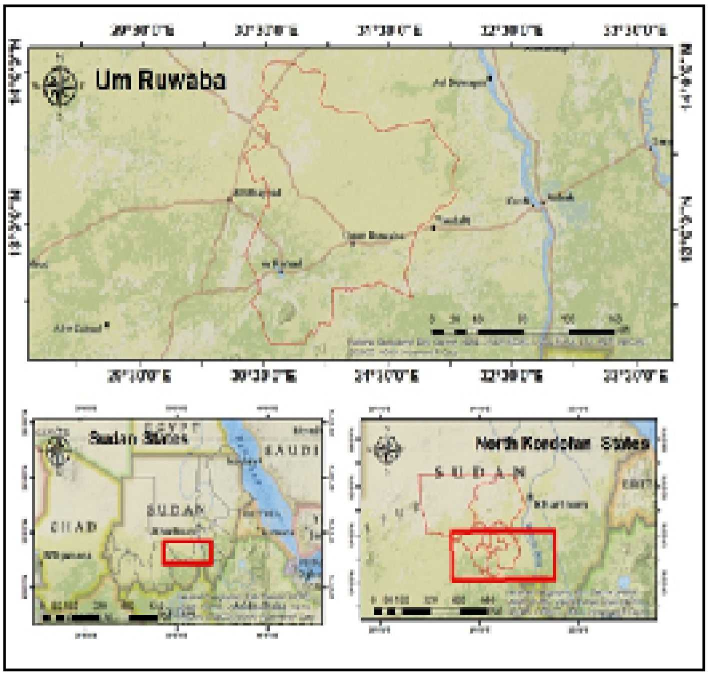


Figure 1. Study Area

METHODOLOGY

NDVI, the most common index for remote sensing of vegetation, is known to be saturated over areas with high variation indexes. Numerous vegetation indexes using the same set of near-infrared and red channels have been developed, even though these indices do not enjoy the same popularity as NDVI, which is known for its capability to distinguish vegetation from other types of land cover, but is not really designed to sense the water content in the vegetation canopy. For the detection of plant water content, the near-infrared region (NIR) and shortwave infrared regions (SWIR) have been used. Thus, NDWI is defined in a similar way to NDVI but uses the near-infrared channel to monitor the water content of the vegetation canopy. Fluctuations in the vegetation canopy are indicators of drought stress.

In this Section, the NDVI technique is used for extracting the various features presented in the band Satellite image of the study area. NDVI is calculated as

NDVI= NIR-RED/ NIR+RED…… (Equation. 1)

NDVI= NIR−RRD/ NIR+RED
NDVI= NIR-RED/ NIR+RED…………………….. (Equation. 1)

Table 1. Datasets characteristics

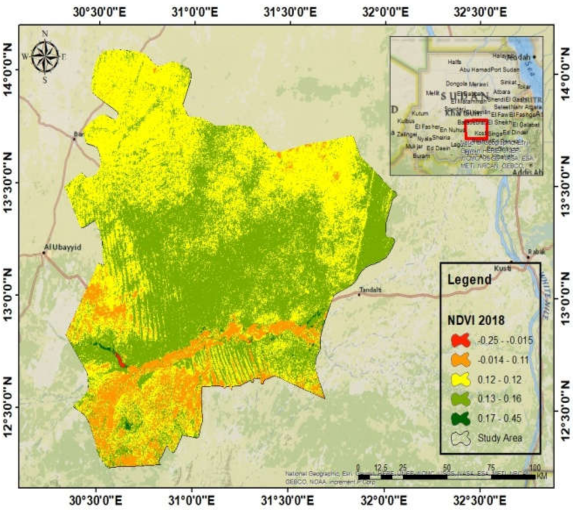
Year	Resolution	date	BANDS	LANDSAT	software	data
2018	30*30	2018-3.1-30	3+5	8	ArcGIS Pro 1.2+ Google Earth engne	USGS
2019	30*30	2019-3.1-30	3+5	8	ArcGIS Pro 1.2+ Google Earth engne	USGS
2020	30*30	2020-3.1-30	3+5	8	ArcGIS Pro 1.2+ Google Earth engne	USGS
2021	30*30	2021-3.1-31	3+5	8	ArcGIS Pro 1.2+ Google earth engne	USGS
2022	30*30	2022-3.1-32	3+5	8	ArcGIS Pro 1.2+ Google earth engne	USGS

Where, RED is visible red reflectance, and NIR is near-infrared reflectance. The wavelength range of the NIR band is (750-1300 nm), the Red band is (600-700 nm), and the Green band is (550 nm). The NDVI is motivated by the observation of vegetation, which is the difference between the NIR and red bands. The very low value of NDVI concerns barren areas of rock, or sand. Moderate values describe shrub and grassland, while high value indicates trees and forests. Bare soil is represented with NDVI values, which are closest to 0, and water bodies, are represented with negative NDVI values. The value of NDVI varies between (-1 to 1). High values of NDVI show dense vegetation and low values show bar soil and rocks. In this study, LANDSAT-8 OLI (Operational Land Imager) with a 30m spatial resolution and ground survey data is used. The Path/Row of the Landsat-8 satellite was found 175/50-175/51-176/50-176/51. The Operational Land Imager (OLI) measures the near-infrared, visible, and short-wave infrared portions of the spectrum. To achieve the objective of the present study the following satellite data for different dates are used the Satellite data used for the study was that of LANDSAT 8; the specifications are given in Table 1.To avoid temporal/seasonal variation effects that may cause different spectral responses, we selected the scenes only from those in the same month in leaf-on seasons. As a result, only products in the March months of 2018, 2019, 2020, 2021, and 2022 meet the requirement and were used for this study. Finally, in order to investigate NDVI values, it is categorized into three different classes of areas with low (-1.0 -0.0), medium (0.0-1.0), and high (>1.0) vegetation density on the basis of NDVI ranges of both 2018, 2019, 2020, 2021 and 2022 images. The low value represents sparse and unhealthy forest, the medium value represents shrubs and grassland and the high NDVI value represents healthy and dense vegetation.

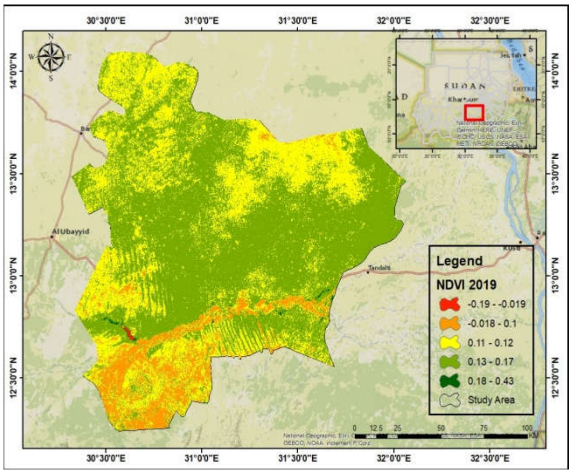
RESULTS AND DISCUSSION

For analysis interpretation negative NDVI values indicate no vegetated surfaced, while the positive ranges from 0 to +1 indicate vegetated areas. As elaborated by many, the higher the NDVI value, the greener the cover type (Deering *et al.* ; 1975). That is to say, where there is a dense vegetation cover, the quantity of the NDVI values increases. Red and NIR stand for the spectral reflection measurements acquired in the visible (Red) and near-infrared regions, respectively. The advantages of NDVI over a simple infrared/red ratio are therefore generally limited to any possible linearity of its functional relationship with vegetation properties.

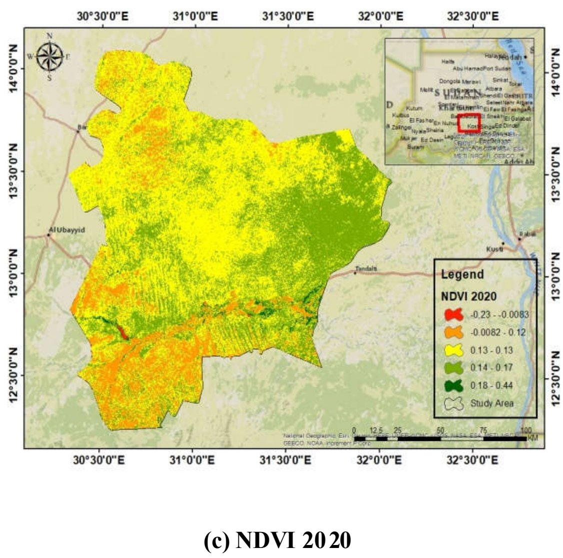
The range of NDVI values in the 2018 image is from 0.17 to 0.45 and in the 2022 image from 0.14 - 0.37. A high NDVI value indicates high vegetation density while a lower NDVI value shows a low density of vegetation. The main vegetation type belongs to the NDVI value 0.0-1.0 are mixed trees with herbs and shrubs including trees like (Hashab (Acacia Senegal), Kitir (Acacia melifra), Taleh (Acacia seyal), and Mikheit (Bosciasenegalensis) are the dense vegetation belong in the >0.1 class of the NDVI range. In terms of total vegetation area, the maximum change is in the low-density vegetation category but the change of medium-density vegetation cover is maximum in the case of high value. The surface's greening is relatively affected in the whole area. This change in vegetation is shown in Figures 2, 3, and 4, 5. These figures are illustrated numerically in Table 2 and Table3 respectively.



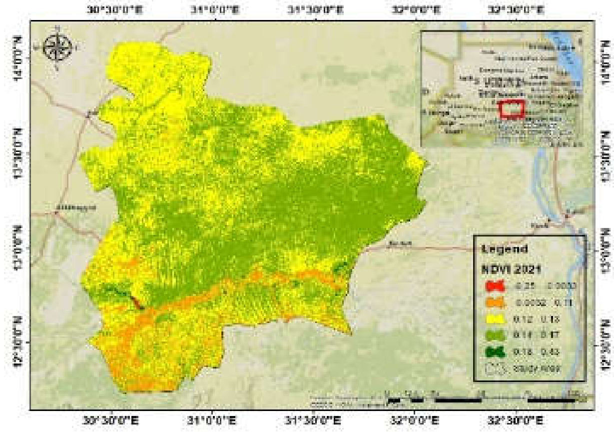
(a) NDVI 2018



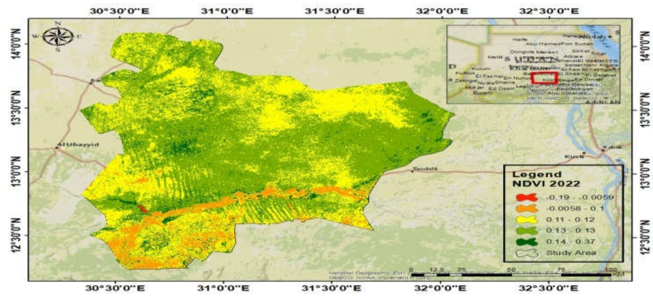
(b) NDVI 2019



(c) NDVI 2020



(d) NDVI 2021

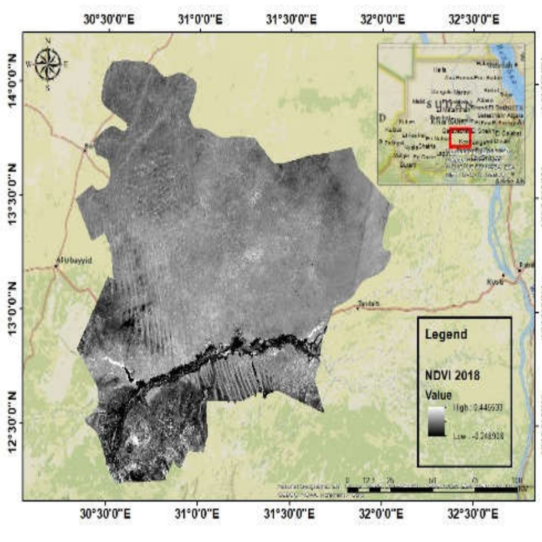


(e) NDVI 2022

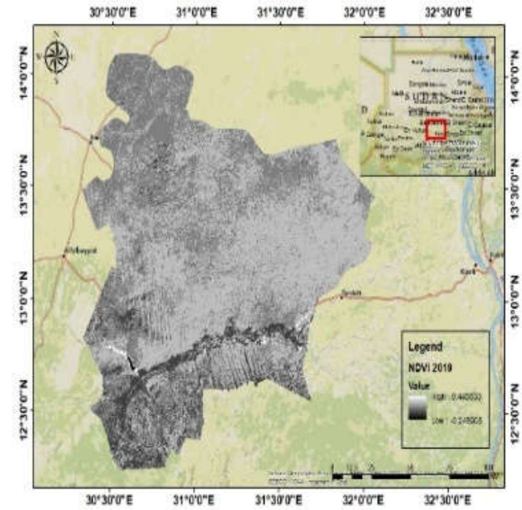
Table 2. Low and High values of NDVI (2018 and 2022) for different monitoring points in Umm Ruwabah Area

YEAR	H Value	L Value
2018	0.17 - 0.45	_0.25 - _0.015
2019	0.18-0.43	_-0.19_-0.019
2020	0.18 - 0.44	_-0.23 - -0.0083
2021	0.18 - 0.43	_-0.25 - -0.0033
2022	0.14 - 0.37	_-0.19 - -0.0059

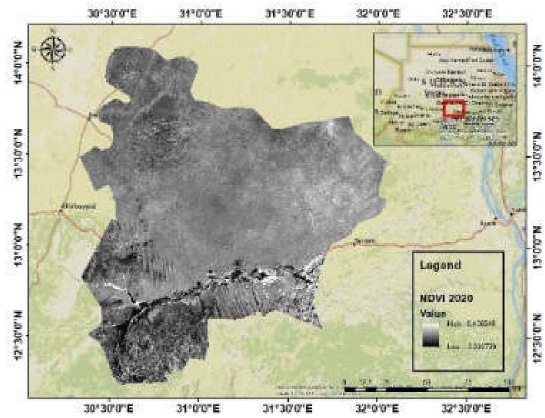
NDVI Figure 2/a and Table 2 show the Normal Difference Vegetation Index (NDVI) spatial distribution for the year 2018 in which high values of the NDVI are between 0.17 - 0.45 and Low values between _0.25 - _0.015 (Fig 3/a, and Table.2) inner and east parts of the study area having more positive values which are showing dense forest. Likewise, the northern part is a moderately dense forest. Also, there is southwestern part shows more negative values comparably with the inner area of the study region south eastern part of the study region shows moderate negative values.



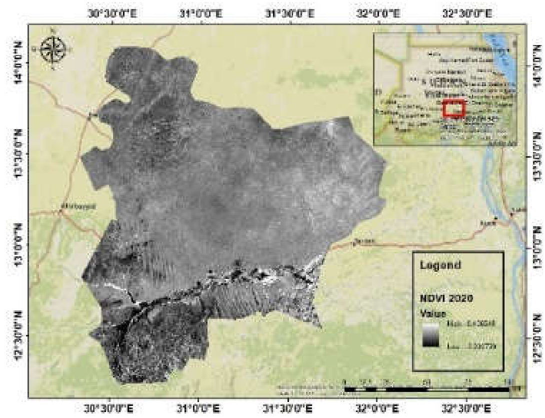
(a) NDVI Value 2018



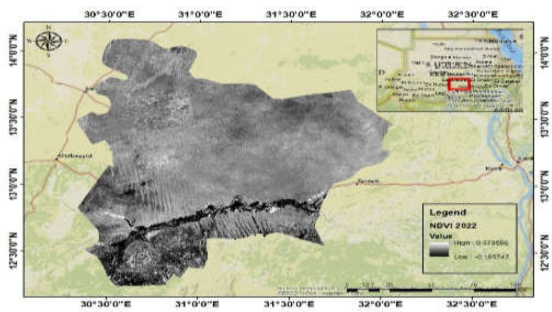
(b) NDVI Value 2019



© NDVI Value 2020



(d) NDVI Value 2021

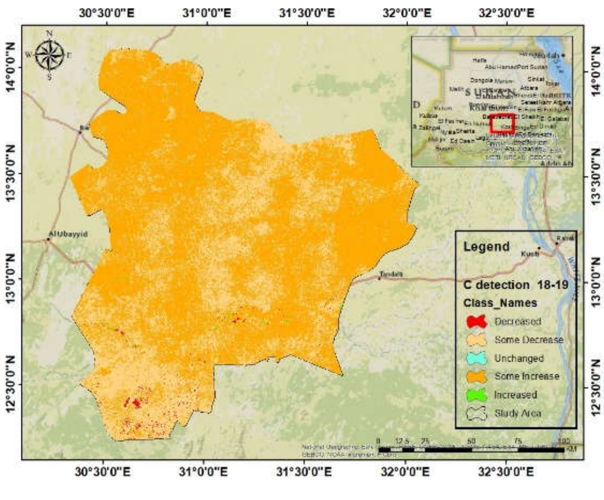


(e) INDVI Value 2022

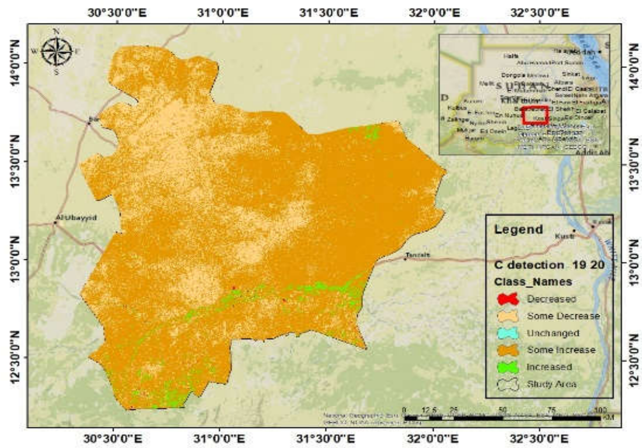
Figure 3. NDVI values in the years 2018, 2019, 2020, 2021, and 2022

NDVI 2019 (Figure. 2/b) shows the Normal Difference Vegetation Index (NDVI) spatial distribution for the year 2019, in which high values of the NDVI are between 0.18-0.43 and low values -0.19_-0.019 (Fig 3/b, and Table 2) shows the increase in the greenery of the area compared with last year. NDVI 2020 Figure. 2/c shows the Normal Difference Vegetation Index (NDVI) spatial distribution for the year 2020, in which high values of the NDVI are between 0.18 - 0.44-.and low values -0.23 - -0.0083 (Fig3/c, and Table 2) This shows a decrease in the greenery of the area compared to the past two decades. From (Figures 2/d and e) the real high NDVI values were measured during 2020 at 0.18 - 0.43 with _-0.25 - -0.0033as low values (Fig3/d, and Table 2)and 2021are 0.14 - 0.37 and _-0.19 - -0.0059(Fig3/e, and Table2)as low values which indicated more rainy season with increase plant growth. NDVI high values in 2022 are 0.14 - 0.37While the low value measured between -0.19 - -0.0059, indicates an increase in the greenery of the area compared to years 2018, 2019, and 2020. In general, the study area had moderate positive values NDVI values vary between 0.14 to -0.45, as usual. This area including the open forest had woody vegetation, and the greener area had surrounding patches of negative values which showed non-green areas. The eastern part and the inner part show high positive values. Also, the northeastern part of the study region has a couple of green patches and most of the area shows moderately dense forest areas the study area has a moderate positive value this area including the open forest had woody vegetation. The northern part and Southern parts show much negative values, showing barren land and areas under agriculture. The study area has high negative values which have many parts under non-green areas and also areas under various human economic activities. The western part of the study area shows the most negative values and increased negative values, which is a sign that economic activities are increasing in the concerted cultivation and grazing areas.

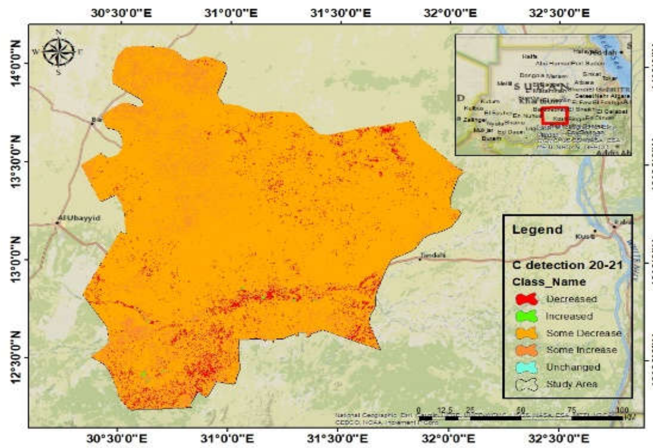
The general range of NDVI values over the years (2018-2022) was scaled in 5 indicators; bare land, sparse, Very light, light, moderate, and dense vegetation. The appropriate high NDVI value was found for densely vegetated areas spatially found in green belts or batches of the Khors and water depressions. The values of 2018, 2019, and 2020 were much drier than the 2021-2022Colour palette containing darker green that indicates mostly dense or high greenness status (healthy vegetation). Yellow and light green indicate moderate conditions of vegetation, while red color indicates sparse vegetation unhealthy vegetation, or degraded land (Ajadi, *et al.* 2016, Cao, *et al.* 2016). The vegetation cover is moderate in the north and inner parts of Umm Ruwabah; the vegetation cover is widely distributed in, grasslands and crops, vegetation in forests, and grasslands with a high NDVI value. The southern part has a low value of vegetation cover; NDVI is negative in areas covered by sand, rock, and desert due to their location in the arid lands. The lowest values are found on the less vegetated soils presumably because reflection from the soil is high, and produces low values in the NIR band and high values in the red band; hence the NDVI values are low



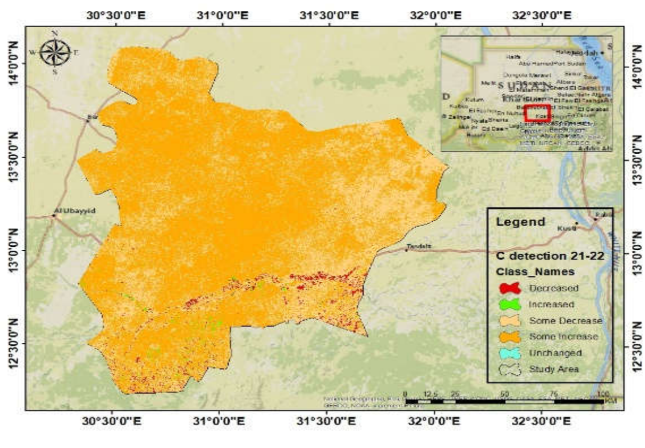
C detection 2018-2019



C detection 2019-2020



C detection 2020-2021



C detection 2021-2022

Figure 4. Change detection of Vegetation Cover from 2018 to 2022

NDVI with used as an index of -1 to 1 (NDVI) for each pixel to discriminate the weather component from the ecosystem component as done by Kogan (1995) for VCI using NDVI. The variations of each drought condition were examined and the scaling was done so that the scaled value -1 means the driest condition and 1 means the wettest condition for NDVI. The result further revealed that the years 2018, 2019, and 2020 experienced the driest conditions as depicted in Figures 2, 3, and 4, 5. Based on the principle slope (calculated by linear regression) value (between −1 and 1) of mean annual NDVI in Um Ruwaba during 2018 - 2022, the land was reclassified from low to high values into five categories: decrease, increase, some decrease, unchanged, and some increase. Table (3) shows the spatial variation of vegetation cover. the decreased area is 10904550 km², some decreased area is 256437900 km², unchanged area is 256437900 km^2, some increased area is 523194360 km^2 and the increased area is 4091340 km^2 (the year 2021-2022). The results by calculating the NDVI value, it was found that the main vegetation cover type has an upward trend at a rate of 0.014 and 0.008. While NDVI has a downward trend at a rate of 0.001 and 0.026 for the NDVI index, the highest value of NDVI was 0.17, 0.18, 0.18, 0.18, and 0.14 for the year 2018, 2019, 2020,2021, and 2022, respectively (Fig. 3) and Table 2. NDVI value has a negative trend which means the surface greening of the study area is being stressed due to the increasing trend of drought events as asserted by previous investigation [ALzubair *et al*. 2019]. The NDVI value was highest in 2019 and lowest in 2022. The driest and wettest conditions were recorded in 2020 in the study area (Fig.3 and 4) The higher NDVI values in 2021 compared to 2022 in the study area could be a result of the large-scale afforestation in degraded land due to various anthropological reasons.

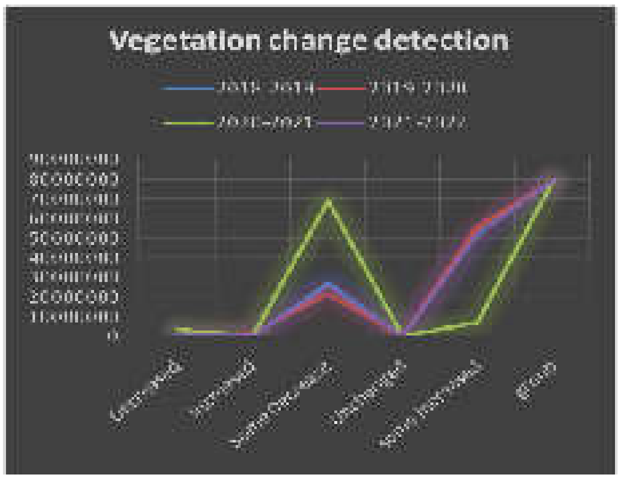


Fig 5. Vegetation change detection 2018 to 2022

Table 3. Change of vegetation cover from 2018 to 2022

ch/year	2018-2019	2019-2020	2020-2021	2021-2022
Decreased	3433500	957930	35065110	10904550
Increased	914280	14290860	1207860	4091340
Some Decrease	271604490	217748160	688231830	256437900
Unchanged	870	810	300	870
some Increased	518675880	561631260	70123920	523194360
group	794629020	794629020	794629020	794629020

High values of vegetation indices and an increase in greenness in 2019-2020 may have different explanations, including driving mechanisms of both climate (an increased amount of precipitation) and human-induced changes in LULC. The implementation of new regulations regarding the conservation of natural areas in Umm Ruwabah appears likely to have played a significant role in vegetation recovery. A real challenge in monitoring vegetation distribution and health with remote sensing lies in the possibility of distinguishing temporary changes caused by fluctuations in climate factors from long-term changes. Only long-term time series analysis in finer temporal scales, together with the analysis of multiple driving factors, could resolve this uncertainty and provide reliable information on vegetation change (Singh 1989).When soil water availability decreases, due to any environmental reason as in the case of water deficit; the green vegetation tends to disappear, and then the values of NDVI decrease.

CONCLUSION

In this study, the vegetation cover has been assessed using the Normalized Difference Vegetation Index (NDVI) technique through the GIS. Five years have been taken to calculate the NDVI of the study area. After calculating the NDVI it shows the year2018 shows 0.17 highest NDVI value and -0.015 was the lowest, in the year 2019 highest NDVI was 0.18 and the lowest was -0.46 and for the year 2020 it was 0.18, and -0.0083 NDVI values. Finally, it is concluded that there is a reduction of greening in the Umm Ruwabah area, it has decreased very rapidly. It has suggested that there is a need for a forest conservation and management plan. NDVI is a significant technique to measure the evolution of surface greening, especially change detection of vegetation patterns and their area. The result of the NDVI study reveals that the vegetation of medium and low density is rapidly reduced by various causes. There is a change in the a whole area. Averaged values of NDVI greenings consistently lower under sparse and bare land conditions, because high NDVI values were confined to the dense vegetation areas. Less greening occurred in areas vulnerable to drought and highly exposed to severe degradation, this negative NDVI trends were associated with sandy and bare soil (Red colour), cultivated, and overgrazed areas. The negative values over the study area may be caused by deforestation and heavy traditional shifting cultivation. On the other hand negative values were attributed to the fact that the majority of the study area became deforested and its greenings would only react more instantly to seasonal rains. Normalized Difference Vegetation Index (NDVI) technique through the GIS is very effective and useful for the decision-making process and future planning concerned with vegetation change and surface greening as a whole.

REFERENCES

Ajadi O, Meyer F, Webley P. 2016. Change detection in synthetic aperture radar images using a multiscale-driven approach. Remote Sens 8:482. https://doi.org/10 3390/rs8060482

Baniya, B.; Tang, Q.; Xu, X.; Haile, G.G.; Chhipi-Shrestha, G (2019). Spatial and temporal variation of drought based on satellite-derived vegetation condition index in Nepal from 1982. Sensors, 19, 430. [CrossRef]

Bechtel A, Puttmann W, Carlson TN, Ripley DA, (1997)" On the relation between NDVI fractional vegetation cover, and leaf area index. Remote Sensing Environment, 62 (3), pp. 241 - 252.

Benson, L, *et al.* , (1997). Nearly synchronous climate change in the Northern Hemisphere during the last glacial termination, Nature

Berger A, Ettllin G, Quincke C, Rodriguez-Bocca P (2019) Predicting the normalized difference vegetation index(NDVI) by training a crop growth model with historical data. Comput Electron Agric: 1–7.

Bhandari, A.K., A. Kumar, 2012. "Feature Extraction using Normalized Difference Vegetation Index (NDVI): A Case Study of Jabalpur City", Proceedings of Communication, Computing & Security.Procedia Technology Volume 6, pp. 612– 621.

Cao G, Zhou L, Li Y (2016.) A new change-detection method in high-resolution remote sensing images based on a conditional random field model. Int J Remote Sens 37:1173–1189. https://doi.org/10.1080/01431161.2016.1148284

Coppin P, Jonckheere I, Nackaerts K, *et al.* (2004) Digital change detection methods in ecosystem monitoring: a review. Int J Remote Sens 25:1565–1596. https://doi.org/10.1080/0143116031000101675Return to ref 2004 in article CrossRef Google Scholar

Dai, A. Drought under Global Warming (2011): A Review: Drought under Global Warming. *WIREs Clim. Chang. 2*, 45–65. [Google Scholar] [CrossRef][Green Version]

De Jong, R.; de Bruin, S.; de Wit, A.; Schaepman, M.E.; Dent, D.L (2011). Analysis of monotonic greening and browning trends from global NDVI time-series. Remote Sens. Environ. 115, 692–702. [CrossRef].

Deering, D. W., J. W. Rouse, Jr., R. H. Haas and J. S. Schell, 1975: Measuring forage production of grazing units from Landsat MSS data.Proc. Tenth International Symposium on Remote Sensing of the Environment, Ann Arbor, MI, 1169-1178.

El Tom, M.A. 1975. The Rains of The Sudan.Mechanisms and Distribution, Khartoum, University of Khartoum press

El-Beltagy, A., & Madkour, M. (2012). Impact of Climate Change on Arid Lands Agriculture. Agriculture & Food Security, 1, Article No. 3. https://doi.org/10.1186/2048-7010-1-3

Elsakov, V. V., Kuliugina, E. E., &Tshanov, V. M. (2013). Trends of vegetation cover changes of the Yugorsky Peninsula in the last decades: comparison of remote and field studies. *Geobotanical mapping*, (2013), 93–111. https://doi.org/10.31111/ geobotmap/ 2013.93.

Franklin, J. (1991). Land cover stratification using Landsat Thematic Mapper data in Sahelian and Sudanian woodland and wooded grassland. *Journal of Arid Environments* 20: 141-163.

Gillespie. T.W., S. Ostermann-Kelm, C. Dong, K.S. Willis, G.S. Okin, G.M. MacDonald (2018) Monitoring changes of NDVI in protected areas of southern California Ecol. Ind., 88 (2018), pp. 485-494. Google Scholar

Hamad MAA, (2018), Assessing awareness and perception on food quality and safety among households in Elobeid. North Kordofan; 6(1):1–4.

Heidari, S., Shamsipour, A., Kakroodi, A.A. *et al.* , (2023), Monitoring land cover changes and droughts using statistical analysis and multi-sensor remote sensing data. Environ Monit Assess 195, 618 https://doi.org/10.1007/s10661-023-11195-9.

Hoffer, R.M. (1978). Biological and physical considerations in applying computer-aided analysis techniques to remote sensor data. In Remote sensing: The quantitative approach. Swam PH Davis SM (Eds), McGraw- Hill, USA, pp 35-98.

IPOC. *Climate Change 2014 Impacts, Adaptation and Vulnerability: Regional Aspects*; Cambridge University Press: Cambridge, UK, 2014. [Google Scholar]Zhang, A.; Jia, G. Monitoring meteorological drought in semiarid regions using multi-sensor microwave remote sensing data. *Remote Sens. Environ.* 2013, *134*, 12–23. [Google Scholar] [CrossRef]

Jong. R. de, S. de Bruin, A. de Wit, M.E. Schaepman, D.L. Dent (2011) Analysis of monotonic greening and browning trends from global NDVI time-series, Remote Sensing. Environmental, 115 (2) (2011), pp. 692-702

Kammerud, T.A. (1996). Soil impact on satellite-based vegetation monitoring in Sahelian Mali. *GeografiskaAnnaler. Series A, Physical Geography* 78: 247-259.

Kwok, R. (2018), Ecology's remote-sensing revolution. *Nature*, 556, 137–138. [Google Scholar] [CrossRef]

Lambin, E.F. (1999). Monitoring forest degradation in tropical regions by remote sensing: some methodological issues. *Global Ecology and Biogeography* 8:191-198.

Lan Y, Zhang H, Lacey R, Hoffmann WC, Wu W,"(2009) Development of an integrated sensor and instrumentation system for measuring crop conditions", Agricultural Engineering Journal, 11, pp.11-15.

Leprieur, C., Y.H. Kerr, S. Mastorchio, and J.C. Meunier. (2000). Monitoring vegetation cover across semi-arid regions: comparison of remote observations from various scales. *International Journal of Remote Sensing* 21: 281-300.

LIU, W.T.; KOGAN, F.N. (1996) Monitoring regional drought using the Vegetation Condition Index. Int. J. Remote Sens.17, 2761–2782. [CrossRef]

Measho, S.; Chen, B.; Trisurat, Y.; Pellikka, P.; Guo, L.; Arunyawat, S.; Tuankrua, V.; Ogbazghi, W.; Yemane, T. (2019), Spatio-temporal analysis of vegetation dynamics as a response to climate variability and drought patterns in the Semiarid Region, Eritrea. Remote Sens. 11, 724. [CrossRef]

Mishra, A.K.; Singh, V.P. A Review of Drought Concepts. *J. Hydrol.* 2010, *391*, 202–216. [Google Scholar] [CrossRef]

Mohamed, N.; Abdou, B. (2016), The relationship between vegetation and rainfall in central Sudan. *Int. J. Remote Sens. Appl. 6*, 30–40. [Google Scholar] [CrossRef]

Mustafa, E.K., Abd El-Hamid, H.T., Tarawally, M., (2021). Spatial and temporal monitoring of drought based on land surface temperature, Freetown City, Sierra Leone, West Africa. Arab J Geosci 14

Nageswara PPR, Shobha SV, Ramesh, KS, Somashekhar RK," (2005), Satellite-based assessment of Agricultural drought in Karnataka State, Journal of the Indian Society of remote sensing ", 33 (3), pp. 429-434.

Philippon, N., E. Mougin, L. Jarlan, and P. Frison. (2005). Analysis of the linkages between rainfall and land surface conditions in the West African monsoon through CMAP, ERSWSC, and NOAA-AVHRR data. *Journal of Geophysical Research* 110: D24115.

Riebsame, W.E, (2020). *Drought and Natural Resources Management in the United States: Impacts and Implications of the 1987–89 Drought*; Routledge: New York, NY, USA. [Google Scholar].

Shiran, M., Mozzi, P., Adab, H., & Zangeneh Asadi, M. A. (2021). Remote sensing assessment of changes of surface parameters in response to prolonged drought in the arid zone of central Iran (Gavkhoni playa). Remote Sensing Applications: Society and Environment, 23, 100575. https://doi.org/10.1016/j.rsase.2021.100575

Singh, A. (1989). Digital change detection techniques using remotely sensed data. International Journal of Remote Sensing, Vol. 10(6), pp.989-1003.

Sobrino, J.A.; Julien, Y. (2011), Global trends in NDVI-derived parameters obtained from GIMMS data. Int. J. Remote Sens. 32, 4267–4279. [CrossRef]

Xu, H.Q.; Wang, M.Y.; Shi, T.T.; Guan, H.D.; Fang, C.Y.; Lin, Z.L. (2018), Prediction of ecological effects of potential population and impervious surface increases using a remote sensing based ecological index (RSEI). *Ecol. Indic. 93*, 730–740. [Google Scholar] [CrossRef]

Yang Y, Zhu J, Zhao C, Liu S, Tong, (2010), The spatial continuity study of NDVI based on Kriging and BPNN algorithm", Journal of Mathematical and Computer Modeling., pp. 77 - 85.

Zeinelabdein KAE, Elsheikh AEM (2015); Geophysical Investigations and Remote Sensing Techniques for Groundwater Exploration in WadiAlmilk Area, North Kordofan State, Sudan. American Journal of Earth Sciences. 2(2):15–21.

Zhang L, Bi X, Li B, Nan B, Zhang X, Yang Z. 2020. Response of grassland productivity to climate change and anthropogenic activities in arid regions of Central Asia. PeerJ 8: e9797 *https://doi.org/10.7717/peerj.9797*

Zhang Zhenyu, Weimin Ju, Yanlian Zhou, Xiaoyu Li, (2022) Revisiting the cumulative effects of drought on global gross primary productivity based on new long-term series data (1982–2018), Global Change Biology, 10.1111/gcb.16178, 28, 11, (3620-3635).

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