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Monitoring Spatial and Temporal Changes in Vegetation Cover using the Normalized Different Vegetation Index and Geographic Information Systems (Case Study Khartoum State)

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ABSTRACT

Vegetation cover undergoes changes (expansion and contraction) over time, and contraction causes economic and environmental losses and damage. This study examines changes in vegetation cover and its classification from other cover types using the ArcGIS geographic information system and the adjusted vegetation variation index. Digital images captured by the American Landsat 7 satellite at different times in the years 2000, 2006, 2012, and 2018 were used. The images were classified into vegetation cover, water bodies, and vegetation-free land using the adjusted vegetation variation index, and the total areas were calculated. Maps were then produced illustrating these classifications, and the results for each year were compared. The study found that there was an expansion in vegetation cover in 2018 compared to previous years.

Keywords: *NDVI, Vegetation Cover, Image, Infrared Band, Index.*

1. INTRODUCTION

Plants are a type of living organism found on Earth's surface, including trees, shrubs, and wild plants, whether small or large, that have grown naturally. They are one of the most important environmental components and a source of food for all living organisms. Natural plants are those that grow spontaneously without human intervention and usually originate in uninhabited places such as deserts and forests. They are a good source of natural medicines and are used in alternative medicine.

Trees protect humans from the sun's rays and provide shade in open areas. They are used as windbreaks and are planted around desert cities to protect them from sandstorms. Plants stabilize the soil and improve its properties. Trees are planted along waterways and canals to protect them from erosion. Trees also mitigate the effects of global warming resulting from climate change. As a natural consequence of the decline in vegetation cover, many environmental and economic damages and losses occur. This necessitates studying changes in vegetation cover to identify areas with plants so that they can be preserved and developed through continuous monitoring and the development of sound plans.

2. VEGETATION IS ONE OF THE MOST IMPORTANT ENVIRONMENTAL

components, playing a major role in maintaining ecological balance. It encompasses all plants found on Earth, from forests and thickets to mosses, gardens, large and small wild plants, trees, and shrubs that have grown naturally without human intervention.

2.1 Importance of Vegetation

It is the basic base of the food chain for all living organisms. It is also considered the most important ecosystem because it contains all types of plants that absorb carbon dioxide during metabolism and produce oxygen necessary for respiration and reducing global warming. It purifies the air and removes toxic gases, dust, and harmful substances suspended in the air.

It maintains a suitable temperature for life, especially by reducing the temperature difference between day and night. It maintains the cycles of organic and mineral elements in the soil and preserves soil moisture and the groundwater cycle. It prevents erosion and soil degradation. It also regulates wind, cloud movement, and rainfall, and regulates their distribution on the Earth's surface. It provides humans with natural materials used for food, clothing, medicine, manufacturing, and raw materials.

2.2 Degradation of Vegetation

Vegetation degradation is considered one of the most important environmental problems facing the world as a result of the imbalance in the relationship between humans and the environment. With the increase in population and technological advancement, the demand for natural environmental resources has increased, leading to their depletion and the destruction of their ecosystems. Among the most important causes of vegetation degradation are:

1. Animal husbandry and overgrazing.
2. Negative, random, and unregulated logging in forests and their use for commercial purposes, such as charcoal and furniture.
3. Migration of people from rural areas, and consequently, the neglect and degradation of agricultural lands.
4. The damages of vegetation degradation include changes in the Earth's climate and geography.
5. Exacerbation of the problem of global warming. Increased soil erosion and the formation of flash floods.
6. Failure to utilize rainwater and prevent its infiltration into the ground to replenish groundwater.
7. Drought and desertification.
8. Depriving lands of their grasses reduces biodiversity, as they serve as a habitat for wildlife.

2.3 Methods of Vegetation Development

Studying and evaluating natural resources in vegetation areas, taking the necessary measures to develop and utilize them effectively, and reintroducing extinct or endangered plants to their native habitat.

Detailed maps of the soil and its natural vegetation should be prepared using satellite imagery to identify its characteristics, classification, and productive capacities. Attention must be given to scientific research and cooperation with organizations working in the field of environmental development and protection through holding scientific seminars and conferences. The phenomenon of vegetation degradation should also be monitored by periodically comparing satellite images from different periods, halting rainfed or irrigated agriculture in vegetation areas, and directing such agriculture towards designated agricultural areas suitable in terms of climate and conditions. Furthermore, it is essential to raise public awareness about the environmental, economic, and medical importance of vegetation and the damage resulting from its degradation, and to enact strict laws to deter violators.

2.4 Plant Indicators

The indices consist of simple mathematical equations that use several ranges of remote sensing images to infer a phenomenon. These indices are built according to scientific facts related to the spectral properties of materials. Based on this fact, several equations have been developed that use the red and near-infrared ranges to study plants. These are called plant indices, and they are:

1) Ratio Vegetation Index (RVI)
2) Difference Vegetation Index (DVI)
3) Normalized Difference Vegetation Index (NDVI)
4) Transformed Vegetation Index (TVI)

2.4.1 Normalized Difference Vegetation Index

It is an index of vegetation cover and consists of images that carry reflections of the red and infrared spectra. These are the two spectra that interact with the leaf surface through absorption and reflection. It has a mathematical formula derived from a digital document used for indirect measurement and is expressed as a ratio, not in units. Its use helps reduce time and cost and increase the effectiveness of fertilization

Vegetation cover is between 1 and -1, where negative values represent other phenomena such as water, etc., zero represents the absence of vegetation cover, and positive values represent the presence of sparse, medium, dense, or very dense vegetation cover (increasing as it approaches 1). The vegetation index measures:

- The degree of greenness (the extent to which the plant contains chlorophyll)
- The degree of correlation with biomass.
- Representation of plant condition

2.4.2 Method of Extracting the Vegetation Index (NDVI)

Natural variation coefficient for green vegetation can be extracted using ArcGIS software. Plants are distinguished from other plants by reflecting a small amount of near-infrared radiation. Therefore, it is possible to correlate plant biomass with the values of the vegetation index, which is calculated from the ratio of the red and near-infrared radiation bands.

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From the following equation:

Adjusted Difference Vegetation Index =

(Infrared + Red) / (Infrared + Red)………..(1)

2.5 Using Remote Sensing and Geographic Information Systems in Vegetation Detection

There are many satellites orbiting to monitor the Earth. These satellites contain sensitive instruments and sensors that measure the amount of sunlight reflected from the Earth's surface through two light bands: the red band and the near-infrared band. In addition to the space-based instruments needed to measure beam characteristics, there is also a need to provide comprehensive digital information about vegetation detection on the Earth's surface, the type of green cover, productivity and health, soil moisture, and other factors.

The process of remote sensing and its analysis in extracting the required and correct information from these radiometric measurements needs statistical information through available references and accurate field surveys.

In order to obtain the appropriate picture, model information for analysis must be provided. Currently, greenness indices and their mathematical equations help in deriving numerical values from spectral measurements.

The process of using and analyzing base maps, aerial photographs, and satellite images to extract information numerically, graphically, and visually is called Geographic Information Systems (GIS) and Remote Sensing (RS). In general, it can be used in the field of assessment, planning, and decision-making, within the topics of land use, climate change, and optimal management for the sustainability of natural resources, as shown in the following points:

Uses of remote sensing in the field of rangeland management...

Use satellite images to provide information on natural resources for national and international planning objectives.

Use remote sensing, especially the NDVI system, as an indicator for the early detection of adverse weather conditions and estimating their impacts on future production

The representation of the plant's condition

Defining constraints and development possibilities, and finding land-use compatibility to enhance productivity and optimize resource management...

Contributes to the development of comprehensive methods for predicting where and how a particular plant will grow under different climatic conditions.

Using satellite imagery and soil survey and analysis maps to create soil composition and distribution maps.

Using satellite imagery to prepare and create contour maps.

The ability to transparently layer maps containing different analytical information for each region helps in creating reference databases.

2.6 Research Problems

Deterioration of the vegetation cover, leading to economic and environmental damage and losses in Khartoum State.

2.7 Research Objectives

Monitoring the phenomenon of vegetation cover deterioration by periodically comparing satellite images at different times using the Geographic Information System (GIS) program (ArcGIS) and images from the American Landsat satellite.

3. THE STUDY AREA

The study area for this study is Khartoum state/sudan city area and populations of the study area are 28,165 square kilometers and approximately 2,682,431 consequently. Geographical location of the study area is between 31.5 and 34 degrees and N 15 and 16 degrees.

4. DATA AND METHODS

The data, consisting of images from the American Landsat (7) satellite, was downloaded from the Earth Explorer website. The images covering Khartoum State were identified and found to be located in the following images: (row) r is the column in which the image is located, and (path) p, where (p174/r49, p173/r49, p172/r49) is the row.

The boundaries of Khartoum State were cropped from the three images using ArcGIS software with the tool:

The cropped portion of each image from both Band 4 and Band 3 to calculate the adjusted plant difference index.

NDVI = (B4-B3)/(B4+B3)……………(2)

B3: Infrared band

B4: Near-infrared band

Before using these bands, their digital numbers must be converted to radiance and then to reflection.

Convert images from DN to radiance according to the following equation:

LA = (gain * DN7) + bias………(3)

Where LA is radiance

The bias and gain are obtained from the following table:

Table 1: The Bias and Gain

Band	Gain	Bias
1	0.778740	-6.98
2	0.798819	-7.20
3	0.621654	-5.62
4	0.639764	-5.74
5	0.126220	-1.13
7	0.043898	-0.39

The reflectance for each beam was calculated using the radiance and the following equation:

$$R_\lambda = \frac{\pi * L_\lambda * d^2}{E_{sun,\lambda} * \sin(\theta_{SE})} \quad \text{..................(4)}$$

where d is the distance between the Earth and the Sun in astronomical units (astronomical units) on the day the image was taken, which is found in the image (metadata), $E_{sun,\lambda}$ is the specific radiance for each beam emitted by the Sun, and SE is the angle of elevation of the Sun, which must be converted from degrees to radians.

Table 2: The Specific Radiance for Each Beam

Band	$E_{sum,\lambda}$[**Watts / (sq. meter *** μ**m)**]
1	1997
2	1812
3	1533
4	1039
5	230.8
7	84.9

5. RESULTS AND ANALYSIS

The radiation and reflection of satellite images of Khartoum State, the adjusted difference for vegetation were calculated using Geographic Information Systems (GIS) software for the years 2000, 2006, and 2018, the result. Figure 1, 2, 3, and 4 shows the NDVI of years 2000, 2006, 2012 and 2018 respectively:

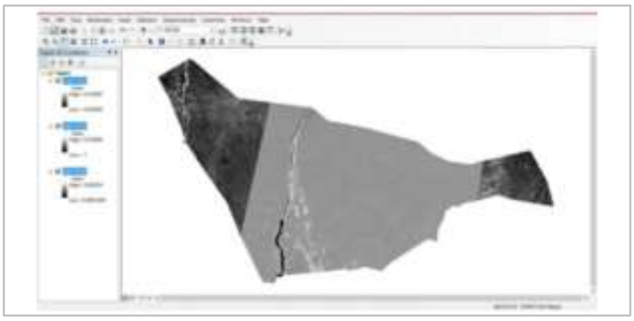

Figure 1: NDVI for The Year 2000

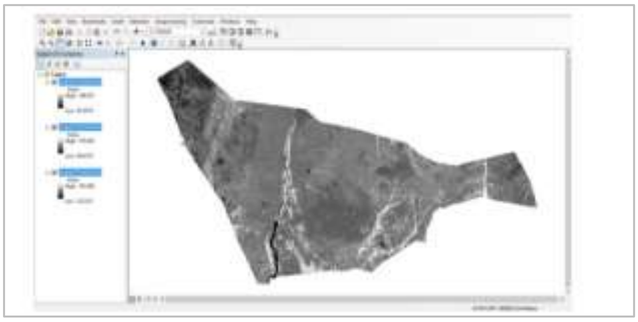

Figure 2: NDVI for The Year 2006

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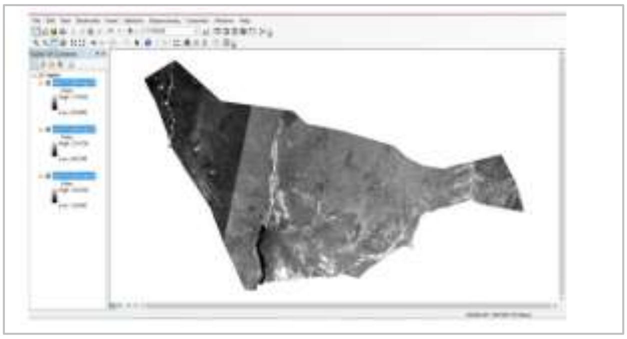

Figure 3: NDVI for The Year 2012

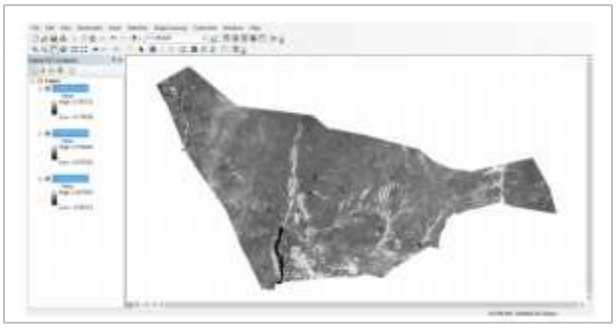

Figure 4: NDVI for The Year 2018

Maps were created and produced showing the vegetation cover and separating it from other cover types (water, barren land). It was found that the vegetation cover was more extensive in 2018 compared to other years. Figures 5, 6, 7 and 8 shows maps of NDVI of years 2000, 2006, 2012 and 2018 of Khartoum State respectively.

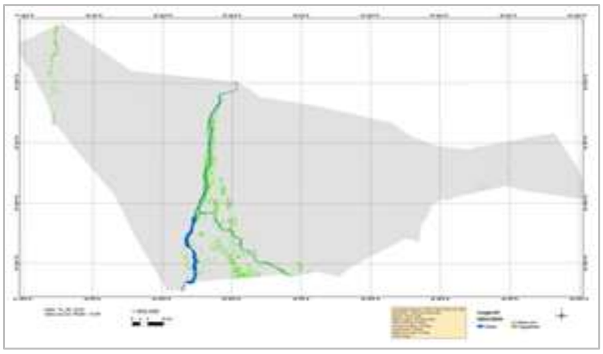

Figure 5: Maps of NDVI of Khartoum State 2000

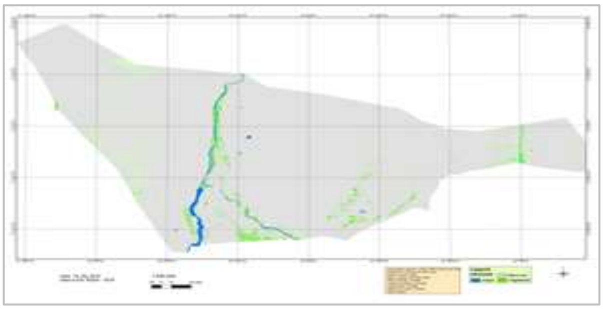

Figure 6: Maps of NDVI of Khartoum State 2006

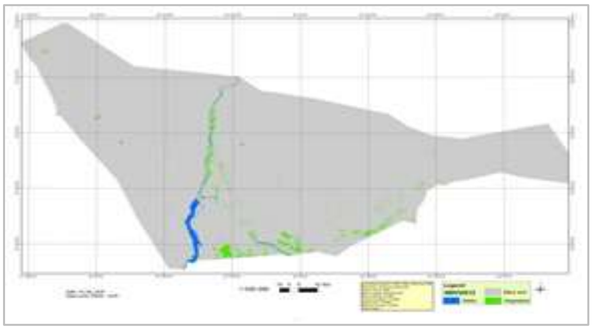

Figure 7: Maps of NDVI of Khartoum State 2012

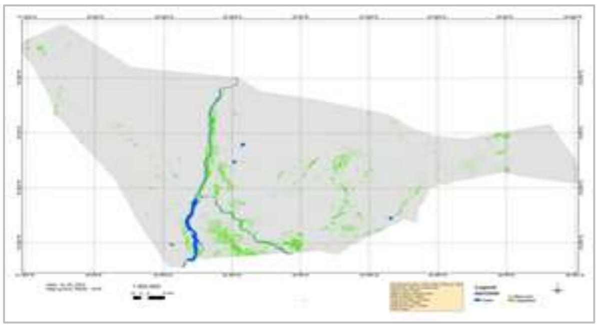

Figure 8: Maps of NDVI of Khartoum State 2018

After calculating the areas for each variety, the following table was produced:

Table 3: The Calculated Areas in Hectares

Year	Water	Non_Veg	Veg	Total
2000	14530.77	2132928.09	33360.57	2180819.43
2006	17054.28	2114319.42	49687.84	2181061.54
2012	14119.29	2132233.11	34709.22	2181061.62
2018	18761.85	2021014.08	14129.4	2181068.33

After calculating the areas, a diagram was created showing the other varieties compared to the plant, as shown in the following figure:

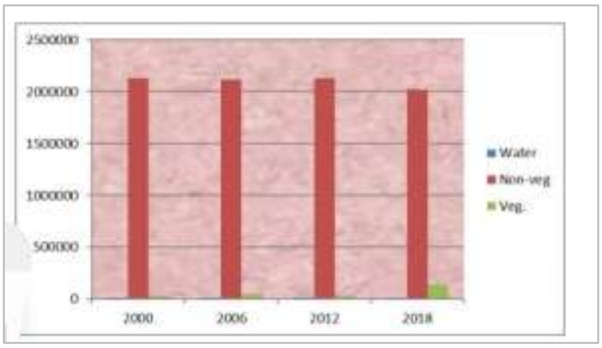

Figure 9: The Area Diagram

6. CONCLUSION

The study confirmed that satellite imagery and vegetation indices are effective tools for detecting changes in vegetation cover over time. The results showed variations in vegetation cover, with a noticeable expansion in 2018 compared to previous years, highlighting the importance of continuous monitoring to support environmental planning and management.

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