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Monitoring the Vegetation Condition of Gorumara National Park Using NDVI and NDMI Indices

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ABSTRACT

The present study was conducted from November, 2022 to June, 2023 aims to analyze and detect changes in vegetation using the Normalized Difference Vegetation Index (NDVI) and Normalized Difference Moisture Index (NDMI) in Gorumara National Park, Jalpaiguri district, West Bengal, India. To calculate NDVI and NDMI values, Landsat 8 level-1 images acquired between 2016 and 2021. Different band combinations of the remote sensing data are analyzed to classify the vegetation condition and cover. For this study, the 4 (Red), 5 (NIR), and 6 (SWIR) multi-spectral band combinations are used separately. The rising use of satellite remote sensing and Geographic Information System (GIS) for civilian purposes has shown itself to be the most cost-effective and time-effective method of mapping and monitoring vegetation conditions and changes. Open-source software such as QGIS and the Semi-Automatic Classification Plugin (SCP) was used for mapping and image pre-processing. According to the NDVI and NDMI classifications, the area under high vegetation and high moisture content has slightly increased by 0.15% and 0.23%, respectively. During the study period the high vegetation and very high moisture content areas covered most areas in 2020 and 2017, respectively. According to the findings, the NDVI and NDMI are very helpful in identifying the area's surface features, which is very helpful for determining the vegetation's general health, providing the required data for long-term conservation efforts, and developing efficient management plans.

KEYWORDS: Landsat 8, NDVI, NDMI, remote sensing, vegetation condition

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Data Availability Statement: Legal restrictions are imposed on the public sharing of raw data. However, authors have full right to transfer or share the data in raw form upon request subject to either meeting the conditions of the original consents and the original research study. Further, access of data needs to meet whether the user complies with the ethical and legal obligations as data controllers to allow for secondary use of the data outside of the original study.

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1. INTRODUCTION

For all living things to survive, forests are essential. Almost one-third of the world's population depends on forests, either directly or indirectly, for a variety of purposes, such as commercial, residential, recreational, and medical (Bera et al., 2020). Acquiring accurate and timely information about the forest is essential. The use of remote sensing and GIS has improved the capacity of humans to use sensors to view the environment and track dynamic changes on the surface of the Earth. Humans can now easily identify changes across a wider area, both temporally and spatially, because of this technological advancement (Taloor et al., 2020). Remote sensing and GIS, have been shown to be very cost-effective and advantageous. Satellite data has become more frequent and has a higher spatial resolution over time. At the same time, new and increasingly user-friendly methods for processing and interpreting geographic data are constantly being added to the inventory of applications. In geoscience and natural resource management, remote sensing and GIS thoroughly understand the environmental and climatological aspects of their applications (Boori et al., 2015; Lillesand et al., 2015; Ganasri and Ramesh, 2016; Kingra et al., 2016; Choudhary et al., 2018). Since the launch of Sputnik, the first satellite in history, in 1957, satellite remote-sensing technology has advanced significantly. The high-resolution Landsat 1 became operational in 1972, and significant advancements in earth monitoring were made possible by the widespread use of the data it produced. With the launch of Landsat 4 in 1982, spatial, geometrical, and radiometric resolutions were markedly improved (Elhag et al., 2021). Up until the launch of Landsat 9 in 2021, the Landsat series underwent several advancements. The ability of remote sensing approaches to determine vegetation cover and condition has reportedly been improved by the integration of multispectral bands such as Thematic Mapper (TM), Enhanced Thematic Mapper Plus (ETM+), Operational Land Imager (OLI), and Thermal Infrared Sensor (TIRS) from Landsat images. According to Lackoóvá et al. (2023), Landsat remains one of the most frequently used satellites, with a spatial resolution of 30 m.

The NDVI, developed by Anonymous (1973), serves as one of the vegetation indices that is most frequently used for the evaluation of vegetation parameters (Roy et al., 2016; Malakhov and Tsychuyeva, 2020; Huang et al., 2021). The use of NDVI vegetation indices and their efficacy in diverse climatic circumstances and landscapes are the subject of numerous articles (Jin et al., 2014; Gandhi at al., 2015; Ozyavuz et al., 2015; Esau et al., 2016; Raynolds and Walker, 2016; Zaitunah et al., 2018; Fan, 2023). When assessing the quantitative parameters of green vegetation, certain of the NIR-RED-based indices have limits that are more or less substantial. Numerous environmental conditions, including soil saturation, cloud cover, air particles, and the structural characteristics of a particular sensor, have been demonstrated to have an impact on the NDVI value (Anonymous, 1999). The water stress level in plants is characterized by the NDMI (Gao, 1996). Most frequently, this measure is employed to track vegetation moisture content and drought stress (Nasiłowska and Kubiak, 2016). NDMI and its variations have proven effective in various vegetation study and classification contexts (Khanna et al., 2013; Elsahabi et al., 2016; Mabrur et al., 2019; Taloor et al., 2021; Berca and Horoias, 2022).

This study's main goal is to apply the NDVI and NDMI indices to track changes in vegetation conditions between 2016 and 2021.

2. MATERIALS AND METHODS

2.1. Description of the study area

The present study, conducted from November, 2022 to June, 2023, aims to analyze and detect changes in vegetation using the Normalized Difference Vegetation Index (NDVI) and Normalized Difference Moisture Index (NDMI) in Gorumara National Park. Gorumara National Park has been selected as the study area. Gorumara National Park is located in the Dooars region of Jalpaiguri district, West Bengal, India (Figure 1). In 1949, the Gorumara Forest was designated as a wildlife sanctuary. Later, in 1992, it received national park status. According to Anonymous (1968) classification, the whole forest tract of Gorumara National Park is classified as a North Indian moist tropical forest type. From a geographic perspective, Gorumara National Park is situated between latitudes 26° 48' 05'' and 26° 41' 20'' N and longitudes 88° 45' 19'' and 88° 51' 18'' E (Saha et al., 2014). The total area of Gorumara National Park is 79.99

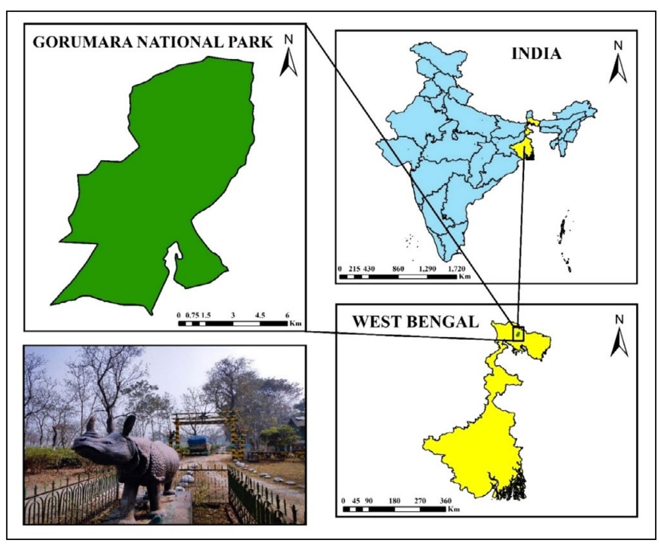

Figure 1: Location map of the study area

km^2. It is a crucial watershed region between the Ganges and Brahmaputra River systems. The study area is 90 m above sea level and is mostly covered in alluvial soil. It receives 375 cm of rainfall on average annually and experiences 15° to 32° C on a monthly average (Sarkar et al., 2009).

2.2. Software used

Image processing and radiometric band correction were performed using QGIS (version: 3.28.5).

2.3. Data collection

Different Landsat 8 level-1 images (2016 to 2021) were obtained from the USGS website (https://earthexplorer.usgs.gov/). Images were obtained around the same time and date to improve accuracy. The collection comprises images from Landsat 8 taken on February 14, 2016, February 16, 2017, February 3, 2018, February 22, 2019, February 9, 2020, and February 11, 2021. They were selected because they had fewer clouds than any other images and were of better quality (Table 1).

2.4. Image pre-processing

The SCP in QGIS software was used to accomplish the radiometric correction for the 4, 5, and 6 bands to improve the interpretation of satellite images (Table 2). To perform a radiometric correction, a digital number (DN) needs to first be converted to reflectance using rescaling factors, and then reflectance at the top of the atmosphere (TOA) must be transformed using a sensor-specific model. With radiometric correction, DN values are mathematically corrected to have a strong connection with ground characteristics (Anonymous, 2021).

Table 1: References to the Landsat 8 datasets used for NDVI and NDMI studies

Date of acquisition	Sun azimuth	Sun elevation	Path	Row	Cloud cover
14th February 2016	144.6354	42.0672	139	041	6.51
16th February 2017	143.9900	42.8818	139	041	4.28
3rd February 2018	147.0019	39.2665	139	041	12.40
22nd February 2019	142.6129	44.5757	139	041	10.85
9th February 2020	145.8163	40.6929	139	041	12.04
11th February 2021	145.1945	41.4529	139	041	11.25

Table 2: Band characteristics of Landsat 8 used for NDVI and NDMI studies

Band number	Bands	Wavelength (μm)	Resolution (m)
Band 4	Red	0.64-0.67	30
Band 5	NIR	0.85-0.88	30
Band 6	SWIR	1.57-1.65	30

(Source: USGS, 2023)

2.5. NDVI and NDMI map generation

The land units were titled in the legend according to their suitable classes.

2.5.1. Calculation of the NDVI

By analyzing the difference between near-infrared wavelengths, which are reflected by vegetation, and red wavelengths, which are absorbed by vegetation, the NDVI is a frequently used measure to detect healthy vegetation on the ground (Taufik et al., 2016). The NDVI was calculated using near-infrared (NIR) and visible red (R) light to look for a single band normalized vegetation index in plants. Using equation 1, the NDVI was generated with band 5 as the NIR and band 4 as the red (Anonymous, 1973).

$$NDVI=(NIR-Red)/(NIR+Red) \quad \text{..................(1)}$$

2.5.2. Calculation of the NDMI

The ratio between the difference and the sum of the reflected radiations in the short-wave infrared (SWIR) and NIR were used to calculate the NDMI, which measures the plant's water stress. Using equation 2, the NDMI was generated with band 5 as the NIR and band 6 as the SWIR (Gao, 1996).

$$NDMI=(NIR-SWIR)/(NIR+SWIR) \quad \text{..................(2)}$$

3. RESULTS AND DISCUSSION

3.1. Derivation of NDVI

The relationship between variations in vegetation growth rate and spectral variability has been extensively studied through the use of the NDVI. Understanding precisely how much green vegetation grows and spotting variations in the vegetation are also helpful. Leaf colors and leaf structure have a significant influence on how incident sunlight interacts with green vegetation. The primary pigment in leaves, chlorophyll, causes the green hue of leaves by reflecting green wavelengths and strongly absorbing light in the red and blue regions of the visible spectrum. When near-infrared light enters a leaf, it passes through several cell walls and air-water barriers, which causes the light to be strongly upwardly scattered (diffusely reflected). Following analysis, it was discovered that between 2016 and 2021, the percentage of places with high vegetation increased slightly from 36.38% to 36.53%, an increase of 0.15%. The areas covered with moderate vegetation expanded considerably from 36.17% to 42.2% within the same period by 6.03%. The regions with low vegetation increased from 9.94% to 15.27% by 5.33%. The percentage of places without vegetation declined by 6.36%, from 11.52% in 2016 to 5.16% in 2021. From 5.99% in 2016 to 0.84% in 2021, the regions containing water bodies drastically decreased by 5.15%.

However, the majority of highly vegetated regions were identified in 2020 (51.53%). In 2018, 42.96% of areas with moderate vegetation were detected. In the year 2020, there were 15.41% additional areas that were mostly covered with low vegetation. The year 2018 had the highest percentage of non-vegetated regions at 12.63%. Areas with water bodies were primarily found in 2017 by 6.44%. In a related study, Gandhi et al. (2015) discovered that between 2001 and 2006, there was an approximate 6% and 23% decline in the categories of forest or shrubland and dry land cover, respectively, whereas there was an approximate 19% rise in agricultural land, 4% increase in built-up land, and 7% increase in aquatic areas (Figure 2 and Table 3).

Table 3: NDVI classes in the study area from 2016 to 2021

NDVI	2016		2017		2018		2019		2020		2021	
	Area (km^2)	Area (%)	Area (km^2)	Area (%)	Area (km^2)	Area (%)	Area (km^2)	Area (%)	Area (km^2)	Area (%)	Area (km^2)	Area (%)
Water body	4.79	5.99	5.15	6.44	3.97	4.96	3.49	4.36	0.38	0.48	0.68	0.84
Non-vegetation cover	9.21	11.52	8.93	11.17	10.1	12.63	9.61	12.02	4.29	5.36	4.13	5.16
Low vegetation cover	7.95	9.94	6.77	8.47	7.73	9.66	6.93	8.66	12.34	15.41	12.21	15.27
Moderate vegetation cover	28.94	36.17	26.23	32.79	34.37	42.96	30.36	37.95	21.77	27.22	33.76	42.2
High vegetation cover	29.1	36.38	32.91	41.13	23.82	29.79	29.6	37.01	41.21	51.53	29.21	36.53
Total	79.99	100	79.99	100	79.99	100	79.99	100	79.99	100	79.99	100

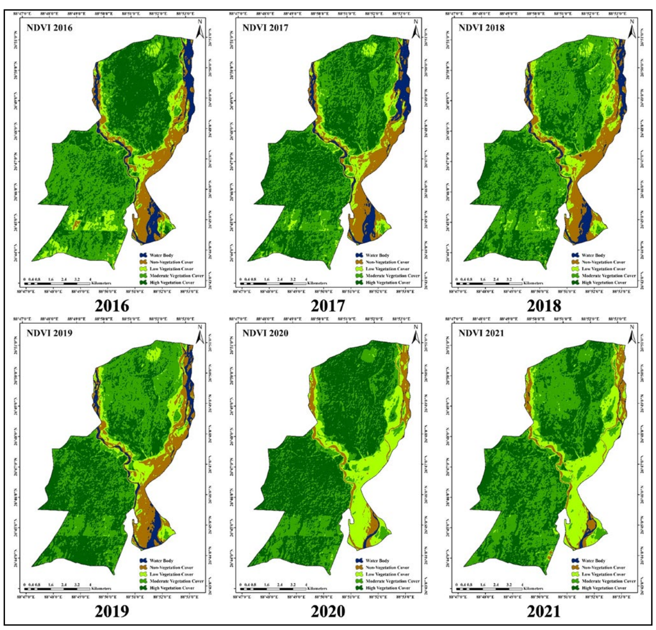

Figure 2: NDVI maps of Gorumara National Park from 2016 to 2021

3.2. Derivation of NDMI

The vegetation cover has changed significantly between 2016 and 2021. According to the NDMI maps, the regions with a very high amount of moisture content have slightly increased from 30.32% to 30.55%, or 0.23%. The regions with high moisture content increased by 2.39% from 32.42% to 34.81% within the same time frame. The regions with moderate moisture content have slightly decreased from 12.09% to 11.67%, or 0.42%. Low-moisture regions had an increase of 1.58%, from 10.69% in 2016 to 12.27% in 2021. From 14.48% in 2016 to 10.7% in 2021, the regions with a very low moisture content have decreased by 3.78% (Figure 3).

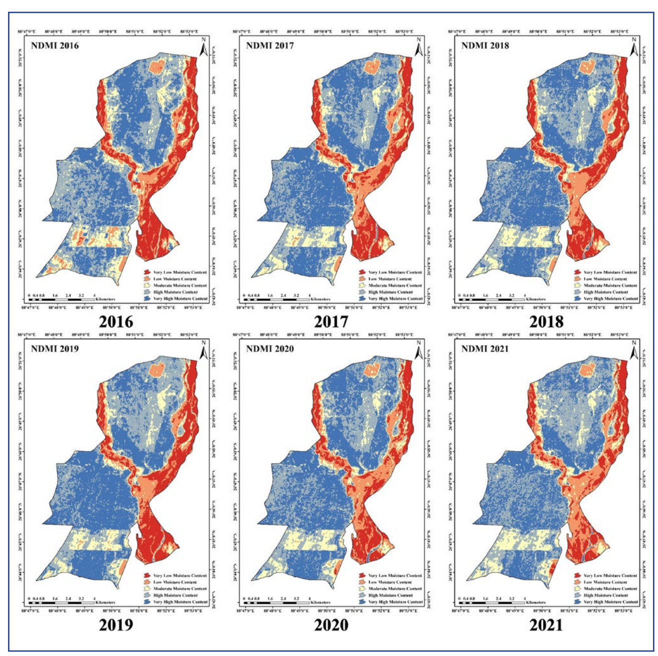

Figure 3: NDMI maps of Gorumara National Park from 2016 to 2021

However, by 37.45% in 2017, the majority of places with very high levels of moisture were identified. The majority of regions with high moisture content were identified in 2021 by 34.81%. The majority of places with moderate moisture content were identified in 2016 by 12.09%. Most areas with low moisture content have been found in 2021 by 12.27%. Areas with very low moisture content were mostly found in the year 2019 by 14.76%. In a related study, Taloor et al. (2021) discovered that the snow-covered high-altitude area and the water body areas have higher moisture value ranges of 0.685 than the plains and low-altitude zones. The area that is devoid of plants and water has the lowest moisture value range, at -0.154. According to Malakhov and Tsychuyeva (2020), NDMI promises to be a useful technique for remotely detecting the non-homogenous cover of vegetation in arid locations (Table 4).

Table 4: NDMI classes in the study area from 2016 to 2021

NDVI	2016		2017		2018		2019		2020		2021	
	Area (km^2)	Area (%)	Area (km^2)	Area (%)	Area (km^2)	Area (%)	Area (km^2)	Area (%)	Area (km^2)	Area (%)	Area (km^2)	Area (%)
Non-moisture content	11.59	14.48	10.02	12.52	10.42	13.03	11.8	14.76	9.7	12.12	8.56	10.7
Low moisture content	8.55	10.69	9.04	11.3	8.56	10.7	7.49	9.36	9.09	11.37	9.81	12.27
Moderate moisture content	9.67	12.09	7.9	9.88	8.19	10.23	8	10	8.09	10.11	9.33	11.67
High moisture content	25.93	32.42	23.07	28.85	24.38	30.48	23.25	29.06	24	30.01	27.85	34.81
Very high moisture content	24.25	30.32	29.96	37.45	28.44	35.56	29.45	36.82	29.11	36.39	24.44	30.55
Total	79.99	100	79.99	100	79.99	100	79.99	100	79.99	100	79.99	100

4. CONCLUSION

Landsat 8 data was used for calculating the NDVI and NDMI indices. According to the classifications, the area under high vegetation and high moisture content has slightly increased by 0.15% and 0.23%, respectively during the study period and high vegetation areas covered most areas in 2020. When dealing with scattered vegetation as well as vegetation with varied densities, the NDVI and NDMI techniques produce better results.

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