ZIBELINE INTERNATIONAL™ PUBLISHING
ISSN: 2773-6202 (Online)
CODEN: JTIOCC

Journal of Technology & Innovation (JTIN)

DOI: http://doi.org/10.26480/jtin.01.2022.11.15

CrossMark

RESEARCH ARTICLE

TEMPORAL VARIATIONS OF NDVI WITH RESPONSES TO CLIMATE CHANGE IN MAYURBHANJ DISTRICT OF ODISHA FROM 2015-2020

Priyanka Mohapatra[a], Ajit Kumar Swain[b], Jyotiprakash Mishra[c]

[a] *Department of Civil Engineering,Centre for Advanced Post Graduate Studies (CAPGS), Biju Patnaik University of Technology (BPUT), Rourkela - 769015, Odisha, India.*
[b] *Department of Forestry, North Eastern Regional Institute of Science and Technology (Deemed University), Nirjuli -791109, Arunachal Pradesh, India*
[c] *District Agromet Unit, Krishi Vigyan Kendra, Mayurbhanj:1 - 757049, Odisha, India*
Corresponding Author Email: ajit.swain7@gmail.com

ARTICLE DETAILS

Article History:

Received 03 April 2022
Revised 09 May 2022
Accepted 18 May 2022
Available online 23 May 2022

ABSTRACT

The study aims to calculate the Normalized Difference Vegetation Index (NDVI) in the Mayurbhanj District of Odisha, analyze the temporal changes in the Normalized Difference Vegetation Index (NDVI) of the study area, and examine the effects or impacts of vegetation change on the environment. The Normalized Difference Vegetation Index (NDVI) values of four different seasons in January, April, July, and October for the years 2015,2016,2017,2018, and 2019 were compared to the NDVIs values of January, April, July, and October for the year 2020 respectively. The changes in vegetation pixel areas were calculated using the raster calculation tool. Analyzing the database of these 6 years, it was found that, the highest significant loss was found in July 2016 at 3381.3 ha. and the lowest at 43.2 in October 2018. The loss was maximum in October 2018 at 3683.7 ha. and lowest in July 2017 at 960.3 ha. No change in vegetation category was highest in the year 2017, October of 3855.6 ha. and lowest in the year 2018, July of 1065.6 ha. In the year 2017, July had the highest gain in the vegetation of 3154.5 ha., the maximum whereas the lowest gain in October 2017 was at 1248.3 ha. The significant gain was maximum in the year 2017, April of 1775.7 ha. and a minimum of 3.6 ha. in October 2016. The year 2015 and 2019 had no more effect on vegetation changes whereas the year 2016-2018 was severely affected by a change in vegetation and they have a huge effect on the environment of Mayurbhanj.

KEYWORDS

Remote Sensing, GIS, VI, NDVI, Change Detection

1. INTRODUCTION

Promoting and facilitating the use of remote sensing imageries for the monitoring and management of national parks and other protected areas have been the focus of many research and governmental agencies. The Multi-Spectral Remote Sensing images are very efficient for obtaining a better understanding of the earth's environment (Ahmadi and Nusrath 2010). Research on the vegetation response to a global change has been a central activity in earth system science during the past two decades (Piao et al., 2015). Monitoring landscape dynamics can answer questions about the spatial extent of land cover types within and adjacent to the parks and the protected areas and how they have changed over time. The monitoring of these vegetation changes using earth observing satellite data has improved our understanding of vegetation dynamics (Tsai and Yang 2016). Vegetation mapping is a very important application of remotely sensed data. Spectral profiles of vegetation clearly show that the peak reflectance can be found in the near-infrared wavelengths mainly because of the internal structure of "green" leaves, and the greatest absorption is in the red wavelengths because of the presence of chlorophyll pigments (Karaburun, 2010).

The satellite-derived Normalized Difference Vegetation Index (NDVI), which is the normalized ratio of red and near-infrared (NIR) is a simple graphical indicator that can be used to analyze remote sensing measurements, often from a space platform, containing live green vegetation (Tucker, 1979). Thus, NDVI is one of the most successful of many attempts to simply and quickly identify vegetated areas and their conditions and it remains the most well-known and used index to detect live green plant canopies in multispectral remote sensing data (Panday, 2012). Once the visibility to detect vegetation has been demonstrated, users tend to also use the NDVI to quantify the photosynthetic capacity of plant canopies. It is important to understand that the NDVI is an indicator of the plant's health but it says nothing about the cause of a particular condition of climate and vegetation plays an important role in the natural carbon cycle (Watson et al., 2000). The vegetation index is rather a hint at what is currently happening on the field (Xue and Su 2017). The NDVI is a dimensionless guide that distinguishes between apparent and near-infrared reflectance of vegetation cover and is frequently used to determine the condition of the green area of land. It is useful in monitoring continental as well as global scale vegetation (Yengoh et al., 2015).

NDVI readings can sometimes be erroneous due to their vulnerability to dirt color and the tendency to saturate under over-dense vegetation. NDVI helps in differentiating vegetation from the types of land cover and specifies its overall state and in agriculture precision is measured using this index (Mulla, 2013). It can locate vegetated areas on the map and detect unusual changes in the growth process. It has been one of the popular and invariably used vegetation indices in remote sensing since the early seventies (Fensholt and Proud 2012). Now, NDVI is adopted and utilized in activities beyond the scope of science. Agriculture is one area where it yields better outcomes. it is most popular due to its ability to cover large areas and the accuracy of its results. It is also used as an environmental indicator to monitor temporal and spatial variation in vegetation density as well as the health and viability of plant cover

Quick Response Code	Access this article online	
	Website: www.jtin.com.my	**DOI:** 10.26480/jtin.01.2022.11.15

Cite The Article: Priyanka Mohapatra, Ajit Kumar Swain, Jyotiprakash Mishra (2022). Temporal Variations of NDVI With Response s to Climate Change in Mayurbhanj District of Odisha from 2015-2020. *Journal of Technology & Innovation, 2(1): 11-15.*

overtime for the derivation of biophysical properties and estimation of net primary production. The NDVI is correlated with many biophysical parameters of the vegetation canopy such as leaf area index (LAI), fractional vegetation cover, vegetation condition, and biomass (Swain and Barik 2015). The four scenarios of NDVI trends for winter (January), pre-monsoon (April), Monsoon (July), and post-monsoon (October) are analyzed in this study for the Mayurbhanj district of Odisha with the remote sensing data of six years.

2. MATERIALS AND METHODOLOGY

2.1 Study Area

Mayurbhanj district is one of the 30 districts in Odisha state in eastern India. It is the largest district of Odisha by area. Its headquarter is at Baripada. Other major towns are Rairangpur, Karanjia and Udala. As of 2011, it is the third-most-populous district of Odisha, after Ganjam and Cuttack. Mayurbhanj is land-locked with a geographical area of 10,418 km^2 (4,022 sq mi) and lies in the northeast corner of the state. The district lies between 21^0 and 22^0 North latitude and 85^0 and 87^0 East longitude (Figure 1).

It borders the Jhargram district of West Bengal in the northeast, the West Singhbhum and East Singhbhum districts of Jharkhand towards the north, the Balasore district in the southeast, and the Kendujhar towards the west. Vegetation coverage change is a very important indication of the ecological environment change. Vegetation change can be readily detected and mapped by satellite remote sensing data. By collecting the satellite imageries, changes in vegetation coverage of the Mayurbhanj district concentrating mostly upon the forest area were detected. Forest and land cover change detection are one of the major applications of satellite-based remote sensing. Satellite images from different dates for a particular geographic area were analyzed for changes are classified into appropriate forest change or land cover change categories.

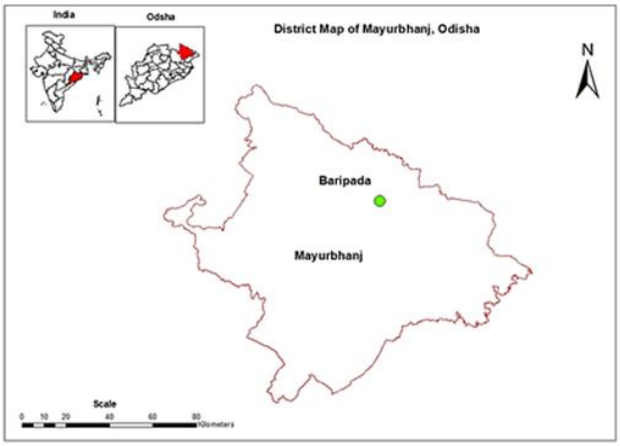

Figure 1: Location map of Mayurbhanj, Odisha.

2.2 Data Used

The study has adopted geospatial technologies for the analysis of the database. The satellite images are relied upon as appropriate informants. AWifs data from Bhuvan NRSC have been used in the study. IRS-P6 is envisioned with different capabilities. The satellite has been modeled to provide both multi-spectral and panchromatic images of the Earth's surface. It has got three sensors namely LISS-III, AWifs, and LISS- IV along with On-Board Solid State Recorder (OBSSR). All the cameras function on the push-broom scanning. For this study, NDVI calculation has been made using seasonal data from the AWifs sensor with a spectral resolution of 56 meters (Table 1), and maps have been prepared for January, April, July, and October from 2015 to 2020.

Table 1: Description of AWiFS Sensor Characteristics.

Satellite / Sensor	Data Acquisition Month	Wavelength of Band (µm)	Spatial Resolution (m)	Swath (km)
IRS-P6 / AWiFS	January April July October	GREEN (0.52 - 0.59)	56	737
		RED (0.62 - 0.68)		
		NEAR IR (0.77 - 0.86)		
		MID WAVE IR (1.55 - 1.70)		

2.3 Software

The Erdas Imagine 2014 has been used for the pre-processing and analysis of satellite images whereas the ArcGIS 10.3.3 has been used for spatial analysis and preparing maps for the study area (Figure 2).

2.4 Theory and Formulation

The NDVI and its change attributed to climate change were investigated based on NDVI, through time-series data. Altogether, 24 images (4 images/year) for the periods of 6 years were downloaded, and raster images were analyzed, the monthly NDVI data were generated from time-series data of NRSC Bhuvan. In this study, the pixels with mean NDVI values less than 0.1 were removed to avoid water bodies. The annual, seasonal, and pixel-wise NDVI trends were computed. The seasons were mainly categorized as winter (January), pre-monsoon (April), Monsoon (July), and post-monsoon (October) based on the climate pattern of India. The NDVI trends in different seasons were calculated using the raster calculation tools in ArcGIS.

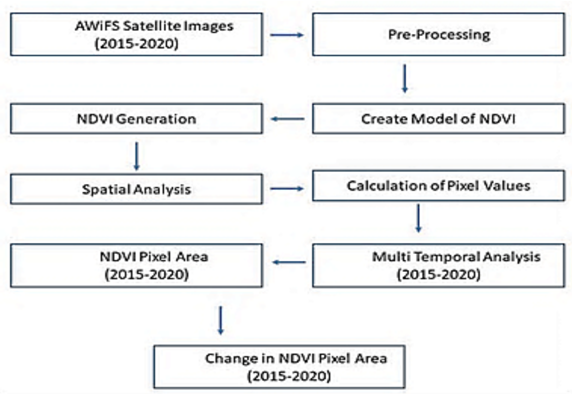

Figure 2: Database and Methodologies of the Study

Vegetation indices allow us to delineate the distribution of vegetation and soil based on the characteristic reflectance patterns of green vegetation. The NDVI is a simple numerical indicator that can be used to analyze the remote sensing measurements, from a remote platform and assess whether the target or object being observed contains live green vegetation or not (Rouse et al. 1974). NDVI is calculated mathematically as,

$$\mathbf{NDVI} = \frac{(\mathbf{NIR} - \mathbf{RED})}{(\mathbf{NIR} + \mathbf{RED})}$$

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 band; it should be larger for greater chlorophyll density. It takes the (NIR - RED) difference and normalizes it to balance out the effects of uneven illumination such as shadows of clouds or hills. The red band is used to estimate changes in vegetation status and measure green biomass, however, it is only sensitive to low chlorophyll. In other words, on a pixel by pixel basis subtracts the value of the red band from the value of the NIR band and divide by their sum. A very low value of NDVI (0.1 and below) corresponds to barren areas of rock, sand, or snow. Moderate values represent shrub and grassland (0.2 to 0.3), while high value indicates temperate and tropical rainforests (0.6 to 0.8). Bare soil is represented with NDVI values, which are closest to 0, and water bodies are represented with negative NDVI values.

3. RESULTS

The raster analysis was performed by comparing two rasters from NDVI of four seasons of January, April, July, and October from 2015 to 2019 with the same seasonal NDVI of 2020. The change in vegetation cover was generated in the above process and was classified into five multiple classes (a) Significant loss (b) Loss (c) no change (d) Gain, and (e) Significant gain to reflect vegetation change direction and extent. The indices value of vegetation was taken only into consideration and the reflectance values of water bodies were not included in the raster analysis processes (Figure 3 and 4).

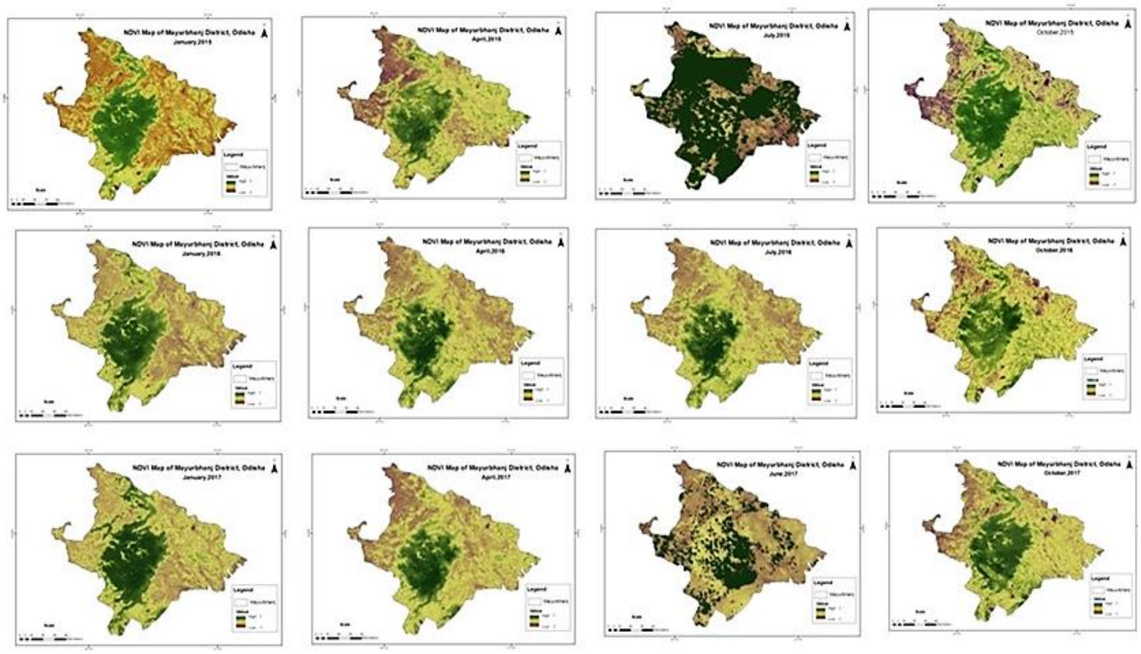

Figure 3: NDVI for January, April, July, October for the years 2015, 2016 & 2017 in Mayurbhanj, Odisha.

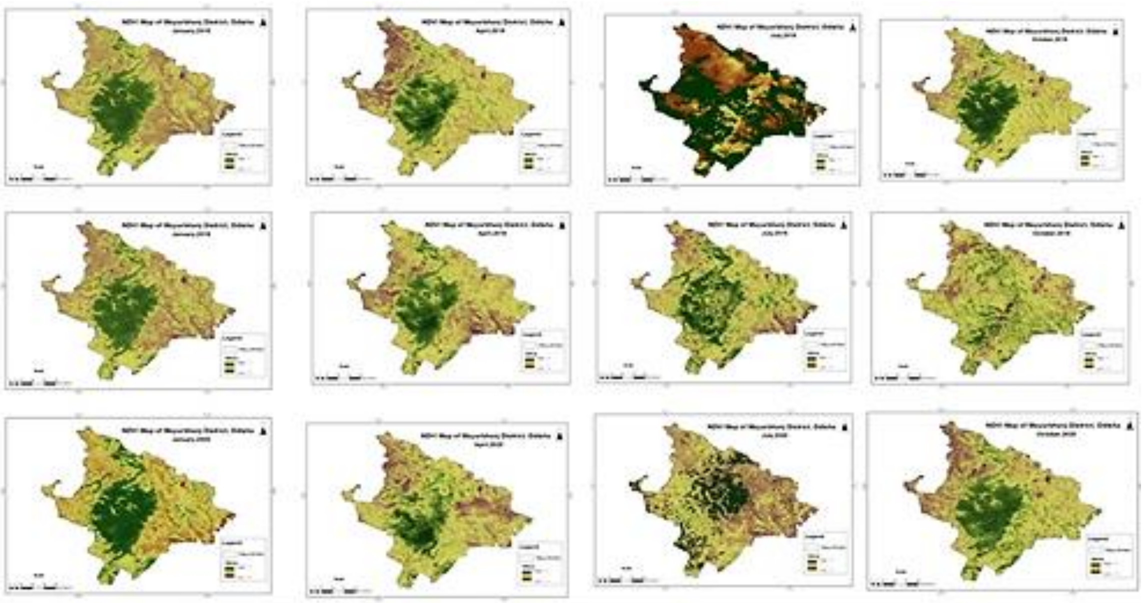

Figure 4: NDVI for January, April, July, October for the years 2018, 2019 & 2020 in Mayurbhanj, Odisha.

During the two years of 2015 and 2020, when a comparison was made to NDVI values and change in vegetation in raster calculation for January for both years, it was found that approximately 3354.3 ha. of vegetation was in the no loss category followed by 2402.1 ha. of loss in vegetation pixel. An area of 2393.1 ha. was in gain whereas an area of 669.6 ha. was in a significant gain. The loss was the lowest in comparison to NDVI of both years in the category of significant loss. It was 542.7 ha. between the two years. For April, it was found that approximately 2588.4 ha. of vegetation was in no loss followed by 2280.6 ha. of loss in vegetation pixel. An area of 2219.4 ha. was in gain whereas an area of 1408.5 ha. was in a significant gain. The loss was the lowest in comparison to NDVI of both years in the category of significant loss.

It was 951.3 ha. between the two years. For July, it was found that approximately 2574 ha. of vegetation was in no loss followed by 2066.4 ha. of loss in vegetation pixel. An area of 1899.9 ha. was in gain whereas an area of 1512.9 ha. was in a significant gain. The loss was the lowest in comparison to NDVI of both years in the category of significant loss. It was 1308.6 ha. between the two years. For October, it was found that approximately 3212.1 ha. of vegetation was in no loss followed by 2996.1 ha. of loss in vegetation pixel. An area of 1827 ha. was in gain whereas an area of 1000.8 ha. was in a significant gain. The loss was the lowest in comparison to NDVI of both years in the category of significant loss. It was 412.2 ha. between the two years (Table 2).

Table 2: Change in NDVI Area Between 2015 – 2020 For Four Different Seasons

Class	Change in NDVI Area (2015-2020) (ha.)			
	January	April	July	October
Significant Loss	542.7	951.3	2574	1000.8
Loss	2393.1	2219.4	1512.9	2996.1
No Change	3354.3	2588.4	1899.9	3212.1
Gain	2402.1	2280.6	2066.4	1827
Significant Gain	669.6	1408.5	1308.6	412.2

During the two years of 2016 and 2020, when a comparison was made to NDVI values and change in vegetation in raster calculation for January, it was found that approximately 3339.9 ha. of vegetation was in no loss followed by 2568.6 ha. of loss in vegetation pixel. An area of 2298.6 ha. was in gain whereas an area of 842.4 ha. was in a significant gain. The loss was the lowest in comparison to NDVI of both years in the category of significant loss. It was 398.7 ha. between the two years. For April, it was found that approximately 3061.8 ha. of vegetation was in no loss followed by 2459.7 ha. of loss in vegetation pixel. An area of 1680.3 ha. was in gain

Cite The Article: Priyanka Mohapatra, Ajit Kumar Swain, Jyotiprakash Mishra (2022). Temporal Variations of NDVI With Response s to Climate Change in Mayurbhanj District of Odisha from 2015-2020. *Journal of Technology & Innovation, 2(1): 11-15.*

whereas an area of 1441.8 ha. was in a significant gain. The loss was the lowest in comparison to NDVI of both years in the category of significant loss.

It was 804.6 ha. between the two years. For July, it was found that approximately 3381.3 ha. of vegetation was in no loss followed by 2536.2 ha. of loss in vegetation pixel. An area of 1815.3 ha. was in gain whereas an area of 1093.5 ha. was in a significant gain. The loss was the lowest in comparison to NDVI of both years in the category of significant loss. It was 535.5 ha. between the two years. For October, it was found that approximately 3473.1 ha. of vegetation was in no loss followed by 3331.8 ha. of loss in vegetation pixel. An area of 1795.5 ha. was in gain whereas an area of 757.8 ha. was in a significant gain. The loss was the lowest in comparison to NDVI of both years in the category of significant loss. It was 3.6 ha. between the two years (Table 3).

Table 3: Change in NDVI Area Between 2016 – 2020 For Four Different Seasons

Class	Change in NDVI Area (2016-2020) (ha.)			
	January	April	July	October
Significant Loss	398.7	804.6	3381.3	757.8
Loss	2568.6	1441.8	2536.2	3331.8
No Change	3339.9	2459.7	1093.5	3473.1
Gain	2298.6	3061.8	1815.3	1795.5
Significant Gain	842.4	1680.3	535.5	3.6

During the two years of 2017 and 2020, when a comparison was made to NDVI values and change in vegetation in raster calculation for January, it was found that approximately 3519.9 ha. of vegetation was in no loss followed by 2465.1 ha. of loss in vegetation pixel. An area of 2190.6 ha. was in gain whereas an area of 736.2 ha. was in a significant gain. The loss was the lowest in comparison to NDVI of both years in the category of significant loss. It was 536.4 ha. between the two years. For April, it was found that approximately 2657.7 ha. of vegetation was in no loss followed by 2278.8 ha. of loss in vegetation pixel. An area of 1775.7 ha. was in gain whereas an area of 1690.2 ha. was in a significant gain. The loss was the lowest in comparison to NDVI of both years in the category of significant loss. It was 1045.8 ha. between the two years. For July, it was found that approximately 3154.5 ha. of vegetation was in no loss followed by 3117.6 ha. of loss in vegetation pixel. An area of 1224.9 ha. was in gain whereas an area of 960.3 ha. was in a significant gain. The loss was the lowest in comparison to NDVI of both years in the category of significant loss. It was 904.3 ha. between the two years. For October, it was found that approximately 3855.6 ha. of vegetation was in no loss followed by 3266.1 ha. of loss in vegetation pixel. An area of 1248.3 ha. was in gain whereas an area of 1053 ha. was in a significant gain. The loss was the lowest in comparison to NDVI of both years in the category of significant loss. It was 25.2 ha. between the two years (Table 4).

Table 4: Change in NDVI Area Between 2017 – 2020 For Four Different Seasons

Class	Change in NDVI Area (2017-2020) (ha.)			
	January	April	July	October
Significant Loss	536.4	1045.8	1224.9	1053
Loss	2465.1	1690.2	960.3	3266.1
No Change	3519.9	2278.8	3117.6	3855.6
Gain	2190.6	2657.7	3154.5	1248.3
Significant Gain	736.2	1775.7	904.5	25.2

During the two years of 2018 and 2020, when a comparison was made to NDVI values and change in vegetation in raster calculation for January, it was found that approximately 3725.1 ha. of vegetation was in no loss followed by 2944.8 ha. of loss in vegetation pixel. An area of 1313.1 ha. was in gain whereas an area of 1202.4 ha. was in a significant gain. The loss was the lowest in comparison to NDVI of both years in the category of significant loss. It was 262.8 ha. between the two years. For April, it was found that approximately 3078 ha. of vegetation was in no loss followed by 2536.2 ha. of loss in vegetation pixel. An area of 2108.7 ha. was in gain whereas an area of 883.8 ha. was in a significant gain. The loss was the lowest in comparison to NDVI of both years in the category of significant loss.

It was 841.5 ha. between the two years. For July, it was found that approximately 2950.2 ha. of vegetation was in no loss followed by 2467.8 ha. of loss in vegetation pixel. An area of 1850.4 ha. was in gain whereas an area of 1065.6 ha. was in a significant gain. The loss was the lowest in comparison to NDVI of both years in the category of significant loss. It was 1027.8 ha. between the two years. For October, it was found that approximately 3683.7 ha. of vegetation was in no loss followed by 3261.6 ha. of loss in vegetation pixel. An area of 1355.4 ha. was in gain whereas an area of 1128.6 ha. was in a significant gain. The loss was the lowest in comparison to NDVI of both years in the category of significant loss. It was 18.9 ha. between the two years (Table 5).

Table 5: Change in NDVI Area Between 2018 – 2020 For Four Different Seasons

Class	Change in NDVI Area (2018-2020) (ha.)			
	January	April	July	October
Significant Loss	262.8	883.8	2950.2	1128.6
Loss	1313.1	2108.7	1850.4	3683.7
No Change	3725.1	3078	1065.6	3261.6
Gain	2944.8	2536.2	2467.8	1355.4
Significant Gain	1202.4	841.5	1027.8	18.9

During the two years of 2019 and 2020, when a comparison was made to NDVI values and change in vegetation in raster calculation for January, it was found that approximately 3078.9 ha. of vegetation was in no loss followed by 2714.4 ha. of loss in vegetation pixel. An area of 2097 ha. was in gain whereas an area of 791.1 ha. was in a significant gain. The loss was the lowest in comparison to NDVI of both years in the category of significant loss. It was 766.8 ha. between the two years. For April, it was found that approximately 2664.9 ha. of vegetation was in no loss followed by 2657.7 ha. of loss in vegetation pixel. An area of 1887.3 ha. was in gain whereas an area of 841.5 ha. was in a significant gain. The loss was the lowest in comparison to NDVI of both years in the category of significant loss.

It was 683.1 ha. between the two years. For July, it was found that approximately 3238.2 ha. of vegetation was in no loss followed by 2952 ha. of loss in vegetation pixel. An area of 1689.3 ha. was in gain whereas an area of 1279.8 ha. was in a significant gain. The loss was the lowest in comparison to NDVI of both years in the category of significant loss. It was 288.9 ha. between the two years. For October, it was found that approximately 3843.9 ha. of vegetation was in no loss followed by 2606.4 ha. of loss in vegetation pixel. An area of 2398.5 ha. was in gain whereas an area of 556.2 ha. was in a significant gain. The loss was the lowest in comparison to NDVI of both years in the category of significant loss. It was 43.2 ha. between the two years (Table 6).

Table 6: Change in NDVI Area Between 2019 – 2020 For Four Different Seasons

Class	Change in NDVI Area (2019-20) (ha.)			
	January	April	July	October
Significant Loss	766.8	683.1	1689.3	43.2
Loss	2714.4	1887.3	3238.2	2606.4
No Change	3078.9	2664.9	2952	3843.9
Gain	2097	2657.7	1279.8	2398.5
Significant Gain	791.1	841.5	288.9	556.2

4. Conclusion

The Change Detection analysis of NDVI is an efficient way of describing the changes observed in the vegetation category. Over a half-decade, there were considerable variations in agricultural land, hilly areas with vegetation, forest, and dry farming. The normalized difference vegetation index technique with different pixel values has been employed for change detection analysis. Analyzing the database of these 6 years, it is found that, the highest significant loss is found in July 2016 at 3381.3 ha and the lowest of 43.2 in October 2018 at 43.2 ha. The loss was maximum in October 2018 of 3683.7 ha. And lowest in July 2017 at 960.3 ha. No change in vegetation was highest in the year 2017, October of 3855.6 ha. and lowest in the year 2018, July of 1065.6 ha. In the year 2017, July has the highest gain in the vegetation of 3154.5 ha. being maximum whereas the lowest gain in October 2017 of 1248.3 ha. Significant gain is maximum in the year 2017, April of 1775.7 ha. and a minimum of 3.6 ha. in October 2016. The year 2015 and 2019 has no more effect on vegetation whereas the year 2016-2018 is severely affected by a change in vegetation and they harm the environment of Mayurbhanj.

The study provides spatial and temporal NDVI trends and the correlation between NDVI and climatic factors on annual and seasonal time scales during the last five years in Mayurbhanj, Odisha. We found positive and negative NDVI trends during the study period. The NDVI distribution and positive NDVI changing ratio were higher in the Similipal biosphere region due to hilly areas during the monsoon period. Thus, rainfall and temperature are recognized as principal climatic factors affecting NDVI but are not limited to Mayurbhanj. Although NDVI helps in monitoring the change in vegetation cover, the high-resolution satellite data supervised classification and ground-truthing would suitably improve the land use classification and accuracy. The change in vegetation area would be more precise with the classification techniques. The overall findings of this study only aid in understanding the relationship between climate and long-term NDVI changes, and the implication of NDVI for carbon dynamics helps to provide scientific knowledge for ecology and environmental management in Mayurbhanj, Odisha

Authorship Contribution Statement

Priyanka Mohapatra: Data collection, conceptualization, methodology, analysis, software, validation, writing of original draft; Ajit Kumar Swain: Data collection, writing, conceptualization, methodology, review, and editing; Jyotiprakash Mishra: Review and editing.

Conflict of Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

The authors are thankful to the Head of the Department of Civil Engineering, BPUT, Rourkela for necessary laboratory facilities and NRSC, ISRO Bhuvan for providing a free AWifs database for the analysis processes.

References

Ahmadi, H., Nusrath, A., 2010. Vegetation change detection of Neka River in Iran by using remote-sensing and GIS. Journal of geography and geology, 2 (1), Pp. 58.

Bhuvan - NRSC/ISRO Open data and product archive: https://bhuvan.nrsc.gov.in/

Fensholt, R., Proud, S.R., 2012. Evaluation of earth observation based global long term vegetation trends—Comparing GIMMS and MODIS global NDVI time series. Remote sensing of Environment, 119, Pp. 131-147.

Karaburun, A., 2010. Estimation of C factor for soil erosion modeling using NDVI in Buyukcekmece watershed. Ozean Journal of applied sciences, 3 (1), Pp. 77-85.

Mulla, D.J., 2013. Twenty-five years of remote sensing in precision agriculture: Key advances and remaining knowledge gaps. Biosystems Engineering, 114 (4), Pp. 358-371.

Panday, P.K., Ghimire, B., 2012. Time-series analysis of ndvi from avhrr data over the hindu kush-himalayan region for the period 1982–2006. Int. J. Remote Sens, 33, Pp. 6710–6721.

Piao, S., Yin, G., Tan, J., Cheng, L., Huang, M., Li, Y., Liu, R., Mao, J., Myneni, R.B., Peng, S., Poulter, B., 2015. Detection and attribution of vegetation greening trend in China over the last 30 years. Global change biology, 21 (4), Pp. 1601-1609.

Rouse, J.W., Haas, R.H., Schell, J.A., Deering, D.W., Harlan, J.C., 1974. Monitoring the vernal advancement and retrogradation (green wave effect) of natural vegetation. NASA/GSFC Type III Final Report, Greenbelt, Md, Pp. 371.

Swain, A.K., Barik, K.K., 2015. Spatial Greening Pattern Estimation of Himachal Pradesh, India Using IRS-P6 AWiFS Seasonal Data. International Journal of Science and Research, 56, Pp. 737.

Tsai, H.P., Yang, M.D., 2016. Relating vegetation dynamics to climate variables in Taiwan using 1982–2012 NDVI3g data. IEEE Journal of Selected Topics in Applied Earth Observations and Remote Sensing, 9 (4), Pp. 1624-1639.

Tucker, C.J., 1979. Red and photographic infrared linear combinations for monitoring vegetation. Remote sensing of Environment, 8 (2), Pp. 127-150.

Watson, R.T., Noble, I.R., Bolin, B., Ravindranath, N.H., Verardo, D.J., Dokken, D.J., 2000. Land use, land-use change and forestry: a special report of the Intergovernmental Panel on Climate Change. Cambridge University Press.

Xue, J., Su, B., 2017. Significant remote sensing vegetation indices: A review of developments and applications. Journal of Sensors.

Yengoh, G.T., Dent, D., Olsson, L., Tengberg, A.E., Tucker III, C.J., 2015. Use of the Normalized Difference Vegetation Index (NDVI) to assess Land degradation at multiple scales: current status, future trends, and practical considerations. Springer.