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Quantifying Vegetation Cover Change In Ajodhya Hill Forest: A Landsat-Based NDVI Study

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ABSTRACT- Forests are pivotal in providing ecological interconnectedness and essential ecosystem services. In this regard, remote sensing techniques are crucial to depict existing forest resources' original state and nature. NDVI is a preliminary and pilot method for simplifying complex multi-spectral image interpretation. Nowadays, it is the most beneficial and approving lead for vegetation assessment. This study aims to quantify vegetation change coverage in the Ajodhya Hill Forest region, Purulia District, using the Landsat-based Normalized Difference Vegetation Index (NDVI). The present research article focuses on identifying vegetation coverage trends and determining the nature, rate, location, and magnitude of vegetation swaps over 20 years. Our analysis reveals a concerning decline in forest cover, particularly in dense vegetation areas, with simultaneous increases in Sparse and No vegetation categories in this region. Change detection analysis highlights the dynamic nature of forest cover attributed to deforestation, forest logging, tourism development, and policy execution. Our findings underscore the importance of effective forest conservation and management strategies to mitigate further vegetation loss and preserve ecosystem integrity.

KEYWORDS- Deforestation; Forest Cover Change; Landsat; NDVI; Ajodhya Hill Forest Region

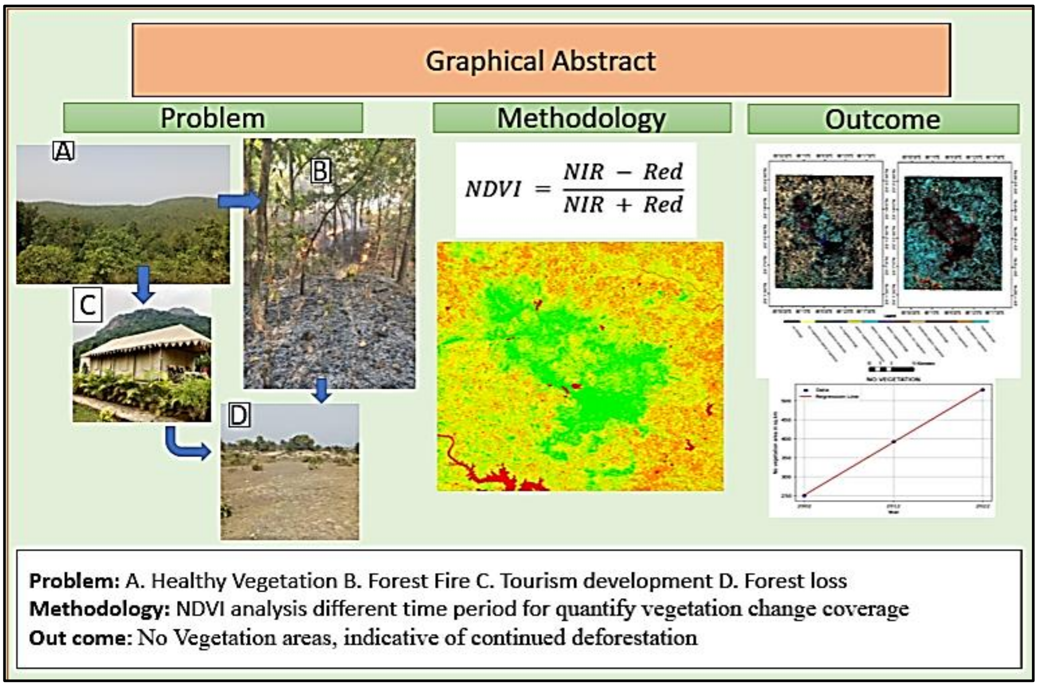

Figure 1: Graphical Abstract

I. INTRODUCTION

The Food and Agricultural Organization (FAO) of the United Nations estimates the entire forest area of the world at 4.06 billion hectares or 31% of the total land area. The tropical region boasts the highest forest coverage, trailed by the boreal, temperate, and subtropical climates [1]. Forests are called biodiversity hotspots because they provide many creatures, such as bacteria, fungi, ferns, flowering plants, insects, birds, reptiles, nematodes, and other organisms [2]. The United Nations Sustainable Development Goal (SDG) 15 calls for the protection, restoration, and promotion of the sustainable use of terrestrial ecosystems and sustainable management of forests, as well as a series of assessment indicators [3]. Its diverse ecosystem supports multifarious physiological units. Due to these reasons, Ajodhya Hill Forest plays a crucial and indispensable role in ecology, sustainable development, and global conservation of biological variability. These services include decarbonization, water regulation, soil conservation, and the maintenance of microclimates. The forest ecosystem plays a vital role in regulating local weather patterns, mitigating soil erosion, and supporting the hydrological cycle, thus ensuring the sustainability of surrounding landscapes [4].

Plants are fundamental elements within an ecosystem, crucially contributing to every stage of its development [5]. The significance of the vegetation in a specific area is crucial for upholding environmental stability in the face of climate change. At the same time, vegetation covers a considerable part of the Earth and plays a vital role in influencing the water cycle [6] [7]. Around 33 percent of anthropogenic carbon emissions are absorbed by forests stored carbon is emitted back into the air [7]. As a result of land use changes, the carbon stored in forests is released back into the atmosphere. The IPCC (2007) human activities leading to deforestation are responsible to nearly a fifth of human-caused GHG emissions. Forests, however, absorb carbon dioxide from the atmosphere, equivalent to 33 percent of human-caused emissions [8].

Land use change activities result in the release of carbon present in the woods back into the atmosphere. The IPCC (2007) a staggering 80% of terrestrial biodiversity underpins the livelihood of over 1.6 billion people, highlighting the intricate link between nature and human well-being. They support 1.6 billion human livelihoods, yet humans are responsible for 32 million acres of deforestation annually [1]. While forest cover diminishes globally [9] [10] an opposite tendency occurs in a few places [11] [12]. Forest plays a vital role in supporting human well-being and the planet's ecological integrity by providing a broad array of ecosystem services, from local livelihoods and socio-economic developments to global ecological and economic benefits. Ajodhya is a region of significant ecological value renowned for its forested hills and rich biodiversity [13]. In the Purulia district of West Bengal, India, Ajodhya is an ecologically important region known for its hilly forests, biodiversity, unique landscape, and tourism industry. This greenery provides habitat for numerous species and plays a vital role in maintaining the regional climate and livelihood of the local communities [14].

Due to the development of the tourism industry, these verdant hills have undergone considerable natural changes over time. However, in recent years, the Ajodhya hill forest has been experiencing significant changes in vegetation cover, primarily due to anthropogenic activities such as deforestation, agriculture, and urbanization, as well as natural factors such as climate change and forest fires [23]. A quantitative change in vegetation cover is essential to understand these activities' effects and formulate effective conservation strategies. Remote sensing technology, particularly Landsat satellite images, has become a powerful tool for monitoring and analyzing vegetation dynamics over large spatial and temporal scales. A commonly employed technique in remote sensing to assess vegetation cover is the Normalized Difference Vegetation Index (NDVI). NDVI is a spectral index that uses satellite imagery's red and near-infrared bands to measure live green vegetation [15]. It has been widely used in environmental and ecological research to monitor vegetation health, detect land use and land cover changes, and assess environmental stressors or vegetation impacts. This study sought to identify and map vegetation cover in the study area and to detect and analyze changes in vegetation over time including their magnitude, location and rate.

II. STUDY AREA

The study area encompasses the Ayodhya Hill Forest, situated within the Dalma Hills, an extension of the Eastern Ghats. This region boasts a unique ecological profile, characterized by undulating terrain, rocky outcrops, and dense vegetation, interspersed with streams and waterfalls. Specifically, the study focused on the dry deciduous forest of Ayodhya Hill, located at 23.238N, 86.118E. The forest is primarily composed of Sal Forest, supplemented by various species such as Palash, Kusum, Mahua, Neem, and Kenda [13]. Geographically, the study area is confined to Ayodhya Hills, Purulia, situated in western West Bengal, India. With an elevation of 610 meters, this region is an extension of Jharkhand's Dalma Hills. The area experiences water scarcity due to limited annual rainfall, ranging from 1100-1500 mm. The local climate is characterized as monsoonal, semi-humid tropical, with average summer and winter temperatures of 29°C and 21.3°C, respectively, and a mean annual precipitation of 1393 mm.See the below figure 2.

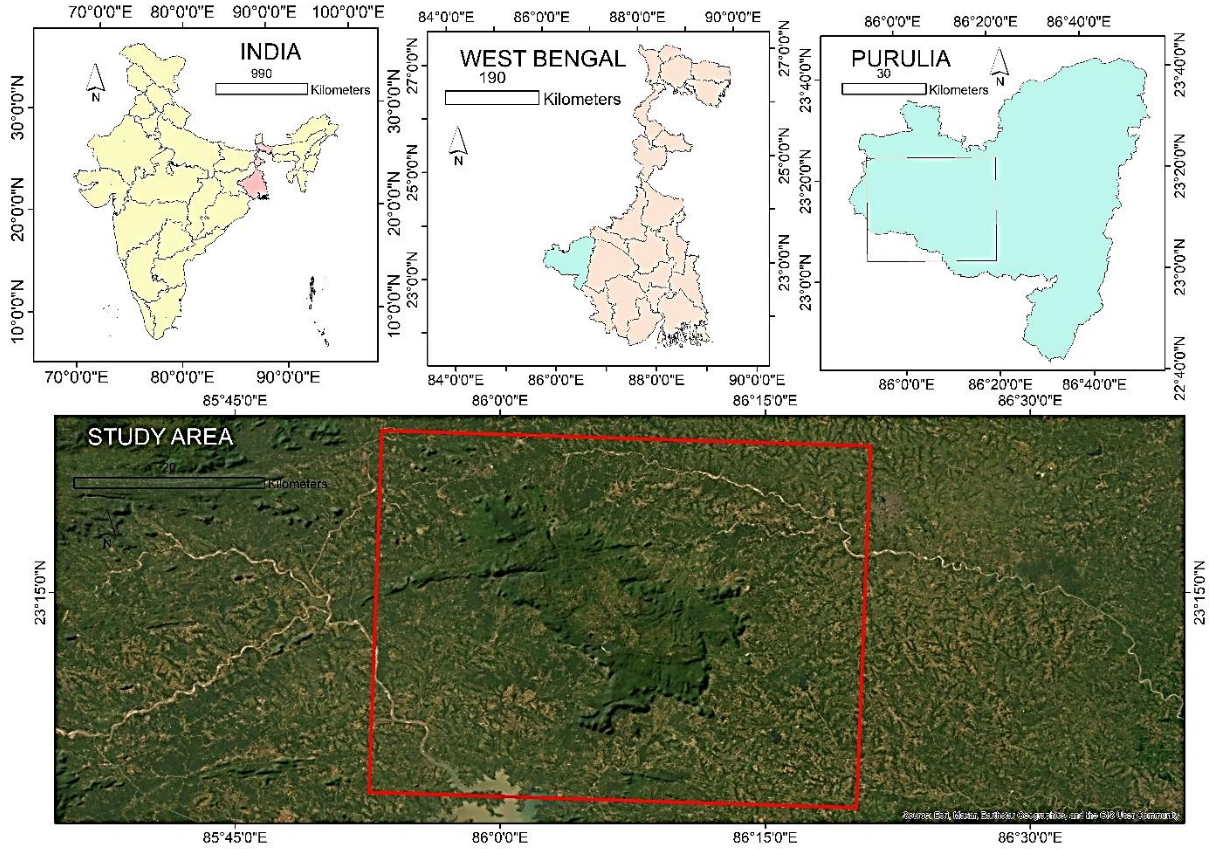

Figure 2: Map of the Study Area

III. MATERIALS AND METHODS

A. Data Used

This study utilized three cloud-free satellite images from Landsat 5 (TM) and Landsat 8 (OLI), obtained from the USGS server, to generate land cover maps (Table 1). The primary objective was to conduct a quantitative assessment of vegetation cover changes in a portion of the Ayodhya Hill Forest using the Normalized Difference Vegetation Index (NDVI). To achieve this, ArcGIS 10.3 software was employed for digital image processing, remote sensing, and GIS-based analysis. NDVI analysis was performed for the years 2002, 2012, and 2022, and corresponding NDVI maps were generated for the study area and surrounding regions. The NDVI provided valuable insights into vegetation health and facilitated the interpretation of green cover dynamics [14].

Table 1: Landsat data Characteristics

Satellite	Sensor	Bands	Date of acquisition	Spatial resolution
Landsat	ETM	4,3,2	Nevember,2002	30 m
Landsat	TM5	4,3,2	November,2012	30 m
Landsat	TM/OLI	5,4,3	November,2022	30 m

B. Methodology

The Normalized Difference Vegetation Index (NDVI) evaluates vegetation by analyzing the difference between the near-infrared spectrum, highly reflected by vegetation [15], and the red spectrum, which is absorbed by vegetation. [16]. For this study, the Normalized Difference Vegetation Index (NDVI) is applied. NDVI is obtained from reflectance images using channels 3 (0.63-0.69 µm) and 4 (0.78-0.90 µm). The technique is used to extract various features from the 3-band satellite image of Ajodhya Hill. Among the indices for vegetation monitoring, the Normalized Difference Vegetation Index (NDVI) is one of the most extensively used [4]. NDVI is the leading technique for detecting vegetation cover and evaluating its health [24]. Satellite-based remote sensing imagery was examined over three decades to assess the changes in forest cover that took place during this time frame. Among the varying methods that have been developed to assess various aspects of the vegetation and forest, normalized difference vegetation index (NDVI) is the most common among the vegetation indices [17].

The composite band has been created using B2, B3, and B4 bands for Landsat 5 and B3, B4, and B5 bands for Landsat 8. After applying atmospheric correction, NDVI was calculated for all Landsat images. NDVI represents the normalized ratio between the near-infrared and red bands of electromagnetic radiation emitted by a substance. [18]. The value of NDVI ranges from (− 1) to (+ 1) [19]. An NDVI value close to +1 signifies the densest vegetation, while a negative NDVI value signifies non-vegetated areas like water bodies, roads, and settlements. NDVI value zero (0) indicates bare land without vegetation. For Landsat 4–5 and Landsat 8 imageries, NDVI is calculated using the following formula, respectively [20].

$$\text{NDVI} = (\text{NIR} + \text{Red})/(\text{NIR} - \text{Red}) \qquad [1]$$

$$\text{NDVI} = \frac{\text{BAND 4} - \text{BAND 3}}{\text{BAND 4} + \text{BAND 3}} \text{-LANDSAT} - 5 \qquad [2]$$

$$\text{NDVI} = \frac{\text{BAND 5} - \text{BAND 4}}{\text{BAND 5} + \text{BAND 4}} \text{-LANDSAT} - 8 \qquad [3]$$

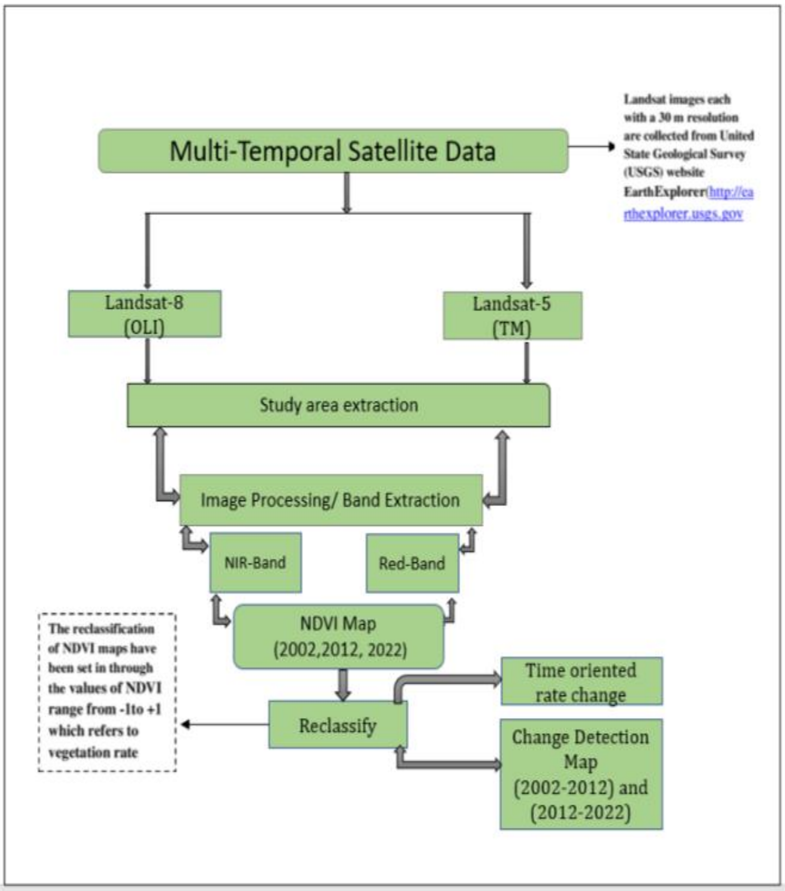

Figure 3: The Flowchart Below Shows a Summary of our Study Methodology

IV. RESULT AND DISCUSSION

A. Forest Cover Change (1992-2022)

The analysis of forest cover change between 1992 and 2002 utilized multi-spectral images from Landsat TM, ETM, and OLI (2002, 2012, and 2022). A comparative analysis of the NDVI results revealed distinct differences between vegetated and non-vegetated areas (Figure 4). The classified images were categorized into four classes: Dense Vegetation, Moderate Vegetation, Sparse Vegetation, and No Vegetation. The assessment of Landsat images from 2002, 2012, and 2022 indicated a declining trend in forest cover over time, particularly in high-priority areas. The NDVI classification results (Figure 4, A, B, and C) demonstrate the spatial distribution of vegetation cover. Notably, the NDVI analysis revealed an increase in "no vegetation" areas from 2002 to 2012, with continued negative growth observed from 2012 to 2022 (Table 2).

Table 2: Area (Ha.) and Proportion (%) of the forest cover categories in the study area in 2002,2012 and 2022

Forest type	2002		2012		2022	
	Area (Ha.)	Area (%)	Area (Ha.)	Area (%)	Area (Ha.)	Area (%)
No Vegetation	250.047	1.28	392.481	2.00	528.921	2.82
Sparse Vegetation	11472.24	58.55	7770.474	39.66	8486.622	45.40
Moderate Vegetation	5353.398	27.32	8568.513	43.73	7284.879	38.97
Dense Vegetation	2516.814	12.84	2861.028	14.60	2392.074	12.79
Total		100		100		100

A significant decline in dense vegetation was observed in the Ayodhya Hill region, with a loss of 124.74 ha over the past two decades (2002-2022). Conversely, moderate vegetation increased from 27.32% in 2002 to 38.97% in 2022, while sparse vegetation decreased by approximately 13% during the same period.

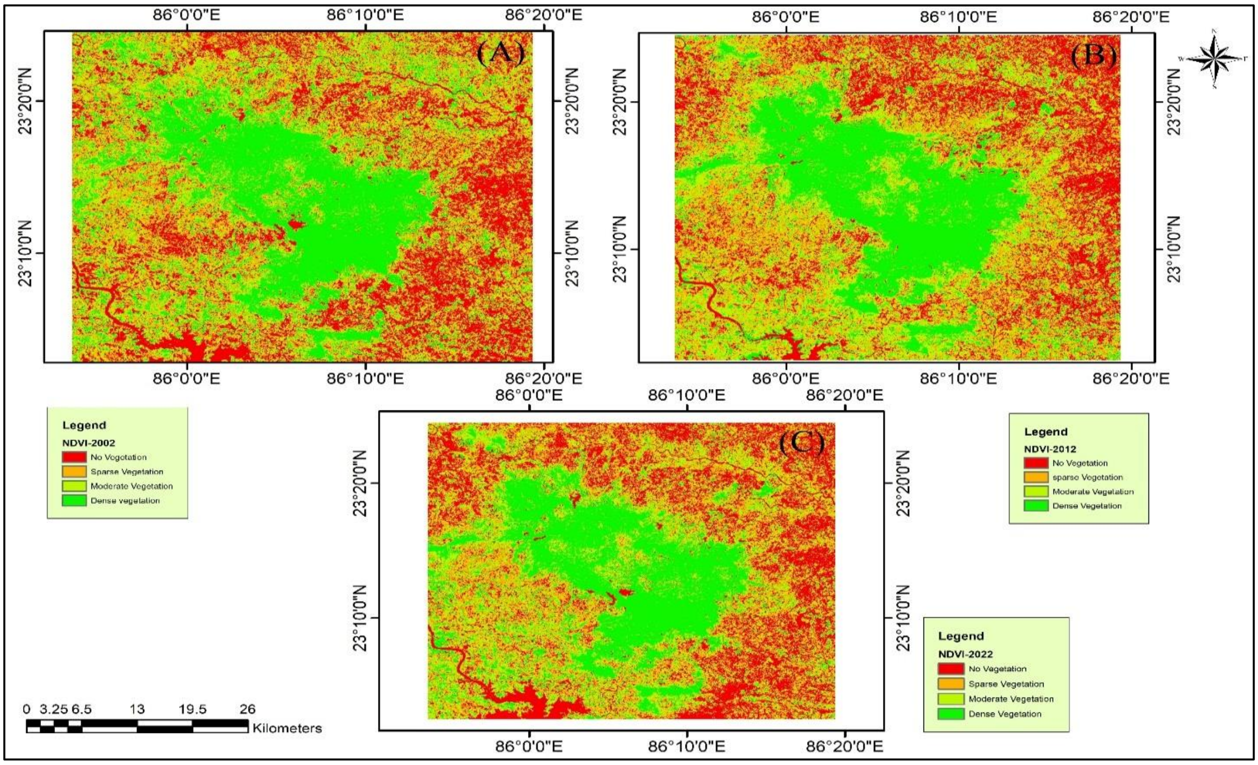

Figure 4: NDVI derived classified map of Ajodhya Hill and adjoining areas for three different years (2002-2022) A-2002, B-2012, C-2022

Figure 5 shows the Correlation analysis that revealed a strong positive relationship between areas with no vegetation and time, whereas dense vegetation areas showed a strong negative correlation. Figure 5 shows the correlation between forest cover and consecutive years. The first graph indicates a highly positive correlation between areas with no vegetation and years. The second graph shows the moderately negative correlation between sparse vegetation area and years. The third graph also shows that there is a moderately positive correlation between moderate vegetation areas and years. Moreover finally, the fourth graph depicts a strongly negative correlation between dense vegetation areas and years. These findings indicate dynamic changes in forest cover, including shifts from dense to moderate vegetation and expansions of non-vegetated areas. Deforestation, forest logging, tourism development, and fuelwood collection contributed to these changes. Our results align with previous studies documenting declining forest cover in the region [21]. The persistent increase in non-vegetated areas underscores ongoing threats to forest ecosystems highlighting the need for enhanced conservation measures and sustainable land management practices. From 2002-2012 and 2012-2022 (Figure 6) the NDVI vegetation change detection analysis continued to reveal shifts in forest cover patterns, signaling ongoing transformations in the study area's ecosystem. The image indicating the 2002-2012(Figure 6) temporal span shows the amount of "No vegetation" maximum persists, which is designated in black color in the mid-portion of the image Side by side, according to FAO (2021), 4000 plants have been rowed in the last five years, which increases the amount of sparse vegetation. Also, we find some chunks are stipulating in yellow colour which proves the area is moving from "Sparse" to "No Vegetation" situated at south western part of the image (Figure 6). On the contrary, image of 2012-2022(Figure 6) shows that after a long decade the area is not showing any improvement in terms of restoration of forest or reforestation because this No vegetation part, shown in black colour remains same as it was ten years earlier. That extreme situation proves no effort has been there to upgrade the greeneries. By applying NDVI methodology to Landsat imagery, changes in vegetation cover were assessed and categorized to understand evolving landscape dynamics. We also detect that the mid-portion of the image (Figure 6) shows a transformation from healthy to "No vegetation," which is shown in red color. Alongside, it is perceived that the northwestern and southeastern areas of the image, which are shown in light brown color, relate to the alteration of moderate vegetation to sparse vegetation.

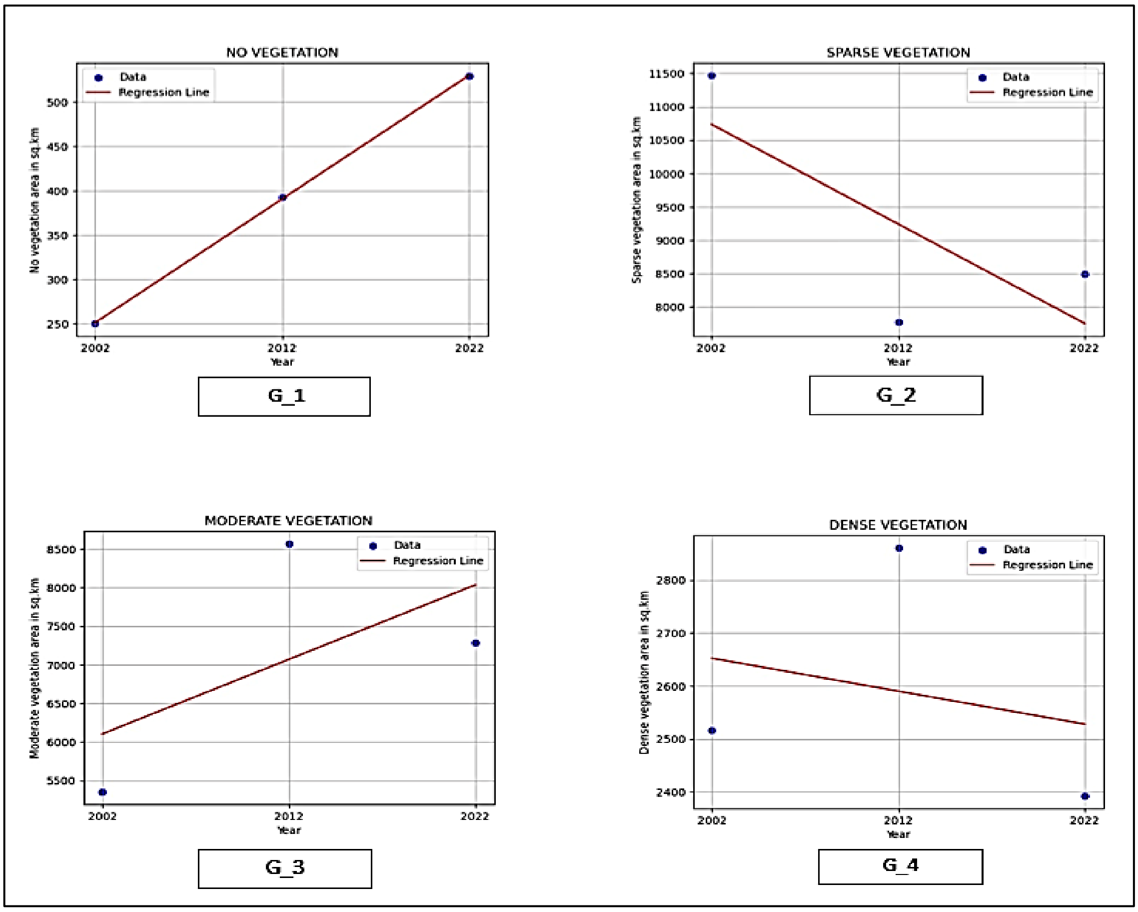

Figure 5: The Change Detection Analysis

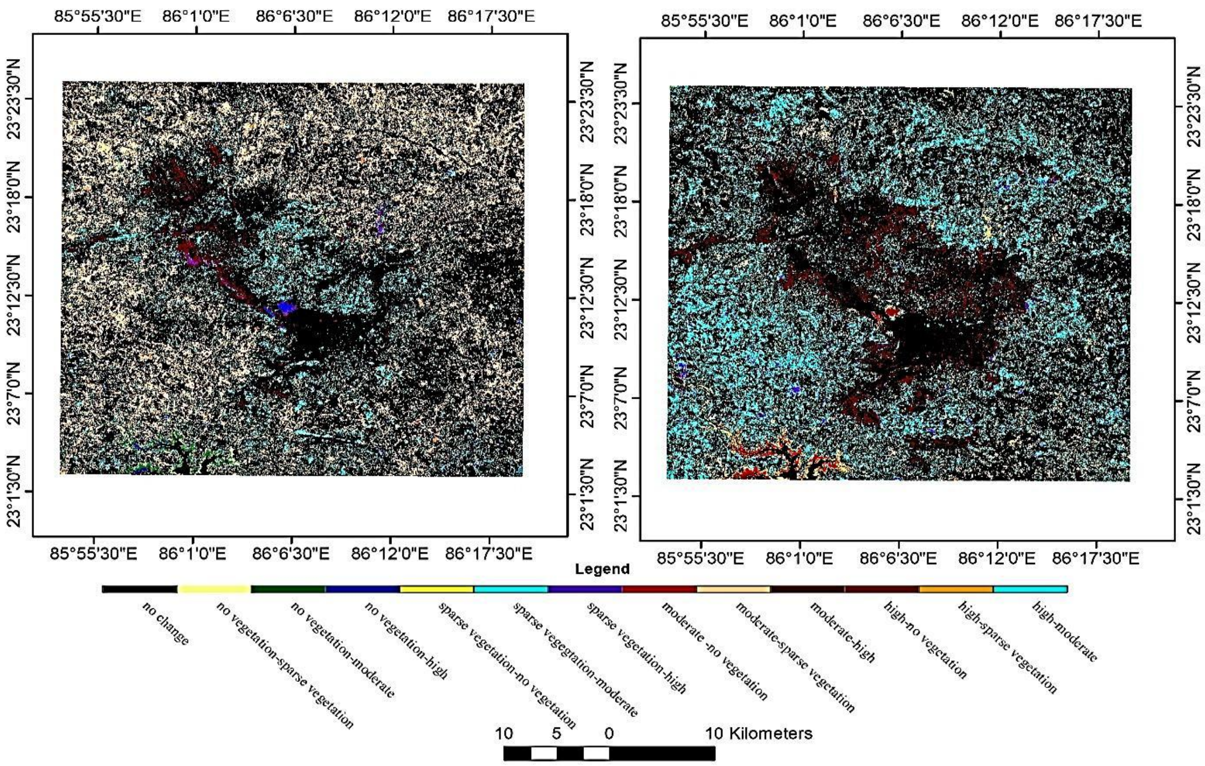

Figure 6: Change Detection Map

V. DISCUSSION

Forests play a critical role in supporting human well-being, sustainable development, and achieving the United Nations' 17 Sustainable Development Goals (SDGs) outlined in the 2030 Agenda. In this district, total forest cover, including social forestry and degraded forests, spans 185,726 hectares, accounting for 29.69% of the district's land area, according to 2009 Satellite Imagery (IRS LISS IV) data [21]. This study employs satellite image analysis to investigate changes in forest cover. Through a detailed examination and personal interviews with local residents, it becomes evident that the forest was once dense and impenetrable. Historically, the study area's forest was dense with indigenous trees and shrubs. However, frequent forest fires during the dry season (March to May) have contributed to the degradation of the forest [25]. The expansion of resorts, hotels, and buildings has led to a decline in dense forest cover. Regression analysis revealed that these factors have resulted in an increase in non-vegetated areas. Human activities, such as population growth, settlement encroachment, and road network development, have accelerated negative forest cover changes. The removal of 159.59 sq. km of scrubland for the PSPP Project and the felling of approximately 3.5 lakh trees have significantly impacted the forest ecosystem [22]. The introduction of eucalyptus plantations has also had adverse effects, as these trees deplete the topsoil and exacerbate soil erosion. Conversations with local residents revealed that the area once boasted vast forestlands with high biodiversity. However, intensive poaching, illegal deforestation, and resource extraction have led to the degradation of the forest. Analysis of forest cover changes between 2002 and 2022 indicates a significant decline in forest cover, with a 1.27 to 2.83% increase in non-vegetated areas. Sparse vegetation has also decreased by approximately 13% over the same period. Natural factors, such as forest fires, and human activities, including poaching and population growth, have contributed to the decline in forest cover. The increasing demand for food and settlement has led to the clearing of forests, exacerbating the problem. The expansion of settlements and agricultural land in hilly areas has led to widespread deforestation, with small trees being cleared to accommodate growing populations and meet increasing food demands. Additionally, cattle grazing has resulted in damage to small trees, further exacerbating forest degradation. Notably, moderate vegetation in the Ayodhya region declined by approximately 7% between 2012 and 2022. NDVI mapping revealed a significant decrease in sparse vegetation, with around 3700 hectares of forest area lost between 2002 and 2012.

VI. CONCLUSION

This study aimed to quantify vegetation cover change in the Ajodhya Hill Forest region of Purulia District using Landsat-based Normalized Difference Vegetation Index (NDVI) analysis. The results offer significant insights. perceptions into the trends and dynamics of forest cover over a 20-year period, highlighting the significant challenges and implications for ecosystem integrity and sustainability. The significant and relevant analysis revealed a concerning decline in forest cover, particularly in dense vegetation areas, accompanied by increases in "Sparse" and "No vegetation" categories. This indicates a shift in the landscape dynamics, with implications for biodiversity, ecosystem services, and environmental resilience. Techniques like NDVI, which is very useful in comprehending the density of vegetation and evaluating swaps in plant health, have become important in the last two decades.

These human-induced activities have contributed to alterations in the ecological makeup of the Ajodhya Hill Forest region, posing threats to its biodiversity and ecosystem functioning. Further research is needed to monitor vegetation changes continuously and assess the effectiveness of conservation measures side by side combined study LULC and NDVI should be implemented to get a better result on recent modification of Ajodhya hill environment. Remote sensing techniques, particularly NDVI analysis, proved invaluable in quantifying vegetation changes and assessing forest cover dynamics over the last two decades.

DATA AVAILABILITY

Availability of data and materials Not applicable.

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CONFLICTS OF INTEREST

The authors declare that they have no conflicts of interest.

REFERENCES

[1] Global Forest Resources Assessment 2020. 2020. Available from: https://catalogue.unccd.int/1481_Global_forest_resources_assessment_FAO_2020_CA8753EN.pdf

[2] B. R. Scheffers, L. N. Joppa, S. L. Pimm, and W. F. Laurance, "What we know and don't know about Earth's missing biodiversity," Trends in Ecology & Evolution, vol. 27, no. 9, pp. 501–510, Jul. 2012, Available from: https://doi.org/10.1016/j.tree.2012.05.008

[3] S. A. Abdullah and N. Nakagoshi, "Forest fragmentation and its correlation to human land use change in the state of Selangor, peninsular Malaysia," Forest Ecology and Management, vol. 241, no. 1–3, pp. 39–48, Feb. 2007, Available from: https://doi.org/10.1016/j.foreco.2006.12.016

[4] Md. A. Islam, A. N. Jimmy, Md. S. Alam, and N. A. Khan, "The use of multi-temporal Landsat normalized difference vegetation index (NDVI) data for assessing forest cover change of Lawarchara National Park," Environment Development and Sustainability, vol. 23, no. 12, pp. 17702–17722, Apr. 2021, Available from: https://doi.org/10.1007/s10668-021-01408-x

[5] N. Khalid, S. Ullah, S. S. Ahmad, A. Ali, and F. Chishtie, "A remotely sensed tracking of forest cover and associated temperature change in Margalla hills," International Journal of Digital Earth, vol. 12, no. 10, pp. 1133–1150, Mar. 2018, Available from: http://dx.doi.org/10.1080/17538947.2018.1448008

[6] S. Piao et al., "Interannual variations of monthly and seasonal normalized difference vegetation index (NDVI) in China from 1982 to 1999," Journal of Geophysical Research Atmospheres, vol. 108, no. D14, Jul. 2003, Available from: http://dx.doi.org/10.1029/2002JD002848

[7] N. Harris and D. Gibbs, "Forests absorb twice as much carbon as they emit each year," World Resources Institute,

Available from: https://www.wri.org/insights/forests-absorb-twice-much-carbon-they-emit-each-year

[8] G. R. Van Der Werf et al., "CO2 emissions from forest loss," Nature Geoscience, vol. 2, no. 11, pp. 737–738, Oct. 2009, Available from: http://dx.doi.org/10.1038/ngeo671

[9] D. Kim, J. O. Sexton, and J. R. Townshend, "Accelerated deforestation in the humid tropics from the 1990s to the 2000s," Geophysical Research Letters, vol. 42, no. 9, pp. 3495–3501, Feb. 2015, Available from: http://dx.doi.org/10.1002/2014GL062777

[10] M. C. Hansen et al., "Mapping tree height distributions in Sub-Saharan Africa using Landsat 7 and 8 data," Remote Sensing of Environment, vol. 185, pp. 221–232, Mar. 2016, Available from: https://doi.org/10.1016/j.rse.2016.02.023

[11] A. Viña, W. J. McConnell, H. Yang, Z. Xu, and J. Liu, "Effects of conservation policy on China's forest recovery," Science Advances, vol. 2, no. 3, Mar. 2016, Available from: http://dx.doi.org/10.1126/sciadv.1500965

[12] L. Li, J. Liu, H. Long, W. De Jong, and Y.-C. Youn, "Economic globalization, trade and forest transition-the case of nine Asian countries," Forest Policy and Economics, vol. 76, pp. 7–13, Dec. 2015, Available from: https://doi.org/10.1016/j.forpol.2015.12.006

[13] D. Das, "Above ground arthropod diversity in a tropical deciduous forest in Ayodhya Hill, Purulia, India," Proceedings of the Zoological Society, vol. 69, no. 1, pp. 141–145, Feb. 2015, Available from: https://doi.org/10.1007/s12595-015-0140-0

[14] P. E. Dennison and D. A. Roberts, "The effects of vegetation phenology on endmember selection and species mapping in southern California chaparral," Remote Sensing of Environment, vol. 87, no. 2–3, pp. 295–309, Oct. 2003. Available from: https://doi.org/10.1016/j.rse.2003.07.001

[15] G. C. S. Negi, "Trees, forests and people: The Central Himalayan case of forest ecosystem services," Trees Forests and People, vol. 8, p. 100222, Feb. 2022, Available from: https://ui.adsabs.harvard.edu/abs/2022TFP.....800222N/abstract

[16] A. Pandey, V. Padhya, S. Chakra, and R. D. Deshpande, "Seasonality in groundwater recharge in Coastal Southwestern India and its hydrological implications based on stable isotopes (δ18O, δD)," Physics and Chemistry of the Earth Parts a/B/C, vol. 130, p. 103396, Mar. 2023, Available from: https://doi.org/10.1016/j.pce.2023.103396

[17] A. A. Gessesse and A. M. Melesse, "Temporal relationships between time series CHIRPS-rainfall estimation and eMODIS-NDVI satellite images in Amhara Region, Ethiopia," in Elsevier eBooks, 2019, pp. 81–92. Available from: https://doi.org/10.1016/B978-0-12-815998-9.00008-7

[18] J. Xue and B. Su, "Significant Remote Sensing Vegetation Indices: A Review of Developments and applications," Journal of Sensors, vol. 2017, pp. 1–17, Jan. 2017, Available from: https://doi.org/10.1155/2017/1353691

[19] Md. H. Rahman and K. Alam, "Forest Dependent Indigenous Communities' Perception and Adaptation to Climate Change through Local Knowledge in the Protected Area—A Bangladesh Case Study," Climate, vol. 4, no. 1, p. 12, Feb. 2016, Available from: http://dx.doi.org/10.3390/cli4010012

[20] S. Saravanan, R. Jegankumar, A. Selvaraj, J. J. Jennifer, and K. S. S. Parthasarathy, "Utility of Landsat data for assessing mangrove degradation in Muthupet Lagoon, South India," in Elsevier eBooks, 2018, pp. 471–484. Available from: https://doi.org/10.1016/B978-0-12-814350-6.00020-3

[21] M. Redowan, S. Akter, and N. Islam, "Analysis of forest cover change at Khadimnagar National Park, Sylhet, Bangladesh, using Landsat TM and GIS data," Journal of Forestry Research, vol. 25, no. 2, pp. 393–400, Apr. 2014, Available from: https://doi.org/10.1007/s11676-014-0467-9

[22] M. Ph, "Trend of changes in annual forest cover of South West Bengal, India," International Journal of Zoology and Animal Biology, vol. 1, no. 5, Jan. 2016, Available from: http://dx.doi.org/10.23880/IZAB-16000130

[23] S. Bhaya and A. Chakrabarty, "Application of geoinformatics in pattern analysis of seditious activity in Purulia district of West Bengal in relation to its geographic and socio-economic background," International Journal of Scientific Research Publications, vol. 6, no. 9, pp. 541–546, 2016. Available from: https://www.ijsrp.org/research-paper-0916/ijsrp-p5774.pdf

[24] Groundxero, "New hydro project at Ajodhya Hills: recipe for a disaster," Groundxero, Oct. 17, 2018. [Accessed: Oct. 17, 2018] Available from: https://www.groundxero.in/2018/10/17/new-hydro-project-at-ajodhya-hills-recipe-for-a-disaster/

[25] A. K. Bhandari, A. Kumar, and G. K. Singh, "Improved feature extraction scheme for satellite images using NDVI and NDWI technique based on DWT and SVD," Arabian Journal of Geosciences, vol. 8, no. 9, pp. 6949–6966, Nov. 2014, Available from: http://dx.doi.org/10.1007/s12517-014-1714-2

[26] A. Goswami, "Identifying the trend of meteorological drought in Purulia district of West Bengal, India.," Environment and Ecology, vol. 37, pp. 387–392, Jan. 2019, Available from: https://www.cabdirect.org/cabdirect/abstract/20193138429

[27] B. Hazarika and N. Bhattacharjee, "Population pressure and its impact on forest resources in north east India," Journal of Positive School Psychology, pp. 4245–4255, 2022. Available from: https://www.researchgate.net/publication/366811511_POPULATION_PRESSURE_AND_ITS_IMPACT_ON_FOREST_RESOURCES_IN_NORTH_EAST_INDIA

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