Assessment of Vegetation Index in Selected Protected Areas of Southern Western Ghats, Kerala, India

G. Shalu, K.Zubereya, S. Anbazhagi, M. Muthuchamy*

Department of Environmental Science, School of Earth Science Systems, Central University of Kerala, Tejaswini Hills, Periya, Kasaragod – 671 316, Kerala, India

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Abstract

The Western Ghats Forest ecosystem is known for its abundance of flora and is impacted primarily by habitat degradation. The Normalized Difference Vegetation Index (NDVI) was used in this study to assess the vegetation changes over time in three protected areas of Western Ghats, including Idukki Wildlife Sanctuary, Eravikulam National Park, and Parambikulam Wildlife Sanctuary, over a 15-year interval (1988-2003 and 2003-2018) using Landsat datasets and ArcGIS 10.6. The result shows that the vegetation in these three protected areas declined dramatically during a decade (1988-2003), perhaps due to anthropogenic activities, deforestation, forest fires, forest plantations, and fragmentation. Historical records confirm that the study areas have been previously subjected to frequent fires, which have deteriorated the forest. In certain locations, clear-felling of forests for plantation was also documented. Later, between 2003 and 2018, vegetation in these areas increased marginally, possibly due to the Government's conservation efforts in protected areas. Further conservation activities in protected area networks, including afforestation with indigenous flora and adequate legal protection, are recommended in this present study.

Keywords: Normalized Difference Vegetation Index (NDVI), protected areas, remote sensing, vegetation, Western Ghats

1. Introduction

Western Ghats (WG), one of the World Heritage sites, accepted as a globally important region for the conservation of biological diversity (UNESCO, 2019). WG is considered as one of the eight hottest hotspots in the World based on five factors include (i.) endemic plants, (ii.) endemic vertebrates, (iii.) endemic plants/area ratio (species per 100 km^2), (iv.) endemic vertebrates/ area ratio (species per 100 km^2), and (v.) remaining primary vegetation (Myers et al., 2000). According to Conservation International, a pioneer organization formerly committed in 1989 for biodiversity hotspots protection, adopted the idea of defining and promoting the concept of hotspots, defined biodiversity hotspots are the region that should contain a significant level of vascular endemics (1,500 species), and at least 70% of the original habitat threatened with devastating effects. WG satisfies both the criteria of the hotspot concept.

WG passes through six states: Kerala, Karnataka, Tamil Nadu, Goa, Maharashtra, and Gujarat. The highest peak, Anamudi situated in the southern portion of the Western Ghats, Kerala (Reddy et al., 2016a). The major vegetation types are evergreen, semi-evergreen, dry deciduous, and moist deciduous. The southern Western Ghats (SWG) region, i.e., Kerala, Tamil Nadu, and Karnataka, are generally rich in the context of species diversity, endemics number, and topographical features than the rest of the WG portions (Nair and Daniel, 1986; Das et al., 2006; Pillay, 2009). By considering WG's enormous value, India's Government is filling the gap of biodiversity conservation by establishing approximately 88 protected area networks all over the WG. According to the 2010 WG serial nomination, 21 protected areas are span into seven sub-clusters of WG, they are; (i.) Agasthyamalai, (ii.) Periyar, (iii.) Anamalai, (iv.) Nilgiri, (v.) Talacauvery, (vi.) Kudremukh, and (vii.)

*Correspondence: mmuthukumar@cukerala.ac.in
Tel: +91 9444158063

Sahyadri. The factors, higher endemism rate, biogeographic province, and the old continuous forest remnants determine the Sub-clusters' selection (IUCN Evaluation Report, 2012).

Apart from its rich biodiversity, WG faces risks from higher human density and anthropogenic pressures. Cincotta et al. (2000) studied the World's biodiversity hotspots; they observed that WG has the highest population density among the hotspots. The higher population pressure of human encroachment, anthropogenic activities, and poor governance hinder the proper conservation of biodiversity in these regions. Jha et al. (2000) observed the loss of forest cover in SWG between 1973 and 1995 as 25.6%. Studies evaluated 5.8% of forest loss in India from 1975 to 2005 (Reddy et al., 2013) and 35.3% of the total forest area deforestation rate in WG from 1920 to 2013 (Reddy et al., 2016[a]). Here, forest conversion is the major driving factor; agriculture holds the second position and follows scrub degradation. Studies clearly show that various anthropogenic activities are directly affecting the natural vegetation in WG. These changes create broad challenges to the living organisms and climate system. So, identifying a specific quantitative rate of vegetation changes is essential in any area concerning biodiversity conservation. Satellite imageries can distinguish the variation in vegetation characteristics and their long-term changes, and this capability proves beneficial when operating in remote or inaccessible areas (Lee and Yeh, 2009). Understanding the processes and patterns of degradation and deforestation is an admirable way to recognize anthropogenic disturbances and progress with forest management's appropriate conservation steps (Reddy et al., 2016b).

There are several ways to analyze vegetation changes, NDVI (Normalized Difference Vegetation Index) is among the most common and widely used index. NDVI is used to identify distinct green vegetation from other landscape features based on the surface area's unique spectral reflectance properties at different conditions (Gashaw et al., 2014). NDVI values vary with the plant phenology and absorption and reflection properties of light. It has been measured based on the light absorption in the red region by plant chlorophyll contents and the reflection of near-infrared radiation due to internal leaf structure (Gandhi et al., 2015).

Comprehensive studies are relatively limited concerning vegetation changes over time in protected areas of WG. Hence, this present study focuses on vegetation changes in three protected areas of SWG, i.e., Idukki Wildlife Sanctuary (WLS), Parambikulam Wildlife Sanctuary (WLS), and Eravikulam National Park (NP) using satellite data and GIS. These areas are crucial because, according to Western Ghats Ecology Expert Panel (WGEEP) Report (2011), these three areas lie in the Ecologically Sensitive Zones (ESZ) of WG based on the factors endemism, IUCN red list, forest cover, elevation, and slope. They are also sensitive to even fewer disturbances. This study's specific objective was to assess vegetation index in protected areas of SWG, i.e., Idukki WLS, Parambikulam WLS, and Eravikulam NP for 1988, 2003, and 2018 using remote sensing and GIS.

2. Materials and Methods

2.1 The Study areas

This study chose three crucial protected areas of Kerala, India, i.e., Idukki WLS, Parambikulam WLS, and Eravikulam NP. Kerala is the state in the southern portion of WG. Idukki WLS, located in the Idukki district of Kerala, lies between 9˚42'-9˚50' N latitude and 76˚54'-77˚05' E longitude (Fig. 1b). The Sanctuary spans 105.364 km^2, and the terrain comprises deep valleys intercepted with shallow hills tops and rock surfaces (Fig. 2a). The major vegetation types are evergreen, semi-evergreen, moist deciduous forest, shola, and grasslands. This Sanctuary featured the Idukki reservoir's water body extending to 33 sq. km (KFWD, 2019a).

Parambikulam WLS is located in Palakkad district and lies between 10º 20'-10º 32' N latitude and 76º 35'-76º 50' E longitude with 285 km^2 (Figure 1c). The Triangular Irregular Network (TIN) model shows that terrain units exhibit undulating hills and broad valleys (Figure 2b). Parambikulam WLS, distinguished by a high endemic rate, is the third-largest protected area in Kerala. Here more than 30% of the site is covered by teak plantations (Sasidharan, 2002). The other vegetation types are evergreen forest, semi-evergreen forest, moist deciduous forest, sholas, and grasslands.

Eravikulam NP is a higher altitude area located in the Idukki district of Kerala, between 10º 06'-10º 19' N latitude and 77º 01'-77º 08' E longitude, and covers an area of 97 km^2 (Figure 1d). Eravikulam NP ecosystem is a unique mosaic of forest and grasslands. Currently, this area is primarily covered by grassland with patches of forest. Along the cliffs and rocky areas mainly found shrublands, and the forest vegetation occupied the valleys and folds (KFWD, 2019b). The terrain featured a higher altitude undulating grassland vegetation with moderate to steep slopes and flat hilltops; in the park's southwest boundary, distributed the tea plantations (Fig. 2c)

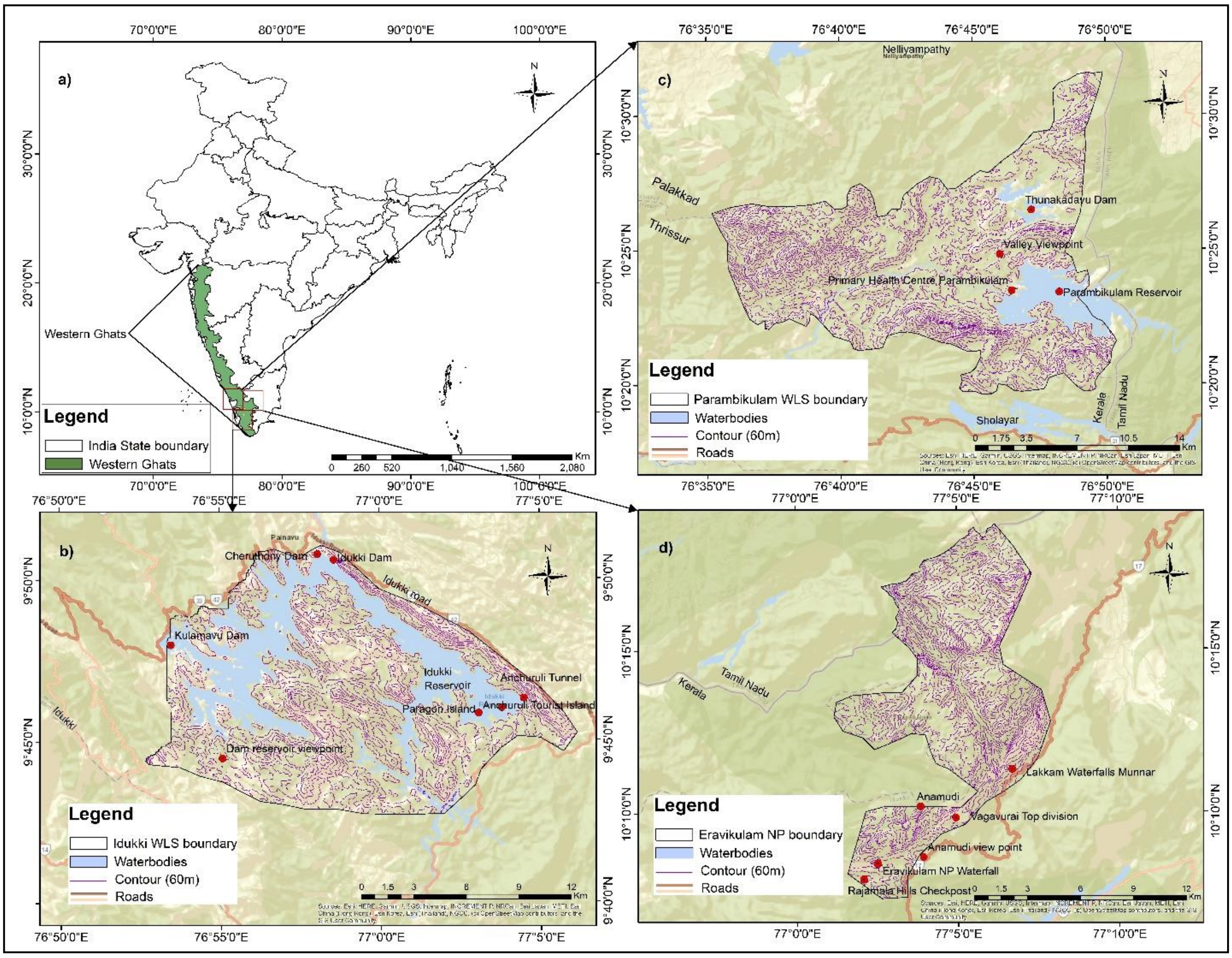

Figure 1. Map of (a) India with Western Ghats; (b) Idukki WLS; (c) Parambikulam WLS; (d) Eravikulam NP

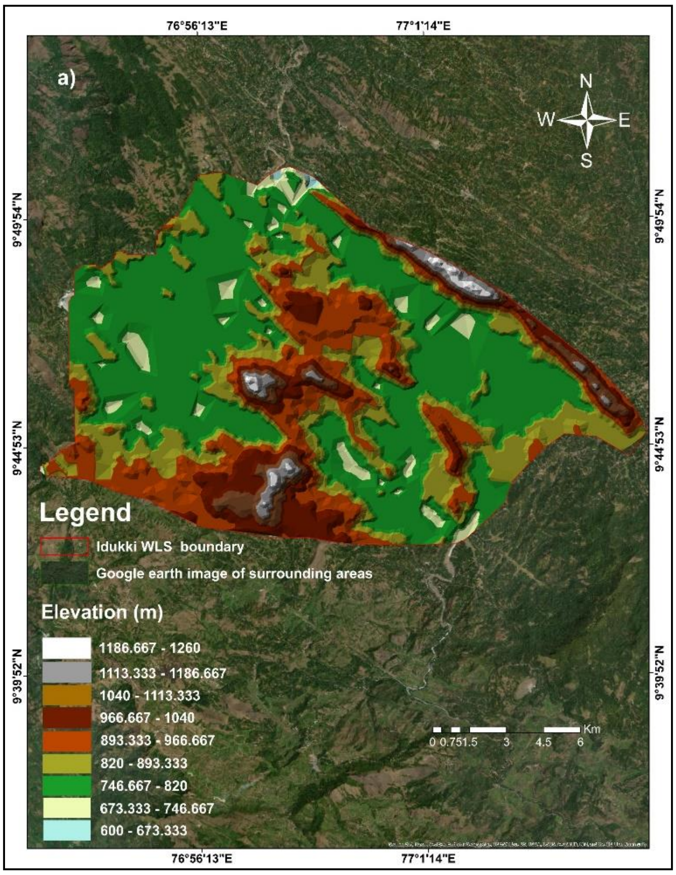

Figure 2(a). Triangular Irregular Network Model of Idukki WLS

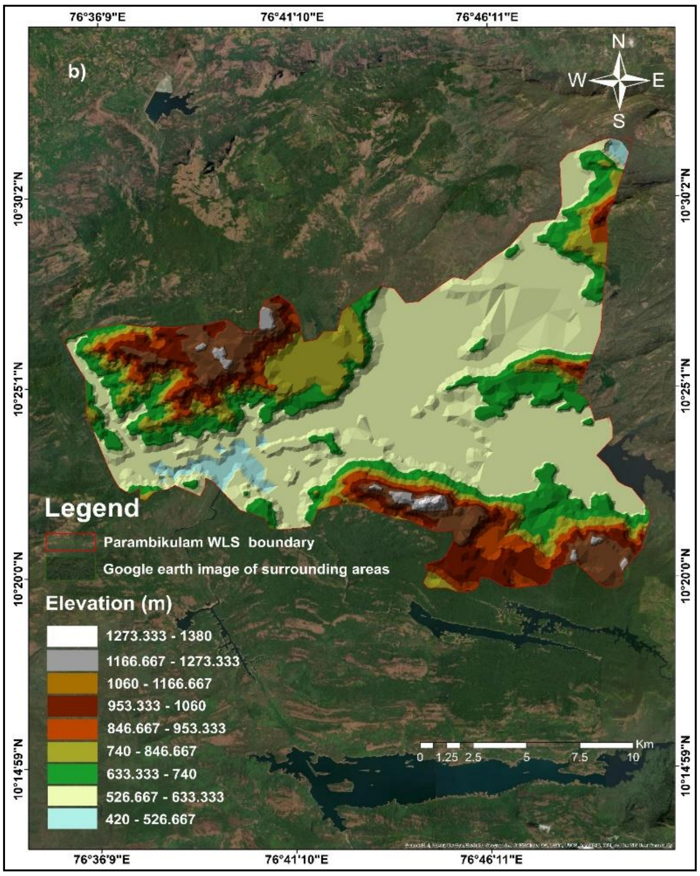

Figure 2(b). Triangular Irregular Network Model of Parambikulam WLS

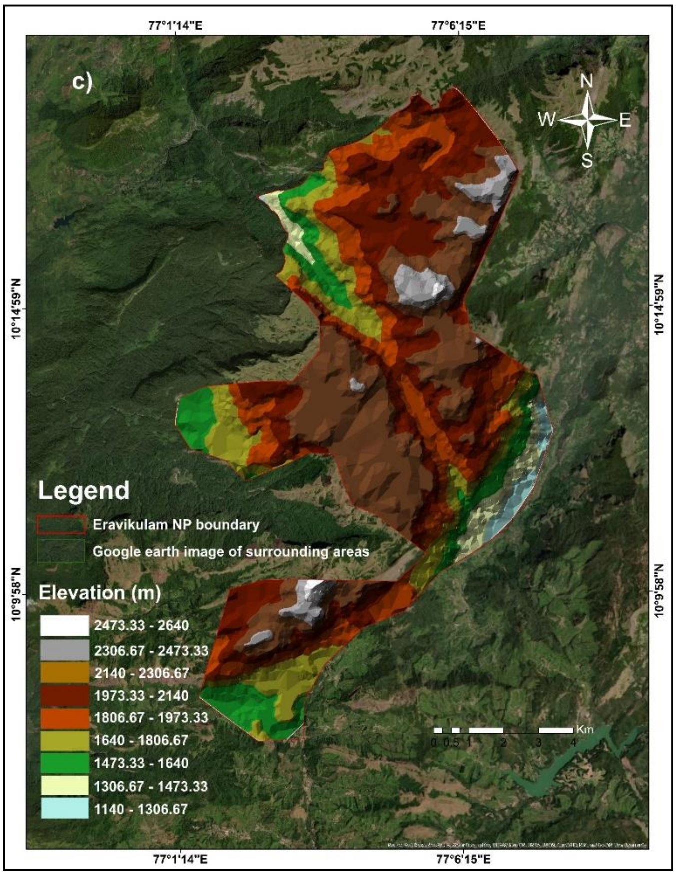

Figure 2(c). Triangular Irregular Network Model of Eravikulam N

2.2 Methods

Cloud-free Landsat images of Idukki WLS, Parambikulam WLS, and Eravikulam NP for 1988, 2003, and 2018 were downloaded from the United States Geological Survey (USGS) Earth Explorer website in GeoTIFF format for NDVI analysis. Landsat 5 Thematic Mapper (TM), Landsat 7 Enhanced Thematic Mapper Plus (ETM+), Landsat 8 Operational Land Imager (OLI) & Thermal Infrared Sensor (TIRS) satellite data were used for this study for 1988, 2003, and 2018 respectively. Details of Landsat data collection has shown in Table 1. For NDVI mapping, the present study used Band 3 (RED) and band 4 (NEAR INFRARED) of Landsat 5 and Landsat 7, whereas, in Landsat 8, the used bands were Bands 4 (RED) and 5 (NEAR INFRARED). NDVI was determined for three protected areas for three different years using equation (1) with ArcGIS 10.3.1.

$$NDVI = \frac{NIR\text{-}RED}{NIR+RED} \tag{1}$$

The vegetation index is quantified by measuring the difference between absorbed light (RED) and the reflected light (NIR) by plants. Here, the NDVI values range from -1 to +1. The values nearer to +1 signifies the probability of dense green vegetation in the area, whereas values closer to zero corresponds to exposed soil, barren land, and rocks. On the other hand, the higher negative values indicate the absence of vegetation or water bodies' presence (Kiage et al., 2007; Gashaw et al., 2014). NDVI maps were prepared and compared with Google earth's image to understand the vegetation changes better.

Downloaded the Shuttle Radar Topography Mission Digital Elevation Model (SRTM DEM) of 30 m resolution from the Earth Explorer website and prepared the Triangular Irregular Network (TIN) model with ArcGIS 10.3.1 software for representing the terrain surface morphology. Details of data collection have shown in Table 1. Fig. 3 shows the conceptual flowchart of the methodology.

Table 1: Details of data collection (Source: USGS)

Study area	Date of the image	Satellite used	Resolution (meters)	Path/Row	Result
Idukki WLS Parambikulam WLS Eravikulam NP	19/01/1988	Landsat 5	30 (Visible, NIR, IR) 120 (Thermal)	144/53	NDVI
	21/02/2003	Landsat 7	30 (Visible, NIR, SWIR, IR) 60 (Thermal) 15 (PAN)	144/53	NDVI
	21/01/2018	Landsat 8	30 (Visible, NIR, SWIR 100 (Thermal) 15 (PAN)	144/53	NDVI
	23/09/2014	SRTM	1 arc-second for global coverage (~30 meters)		TIN

*SWIR (Short-wave Infrared), IR (Infrared), PAN (Panchromatic)

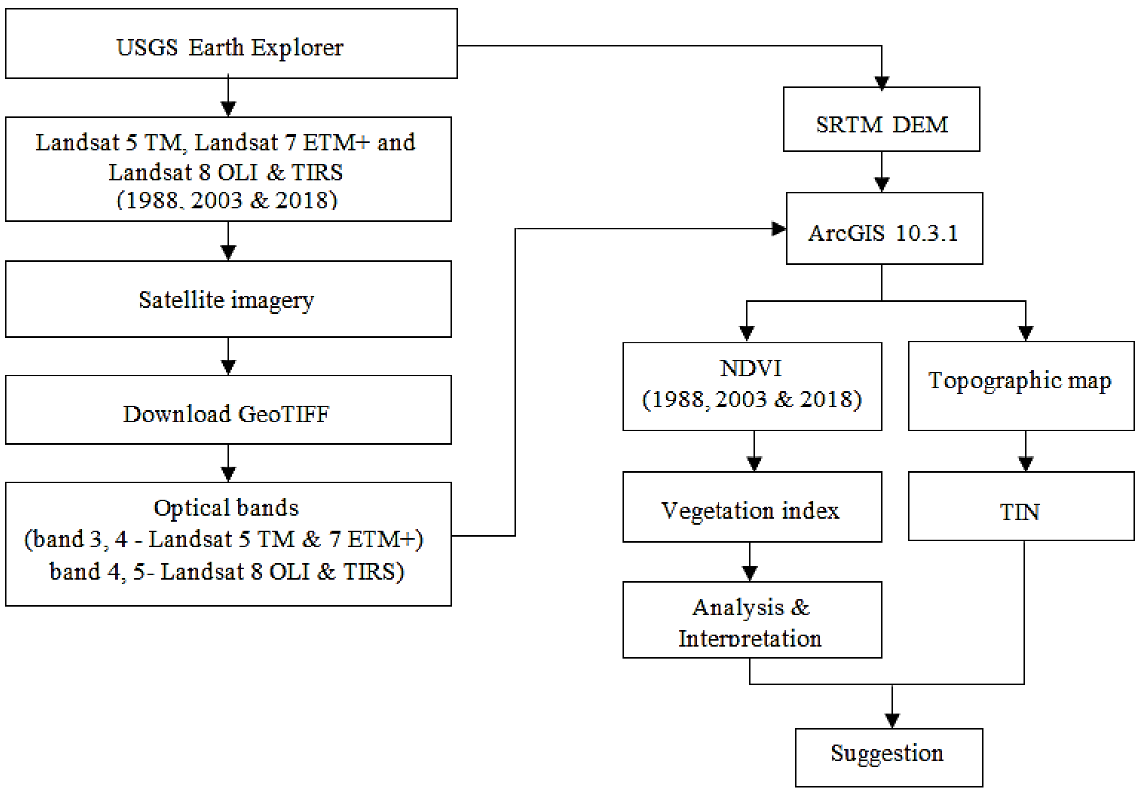

Figure 3. Schematic representation of the research procedure

3. Results and Discussion

Monitoring the changes in forest ecosystems, especially in protected areas, is essential to understanding how vegetation changes over time. Integrating the data from remote sensing and GIS makes it possible to detect vegetation changes in past and present scenarios. The present study analyzed the vegetation index of Idukki WLS, Parambikulam WLS, and Eravikulam NP over the past two decades (1988-2003 and 2003-2018); the results are presented in Figure 4, 5, and 6.

3.1 NDVI analysis of Idukki Wildlife Sanctuary

NDVI map prepared from Landsat image of Idukki WLS for 1988, 2003, and 2018 shown in Figure 4. The extreme negative values shown in the figure correspond to water bodies. The values computed for 1988 range from -0.416 to 0.706 (Figure 4a). Uniformly distributed higher NDVI values indicated the healthy and dense vegetation all over the Sanctuary, and lower values correspond to water bodies. Compared to the higher values of 1988, the NDVI values showed a sharp decline in 2003 across the sanctuary area (-0.458 to 0.447) (Figure 4b). Uniformly distributed dense vegetation in 1988 turned to scattered patches in 2003. These observed changes pointing towards the Sanctuary's important land use and land cover changes may be due to anthropogenic activities, deforestation, or natural calamities. Idukki WLS showed a higher fragmentation rate, and 18.83% of forest cover was reduced from 1975 to 2005 (Athira et al., 2017). Pillai (2005) reported that Idukki WLS experienced grazing pressures, forest fires, firewood collection, and encroachment from the tribal settlements inside and around the Sanctuary. In addition to these factors, habitat degradation, fragmentation, reservoir development, and the invaded exotic species have changed the original vegetation structure. Subsequently, it converted large forest segments to scattered patches with a relatively open canopy (KFWD, 2019a). These changes might be why lower NDVI values and the scattered nature of forest tracts in 2003. Fire is one of the significant threats that continuously occur in this area. Ajin et al. (2016) prepared the forest fire risk zone map of Idukki WLS by considering land cover, elevation, slope, distance from the road, and settlement. According to this study, human-caused circumstances are the most important variables in fire ignition. Further analysis of this present study revealed that NDVI values are slightly increased from -0.079 to 0.539 in 2018 (Figure 4c), resulting from conservation measures implemented in this Sanctuary after 2003. Reports say that no unusual deforestation activities occurred after 2005 (Athira et al., 2017).

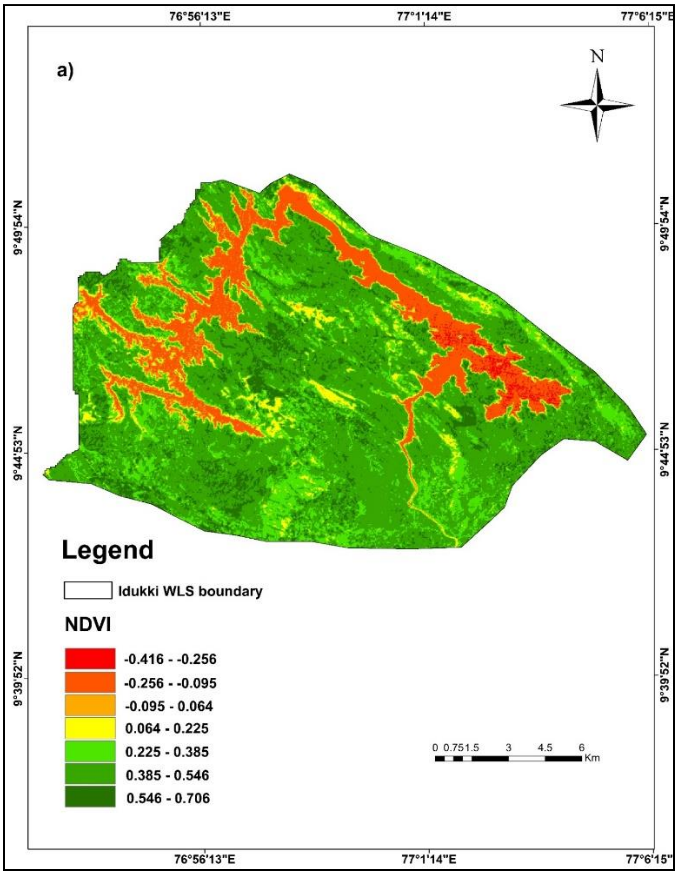

Figure 4(a). Normalized Difference Vegetation Index map of Idukki WLS for 1988

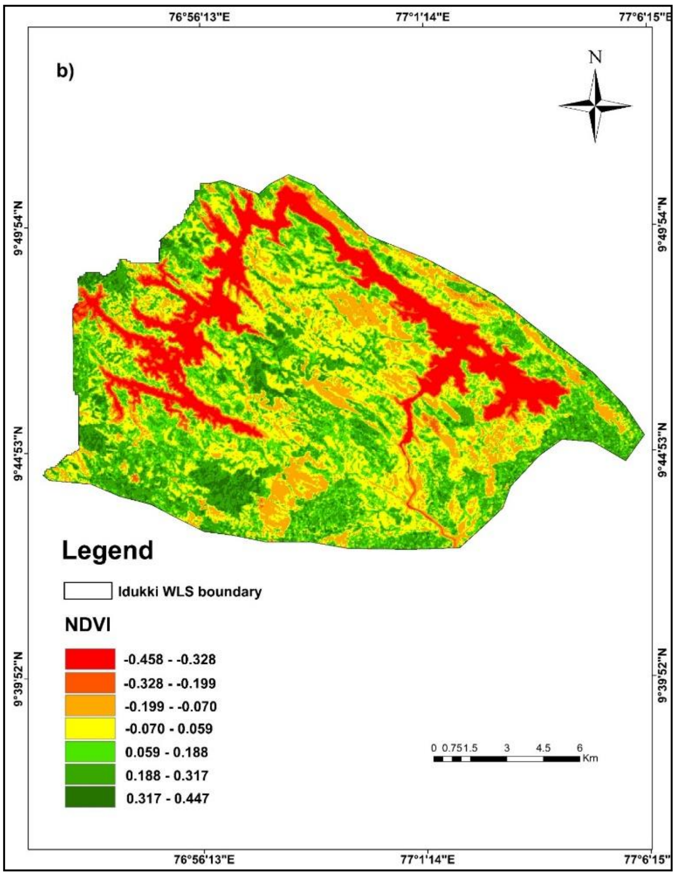

Figure 4(b). Normalized Difference Vegetation Index map of Idukki WLS for 2003

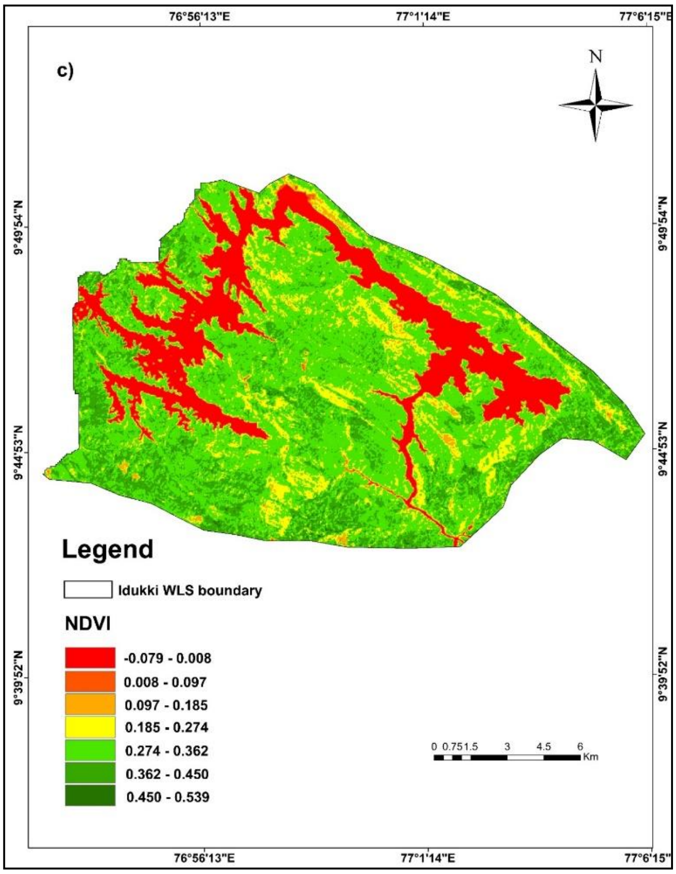

Figure 4(c). Normalized Difference Vegetation Index map of Idukki WLS for 2018

3.2 NDVI analysis of Parambikulam WLS

Computed the NDVI value of Parambikulam WLS for 1988, 2003, and 2018, and results presented in Figure 5. The extreme negative values shown in Figure 5 correspond to water bodies. NDVI value of 1988 was shown a satisfactory index of -0.363 to 0.718, and dense vegetation was covered a significant portion of the area (>0.4) (Figure 5a). These NDVI indices displayed changes in succeeding years. In 2003, the higher values were reduced to a minimum of -0.475 and a maximum of 0.451 (Figure 5b). This difference implies a drastic decline in vegetation index over a decade (1988-2003) within the study area. Some of the case studies were conducted in WG by researchers supporting the observation mentioned above. Reddy et al. (2016a) found that WG lost 35.3% of its total forest area from 1920 to 2013. Specifically, WG of Kerala experienced a higher loss of forest area, and the rate of deforestation was 0.51 from 1985 to 1995 and 0.02 from 1995 to 2005. In Parambikulam WLS, a considerable portion of natural forest was converted to plantation. Unsustainable logging performed in most of the evergreen and moist deciduous forest areas for timber extraction in the past, and later, planted teak in those areas. Primary forests remain only in hilly areas, protected by their complex terrain features (Sasidharan, 2002). Mariappan and Nagamani (2014) have similar views; massive felling has occurred in Parambikulam mainly for industrial purposes, then, after the area was declared as a sanctuary in 1973, teak has been planted on a larger scale. The present study observed that most of the Parambikulam WLS covered by dense evergreen and moist deciduous forest in 1988. When it comes to 2003, teak plantations replaced most of the central and eastern parts of vegetation. The observed lower NDVI values of teak plantations may be attributed to younger contiguous trees with less crown cover. Athira et al. (2017) reported that in Parambikulam WLS, the forest area was 243.23 km^2 in 1985 and was reduced to 233.54 km^2 in 1995, also witnessed a significant loss of core area and a higher level of forest fragmentation between 1985 and 1995. In 2018, the Sanctuary displayed a slight increase in NDVI from -0.074 to 0.509 (Figure 5c). The dense vegetation also followed the same trend, and there was no significant loss observed. This observation indicates the Government has taken conservation efforts concerning forest areas after 2003. Reports show that indigenous evergreen species were concerned for regeneration, and they are successfully growing in teak plantations of Parambikulam WLS (Sasidharan et al., 2002).

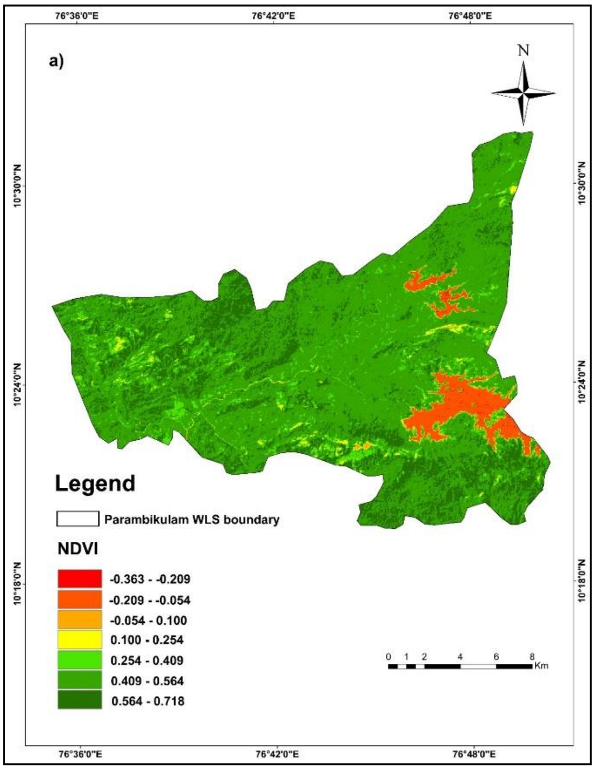

Figure 5(a). Normalized Difference Vegetation Index map of Parambikulam WLS for 1988

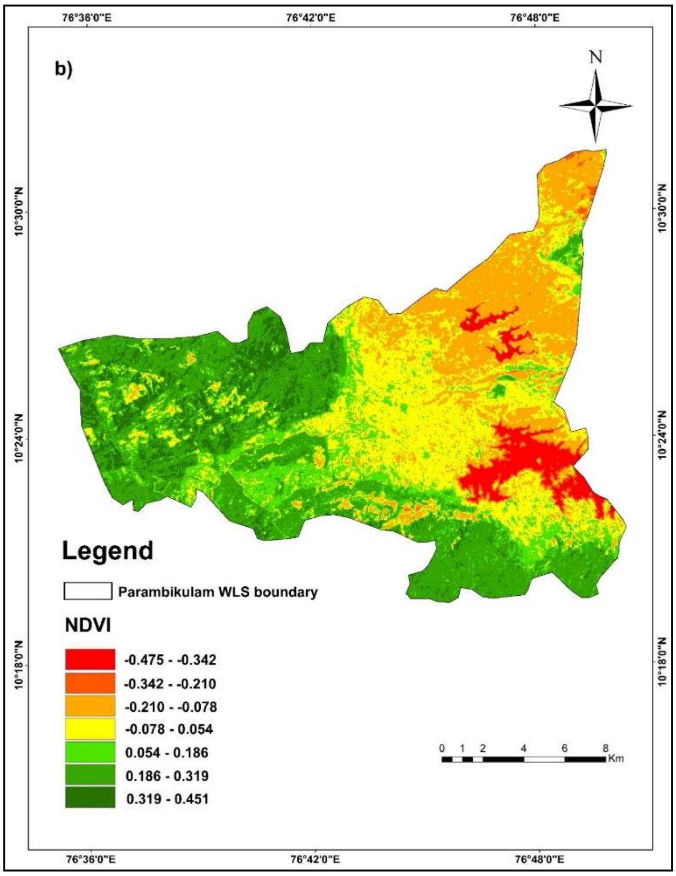

Figure 5(b). Normalized Difference Vegetation Index map of Parambikulam WLS for 2003

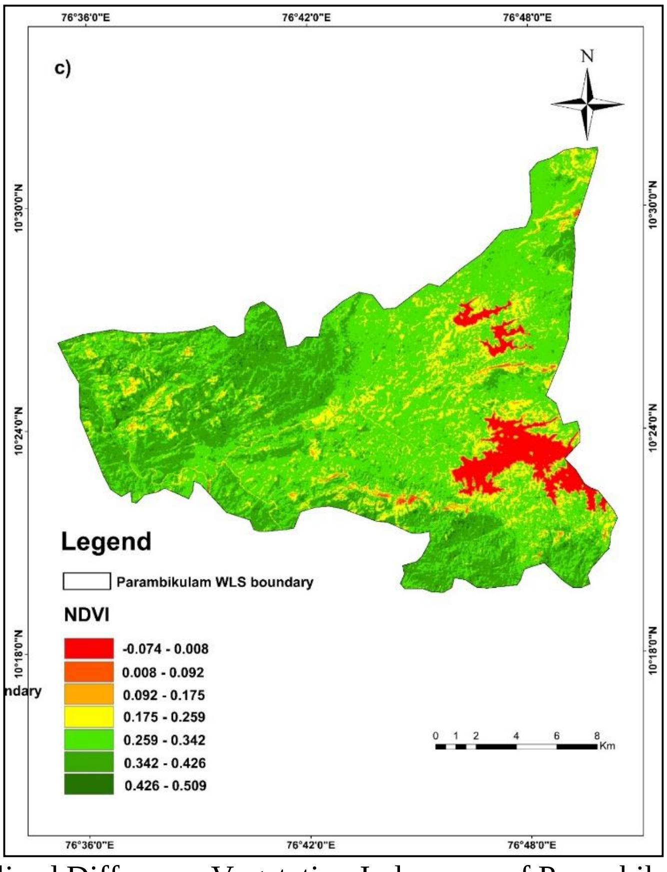

Figure 5(c). Normalized Difference Vegetation Index map of Parambikulam WLS for 2018

3. 3 NDVI analysis of Eravikulam National Park

The NDVI map of Eravikulam National Park for 1988, 2003, and 2018 was prepared from Landsat datasets (Figure 6). The NDVI values of 1988 vary from -0.058 to 0.782 (Figure 6a). The higher values from 0.542 to 0.782 indicated the dense vegetation, attributed to the dense crown and closed canopy of shola, moist deciduous, semi-evergreen, and evergreen forest. Grassland, shrubland, and forests primarily covered this area; also found the tea plantation on the park's southwest boundary. The analysis showed that the grasslands mainly covered the terrain above 1973m, and the forest patches were presented in gullies and prominent in valleys. In 1988, grass and shrubs extensively covered almost all the high elevated areas and rock surfaces, which showed an NDVI value of 0.061 to 0.421. Later, these higher values were reduced to a lower range of -0.347 to 0.538 in 2003 (Figure 6b). Dense vegetation showed a significant decrease (0.285-0.538) in the NDVI values. The other prominent observation noted in 2003 was that rock became exposed in several places of NP. It showed negative values of -0.347 to -0.221, indicating the absence of vegetation or considerably less vegetation. The deforestation studies were done in WG for different periods provided here to support the present study's observations. From 1973 to 1995, a substantial decrease of open forest noted in Eravikulam NP and plantations increased at an annual rate of 5.62%. The reduction in forest area reported here can be linked with increased plantations (Jha et al., 2000). Also, reports showed that invasive tree species *Acacia mearnsii* planted in nearby tea plantations as a shade tree escaped and spread to this NP and adversely affected the endemics density (Karunakaran et al., 1998; Sankaran et al., 2005). Over the past few decades, grazing, illegal logging, and forest fires have occurred frequently. Technical reports on the fire of 7th March 2002 and 5th February 2003 mentioned, almost 0.8 ha and 30 ha of the NP burned, respectively (KFWD, 2019b). NDVI analysis of 2003 noted that rock was exposed in many areas, which might link with this tragic fire. Athira et al. (2017) stated that Eravikulam NP consisted of 50.63 km^2 forests in 1985 and decreased up to an area of 47.84 km^2 in 2005. Also, they categorized this area as highly fragmented due to its higher forest patches. These fragmented patches should hinder the successful movement of organisms and is a matter of more significant concern. More studies on the effects of forest fragment patches on plant density and animal interactions and the encroachment of tea plantations into park areas are needed. The present study observed that NDVI values again showed a slight increase in 2018 (-0.014-0.548) compared with 2003 (Figure 6c). The result revealed several conservation implications adopted in Eravikulam NP. According to the 2012-13 to 2021-22 management plan for Eravikulam NP, specific conservation measures implemented to sustain the ecosystem of the protected area, which are: (i.) delineated distinct boundaries with the tea estate; (ii.) frequent and systematic patrolling ensured to reduce illegal activities in the park and adjoining areas; (iii.) involvement of the local community in systematic fire management planning and implementation; (iv.) practised controlled burning of grasslands; (v.) introduced new visitor management system; here the highlighted point was the formation of Eco-Development Committee (EDC) by including tribal and professional members. These conservation measures reduced the overburden of ecosystems and biodiversity. Also significantly reduced illegal felling of trees and fire incidents since 2006 (KFWD, 2019b) Notably, Eravikulam NP showed a stable forest cover after 2005, preferably saying no deforestation occurred after 2005 while considering the periods from 1975 to 2013 (Athira et al., 2017).

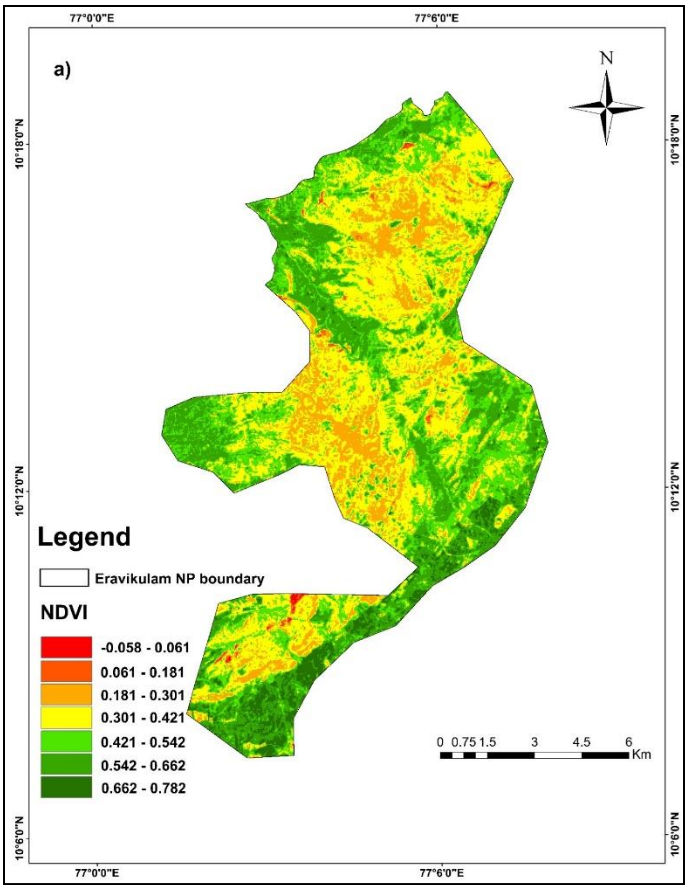

Figure 6(a). Normalized Difference Vegetation Index map of Eravikulam NP for 1988

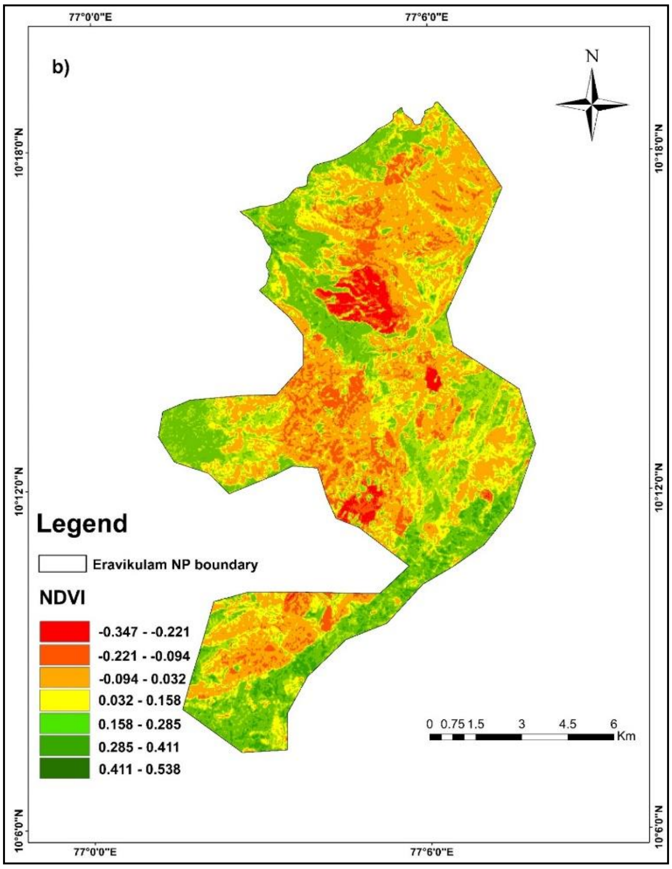

Figure 6(b). Normalized Difference Vegetation Index map of Eravikulam NP for 2003

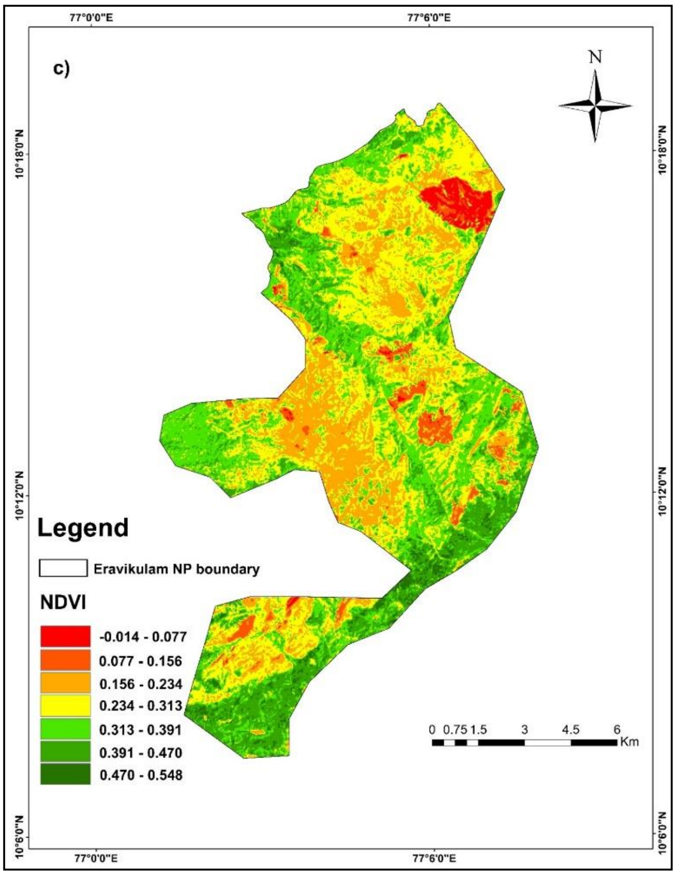

Figure 6(c). Normalized Difference Vegetation Index map of Eravikulam NP for 2018

4. Conclusion

Remote sensing and GIS are essential tools to detect vegetation changes. NDVI is the measure to analyze the vegetation status of the area. The visual observation of the NDVI images and Google earth verification of the Idukki WLS, Eravikulam NP, and Parambikulam WLS for 1988, 2003, and 2018 showed that the vegetation significantly reduced during the period from 1988 to 2003. This decrease in vegetation may attribute to a high rate of deforestation, developmental activities, forest fires, grazing, and fragmentation. Also, observed clear-felling of forests for plantation in some of the areas. All these activities are altering the pattern of biodiversity and reduce the quality of the ecosystem. The vegetation slightly increased in 2018 because of the Government's significant conservation measures in protected areas. Legal regulation of the diversion of forest land to non-forest and plantation, Biological Diversity Act (2002), Biological Diversity Rules (2004), Biodiversity Boards' formation for the respective states are crucial moves from the government authority. This study recommended further conservation efforts in protected areas, including afforestation with indigenous plants and proper legal protection.

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