# Effective Usage of GIS and Remote Sensing for Sustainable Development of Rubber Industry

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**Area of the Paper:** Computer Science.
**Type of the Paper:** Research Case Study.
**Type of Review:** Peer Reviewed as per |C|O|P|E| guidance.
**Indexed In:** OpenAIRE.
**DOI:** https://doi.org/10.5281/zenodo.10571934
**Google Scholar Citation:** IJCSBE

**How to Cite this Paper:**
Anand, S. S. & Kini, S. (2024). Effective Usage of GIS and Remote Sensing for Sustainable Development of Rubber Industry. *International Journal of Case Studies in Business, IT, and Education (IJCSBE)*, *8*(1), 115-134. DOI: https://doi.org/10.5281/zenodo.10571934

**International Journal of Case Studies in Business, IT and Education (IJCSBE)**
A Refereed International Journal of Srinivas University, India.

Crossref DOI: https://doi.org/10.47992/IJCSBE.2581.6942.0338

Paper Submission: 04/09/2023
Paper Publication: 27/01/2024

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**ABSTRACT**

**Background/Purpose**: *All nations, developed or developing, place the greatest emphasis on agricultural sustainability. In order to manage and produce agriculture sustainably, remote sensing based and geographical information system (GIS) technique is becoming increasingly significant instruments. In this work, we examine the integrated application of RS and GIS technology in various locations for sustainable agricultural growth and management of Rubber Industry in India. Remote sensing and Geographical Information System (GIS) are the most recent technologies or support systems or tools that will generate much more accurate results and conduct various geographic analyses even in the most complex situations.*

**Objective**: *Using various studies as case studies, this paper examines the various ways in which the natural rubber industry and cultivation area can be improved using GIS and remote sensing technology.*

**Design/Methodology/Analysis:** *Using the ABCD analysis, data from scholarly papers, online articles, and other sources are analyzed and presented. Additional sources are used to collect inputs for the case study, mainly include specific reports, circular and Rubber science magazine articles.*

**Findings/Result:** *This paper examines the areas in which the Natural Rubber industry can be improved using GIS and Remote sensing technology. Traditionally, human-centered land survey, soil survey, Rubber area survey, Plant disease diagnosis, soil mineral survey etc.were very time consuming and expensive. Using GIS & RS field, we are able to overcome these shortcomings.*

**Originality Value:** *This research investigates the various applications of GIS and RS, which aids in the development of the natural rubber industry.*

**Type of Paper:** *Industry Analysis-based Research Case Study.*

**Keywords:** Geographic Information System, Remote sensing, Mapping, ABCD analysis, Normalized Difference Vegetation Index, Web GIS.

## 1. INTRODUCTION :

GIS is becoming more popular in business since it is an important program for accessing the richness of information that is tied up in the information that identifies the location (for example, homes, postal codes, regions, longitude, and latitude). ArcGIS is a decision -oriented tool allowing users to mix geographical data (such as maps) and databases (such as images or graphs) to make decisions. The ability to incorporate spatial relationships between objects into analyses is a crucial characteristic of GIS that sets it apart from other information systems. As a result, users have the chance to get more value out of their data, since most data have a sizable regional component. A GIS, which stands for geographic information system, is an electronic information system that provides tools for collecting, integrating, and managing data.

The acquiring of knowledge about a thing or event without direct touch with the object is referred to as remote sensing. The word specifically refers to acquiring information about Earth and other planets.

Remote sensing is utilized in a wide range of disciplines, including geophysics, geography, land surveying, and the vast majority of Earth scientific discipline (for example, exploration geophysics, hydrology, ecology, meteorology, oceanography, glaciology, geology); Among other things, it has military, intelligence, commercial, economic, planning, and humanitarian applications. Remote sensing is the use of sensor technology based on satellites or aircraft to identify and classify items on Earth. It includes the surface, atmosphere, and oceans based on data propagation (e.g. electromagnetic radiation). One of three things can happen when electromagnetic energy strikes vegetation during hyperspectral remote sensing in agriculture. The energy will be reflected, consumed, or delivered depending on the wavelength of the radiation and the characteristics of the plant. Remote sensing technology can identify reflected, absorbed, and transmitted energy. Monitoring crop health is a crucial role for remote sensing in agriculture (Kingra, P. K. et al. (2016). [1]). Optical sensing (VIR) allows one to look beyond visible light into infrared wavelengths, which are very susceptible to crop vigor, harm, and strain. Recent technological advances have enabled farmers to monitor their fields and make crop managerial choices in real-time. Crop identification using remote sensing also aids in identifying crops impacted by weather, pests, and other factors. Natural rubber (NR) is a significant industrial plantation crop in the country and a key ingredient in the rapidly expanding rubber goods manufacturing sector. As a result, NR consumption rises in tandem with production and economic expansion in the country (RRII and RTII, 2012). In 2012, roughly 734781 hectares of NR cultivation were under planting in India, with 71% of the total land is in the regular rubber-growing regions of middle Kerala, South Tamil Nadu state Kanyakumari (IRS, 2013). The remainder of the territory is divided into various Western Ghats valleys in Maharashtra and Karnataka, as well as to a lesser degree in Andra Pradesh (AP), Odessa, and north-eastern (NE) states particularly Nagaland, Manipur, Arunachal Pradesh. Mizoram, Meghalaya, Tripura and Assam. Many studies are completed using GIS and RS methods, according to RRII research articles. Some of them are the spatial variation in the availability of calcium and magnesium within soils in south Indian rubber growing regions, The Rubber's Soil Information System (Rubsis) is a decision-making tool for avoiding fertilizer application in rubber plantations based on the spatial variability of available sulphur in south Indian rubber growing soils. Using remote sensing technology, identify and map natural rubber plantations and potential cultivation areas in Assam. A satellite-based real-time remote sensing system was used to evaluate leaf fall in agricultural natural rubber plantations in effect by aberrant leaf fall diseases in real time, Using Modis Terra satellite data to assess agricultural drought in natural rubber plantations, advantage of remote sensed data and gis output for calculating the hectares covered by natural rubber production in India, In Kanyakumari district, a spatial-temporal investigation of the rubber area and its relationship with soil and topography was conducted. The application of remote sensing and geographic information systems to the assessment of the erodibility of rubber soils. (Zolekar, R. B. et al. (2015). [2]).

## 2. RELATED RESEARCH WORK :

Under the parliament Rubber Act 1947 law, the Indian government established the Rubber Board to promote the general growth of the country's rubber business. Rubber Research Institute of India Kerala (RRII) is a research institute affiliated with the Rubber Board situated in 5 km from Kottayam, Kerala. Its primary mission is to conduct research on rubber growth and productivity, as well as rubber-related technologies. Numerous research-related studies conducted here under scientists. The table below includes the significant studies that have been done in the area of GIS and remote sensing. The integration of GIS and remote sensing in agriculture enables data-driven decision-making, increased operational efficiency, and sustainable farming practices (Jessy, M.D. et al. (2019). [3]). These technologies empower farmers with valuable insights and tools to optimize crop production, conserve resources, and reduce environmental impact GIS can be employed to create detailed soil maps, incorporating data on soil type, moisture content, pH levels, and nutrient distribution. The recent articles from 2014 to 2022 containing the related work are collected using the keyword search method in Google Scholar using keywords such as Geographic Information System (GIS), Remote Sensing (RS), Application of Rubber area mapping with GIS & RS, and Rubber Information System (RIS).

**Table 1:** Publications on applying GIS & RS techniques in Heveabrasiliensis.

| S. No. | Field of Research | Focus | Reference |
|---|---|---|---|
| 1. | GIS & Remote sensing | Monitoring of Leaf Retention in Real Time. | Shankar Meti & Pardeep Balan, (2014). [4] |
| 2. | GIS & Remote sensing | Drought assessment and monitoring | Shebin & Meti, (2014). [5] |
| 3. | GIS & Data analysis | Analysis of the rubber area's spatial and temporal relationships with soil and topography. | Meti & Shankar, (2014). [6] |
| 4. | GIS & Web GIS | Rubber Soil Information System (Rubsis): A Decision Making Tool for skipping fertilizer application in Rubber plantations. | Balan & Pradeep, (2020). [7] |
| 5. | GIS & Data Statistics | Checking spatial variability of Zn and B in Plants. | Annie Philip & Ulaganan, (2020). [8] |
| 6. | GIS & Geo-Remote sensing | Using GIS & RS landslide prone detection. | Jessy & Pradeep, (2021). [9] |
| 7. | GIS & Photogrametry | Geo-spatial mapping and terrain characterization | B. Pradeep& Krishnakumar, (2015). [10] |
| 8. | GIS & Remote sensing mapping | Remote sensing and GIS are used to estimate the area under natural rubber cultivation in India. | B. Pradeep & James Jacob, (2016). [11] |
| 9. | GIS Web | Fertility status checking of Rubber growing Soils of Karnataka, south India. | P. Prasannakumari, & Jessy, (2021). [12] |

## 3. OBJECTIVES :

(1) To utilize MODIS satellite data, the normalized difference Vegetation index, and data on land surface temperature to investigate and assess drought regions.
(2) To finds the Land slide prone area's using district wise land slide susceptibility zone data.
(3) Gaining knowledge on how to find abnormal leaf fall disease in Rubber plantations identified by Satellite based remote sensing technique.
(4) To understands the working methodology of Rubber Soil Information System (Rub SIS).
(5) To learn about how to identify acreage estimation of potential Rubber cultivation area's using high resolution IRS data.

## 4. METHODOLOGY :

### 4.1 Modis Terra Satellite data for assessing agricultural drought in natural Rubber plantations:

Drought evaluation and monitoring are critical components of crop management, peculiarly in the face of global heating and climatic variations. Latex, as an abiding crop, faces water constraint at various stages of development. Drought monitoring in actual or close to real time is necessary for effective drought management measures to be implemented. Remote sensing tools based on satellites are

becoming increasingly useful in diagnosing and inspecting drought in a range of yield (Pradeep, B et al. (2014). [4]). Dreadful dryness during the sunny season drastically lowers natural rubber development and yield, this study calculate the spatial parameters of stress in agricultural drought in latex tree colony in Tamilnadu south state Kanyakumari and Kerala. It is processed by satellite helped remote sensing and gis data. A parameter called land surface reflectance and thermal characteristics created from Terra MODIS combined both inputs. Deviation in land surface temperature commonly called LST and NDVI - Normalized Difference Vegetation Index over specific area was calculated. The VTCI-Index of vegetation temperature condition calculates the different stages of an NDVI's vegetation temperature. Its given indirect status of soil moisture. According to previous studies (Shebin, S. M. et al. (2014). [5]), during summer season VTCI is a suitable proxy for measuring drought stress in southern states Kerala and Tamilnadu states Kaniyakumari region.
The study region included Latex tree growing areas in middle Kerala and the south of Kanyakumari district in Tamil Nadu. This was located between the longitudes 74o 48' 33.10"E and 77o 38' 35.43"E, as well as the latitudes 7o 58' 56.27"N and 12o 53' 19.11"N, and has a total geographic area of 40550.637 sq.km. This region's topography is highly undulating, with elevations ranging from 0 to 2692m. Annual precipitation ranges from 2000 to 5000 mm, with an average of 3000 mm.

### 4.2 Materials & Methods:

For the time period, the satellite data used for the study are the 8-day composite MODIS 11 A2 Land Surface Temperature and the 16-day composite MODIS13A2 (NDVI)- normalized difference vegetation index shown in Table 2.

**Table 2:** Satellite data used and its date of Pass-

| Satellite data used | Acquisition start date | Acquisition end date |
|---|---|---|
| MODIS 11 A2 LST | 01/01/2010 | 08/01/2010 |
| | 02/02/2010 | 09/02/2010 |
| | 06/03/2010 | 13/03/2010 |
| MODIS 13 A2 NDVI | 06/03/2010 | 21/03/2010 |

**Preprocessing:** The following preprocessing steps were followed for the MODIS data.

1. Convert the different file format
2. Layer stacking process
3. Reprojection of input data
4. To be multiplied with the scaling factor
5. Subdividing the research area

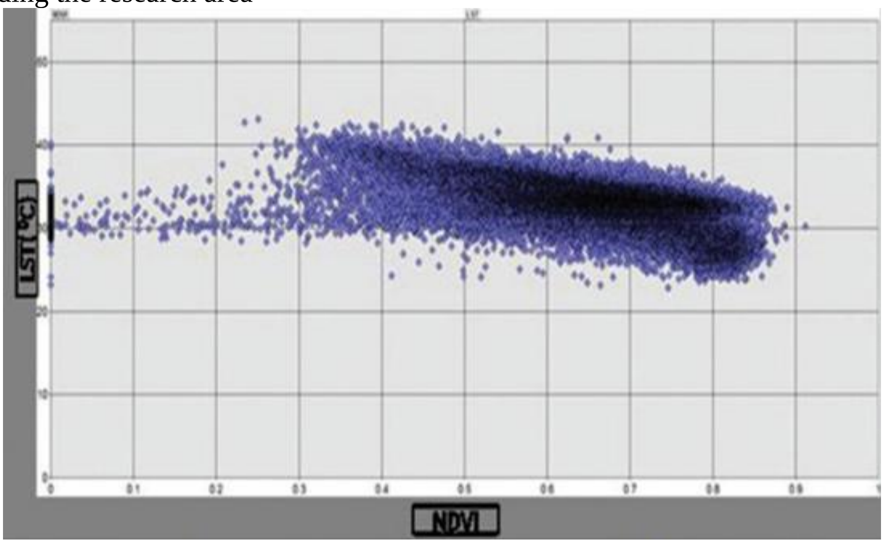



**Fig. 1:** Normalized difference between vegetation index and land surface temperature

**Source:** RRI

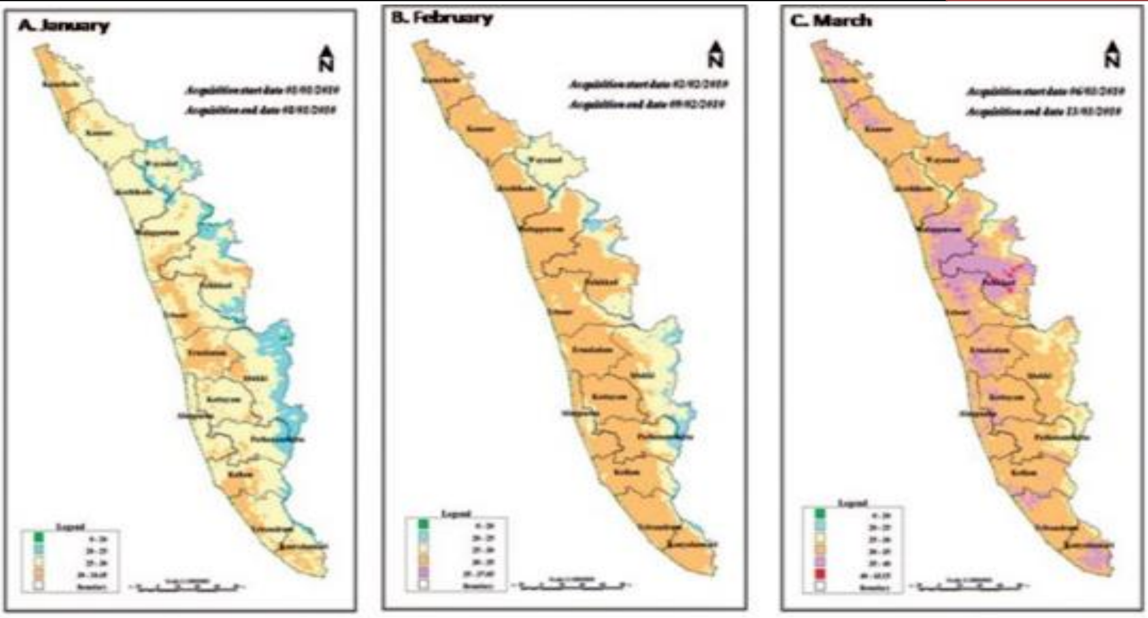



**Fig. 2(A-C):** Kerala and Kanyakumari land surface temperature January to March 2010

**Source:** RRI

The WGS 1984 projection is a Sinusoidal projection. Following projection, the MODIS LST values were divided by 0.02 and converted to degrees celsius.MODIS NDVI data were generated similarly by multiplying DN values by a scale factor of 0.0001. The PCI Geomatica10.3.2 software was used to complete all of these stages (Meti, et al (2014). [6]).

MODIS LST from various time periods was used to overlay on the study region, demonstrating how LST varies spatially over time.

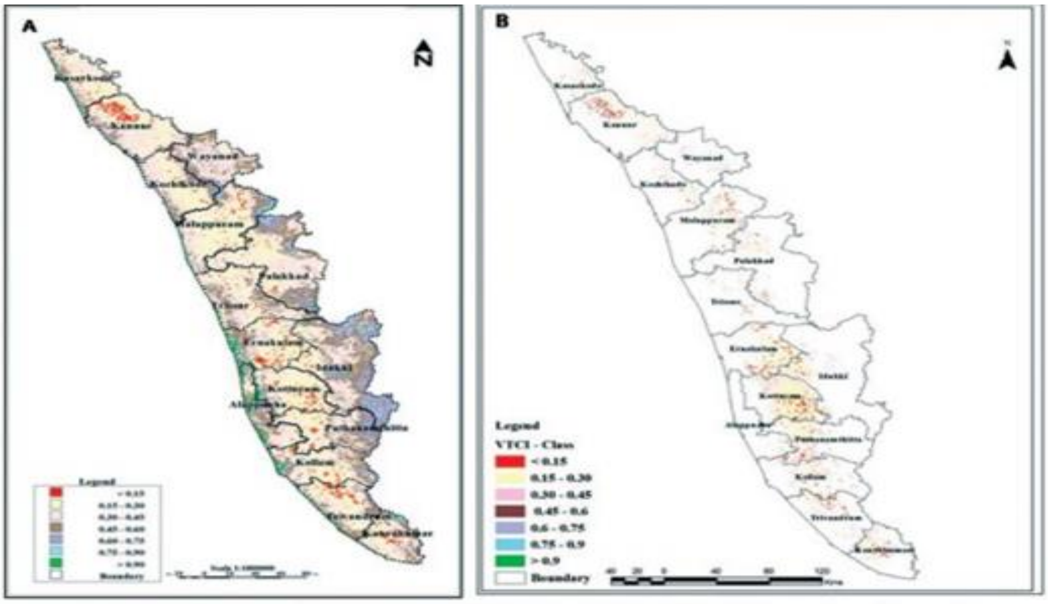



**Fig. 3: (A)** Kerala and Kanyakumari VTCI March 2010 and **(B)** Rubber area under stress

**Source:** RRI

The VTCI (vegetation thermal condition index) is an indication of drought monitoring indicators developed from Terra MODIS NDVI and LST data. As summer approached from January to March, the proportion of LST variations across pixels with a specific NDVI score in adequately broad research areas quickly increased. LST below 200°C accounted for 0.61 percent of total area in January and 0.4 percent in March (Pradeep, B. et al. (2019). [7]). LST was above 300°C in only

19.9% of the land area in January, but this rose to 88% in March. Because the region's LST unexpectedly rose in March, VTCI was computed only for that month (fig 1). The resulting map was overlaid with previously mapped rubber areas using satellite images to determine the geographic extent of rubber holdings under stress. With a 0.15 interval, it was classified in to seven distinct classes. The lower the class, the greater the dry stress, and thus the lower the VTCI. (0-0.15). With an interval of 0.15, VTCI ranging from 0 to 1 has been classified into seven distinct classes. The lower the VTCI, the greater the drought stress; thus, the lowest class (0-0.15) will be high stress areas, while the highest class (0.9-1.0) will be low stress regions (Carlson, T. N. et al. (1994). [13]). It was discovered that approximately 2.34 percent of the total geographical area of Kerala and Kanyakumari was in the low VTCI category, indicating high moisture stress, and only 1.32 percent of the total geographical area was in the high VTCI category, indicating no or low drought. Using LISS III satellite imagery data, a 519909 hectare traditional natural rubber (NR) area including the whole state of Trivandrum, Cochin and Malabar area and the Kanyakumari district in the southern part of Tamil Nadu was found Fig 2(A-C). Spatially delimited NR data were superimposed on a VTCI map and divided into several VTCI classes to determine the breadth and intensity of stress on NR plants. During the study time, 8.36 percent of the total NR area of Kerala and Kanyakumari was classified as 0-0.15. If the VTCI value is near to zero, the vegetation will be stressed. The area was classified as having no or moderate stress. None of the rubber area came under the no or low stress category (fig 3A-3B).

### 4.3 Methods for Landslide Prone Area Identification in Rubber plantation's Using GIS & RS:

The conventional rubber-growing zones of Kerala produce more than 75% of India's natural rubber (NR). Two large landslides in the state's mountainous regions in recent years have killed countless people and caused significant environmental and property damage. The majority of natural rubber plantations are located in the state's Western Ghats foothills, which are prone to landslides due to their undulating and sloping topography. One factor that can cause instability in a hilly area where natural rubber is a prevalent crop is abnormally heavy rains. The region beneath rubber (aged three years and above) was geospatially evaluated using satellite data to calculate the statistics values of rubber plantations in relation with their susceptibility to landslides. This was accomplished with the help of landslide-prone areas in the Kerala region. Rubber plantations in Kerala were classified based on their susceptibility to slides using district-by-district landslide vulnerability zones (shape files) accessible on the Kerala State Disaster Management Authority (KSDMA) platform. Several databases, including topographical maps, satellite imagery, real-time data, and geotechnical research, were combined to construct these landslide-prone zones (Annie Philip, P. et al. (2020) [8]). The landslip zones of each district in Kerala were classified using these maps as low, medium, or high susceptible zones (Figure 4). Using satellite-derived rubber colony maps, these landslip zones were geospatially examined (age three and up), and the precise position of rubber fields in each of them was found. The extent of rubber plantations in moderate and high landslide-vulnerable zones was assessed for each district in Kerala. Using spatially overlay techniques to determine the quantity of NR area within the extremely sensitive landslide zone, rubber plantations were graded further based on slope in very risky landslide zones. Terrain plays a crucial role in landslide susceptibility. DEM (Digital Elevation Model) data can be utilized to extract slope and aspect information, which helps identify areas with steep slopes that are prone to landslides. High resolution DEMs can be derived from remote sensing data, such as aerial imagery or satellite data. Land Cover Classification remote sensing data, such as satellite imagery, can be used to classify land cover types within the rubber plantation. Dense vegetation, bare soil, or areas with less vegetation cover may exhibit varying degrees of landslide susceptibility.

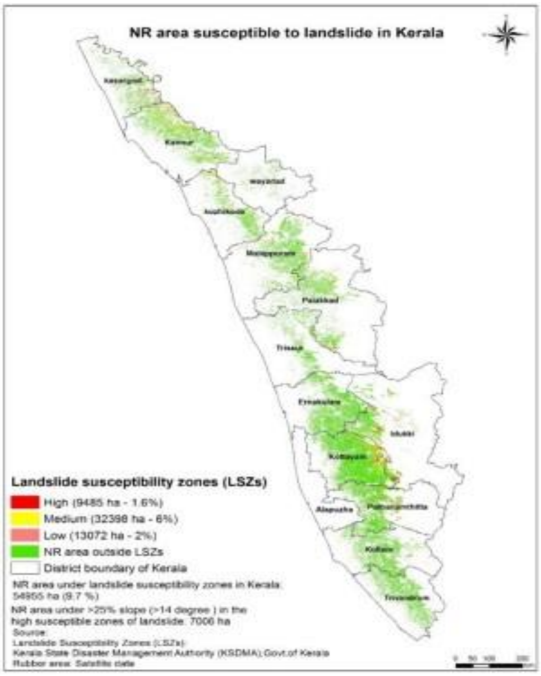



**Fig 4:** Kerala's rubber acreage is distributed under distinct landslip susceptibility zones

**Source:** RRI

**Table 3:** Kerala's rubber acreage is divided into several landslip vulnerability zones.

| | | **Rubber area age (three years and above) in the landslide susceptibility zones (ha)** | | |
|---|---|---|---|---|
| **S. No.** | **Districts** | **Low** | **Medium** | **High** |
| 1 | Trivandrum | 162 | 12 | 3 |
| 2 | Kollam | 364 | 443 | 90 |
| 3 | Pathanamthitta | 3814 | 1668 | 512 |
| 4 | Alappuzha | 0 | 0 | 0 |
| 5 | Kottayam | 3266 | 7491 | 2371 |
| 6 | Idukki | 0 | 4961 | 2132 |
| 7 | Ernakulam | 299 | 900 | 65 |
| 8 | Trissur | 0 | 439 | 15 |
| 9 | Palakkad | 0 | 2479 | 909 |
| 10 | Malappuram | 0 | 2576 | 287 |
| 11 | Kozhikode | 0 | 2903 | 495 |
| 12 | Wayanad | 0 | 495 | 0 |
| 13 | Kannur | 0 | 7976 | 2121 |
| 14 | Kasargod | 5167 | 55 | 485 |
| | Total | 13072 (1.6%) | 32398 (6%) | 9485 (2%) |

**Source:** RRI

**Table 4:** Slope of rubber plantations in high-risk landslip zones

| **S. No.** | **District** | **Slope (degree) range in the high susceptible zones of landslide** | **Rubber area under >25% slope (>14° in the high susceptible zones of landslide(ha)** |
|---|---|---|---|
| 1 | Trivandrum | 2-47 | 2 |

| | | | |
|---|---|---|---|
| 2 | Kollam | 1-55 | 70 |
| 3 | Pathanamthitta | 1-56 | 367 |
| 4 | Alapuzha | - | 0 |
| 5 | Kottayam | 1-69 | 1743 |
| 6 | Idukki | 1-66 | 1677 |
| 7 | Ernakulum | 2-61 | 53 |
| 8 | Trissur | 2-43 | 6 |
| 9 | Palakkad | 2-62 | 687 |
| 10 | Malappuram | 1-61 | 221 |
| 11 | Kozhikode | 1-64 | 377 |
| 12 | Wayanad | - | 0 |
| 13 | Kannur | 1-60 | 1469 |
| 14 | Kasargod | 2-65 | 334 |
| | **TOTAL** | | **7006** |

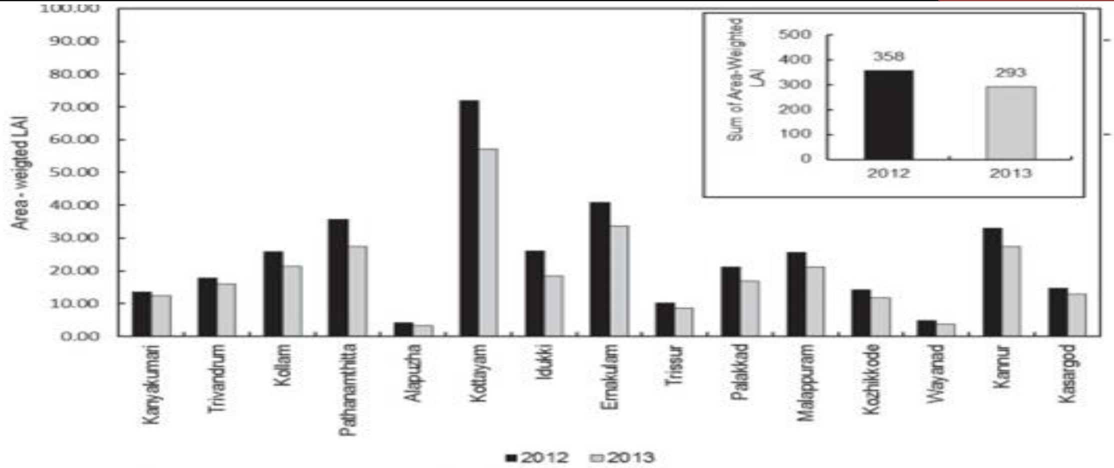
**Source:** RRI

Figure 4 shows that 2% of the entire rubber territory of 107709 hectares (those three years old) in the Kottayam district is in high landslide prone zones, 7% in medium landslide susceptible zones, and 3% in low landslide susceptible zones. Landslide-vulnerable zones in Kottayam district were categorized as either low, medium, or elevated with 12 panchayats in Meenachil and Kanjirappally taluk's designated as very susceptible (Table 3). Poonjar, Thekkekara in Meenachil Taluk had the largest high vulnerable zone land (660 hectares), next to Mundakayam part of Kanjirapally Taluk (443 hectares). Additionally included in this group is the 381-acre Kootickal, Panchayat in the Kanjirapally Taluk. Rubber plantations in high landslip-prone zones varied widely in slope, ranging from 1-69 degrees in all districts. (Table 4). However, above a slope of 14 degrees, a significant area in the high-risk category for landslides was discovered. Evidence suggests that landslip vulnerability should also be taken into consideration when recommending water and soil conservation strategies, and other farming procedures, such as inter cropping, dependent on the degree of gradient. Statistics also indicate that the likelihood of landslides in rubber fields cannot be predicted just by the slope (Pradeep. B. et al. (2021). [9]). Zones of medium, high, and low receptivity were found and classified as rubber plantations in Kerala's landslide-prone regions. A significant portion of Kerala's rubber plantation is located in landslide-prone areas. Rubber fields were more prevalent in high landslip susceptibility zones in the districts of Kottayam, Idukki, Kannur, and Palakkad. A large area, spanning multiple districts, is also prone to medium landslides. To minimize soil disturbance, it is also preferable to use extreme caution in rubber plantations located with low avalanche susceptible zones. Rubber should also be planted in these deep soil areas in little trenches. Avoid cutting raised beds, excavating sediment pits, and growing intercrops that disturb the soil. Installation of suitable drainage is required to remove too much water from the area. Despite the significant degree of skepticism in predicting rainfall-induced landslides, driven by technology integrated solutions to lessen the impact of such risks on ecosystems and society must be created. Multiple parameters, such as slope, aspect, land cover, soil type, and hydrological characteristics, can be combined through a multi-criteria analysis in GIS. This method assigns weights to each criterion based on their relative importance and combines them to generate a landslide susceptibility index map (Pradeep, B. et al. (2015). [10]). Historical landslide data within or near the rubber plantation can be analyzed and integrated into the GIS analysis. This information helps validate the accuracy of the model and identify areas with a previous history of landslides, indicating a higher likelihood of future events.

### 4.4 Real-time monitoring of leaf retention in natural rubber plantations impacted by anomalous leaf fall disease utilizing satellite-based remote sensing technologies:

In 2013, the majority of India's traditional natural rubber-growing areas, which stretch from Kasaragod district in the north to Kanyakumari district in the south, were subjected to heavy and prolonged rains. As a result, there were numerous cases of the fungus Phytophthora sp.-caused abnormal leaf fall (ALF) illness. The first example of real-time LAI monitoring in natural rubber holdings using satellite-based remote imaging technology is discussed here (Shankar .M et al. (2016). [11]). Leaf persistence was studied monthly between April and December 2014 using real-time aerial-based sensing data from rubber holdings scattered over the country's typical rubber-growing area, which had previously been mapped using satellite photographs. Using satellite data, similar estimates of the corresponding LAI statistics for 2012 were made. LAI decreased significantly as the monsoon progressed in both years, but in many districts in 2013, the reduction was much greater and more prolonged than in 2012, indicating that ALF disease caused increased leaf fall in 2013. The north and central of Kerala saw a higher drop than the south. Despite the unusually severe 2013 monsoon, the Kanyakumari district, which is normally free of ALF disease, witnessed significant loss of leaves as a result of the illness in the month of June 2012 and July and June of that year. From April to December, weighted mean LAI was calculated using LAI and percent of total area. This was noticeably lower in 2013 than in 2012.

Poor leaf retention (net primary productivity) has an impact on rubber production, carbon sequestration, and biomass production. Using satellite images, the distribution of rubber across the entire traditional area was recently mapped. (RRII, 2014) (Boegh, E., et al. (2011). [12]). The LAI, or leaf area to ground area ratio, was derived using MODIS Terra satellite data. Monthly composite one km LAI mosaic tile data (MOD15A3) for the study area (Kanyakumari district south of Tamil Nadu, Kasargod in district of Kerala in the north) were obtained from the website of the USGS (http://glovis.usgs.gov) from April to December 2012 and 2013.The MODIS- Hierarchical Data Format (HDF) was converted using the MODIS tool. All tiles were reprojected and mosaicked using the image processing software Geomatica 10.3.1. The research region was clipped and a scale factor was applied to the MODIS data sets to get LAI values. The missing numbers and noise from clouds and other factors were eliminated from the MODIS tiles, and a uniform rubber region was chosen for research (Carlson, T. N., et al. (1994). [13]). The LAI raster pictures were placed on a distribution map of rubber-growing regions obtained previously with satellite imagery (RRII, 2014). The LAI quality indicators of the rubber-growing regions were then retrieved. The monthly district mean LAI was calculated, and district-level LAI images were made. The LAI raster pictures were placed on a distribution map of rubber-growing regions obtained previously with satellite imagery (RRII, 2014). The LAI quality indicators of the rubber-growing regions were then retrieved. The monthly district means LAI was calculated, and district-level LAI images were made (Fig. 5). From April to December, a district with a larger rubber area has a higher weight associated with its mean LAI, and vice versa. Districts with a higher amount of rubber area in Ernakulam, Kottayam and Pathanamthitta have a higher area-weighted LAI. (Fig. 6). Correspondingly, locations with relatively little rubber land, such as Alappuzha and Idukki, have extremely little area-weighted LAI (Fig. 5). From April to December 2012, there were 358 area-weighted LAIs across all districts. This reduced by 22% to 293 during the same time period in 2013. Figure 5 is an inset. It seems doubtful that a fall in rubber yield will be accompanied by a decrease in the total of area-weighted LAI. Given the importance of leaf persistence in rubber output, it is not surprising that a significant fall in area-weighted LAI results in yield loss. We anticipate a 10-15% decrease in yield loss in 2013 compared to 2012. Obtain high-resolution satellite imagery with suitable spectral bands and spatial resolution. Options include optical sensors like multispectral or hyper spectral sensors, which capture information across different wavelengths. Acquire imagery at regular intervals to track changes in leaf retention over time. Pre-process the satellite imagery to correct for atmospheric effects, radiometric calibration, and geometric correction. Then, perform image analysis techniques to extract relevant information about leaf retention. This may involve image segmentation, classification, or vegetation indices calculation (Reichenbach, P., et al. (2014). [14]).




***Area-weighted LAI between April and December in a different district during 2012 & 2013.Sum of area-weighted LAI for the same period is given in the inset.***

**Fig. 5:** Area weighted LAI between two months.

**Source:** RRI

### 4.5 Rubber Soil Information System (Rubsis): A Decision-making Tool for Deferring Fertilizer Application in Rubber Plantations:

Rub SIS, developed by the Rubber Board's Rubber Research Institute of India (RRII) in collaboration with different agencies, namely the Indian Institute of Information Technology and Management in Kerala (IIITMK), the National Bureau of Soil Survey and Land Use Planning, ICAR, and the National Remote Sensing Centre, ISRO, connects soil data to the fingerprints of rubber growers and proposes the optimal mix and quantities of chemical fertilizers that its holding requires. It is an inexpensive tool for the scientific and long-term management of rubber-growing soils (Chen, J. M., et al. (1992). [15]). Thematic layers of SOC and soil depth were retrieved from the Rubber Soil Information System (Rub SIS) database, This was recently constructed by the Rubber Research Institute of India using spatial overlay analysis, the extent of the latex zone with increased soil OC status and a depth of more than one meter was determined. For regions that met both of these requirements, the net savings, including fertilizer and labor costs, were calculated. Fertilizer applications on 1,61,912 acres of mature rubber land in Kerala and the Kanyakumari region of Tamil Nadu can be avoided for short periods of time, resulting in a net annual savings of Rs. 87 crores. Kottayam had the highest net annual savings (Rs.27.4crore per year),while net annual savings in all other districts wireless than Rs.10core per year. Geospatial analysis was useful in identifying mature rubber areas where fertilizer could be skipped for brief periods of time, potentially lowering cultivation costs and avoiding unnecessary pollution. Rubber Board conducted extensive soil sampling in South India's rubber growing regions and discovered that approximately 75% of the total rubber growing regions had high soil organic carbon status (Table-5).

**Table 5:** District-level net annual savings from avoiding chemical fertilizers in Kerala's rubber plantations and Tamil Nadu's Kanyakumari district.

| **Districts** | **Rubber area in each district (Ha)** | **Mature NR area qualifying for skipping fertilizers (Ha)** | **% of mature NR area qualifying for skipping fertilizers** | **Net annual savings due to fertilizer skipping (in core)** |
|---|---|---|---|---|
| Kottayam | 110724 | 50765 | 45.8 | 27.4 |
| Pathanamthitta | 55845 | 17623 | 31,5 | 9.5 |
| Kannur | 54292 | 16410 | 30.2 | 8.8 |
| Ernakulam | 66155 | 15121 | 22.8 | 8.1 |

| | | | | | |
|---|---|---|---|---|---|
| Malappuram | 38835 | 14172 | 36.4 | 7.6 | |
| Kasaragod | 25424 | 12232 | 48.1 | 6.6 | |
| Idukki | 37348 | 12107 | 32.4 | 6.5 | |
| Palakkad | 32119 | 5880 | 18.3 | 3.1 | |
| Kollam | 38998 | 4516 | 11.5 | 2.4 | |
| Kozhikode | 20895 | 2845 | 13.6 | 1.5 | |
| Trivandrum | 27657 | 1149 | 4.1 | 0.6 | |
| Alapuzha | 4421 | 1099 | 24.8 | 0.6 | |
| Trissur | 15734 | 760 | 4.8 | 0.4 | |
| Kanyakumari (TN) | 21948 | 7234 | 32.9 | 3.9 | |
| **Total area (Ha)** | **550395** | **161911** | **29.4** | **87** | |
| | | | | | |

**Source:** RRI

For the study, the rubber-growing regions of Kerala (excluding Wayand district) and Tamil Nadu's Kanyakumari district were chosen. The rubber distribution map, SOC, and soil depth of the study region were used in the analysis. RRII and ATMA (2014) created a spatial distribution map of rubber plantations in the study area in 2012-2013, which was used in the research. The Rubber Soil Information provided the soil organic carbon content and soil depth distribution for the research area. Using chemical fertilizer costs and man power charges, the district-wide net savings from fertilizer skipping (fertilizer dose as N, P, K @ 30:30:30 kg as urea, rock phosphate, and the muriatic of potash) were estimated. The online platform of Information System (Rub SIS). The extent of rubber area with high SOC (>45,000 kg ha1) and soil depth of more than one meter was estimated using a geo-spatial overlay method, and these areas were classified for skipping chemical fertilisers. Using chemical fertilizer costs and labour charges, net fertilizer savings (fertilizer dose as N, P, K @ 30:30:30 kg as urea, rock phosphate, and potash muriatic) were estimated district wide. (Heiskanen, J. (2006). [16]). Approximately 1,61,914 ha of mature rubber acreage in Kerala and Tamil Nadu had high SOC status and more than one meter soil depth, indicating that fertilizer application may be omitted for limited periods. In this region, the annual net savings from not using fertilizers would be Rs. 88 cores (Table 5) (Pradeep, B., et al. (2022). [17]). The Kottayam district had the highest calculated savings (Rs.27.6crore with net savings of less than 10 cores reported in all other districts (George, S., et al. (2011). [18]). Kottayam district had the highest share of areas avoiding chemical fertilizers (50766 ha), followed by Pathanamthitta (17623ha), Kannur (16411ha), Ernakulam(15121ha), Malappuram (14172ha), Kasaragod (12233ha), and Idukki (12117ha). The study also suggested that mature rubber plantations might be considered partially independent ecological systems with a regular cycle of nutrient uptake and disposal to the soil, and that it is conceivable to skip fertilizers in well-maintained rubber plantations with proper topographical conditions (Varghese, M. et al. (2001). [19]). The study revealed the effectiveness of the Rub SIS platform in identifying rubber sites with high organic carbon status and soil depths larger than one meter where chemical fertilizer application might be avoided for short periods of time. There are 161912 hectares of mature rubber planting regions in middle Kerala and south of Kanyakumari district of Tamil Nadu with high soil OC and soil depths of one meter and above. If fertilizer is not applied in these areas, a net annual savings of approximately Rs. 87 cores is expected.

### 4.6 Estimation of the Area of Natural Rubber Tree Farms in India using a Geospatial Decision Making System:

In order to create a geospatial decision-making system for the nation's NR plantations industry, the current effort utilized earth- observatory satellite data to map the area of existing natural rubber crops across India. The research made use of both Indian and overseas satellite data. Based on the phonological of rubber trees, multi-resolution, and mega-temporal satellite data were collected for the delineation, mapping, and evaluation of the spatial area of NR farms. Standard optical interpretation, classification of satellite data, on the screen vectorization, thorough ground truth, information from an assessment of NR areas, and more.

Around 722442 hectares of the nation's NR trees three years old and older have been estimated from satellite-based data. Kerala was the state with the largest anticipated NR plantation spatial extent (558700 hectares), followed by Tripura (76956 hectares), Karnataka (31234 hectares), and Assam (30,805 hectares). Traditional NR growing areas accounted for 78% of total Natural Rubber (NR) plantations in the country, with the Northeast (19%) and the Konkani region (6%) trailing behind. India was the first country to use satellite imagery to map all of its Natural Rubber plantations, and it is a useful tool for tracking changes to the country's Natural Rubber farm ecosystem across time and space (Meti, S., et al. (2008). [20]). The study included all of India's NR-producing states; the research encompassed all of India's NR-producing states. To map NR cultivation, states in the northeastern region, including Tripura, Assam, Meghalaya, Nagaland, Manipur, Mizoram, Arunachal Pradesh, and Kerala and Kanyakumari district of Tamil Nadu, as well as Andhra Pradesh, Odisha, West Bengal, and Nicobar Islands, was chosen. The study estimated the acreage of NR plantations using multi-temporal and multi-resolution satellite data.

Due to the deciduous phenomenon, rubber trees shed their leaves in December and January (defoliation) then fully defoliate in March and April (defoliation). Cloud-free satellite data of NR growing regions in the country were collected during March and April based on the phonological stages of NR plantations (Table 6). To assess the spectral distinctiveness of the rubber tree, the spectrum reflectance properties of rubber trees and other dominating types of vegetation were investigated. The current study included data from both medium and high-resolution satellites. IRS LISS III (23.6m), LISS IV (5.9m), Cart sat PAN (2.5m), Sentinel 2A/2B MSI (10m), and Landsat 8(30m) satellite photos were used to build a map of NR plantation spread (Table 6).

**Table 6:** Detail of satellite data used for mapping natural rubber plantations in the country.

| Satellite data | Sensor and spatial resolution | Year of satellite data |
|---|---|---|
| IRS Resource sat I&II | LISS III - 23.5m, LISS IV - 5.8m | 2012, 2013, 2010 to 2012 |
| Cart sat | PAN -2.5m | 2010 to 2012 |
| Land sat 8 | OLI - 30m | 2014 to 2018 |
| Sentinel 2A/2B | MSI - 10m | 2018 |

**Source:** RRI

To collect information on NR plantation distribution, a GPS-aided extensive ground survey was conducted across India's NR-growing states. Prior to the ground truth, detailed information on NR growing districts/taluks/panchayats was gathered from Rubber Board Regional Offices across India. Latitude and longitude positions from NR holdings were randomly collected from over 12000 places around the country and used to thoroughly verify NR distribution maps obtained from satellite data (Fig. 6). To begin with, work was done in cooperation with Regional Remote Sensing Centre-South (RRSC-S), Indian Space Research Organization (ISRO), to standardize the technique of delineating NR plantations using high-resolution satellite data (Carto merged LISS IV) [25]. First, effort was done to standardize the method of identifying NR plantations using high-resolution satellite data in collaboration with Regional Remote Sensing Centre South (RRSC-S), Indian Space Research Organization (ISRO). LISS IV was cartooned together.

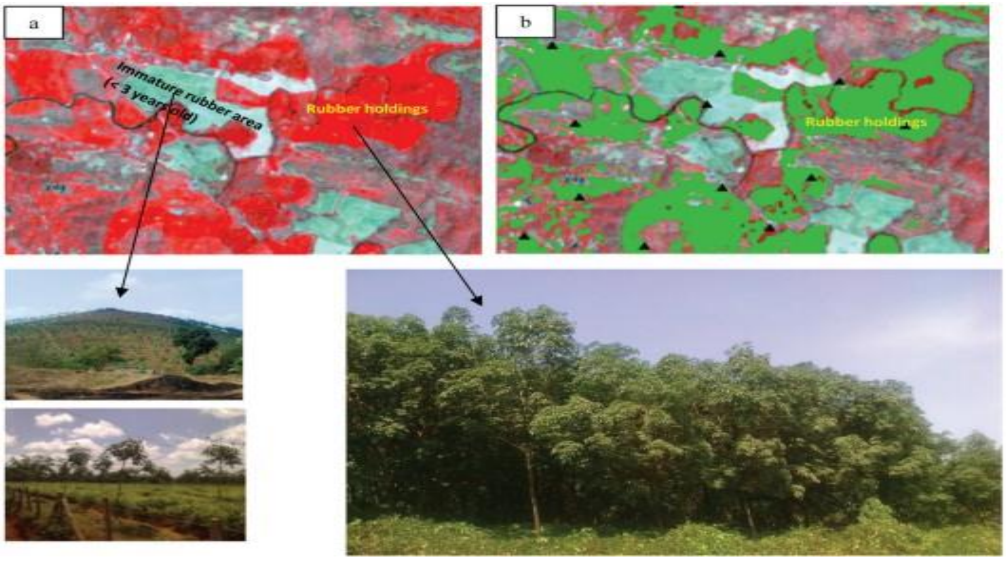



**Fig. 6:** Satellite images show rubber plantations age less than three years old and above (6 a & b). Green color patches are the rubber holdings extracted from satellite data.

**Source:** RRI

Natural rubber plantations were differentiated from other plants using multi-spectral satellite photos (Fig.8). Because to the deciduous nature of NR trees, their leaves drop down in December and January and they totally defoliate in February and March, with sporadic expansions in to April (Fig.8a-b).NR holdings exhibit a distinct red spectral reflectance in the near infrareds area (0.79-0.87 m) in satellite images during this season (Wan, Z., et al. (2004). [21]). Natural rubber holdings appear as bright red regions in optical satellite images. Patches of NR holdings become more obvious as satellite data's spatial precision increases. (Fig. 7a-7d). Due to leaf fall in the months of December and January, natural rubber patches showed low NDVI. This season, NR holdings have a conspicuous crimson spectral reflectance in the near infrared region (0.76-0.88 m) of satellite images. Natural rubber holdings appear as bright red areas in optical satellite imagery. Patches of NR holdings become more visible as the spatial precision of satellite data improves. (Fig- 7a-7d). Natural rubber patches had low NDVI during the months of December and January due to leaf fall (Kroh, P., (2017) [22]).

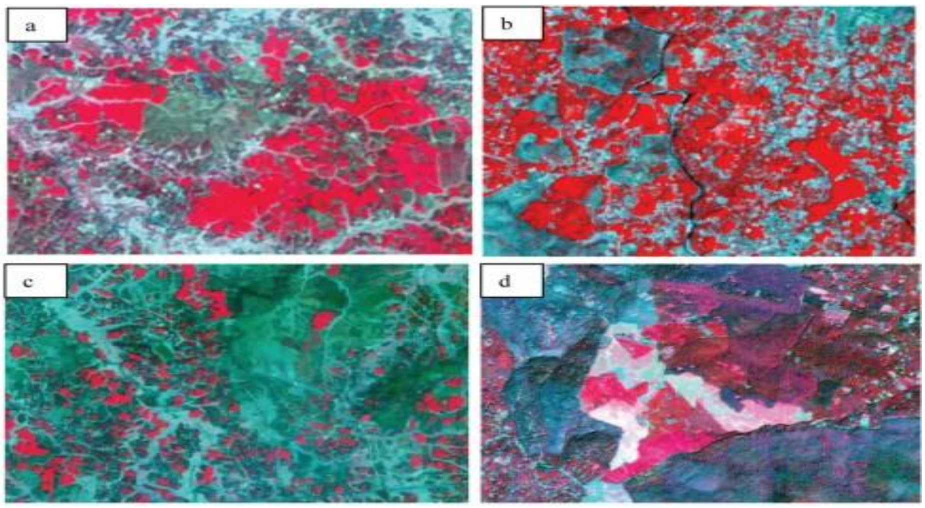



**Fig. 7:** Rubber plantations in different satellite data- a) Landsat 8 OLI (30m), b) IRS LISS III (23.5m), c) Sentinel 2 MSI (10m), d) LISS IV (5.8m).

**Source:** RRI

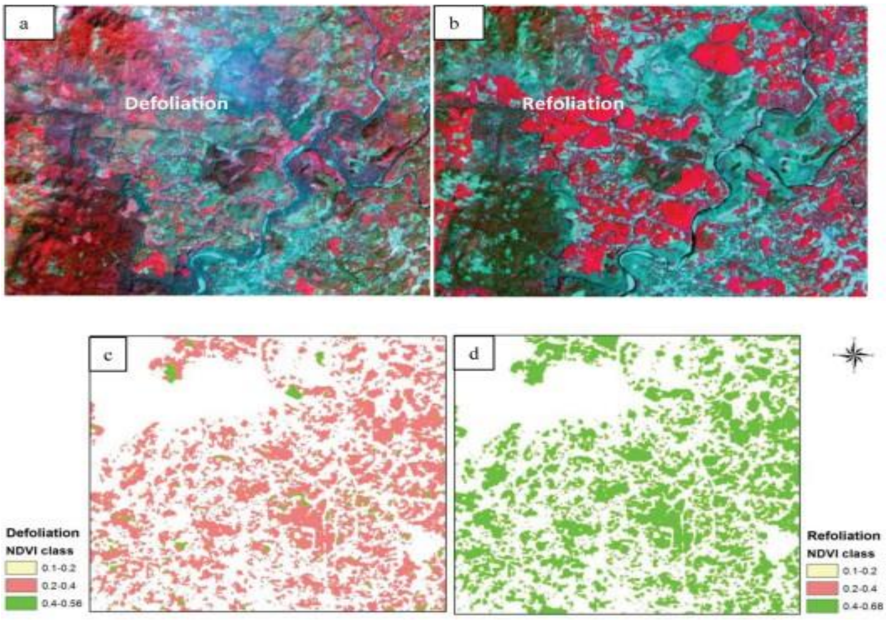



**Fig. 8:** IRS LISS III satellite data showing defoliation (December- January) and defoliation (March-April) of rubber plantations (8a & b). Normalized Difference Vegetation Index (NDVI) of NR plantations (part of the study area) after defoliation and defoliation period (8c & d).
**Source:** RRI

**Table 7:** Satellite-based mapping is for plantations of age three years and above estimated from different states in India. Survey statistics for the corresponding period recorded a total area of about 74168ha (age three years and above) and the variation accounted is 19028 ha (2.6%).

| **State/District** | **Acreage of Rubber(ha)** | **Years of satellite data used** |
|---|---|---|
| ***Traditional area*** | | |
| Kerala | 536652 | 2012, 2013 |
| Kanyakumari district (TN) | 21948 | 2013 |
| ***Konkani region*** | | |
| Karnataka | 31232 | 2013 |
| Goa | 424 | 2013 |
| Maharashtra | 1133 | 2013 |
| **North-eastern states** | | |
| Tripura | 76954 | 2018, 2015 |
| Assam | 30804 | 2018 |
| Meghalaya | 7950 | 2015 |
| Nagaland | 10730 | 2017 |
| Mizoram | 874 | 2017 |
| Manipur | 1062 | 2017 |
| Arunachal Pradesh | 718 | 2016 |
| **Other states** | | |
| Andhra Pradesh | 239 | 2014 |
| Odessa | 560 | 2014 |
| West Bengal | 250 | 2016 |

| | | |
|---|---|---|
| Andaman & Nicobar Islands | 910 | 2014 |
| **Total** | | **722440** |

**Source:** RRI

**Table 8:** Satellite-based spatial-temporal expansion of natural rubber plantations

| State | NR area (ha) and year | NR area (ha) and year | Extent of expansion (ha) |
|---|---|---|---|
| Kerala & Kanyakumari dist. (TN) | 5,19,909 (2005-2006) | 5,58,600 (2012-2013) | 38,691 |
| Karnataka | 20,972 (2009-2010) | 31,232 (2013) | 10,260 |
| Tripura | 48,037 (2011-2012) | 76,954 (2018, 2015) | 28,917 |
| Assam | 16,872 (2011-2012) | 30,804 (2018) | 13,932 |

**Source:** RRI

Natural rubber production has increased in the northeastern states, particularly in Tripura and Assam, over the last two decades (Trisurat, Y., et al. (2000). [23]). The north eastern states rank second in the country in terms of NR production. Based on remote sensing data, Tripura's NR cultivation area is estimated to be around 76954 ha (as of 2018), whereas a 2012 estimate showed 48037 ha, which is 28917 ha less than the current estimate (Table 7) (Satheesh, P. R., et al. (2011) [24]). Tripura's NR farming increased dramatically after 2012(fig 8a-b). The amount of NR measured by satellite in Assam in 2011-2012 was 16872 hectares (Ray, P. et al. (2021). [33]). (fig 8c-d).]. The Konkani regions of Karnataka, including Dakshin Kannada, Udupi, Coorg, Chikamagalur, and Shimoga, have extensive NR cultivation. The amount of natural rubber land in Karnataka was estimated to be around 31233 hectares using remote sensing (Table 7). Based on satellite data from 2009-2010, an earlier estimate of the NR area in this state was 20972 hectare, indicating a 10261 hectare increase between 2010 and 2013(Table 8) (Ray, P., et al. (2021) [25]).

## 5. ABCD ANALYSIS :

Advantages, Benefits, Constraints, and Disadvantages are abbreviated as ABCD. Business models, operational concepts/ideas, business plans, and business/functional systems are all analyzed (Shubhrajyotsna Aithal, et al (2016). [26]). The analysis framework comprises many factors influencing various establishing issues, which are organized into four constructs: advantages, benefits, limitations, and drawbacks, followed by identification of constituent key elements (Aithal, P. S. (2016). [27]). Prioritizing components and constituent important elements allows quantitative research to be undertaken (Aithal, P. S. et al. (2017). [28]). Some of the determining concerns and potential influencing elements in ABCD analysis are organizational problems, operational problems, administrative difficulties, technological challenges, environmental and social issues, and so on (Aithal, P. S. (2017). [29]). The suitable implementation of GIS and remote sensing technology in the rubber business produces very effective results in the agriculture sector. In this study, we will look at how the ABCD model is used in industry from a technological standpoint, as well as its advantages, benefits, limitations, and downsides. (Aithal, P. S., et al (2016). [30]).

**Table 9:** The table showing ABCD analysis applied in Rubber Industry with the base of technological parameters (GIS & Remote sensing methodology).

| | |
|---|---|
| **Advantage** | • Visualization<br>• Monitoring<br>• Management<br>• Real-time analysis<br>• Predictions |

| | |
|---|---|
| **Benefits** | • Optimize Planning and Decision Making<br>• Enhance Business Operations and Marketing<br>• Reduce operational cost<br>• Better way to record data<br>• Effective planning |
| **Constraints** | • Lack of Standardization<br>• Consistency<br>• Dissemination of Data<br>• Security issues<br>• GIS software's are costly |
| **Disadvantages** | • Expensive for small areas<br>• Skilled labors shortage<br>• Affect environment changes<br>• Electromagnetic radiation effects<br>• Data interpretation can be difficult |

## 6. FINDINGS OF THE STUDY :

In this work, we analyzed, examined, and identified several GIS and remote sensing-based investigations. Drought evaluation and monitoring using Modis Tera satellite data, identification of landslip prone areas in rubber plantations using GIS, finding satellite-based remote sensing technology to monitor leaf retention in natural rubber plantations impacted by anomalous leaf fall disease in real-time, and so on. The Rubber Soil Information System (Rubsis) was also developed-Using a geospatial decision-making system, a decision-making tool for deferring fertilizer application in rubber plantations and estimating the extent of natural rubber tree farms in India was developed. With the help of ABCD analysis we find its advantages, benefits, constraints and disadvantages.

## 7. SUGGESTIONS :

(1). VTCI is generated from LST, which is a function of soil moisture over time (among other characteristics), thus it connects not only to recent but also to prior rainfall events. The analysis of real-time LST satellite data and NDVI to determine the temporal fluctuation of drought distribution with respect to crop growth stage for a specific region is essential for drought planning.

(2). Rubber plantations in landslide-prone areas of Kerala were demarcated and classified into low, medium, and high landslide susceptibility zones. A large area of rubber plantations in Kerala is located in landslide-prone locations. The extent of rubber plantation area in high landslip susceptibility zones was greater in Kottayam, Idukki, Kannur, and Palakkad districts.

(3). When utilized to evaluate and showcase agricultural surroundings, remote sensing and geographic information systems have shown to be extremely helpful to both farmers and enterprises. Because canopy variables govern crop development and health stages, spectral information is an important component of satellite data for plant simulation.

## 8. CONCLUSION :

Agriculture is critical to every country's prosperity. It is an important trading industry for a country with a strong economy. Damage from droughts, floods, and other severe weather conditions can also be evaluated utilizing satellite imagery and geographic data systems (GIS) (Sumangala, N., et al. (2022). [31]). The two most essential inputs for agricultural meteorology are meteorological and vegetation data. Remote sensing applications are a useful and efficient method of detecting pest and disease infestations (Patel, N. R., et al. (2012). [32]). It is one of the most powerful tools for analyzing and monitoring climate change. Rubber economic significance and ramifications for industrial requirements have also been recognized. Expanding plantation acreage is the most likely method for boosting rubber production in order to fulfill increased demand for natural rubber. Growth policies should strike a balance between production objectives and the maintenance of ecosystem functions. Because Northeast India has the potential to be India's next major rubber planting region, suitable plantation areas must be found. Open-access satellite data would aid in the compilation of the most recent national NR distribution maps (Guerra-Hincapie, J. J. et al. (2023). [33]). Scientific discoveries based on NR distribution maps are crucial for the development of a complete geospatial information platform that will serve as an interactive GIS database of NR cultivation throughout the country. In the future, the combination of multimodal satellite data and improved remote sensing technologies like UAVs could become practical instruments for managing agricultural fields, including NR plantations. Additionally, in rubber plantations situated in low avalanche risk areas, extreme caution should be used to reduce soil disturbance. In these deep soil areas, rubber should also be planted in small trenches.

## REFERENCES :


[1] Kingra, P. K., Majumder, D., & Singh, S. P. (2016). Application of remote sensing and GIS in agriculture and natural resource management under changing climatic conditions. *Agricultural Research Journal*, *53*(3). Google Scholar

[2] Zolekar, R. B., & Bhagat, V. S. (2015). Multi-criteria land suitability analysis for agriculture in hilly zone: Remote sensing and GIS approach. Computers and Electronics in Agriculture, 118, 300-321. Google Scholar

[3] Jessy , M D., Bhaskar, Datta. *(2019).* Rubber based cropping system in north east India, *Rubber Science,* 32(3), 272-282. Google Scholar

[4] Pradeep, B., Meti, S., & James, J. (2014). Satellite based remote sensing technique as a tool for real time monitoring of leaf retention in natural rubber plantations affected by abnormal leaf fall disease. *The International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, 40, 885-889. Google Scholar CrossRef /DOI

[5] Shebin, S. M., Shanker Meti, J. J., Pradeep, B., &Jessy, M. D. (2014). Assessing agricultural drought in natural rubber plantations using modis terra satellite data. *Rubber Science*, *27*(1), 8-14. Google Scholar CrossRef /DOI

[6] Shankar, M., Pradeep, B., James, J., Meerabai, M., &Jessy, M. D. (2014). Spatio-temporal analysis of rubber area and its association with soil and topography in Kanyakumari district. *Rubber Science*, *27*(2), 182-192. Google Scholar CrossRef /DOI

[7] Pradeep, B., Jacob, J., &Jessy, M. D. (2019). Rubber soil information system (rubsis): a decision-making tool for skipping fertilizer application in rubber plantations. *Rubber Science*, *32*(1), 63-67. Google Scholar CrossRef /DOI

[8] Annie Philip, A. Ulaganathan, et al. (2020). Spatial Variability of Plant available Zinc And Boron in the traditional Rubber Growing Regions and Konkan Region of India. *Rubber Science, 33(2): 152-163*. GoogleScholar CrossRef /DOI

[9] Pradeep B, Jessy M.D and James Jacob (2021). Delineating Rubber Plantations in Landslide Prone Areas Of Kerala, India Using Remote Sensing and Gis. *The 42nd Asian Conference on Remote Sensing (ACRS2021) 22-24th November, 2021 in Can Tho University, Can Tho city, Vietnam*.189. Google Scholar CrossRef /DOI

[10] Pradeep, B., Jacob, J., & Krishnakumar, R. (2015). Geo-spatial mapping and terrain characterization of natural rubber plantations in Karnataka, Maharashtra and Goa. *Rubber Science*, *28*(3), 227-236. Google Scholar CrossRef /DOI

[11] Shankar, M., Pradeep, B., Jacob, J., Shebin, S. M., &Jessy, M. D. (2016). Application of remote sensing and GIS for estimating area under natural rubber cultivation in India. *Rubber Science*, *29*(1), 7-19. Google Scholar CrossRef /DOI

[12] Boegh, E., Soegaard, H., Hanan, N., Kabat, P., &Lesch, L. (1999). A remote sensing study of the NDVI–Ts relationship and the transpiration from sparse vegetation in the Sahel based on high-resolution satellite data. *Remote sensing of Environment*, *69*(3), 224-240. Google Scholar CrossRef /DOI

[13] Carlson, T. N., Gillies, R. R., & Perry, E. M. (1994). A method to make use of thermal infrared

temperature and NDVI measurements to infer surface soil water content and fractional vegetation cover. *Remote sensing reviews*, *9*(1-2), 161-173. Google Scholar↗ CrossRef /DOI↗

[14] Reichenbach, P., Busca, C., Mondini, A. C., & Rossi, M. (2014). The influence of land use change on landslide susceptibility zonation: the Briga catchment test site (Messina, Italy). *Environmental management*, issue -*54*, 1372-1384. Google Scholar↗ CrossRef /DOI↗

[15] Chen, J. M., & Black, T. A. (1992). Defining leaf area index for non‐flat leaves. *Plant, Cell & Environment*, *15*(4), 421-429. Google Scholar↗ CrossRef /DOI↗

[16] Heiskanen, J. (2006). Estimating above ground tree biomass and leaf area index in a mountain birch forest using ASTER satellite data. *International Journal of Remote Sensing*, *27*(6), 1135-1158. Google Scholar↗ CrossRef /DOI↗

[17] Pradeep, B., Sylas, V. P., & Jessy, M. D. (2022). A framework for assessing the vulnerability of rubber plantations to the impacts of climate change with special reference to Kerala, India. *Journal of Rubber Research*, volume 1-13. Google Scholar↗ CrossRef /DOI↗

[18] George, S., & Joseph, P. (2011). Natural rubber plantation: a nutritionally self-sustaining ecosystem. *Natural Rubber Research*, *24*(2), 197-202. Google Scholar↗ CrossRef /DOI↗

[19] Varghese, M., Sharma, A. C., & Pothen, J. (2001). Addition of litter, its decomposition and nutrient release in rubber plantations in Kerala. *India B Nat Rubb Res*, *14*(2), 116-124. Google Scholar↗ CrossRef /DOI↗

[20] Meti, S., Rao, D. V. K. N., Nair, N. U., & Jacob, J. (2008, November). Distribution of natural rubber cultivation in relation to soil and landscape attributes in India. In *Proceedings of the 29th Asian Conference on Remote Sensing (ACRS), Colombo, Sri Lanka*, 2008, 10-14. Google Scholar↗ CrossRef /DOI↗

[21] Wan, Z., Wang, P., & Li, X. (2004). Using MODIS land surface temperature and normalized difference vegetation index products for monitoring drought in the southern Great Plains, USA. *International journal of remote sensing*, *25*(1), 61-72. Google Scholar↗ CrossRef /DOI↗

[22] Kroh, P. (2017). Analysis of land use in landslide affected areas along the Łososina Dolna Commune, the Outer Carpathians, Poland. *Geomatics, Natural Hazards and Risk*, *8*(2), 863-875. Google Scholar↗ CrossRef /DOI↗

[23] Trisurat, Y., Eiumnoh, A., Murai, S., Husain, M.Z. and Shrestha, R.P. (2000). Improvement of tropical vegetation mapping using a remote sensing technique: A case of KhaoYai National park, Thailand. *International Journal of Remote Sensing*, Volume issue 21(10), 2031-2042. Google Scholar↗ CrossRef /DOI↗

[24] Satheesh, P. R., & Jacob, J. (2011). Impact of climate warming on natural rubber productivity in different agro-climatic regions of India. *Natural Rubber Research*, *24*(1), 1-9.Google Scholar↗ CrossRef /DOI↗

[25] Ray, P., Chattaraj, S., Bandyopadhyay, S., Jena, R. K., Singh, S. K., & Ray, S. K. (2021). Shifting cultivation, soil degradation, and agricultural land‐use planning in the northeastern hill region of India using geo‐spatial techniques. *Land Degradation & Development*, *32*(14), 3870-3892. Google Scholar↗ CrossRef /DOI↗

[26] Shubhrajyotsna Aithal, & Aithal P. S., (2016), ABCD analysis of Dye doped Polymers for Photonic Applications, IRA-*International Journal of Applied Sciences*, 4(3), 358-378 Google Scholar↗ CrossRef /DOI↗

[27] Aithal, P. S. (2017). ABCD Analysis as Research Methodology in Company Case Studies. *International Journal of Management, Technology, and Social Sciences (IJMTS)*, *2*(2), 40-54.Google Scholar↗ CrossRef /DOI↗

[28] Aithal, P. S. (2016). Study on ABCD analysis technique for business models, business strategies, operating concepts & business systems. *International Journal in Management and Social*

*Science*, *4*(1), 95-115. Google Scholar↗ CrossRef /DOI↗

[29] Aithal, P. S. (2017). ABCD Analysis as Research Methodology in Company Case Studies. *International Journal of Management, Technology, and Social Sciences (IJMTS)*, *2*(2), 40-54.Google Scholar↗ CrossRef /DOI↗

[30] Aithal, P. S., Kumar, P. M., & Shailashree, V. (2016). Factors & elemental analysis of six thinking hats technique using ABCD framework. *International Journal of Advanced Trends in Engineering and Technology (IJATET)*, *1*(1), 85-95. Google Scholar↗ CrossRef /DOI↗

[31] Sumangala, N., & Kini, S. (2022). Impact of Adopting Machine Learning Methods on Indian Agriculture Industry-A Case Study. *International Journal of Case Studies in Business, IT and Education (IJCSBE)*, Volume issue *6*(2), 446-458. Google Scholar↗ CrossRef /DOI↗

[32] Patel, N. R., Parida, B. R., Venus, V., Saha, S. K., & Dadhwal, V. K. (2012). Analysis of agricultural drought using vegetation temperature condition index (VTCI) from Terra/MODIS satellite data. *Environmental monitoring and assessment*, *184*(1), 7153-7163. Google Scholar↗ CrossRef /DOI↗

[33] Guerra-Hincapie, J. J., Gil-Restrepo, J. P., Huertas-Beltran, R. L., Gutiérrez-Vanegas, A. J., Correa-Pinilla, D. E., & de Jesus Córdoba-Gaona, O. (2023). Phenology and South American leaf blight of polyclonal seedlings population of natural rubber trees in Colombia. *Industrial Crops and Products*, *199*, 116745. Google Scholar↗ CrossRef /DOI↗

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