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Remote Sensing Based Forest Health Analysis Using GIS along Fringe Forests of Kollam District, Kerala

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***Abstract:**The health of the forest vegetation is one of the driving factors and indicator of climate change impacts. Fragmentation of the forests on the other hand brings out the implications of the various stressing factors on the spatial extent of the forests especially the increasing population and industrialization, which has always impacted the forested regions in the form of deforestation for commercial purposes and conversion of forest land for cultivation. Hence there is a demand for spatial assessment and continuous monitoring of the forested regions. With a wide range of advancing technologies, remote sensing methods are increasingly being employed for monitoring a number of remotely measurable properties of different types of vegetation.This study forecasts utilitarian application of remote sensing as a tool to assess the health of the forest regions. Multispectral satellite image derived vegetation indices like broadband Greenness is used as a combined tool to generate a comprehensive health metrics for the forest canopy. Various band ratio exist for above factor depending on the bands available in the selected dataset. The estimated vegetation indices can be used to generate the final health map of forest regions.*
***Keywords:**Forest Health, Vegetation Indices, Remote Sensing, GIS*

I. INTRODUCTION

Forests refers to those landscapes with natural tree stands of at least 5m in-situ, whether productive or not and excludes the tree stands in agriculture production systems. Forest health is defined as the perceived condition of a forest derived from concerns about such factors as age, structure, composition, function, vigour, presence of unusual levels of insects or diseases, and resilience to disturbance (Martin and Aber., 2006). Major concerns about forest health overwhelmingly focused on the eradication of undesirable pests and disease-causing pathogens, such as insects and fungi, or environmental disruptions such as fire, which could weaken or kill trees.

An healthy forest ecosystem exhibits following characteristics:, 1) the physical environment, biotic resources, and trophic networks to support productive forests during at least some seral stages; 2) resistance to dramatic change in populations of important organisms within the ecosystem not accounted for by predicted successional trends; 3) a functional equilibrium between supply and demand of essential resources (water, nutrients, light, growing space) for major portions of the vegetation; and 4) a diversity of seral stages, cover types, and stand structures that provide habitat for many native species and all essential ecosystem processes. Specification within these four criteria allow for definitions of forest health which span the gap between landscapes which are natural, (Haile et al ., 2014) e. g. near pristine (i.e., pre-industrial or presettlement characteristics) and landscapes which are artificial, e.g. intensively managed for industrial uses (Hansen et al., 2000) Stress in forests displays a variety of symptoms, some of which may be detected by remote sensing.

Ecological indicators are used to assess the condition of ecosystems, provide early warnings of changes away from reference conditions, and facilitate identification of causes of deviations from reference conditions (Haines-Young etal ., 1996) Some of the most important of these factors, or those that best represent multiple facets have been selected as indicators of health. Indicators commonly used in forest health monitoring include tree mortality, tree crown condition, growth of trees (as shown by basal area, height or volume changes through time), plant diversity, dominance of native species, soil Morphology and chemistry (Morse et al., 2005), abundance of lichen communities, etc. Once forest health "indicators" are selected, they should be measured over time using designed experin1entation or long-term monitoring programs to quantify trends and changes.

Analysing vegetation using remote sensing data requires knowledge of the structure and function of vegetation and its reflectace properties. This knowledge is enabled to link vegetative structures and their condition to their reflectance in an ecological system

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of interest. Vegetation reflectance properties are used to derive vegetation indices (VIs). VIs are constructed from reflectance measurements in two or more wavelengths across the optical spectrum to detect specific characteristics of vegetation, such as total leaf area and water content. Each category of indices typically provides multiple techniques to estimate the absence or presence of a single vegetation property. For different properties and field conditions, some indices within a category provide results with higher validity than others. The VIs provided in ENVI are not designed to quantify the exact concentration or abundance of any given vegetation component. Instead, they are intended for use in geographically mapping relative amounts of vegetation components, which can then be interpreted in terms of ecosystem conditions. Vegetation Indices are models that use the characteristic reflectance properties of green vegetation in specific wavelengths to represent a particular property of vegetation.

Wehr et al., (1999) proposed methods for mapping and monitoring forest status through the creation of departure maps from average NDVI, TCT greenness and wetness index derived from an expanding time-series of Landsat imagery. The departure classification used clearly delineated built-up features within the negative departure from average class. Forest water stress (foliar moisture) were determined using regression equations from inputs of vegetation and moisture indices or PCA and TCT transformed data (Ceccato et al., 2002; Leckie, 2003). Vegetation indices are commonly used to quantify vegetation cover, vigour and density in remote sensing. The Normalised Difference Vegetation Index (NDVI), which distinguishes actively growing vegetation from background features, is the most widely used vegetation index in remote sensing studies (Hansen et al.,2000). Other indices for measuring cover commonly used include, the Soil Adjusted Vegetation Index (SAVI), Enhanced Vegetation Index (EVI), Modified Soil Adjusted Vegetation Index (MSAVI) and the Transformed Soil Adjusted Vegetation Index (TSAVI) (Qi et al.,1994). Measures of plant regeneration can be well-versed by changes in land cover through change detection analysis including increases in cover (Lunetta et al., 2004) and changes in canopy roughness as vegetation ages, however methods are not well developed. Studies of vegetation health using vegetation moisture (Gao, 1996), biochemical properties of plants including chlorophyll content (Coops et al., 2003; Houborg et al., 2011), and other leaf pigments were also conducted in Australian brushland. Primary productivity, Lignin and nitrogen content were measured using remote sensing to in ecosystem functioning (Gillis et al., 2005). They had employed chlorophyll fluorescence imaging to detect stress in vegetation, which is a pre-visual indicator of stress as well.

A recent study conducted by National Remote Sensing Centre on Habitat monitoring and conservation prioritisation in Protected Areas of Western Ghats, typifies that Protected Areas in Kerala were unchanged since 2006 notifying increased effectiveness of conservation strategies. The study also accentuatedthat forests of Mathikettan Shola National park, Aralam, Kottiyur, Shendurney and Neyyar Wildlife Sanctuaries, Parambikulam National park, Pampadum shola, Silent Valley and Anamudi National parks bagged top positions in terms of forest health on other hand Kurinjimala Sanctuary, Thattekad Bird Sanctuary, Chimmony Wildlife Sanctuary, and Eravikulam National Park are on the verge of high fragmentation rate.

The framework of this study appends analysis of forest health along Kollam Fringe Forests using NDVI, ARVI and SIPI vegetatin indices subsequent reclassification and weighted sum overlay analysis yielding forest health map elucidating forest health status of Thenmala Range, Pathanapuram Range, Anchal range, Arienkavu range , Achenkovil Range and Kulathpuzha Range on a five point scale.

A. Study Area

Kollam forests has a total areal extent of 971.76602 Km^2 The study area lies between 76° 50' and 77° 20' East longitude and 8° 50' and 9° 10' North latitude (Figure 1). Kollam forests lies 100-1785m above the mean sea level. Kollam forests has a tropical humid climate, with an oppressive summer and plentiful seasonal rainfall. The district experiences oppressive summers and cool winters. Temperature is almost steady throughout the year. The average temperature is around 25° Celsius to 32° Celsius. Summers usually begin from March and extend till May(Aditya et al 2016). The area under forest in Kollam it falls in Thenmala, Punalur (163sq.km) and a portion of Achenkvoil (269sq.km) forest division. Thenmala Range, Aryankavu Range and Shendurni Sanctuary Constitute the Thenmala division (298 sq.km). Achenkovil Range, Kallar Range and Kanayar Range, make up the Achenkovil division while Punalur division includes Pathanapuram and Anchal Ranges (241sq.km). The main drainage basin is the Kallada River which is formed by 3 major rivers Shendurney, Kazhuthuruthy and Kulathupuzha. Amidst Shendurney Wild Life sanctuary lies an artificial lake of 18 sq. km formed by the Thenmala (Parappar) Dam built across the Shenduruny and Kulathupuzha rivers. Achenkovil River originates from the Western Ghats and covers a basin area of 1484 km^2 and the main channel length is 128 km. The River joins Pamba River at Veeyapuram and finally debouches into the Vembanad Lake. Achankovil, Ayirur, Ithikkara, Kallada, Pallikkathodu and Vamanapuram are the major water sheds of Kollam. The vegetation types in these forest ranges include evergreen forest, semi evergreen forest, moist deciduous forest, Myristica swamp, etc.(Asok and Sobha, 2013). About 53 patches of Myristica swamps have been identified in Anchal and Kulathupuzha.The study area is a native locality for several endemic and threatened species of Western Ghats.

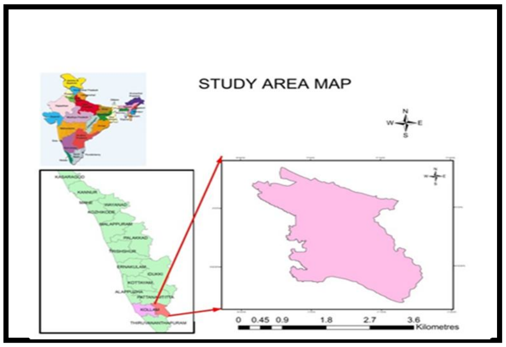

Figure No.1 Location map of study area

II. MATERIALS AND METHODS

Datasets and methods adopted in a bid to fetch supervised classified images and fragmentation maps are portrayed in following sections:

A. Satellite Data

For base map preparation of the study area series of satellite imageries were acquainted from Google Earth 7.0v which was combined manually and used as field level investigation for feature recognition. The latest high resolution satellite imagery Landsat 8 OLI-TIRS satellite imagery dated 18^{th} January 2017 having path 144 and row 54, the adjacent scene dated 11^{th} January 2017 with path and row 143 and 54 were downloaded from Earth explorer data search engine owned by USGS**.** The survey of India Toposheets numbered H1 and H5 with scale of 1:50000 covering the study area were used for reference purpose. H1 toposheet contains Kollam whereas H5 contains Tamil Nadu.

SATELLITES	SENSORS	BAND COMBINATIONS	DATE OF ACQUISITION	PATH/ROW	SPATIAL RESOLUTION
Landsat 8	OLI-TIRS	NIR, R, G (5,4,3)	18^{th} January 2017	144/54	30m
Landsat 8	OLI-TIRS	NIR, R, G (5,4,3)	11^{th} January 2017	143/54	30m

Table No.1 Spatial Data Source

B. Preprocessing

The time series spatial data acquired from Land sat series Multispectral Sensor and Thematic mapper were downloaded from public domain. The Land sat TM image has been geo-referenced to the Universal Transverse Mercator (UTM) projection zone 43, with a spatial resolution of 30 m. The multispectral satellite image contains seven spectral bands, i.e., bands 1–3 represent the visible part of the electromagnetic spectrum with wavelengths of 0.450– 0.515, 0.525–0.605 and 0.630–0.690 µm, respectively. Band 4 represents the near infrared (IR) with wavelengths of 0.760–0.900 µm and bands 5 and 7 represent mid IR with wavelengths of 1.550–1.750 µm and 2.080–2.350 µm. Band 6 and 8 are present in the thermal IR and panchromatic respectively; however, these bands are not taken into account in this study. Satellite data are distorted by earth's curvature, relief displacement, and acquisition geometry of satellites. Variation in altitude, aspect, velocity and panoramic distortion which is corrected by way of atmospheric and radiometric correction. The remote sensing data obtained were geo-referenced, geo-corrected, rectified and cropped pertaining to the study area. Geo-registration of remote sensing data (Land sat data) has been done using known points (such as road, intersections, etc.) collected from geo-referenced topographic maps published by the Survey of India and Google Earth Images .

C. Forest Health Assessment

The study objective of assessment of forest health was accomplished using multispectral spatial data Land sat series and collateral data such as Survey of India (SOI 1988) topographic maps of No:58 G/3 with a scale 1:50000, were used for this purpose. The areas were first scanned and then registered using ENVI software. Kollam forest boundary was digitised in a personal Geodatabase using Forest division map. For georeferencing, ground control points at the intersection of latitude–longitude were selected. Two adjacent scenes of Landsat 8 OLI dated 11th January 2017 and 18th January 2017 were downloaded. 11th January 2017 dataset was having path number 144 and row 54, whereas 18th January 2017 dataset was having path number 143 and row 54. Both the scenes were FLAASH atmospherically corrected(wherein layer stacking occurred on default basis) and were subjected to seamless mosaic. The mosaicked dataset was subsetted with the earlier digitised study boundary. This subsetted dataset was subjected in calculating NDVI- Normalised Difference Vegetation Index , ARVI- Atmospherically Resistant Vegetation Index both comprising greenness vegetation indices and SIPI– Structural Insensitive Pigment Index of Light Use Efficiency Indices , during which clouds , cloud shadow and water bodies were completely masked out, as a result the pixel vales showed no data in masked regions. Foresaid indices were used due to the availability of band combinations in the dataset The Calculated Vegetation indices were imported to ArcGIS , wherein the datasets were reclassified using raster reclassify tool based on the pixel values for ARVI and NDVI i.e. -1-0 = no vegetation , 0.2 – 0.4= vegetation 1, 0.4 – 0.6 = vegetation 2, 0.6 – 0.8 = vegetation 3, 0.8 – 1.0 = vegetation 4, where as in SIPI data set , reclassification was done as 0 – 0.8 = no vegetation , 0.8 – 1.0 = vegetation 1, 1.0 – 1.2 = vegetation 2, 1.2 – 1.4 = vegetation 3, 1.4 – 1.6 = Vegetation 4, 1.6- 1.8 vegetation 5, 1.8 – 2.0 = vegetation 6.Spectral indices are combinations of surface reflectance at two or more wavelengths that indicate relative abundance of features of interest. Vegetation indices are the most popular type, but other indices are available for burned areas, man-made (built-up) features, water, and geologic features.

1) *NDVI Calculation:* NDVIorNormalised Difference Vegetation Index is widely used vegetation index for retrieval of vegetation canopy. It is a satellite derived global vegetation indicator which measures relative biomass. NDVI was calculated using band 5 and band 4 of Landsat 8 with the aid of spectral indices tool. This index is a measure of healthy, green vegetation. The combination of its normalized difference formulation and use of the highest absorption and reflectance regions of chlorophyll make it robust over a wide range of conditions.

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

It can, however, saturate in dense vegetation conditions when LAI becomes high. The value of this index ranges from -1 to 1. The common range for green vegetation is 0.2 to 0.8.

2) *ARVI Calculation:* ARVI – (Atmospherically Resistant Vegetation Index) is an enhancement to the NDVI that is relatively resistant to atmospheric factors (for example, aerosol). It uses blue reflectance to correct red reflectance for atmospheric scattering. It is most useful in regions of high atmospheric aerosol content, including tropical regions contaminated by soot from slash-and-burn agriculture.

$$\mathbf{ARVI = NIR - [RED - \Gamma\ (BLUE - RED)]\ /\ NIR - [RED - \Gamma\ (BLUE - RED)]}$$

The gamma constant is a weighting function that depends on aerosol type. ENVI uses a value of 1 for gamma. The value of this index ranges from -1 to 1, with higher pixel values corresponding to healthier and greener vegetation. Band 5(NIR), 4 (RED) and Band 2 (BLUE) were used in estimating ARVI values.

3) *SIPI Calculation:* SIPI (Structure Insensitive Pigment Index**)** is a reflectance measurement designed to maximize the sensitivity of the index to the ratio of bulk carotenoids (for example, alpha-carotene and beta-carotene) to chlorophyll while decreasing sensitivity to variation in canopy structure (for example, leaf area index). Increases in SIPI are thought to indicate increased canopy stress (carotenoid pigment). Applications include vegetation health monitoring, plant physiological stress detection and crop production and yield analysis. SIPI is defined by the following equation

$$\mathbf{SIPI} = \rho_{800} - \rho_{445}\ /\ \rho_{800} - \rho_{680}$$

The value of this index ranges from 0 to 2. The common range for green vegetation is 0.8 to 1.8. Band 5(NIR), 4 (RED) and Band 2 (BLUE) were used in estimating SIPI values.

D. Reclassification

Each Vegetation indices were reclassified using reclassify tool of spatial analyst in ArcGIS. ARVI and NDVI were reclassified by assigning 0-6 as new values to ranges between -1 to 0.8, wherein 0 being non-vegetation classes, 6 being clutter classes and 1-5 new values being vegetation classes (as the new values increases greener vegetation gets saturated hand-in-hand). Additional clutter classes were added so as to prevent overlapping of erroneous pixels with the desired ones. The accuracy of calculated vegetation indices were estimated by assessing their respective horizontal spectral profiles. The reclassified vegetation indices underwent raster overlay analysis to create a forest health map showing different status of forest health.

E. Overlay Analysis

The weighted sum function of overlay tool in spatial analyst tool of arc is used, ARVI, NDVI and SIPI were the input features that elicited an output with 0-18 range as minimum and maximum values. This output was reclassified further to 5 different ratings, with 3 class interval of each range. All the three indices have equal contribution in weighted sum analysis. The differentiation depends on pixels falling in maximum classification area of all three indices. Finally a forest health map scaling from poor to excellent vegetation was conceived.

The Weighted Sum function provides the ability to weight and combine multiple inputs to create an integrated analysis. It is similar to the Weighted Overlay function in that multiple raster inputs, representing multiple factors, can be easily combined, incorporating weights or relative importance. The Weighted Sum function does not rescale the reclassified values back to an evaluation scale, allows floating-point and integer values maintains its resolution as well.

III. RESULTS AND DISCUSSION

Byemploying foresaid methodologies following results are obtained, which has been listed in following sections.

A. Forest Health Analysis

Total Area of Kollam Forests is approximately 971.76602 Km^2. Forest Health analysis is executed by NDVI analysis, ARVI analysis, SIPI analysis and finally by weighted sum analysis of all the three indices generating Forest Health Map. For the creation of ARVI, NDVI and SIPI clouds, cloud shadow and water body are masked out, thereby showing their respective pixel values as zero.

B. NDVI Analysis

The values of NDVI ranges from -1 to +1. NDVI computed for Kollam Forest in 2017 is depicted in Figure 2 and Figure 3. From the figures it is apparent that almost all the forest ranges – Thenmala Division, Achenkovil Division, Punalur Division and Kulathupuzha Ranges are greener and saturated vegetation. Figure 3 perspicuously sketches the vegetation categories with different NDVI range.

From Figure 3 it can be ascertained that- A clutter class ranging (-0.6666 - -1) has been assigned so as to prevent overlapping of erroneous pixels with accurate pixels. Non vegetation class encompasses barren land, Linear structures like Ottakal Railway Station Road, Kollam- Thenkasi Road covers an area of 10.836 Km^2. Non vegetation classes such as roads, urban settlements comprise NDVI value range of -1 – 0 covers an area of 0.1017 Km^2. Non vegetation classes which doesn't fall in forest area such as aquatic weeds, chlorophyll content in Thenmala Reservoir exhibits NDVI value range 0 – 0.2 covering an area of 9.729 Km^2. Forests with NDVI value range 0.2 – 0.4 wraps an area of 11.2104 Km^2 in North, South West and South East portion of Kollam forests such as Onthupacha, Punnala, Ottakal regionsNorth Eastern and North Western part of Kollam Forest namely Aruvappulam Park, Edamon, a minor portion of Pathanapuram range and sparsely distributed manmade plantations on banks of Kallara River and Thenmala Reservoir. Forests with NDVI range 0.4 – 0.6 envelops an area of 80.3898 Km^2, found in minor portion in most of the forest ranges such as in North West part of Pathanapuram Range - Kadackamon, Vazhathope, Piravanthur, Edamon, North west part of Anchal Range. Forests with NDVI range 0.6 -0.8 covers a substantial area of 853.8399 Km^2 of Kollam Forests particulary in Thenmala range – Shendurney Wildlife sanctuary, Rosemala in the Eastern Portion, Achenkovil, Kallar and Kanayar Ranges of Achenkoil Division, Anchal and Pathanapuram range of Punalur division has greatest NDVI values.

Water Bodies(Thenmala Reservoir, Kallar River)and cloud shadows are masked out for this analysis. Probable justification for such healthy forests may be due to social forestry , agroforestry, Supreme Forest management strategies by considering a substantial portion of forest as protected area thereby reducing human interferences, Early Pest and invasive species detection, better resilience capability.

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Similar studies using NDVI analysis for forest health assessment was done by Jyrki etal., 2008 to detect dust and seepage contaminated forests in North-East Finland using NDVI. The final results were classified as stressed of healthy in the areas representing predefined classes such as – Dust contaminated Pine, Dust contaminated Coniferous, Dust Contaminated birch, Seepage contaminated Birch and Healthy Forest, which is again reclassified generating a forest health map showing healthy forest (70.42% of forest area) and stressed forest (29.58% of forest area). NDVI method with statistical data was also used by Wanting et al 2009 to examine post hurricane forest health of Athens, USA which created a forest health map showing hurricance damaged areas (49.56 % of forest area) and hurricance resistant area(50.44% of forest area) .

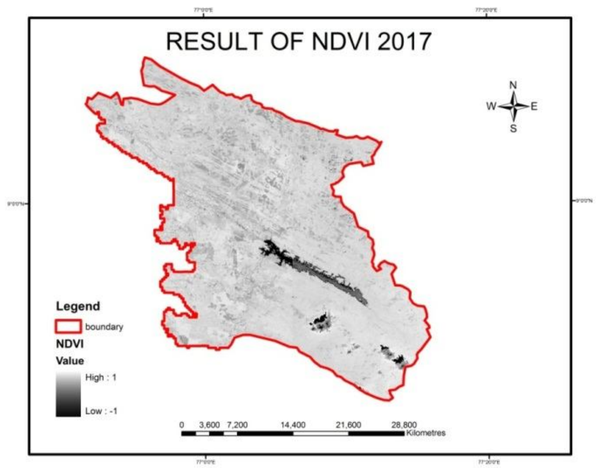

Figure No. 2 Result of NDVI 2017

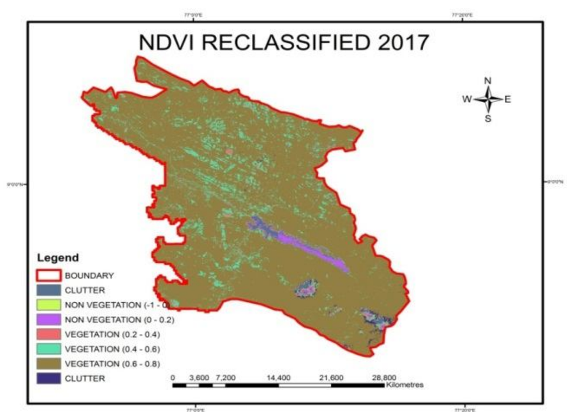

Figure No. 3 NDVI Reclassified 2017

C. *ARVI Analysis*

The value of ARVI ranges from -1 to +1, with higher pixel values corresponding to healthier and greener vegetation. ARVI computed for Kollam Forest in 2017 is depicted in Figure 4 and Figure 5. From the figures it is apparent that almost all the forest ranges – Thenmala Division, Achenkovil Division, Punalur Division and Kulathupuzha Ranges are greener and saturated vegetation. Figure 5 perspicuously sketches the vegetation categories with different ARVI range.

From Figure 5 it can be ascertained that non vegetation class encompasses barren land, Water Bodies, Linear structures like Ottakal Railway Station Road, Kollam- Thenkasi Road covers an area of 185.5836 Km^2 . Forest bearing ARVI value range of -1 – 0 covers an area of 0.0018 Km^2. Forest with ARVI value range 0 – 0.2 covers an area of 2.6181 Km^2, which involves Man made plantations next to Kallara river and Thenmala Reservoir.. Forests with ARVI value range 0.2 – 0.4 wraps an area of 19.899 Km^2, it is seen scattered unevenly all over Kollam forest, but found in greater number in North west and South West portion in such as Edamon, Karavoor, Onthupacha , Punnala , Ottakal regions. Forests with ARVI range 0.4 – 0.6 envelops an area of 57.3777 Km^2, found in minor portion in most of the forest ranges such as in North West part of Pathanapuram Range - Kadackamon, Vazhathope,

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Piravanthur, Edamon, North west part of Anchal Range, South West Portion of Thenmala region. Forests with ARVI range 0.6 -0.8 covers an area of 139.8321 Km^2 of Kollam Forests found disperse particularly in Thenmala range – Shendurney Wildlife sanctuary, Rosemala in the Eastern Portion. Forests with ARVI range 0.8 -1.0 covers substantial area of 565.4979 Km^2 of Kollam Forests, Achenkovil, Kallar and Kanayar Ranges of Achenkoil Division, Anchal and Pathanapuram range of Punalur division has greatest ARVI values.

Similar studies using ARVI analysis for forest health assessment is done by Atmopawiro2004 in Amazon Forests which resulted in mathematical models from which -testing for differences in change over time among groups—foliar transparency; estimating change using covariates—impact of drought on change in foliar transparency; estimating plot values for unmeasured years—comparison of observed and predicted (Best Linear Unbiased Predictions) values of foliar transparency, dieback, and total volume; and estimating tree heights—examples of using estimated tree heights to estimate tree health.

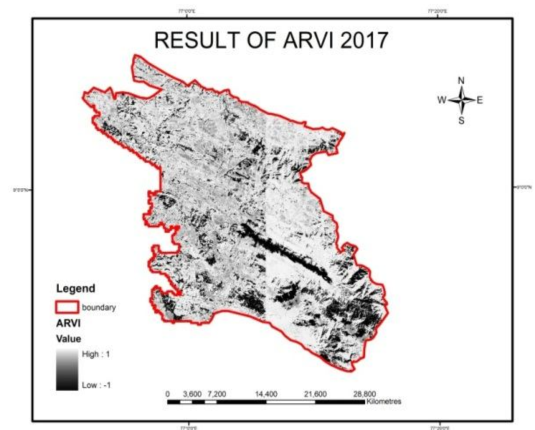

Figure No. 4 Result of ARVI 2017

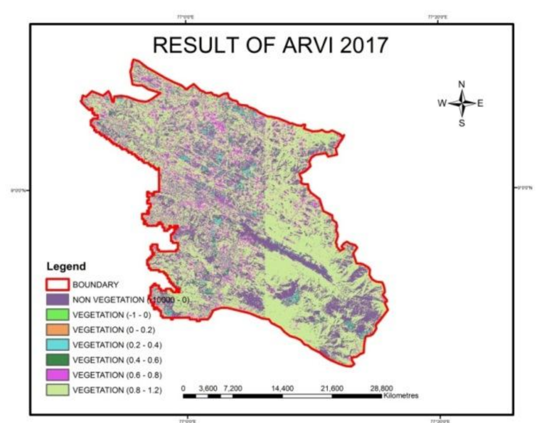

Figure No.5 ARVI Reclassified 2017

D. SIPI Analysis

The values of SIPI ranges from 0 to 2. Increases in SIPI are thought to indicate increased canopy stress (carotenoid pigment). The common range for green vegetation is 0.8 to 1.8. SIPI computed for Kollam Forest in 2017 is depicted in Figure 6 and Figure 7. From the figures it is apparent that almost all the forest ranges – Thenmala Division, Achenkovil Division, Punalur Division and Kulathupuzha Ranges exhibits lower stress pigments. Figure 7 perspicuously sketches the vegetation categories with different SIPI range. From Figure 7 it can be ascertained that non vegetation class encompasses barren land, Linear structures like Ottakal Railway Station Road, Kollam- Thenkasi Road covers an area of 30.3669 Km^2 . Forest bearing SIPI value range of 0- 0.2covers an area of 0.0396 Km^2 Forest with SIPI value range 0.2 – 0.4 covers an area of 0.09 Km^2. Forests with SIPI value range 0.4 – 0.6 wraps an area of 1.5786 Km^2 found scattered North- East South West and South East portion of Kollam forests such as

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Onthupacha , Punnala , Ottakal regions. Forests with SIPI range 0.6 – 0.8 envelops an area of 19.2888 Km^2, found in minor portion in most of the forest ranges such as in North East part of Kollam forests, North west part of Anchal Range , but more confined in Shendurney wildlife sanctuary and Rosemala. Forests with SIPI range 0.8 – 1.0 covers a substantial area of 852.9813 Km^2 of Kollam Forests particularly in Thenmala range – Shendurney Wildlife sanctuary, Rosemala in the Eastern Portion , Achenkovil, Kallar and Kanayar Ranges of Achenkoil Division, Anchal and Pathanapuram range of Punalur division has greatest SIPI values. This scenario reflects that greener vegetation is present in all of the four forest divisions, moreover North East of Kollam Forests ,Shendurney Wildlife Sanctuary and Rosemala are suffering from stressed conditions, which makes forest health prone to deterioration in future.Similar studies using SIPI analysis for forest health assessment is done byHarper etal 2005, Canada, made for estimation of chlorophyll a and b for stress and choruses detection in open tree crops and row-structured crop canopies demonstrate the validity of combined indices such as SIPI/ARVI, both at the leaf and canopy levels. Correct estimation of Cab at the canopy level was successful using appropriate radiative transfer simulation with PROSPECT linked to SAILH-FLIM (orchard crops) and row MCRM (row-structured crops such as vineyards). SIPI analysis was used by Muller et al., 2009 to assess changes in leaf water status, pigment concentration and photosynthetic traits during water-stress and recovery. In general, SIPI was very sensitive to leaf water status, pigments concentrations and *A*. The SIPI was the most reliable index in the prediction of plant water-status. Finally, *A* was likely mainly inhibited by leaf CO_2 conductance parameters during water-stress; whereas under non-photorespiratory conditions, CO_2 conductance was not the major limitation to photosynthesis. In consideration of a predicted future elevated atmospheric [CO_2], it is possible that sclerophyll plants will likely out-perform mesophyllous vegetation.

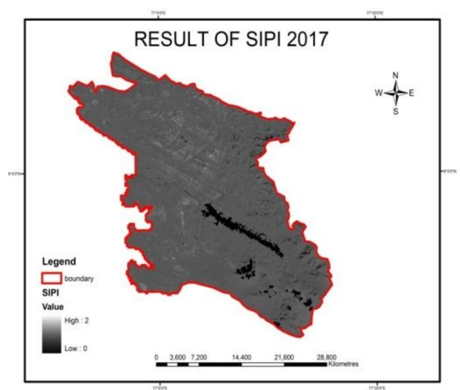

Figure No. 6 SIPI 2017

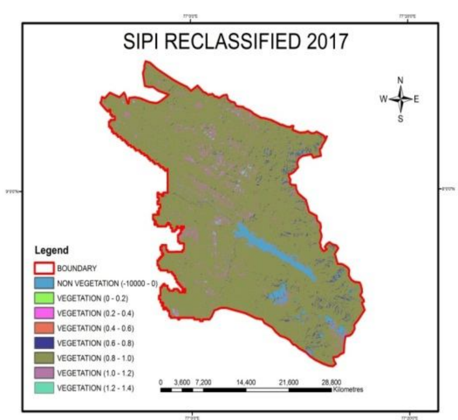

Figure No. 7 SIPI Reclassified 2017

E. Overlay Analysis

The weighted sum analysis of all three vegetation indices resulted in a forest health map having 18 and zero as maximum and minimum value respectively. Ranking in forest health map was given as 0-3 = non vegetation; 3 – 6 = poor vegetation, 6-9 = moderate vegetation, 9- 12 = good vegetation, 12 – 15 = very good vegetation; 15 – 18 = excellent vegetation.

Non Vegetation such as built up covers 18.2412sq.km of the study area such as Kollam-Tenkasi Road, Thiruvananthapuram-Thenmala Road, Settlements Namely Thingalkarikkom , Poor Vegetation covers an area of 11.115 sq.km, Moderate Vegetation covers an area of 16.9812 sq.km which involves a minor portion of Kulathupuzha ranges ,Achenkovil Division, a smaller portion in Thenmala Reserve Forest; Good Vegetation covers an area of 150.4143 sq.km involving inner core of Shendurney Wildllfie Sanctuary, core and transition zone of Kulathupuzha and Anchal Ranges , core regions Pathanapuram and Thenmala Ranges; Very Good Vegetation covers an area of 203.481 sq.km in which Transition zone and core zone of Punalur ranges, Edamon, Karavoor is involved and Excellent Vegetation forms a substantial portion covering 569.880 sq.km in which Thenmala Division is the healthiest forest , then comes the Achenkovil division, followed by Ariankavu Range and Punalur Division.

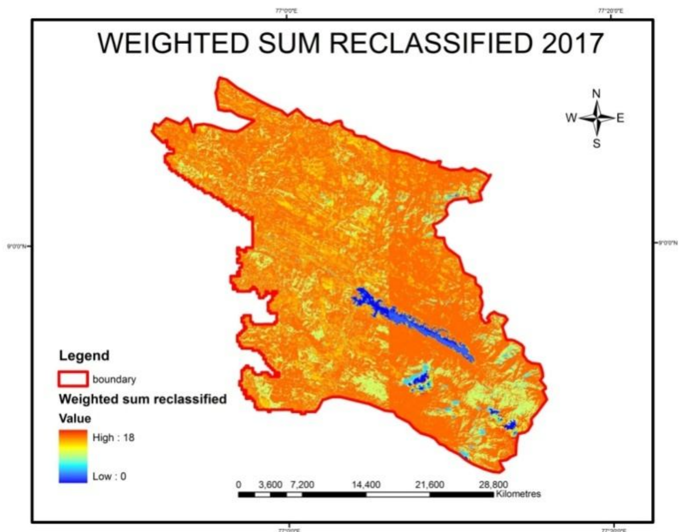

Figure No. 8 Weighted Sum Reclassified 2017

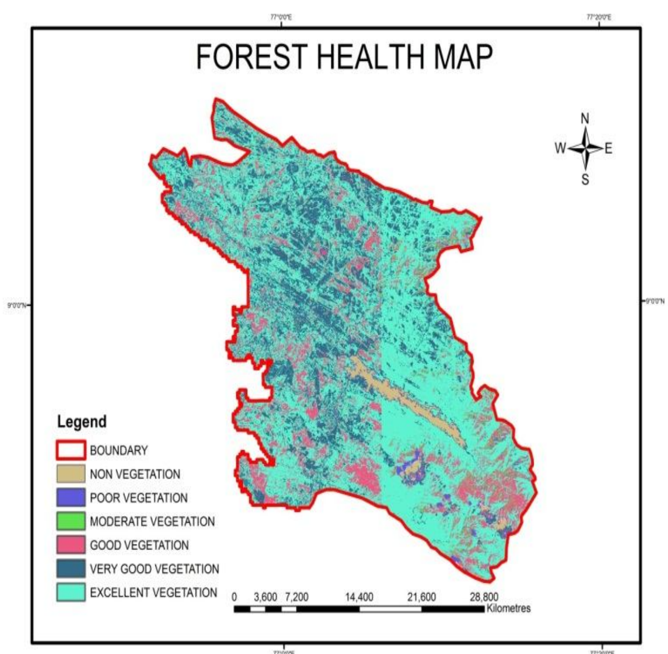

Figure No. 9 Forest Health Map

SCALE	CLASS	AREA COVERED (Km^2)
0	Non Vegetation	18.2412
1	Poor Vegetation	11.115
2	Moderate Vegetation	16.9812
3	Good Vegetation	150.4143
4	Very Good Vegetation	203.481
5	Excellent Vegetation	569.88

Table No. 2 Areal extent of forest health classes

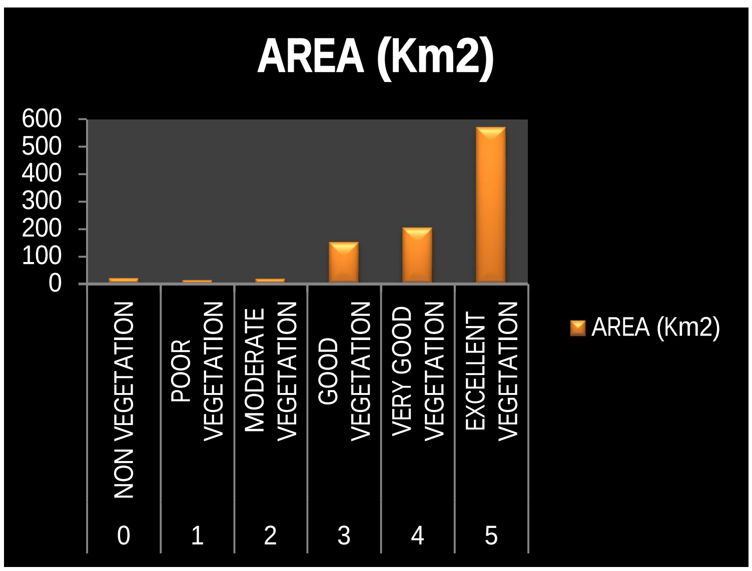

Figure No.10 Kollam Forest Health Statistics

IV. CONCLUSION

Identification and quantification of forest health and Forest fragmentation, has become an alarming issue that needs to addressed at the earliest. This concept has become prevalent only after the society became aware of irreversible value of forest resources, that were exploited unsustainably to meet their demands. Remote sensing and GIS has highly revolutionised in this field mainly due to its user friendly programming, feasible accessibility.

Assessment of forest health using spectral indices tool of ENVI which are calculated using various band combinations. Results showed that the selection of VI combination has significant impact on classification results. When the stress level gradually dies out and distance from contamination source increases, classification results degrade. Overall results of this study show that spectral indices and reclassify tool of ENVI and ArcGIS 9.3 can provide valuable information in rating forest health status.

Forest health map generated provides guidance in assessing forest health status. Most healthiest forest is Thenmala division followed by Achenkovil , Ariankavu , Punalur and Anchal ranges. Approximately 58.599% of Kollam forest has excellent forest health status. 21.009 % of Kollam forests are in very good condition. 15.447% of Kollam forests are in good condition. 1.75% of forests has poor forest health may be due to pest infestation, invasion of alien species, improper implementation forest management strategies.

V. PERPETUATION MEASURES

As per 2017 dataset, Kollam district bears most of the Excellent Forests. Following are well practiced mitigatory measures for perpetuating forest health.

A. For ecological restoration thinning projects natural references provide guideposts for the "ICO" (individuals – clumps – openings) approach to determining which trees to remove and which trees to leave during.

B. Providing the best available information for reliable monitoring; facilitating policy dialogues for increased awareness; and building capacity for sustainable management are vital for the forests health.

C. Repeated harvesting**.** Harvesting again will maintain the open, sunny conditions that favour young forests.

D. Discing and mowing. Disturbing the soil through shallow tillage (also known as "discing") and mowing check the older growth while stimulating the regrowth of grasses and forbs and the resprouting of many woody species.

E. Burning**.** Frequent fires were a natural part of the cycle that gave rise to young forests, and reintroducing fire can help to restart that cycle. Like discing, mowing and harvesting, controlled burning knocks back older growth to let younger trees and plants thrive.

F. Increasing amount of vegetation by afforestation and reforestation technique along linear structure like roads, and provision of green belts of 2Km width in between power stations

G. Prevention, to keep exotic species from becoming established or spreading farther.

H. To prevent wildfire through fuels reduction, to prevent disease and insect damage through hazard reduction.

I. Integrated management, to deal with exotic agents now firmly established, to re-establish appropriate levels and functions of native insects and diseases

J. Restoration, of damaged watersheds, of fire in the ecosystem, of tree species and structures that have become scarce

K. Monitoring, to track broad vegetation trends, to evaluate the effectiveness of treatments, make adaptations to learn, and to detect emerging problems.

L. Reducing human intervention in buffer and core areas, thereby improving habitat quality for wildlife.

M. Reducing settlements within the core areas , thereby reducing perforated forest formations

N. Minimising overgrazing inside the sanctuary, these activities nay be confined to buffer and core areas.

O. Prolonged monitoring for innate degradation such as landslides, and forest fires.

P. Implementation and planning of long term conservation programmes and effective eco-tourism strategies within the sanctuary.

Q. Effective implementation of strict legal measure in converting forest to non-forest areas.

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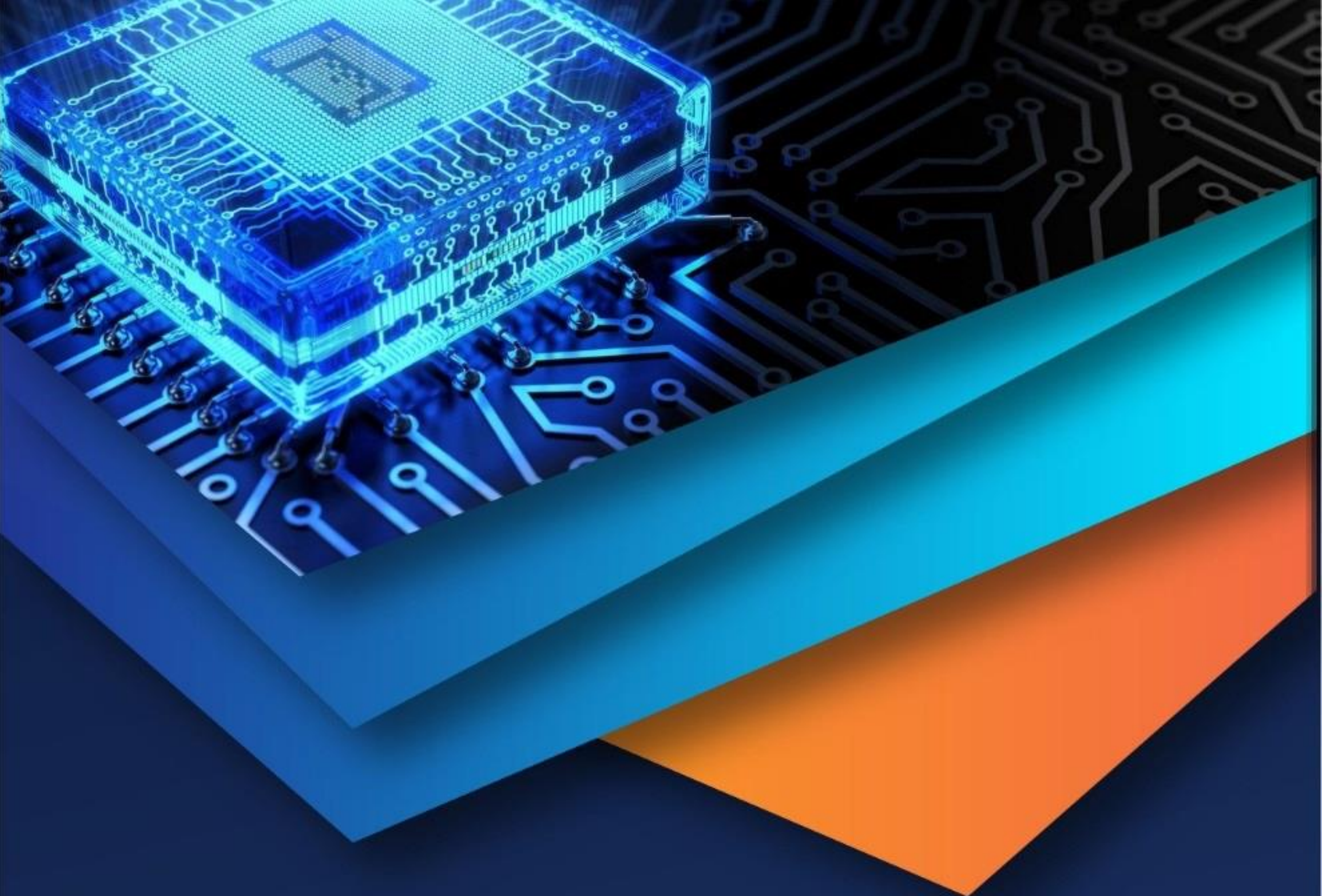

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