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Forest Canopy Estimation Using Forest Canopy Density Model (FCDM) and Satellite Data of Noamundi and Jagarnathpur (West Singhbhum District) Jharkhand

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ABSTRACT

Forest Canopy density is a major factor in evaluation of forest status and is an important indicator of possible management interventions. Estimation of forest canopy cover has recently become an important part of forest inventories. The increasing use of satellite remote sensing for civilian use has proved to be the most cost effective means of mapping and monitoring environmental changes in terms of vegetation and non-renewable resources, especially in developing countries. Data can be obtained as frequently as required to provide information for determination of quantitative and qualitative changes in terrain. Forests as a part of the wild life interaction of the human societies have a special place in economic development and stability of water and soil resources in most of the countries around the world. But because of various reasons such as increase and development of population, increasingly altering forests for other unsuitable applications such as agriculture, providing energy and fuel, millions of hectares from this natural resource are destroyed every year and the remainder of the surfaces changes quantitatively and qualitatively. For better management of the forests, the change of forest area and rate of forest density should be investigated using advanced techniques. It is possible that there is no change in the area of forest during the time but the density of forest canopy is changed. This model calculates forest density using the four indexes of soil, shadow, thermal and vegetation. For this, the LANDSAT TM and OLI images from different dates and years are used. At first, the forest density map was prepared by using Biophysical Spectral Response Modeling for two images. Overall accuracy 84.25% for 2007 and 80.06% for 2017 and kappa coefficient 0.8236 for TM 2007 and kappa coefficient 0.8225 for OLI 2017 image was achieved. Then, the changing of the area and forest density during these periods was distinguished. Aster DEM is used to calculate Aspect, Elevation, Hill shade maps. Aspect, Elevation and Hill shade map point out the dense forest from our region. At last, the change in area of forest is distinguished by using the Forest Canopy Density model map and map formed by interpretation of Aspect, Elevation, Hill shade map.

Keywords: Forest canopy density model, Aster DEM, Aspect, Elevation, Hill shade map

INTRODUCTION

Forest canopy cover, also known as canopy coverage or crown cover, is defined as the proportion of forest floor covered by the vertical projection of the tree crowns [1]. The human intervention in nature reduces the number of trees per unit area and canopy closure [2]. International Tropical Timber Organization (ITTO) has developed a new methodology wherein, forest position is the value put on the base of its cover relation between mass and size. Forest stands or cover types consist of a plant community made up of trees and other woody vegetation, growing more or less closely together [3-6]. It has become compulsory to monitor the current status of forests .Understanding of altitudinal variation of forest cover density in Jharkhand state area thus plays a major role in this context. The forest cover condition defines land cover classification and various altitudinal ranges with forest cover density. Forest density expressing the stocking status build up single major stand physiognomic character of forest: so for the scientific forest management,

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the knowledge of forest density classes is necessary at the local, regional, state and national levels purposes [7-11].

The Forest Canopy Density (FCD) Mapping and Monitoring Model utilizes forest canopy density as an essential parameter for characterization of forest conditions. FCD data indicates the degree of degradation, thereby also indicating the intensity of rehabilitation treatment that may be required. The remote sensing data used in FCD model is LANDSAT TM & OLI data. The FCD model comprises of bio-physical phenomenon modeling and analysis utilizing data derived from four indices: Advanced Vegetation Index (AVI), Bare Soil Index (BI), Shadow Index or Scaled Shadow Index (SI, SSI) and Thermal Index (TI). It determines FCD by modeling operation and obtaining from these indices. The canopy density is calculated in percentage for each pixel. The FCD model requires less information of ground truth just for accuracy check and so on. FCD model is based on the growth phenomenon of forest.

OBJECTIVES OF THE STUDY

The main aim of this study was Forest Canopy Estimation using FCD model using satellite images of Noamundi and Jagarnathpur areas in Jharkhand. To accomplish this, the specific objectives are as follows:

1. To derive Land Use Land Cover map (LU/LC) of the study area (Noamundi and Jagarnathpur).
2. To derive forest canopy indices such as Advance Vegetation Index, Bare Soil Index, Canopy Shadow Index, Thermal Index using satellite data in the year 2007 and 2017 for studying temporal dynamics of canopy cover.
3. To estimate chlorophyll content of the species present in the study area with the instrument.

STUDY AREA

Noamundi and Jagarnathpur district forms the southern part of Jharkhand state and is the largest district in the state. The district spreads from 21.97°N to 23.60°N and from 85.00°E to 86.90°E.The forest covers an area of 820 km² **(Figure 1)**.

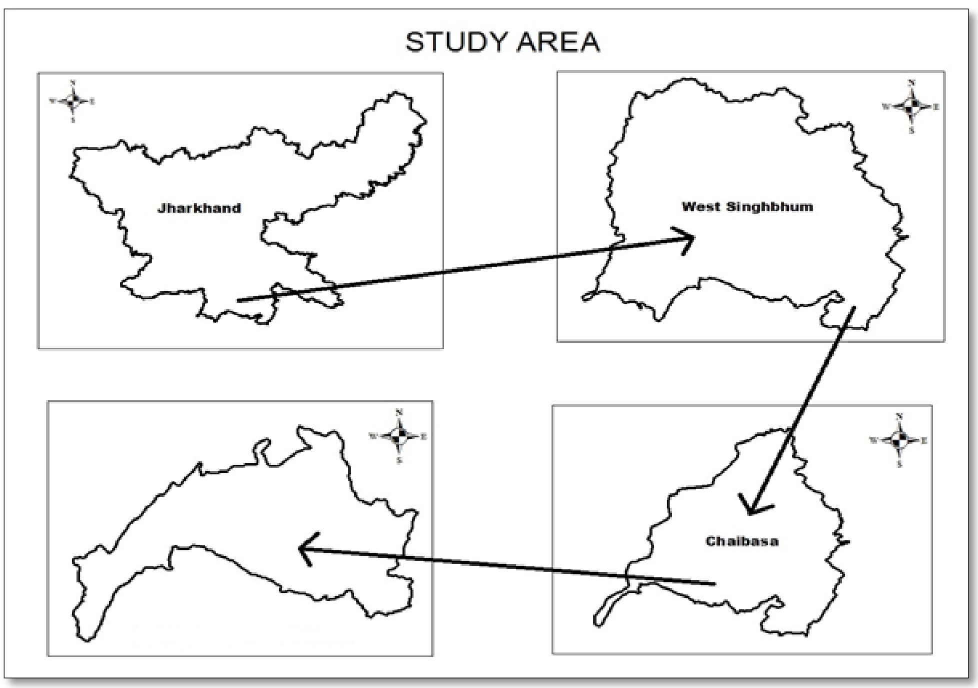

Figure 1. Location map of the study area.

DATA USED AND METHODS

Satellite imageries and ancillary data were collected in order to identify forest canopy estimation using forest canopy density model. The image data that were used for this study are Landsat TM and OLI. Topographic maps of Open Series at the scale of 1:50,000 were procured from the Survey of India (SOI). Study area boundary was generated from collateral or ancillary data that was a block-level map of the West Singhbhum, the study area. The methodological flow chart of the study, **Figure 2** represents all about the procedure, methods, and steps used to achieve the main aim of the study that is to map the Forest Canopy Estimation Using Forest Canopy Density Model (FCDM) and Satellite Data of Noamundi and Jagarnathpur (West Singhbhum District), Jharkhand.

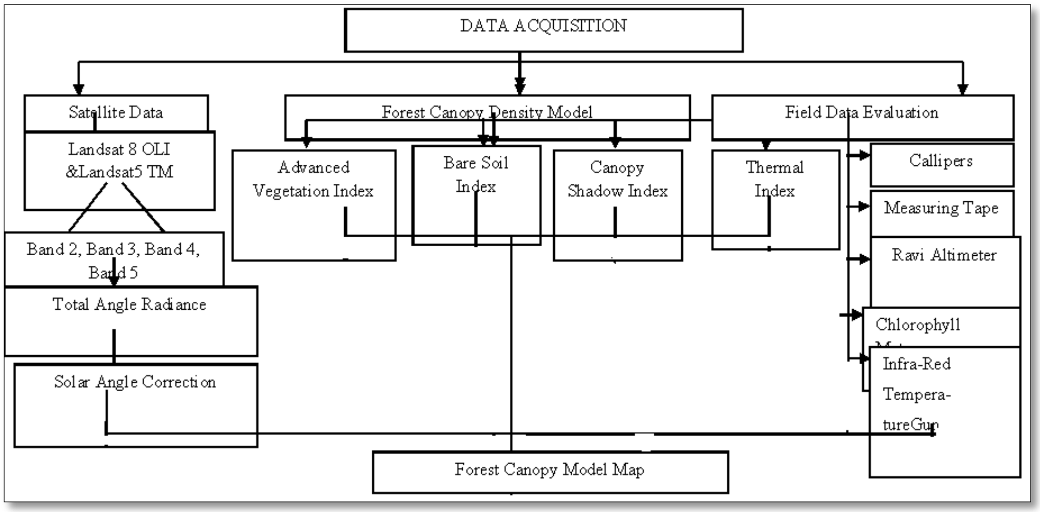

Figure 2. Showing methodology and procedure.

RESULTS AND DISCUSSION

Objective 1

Using supervised classification method LANDSAT 8, OLI and 5 TM classifies in the year 2017 and 2007. While preparing land use land cover change of Noamundi and Jagarnathpur, it was distributed into eight classes' viz., settlement, agriculture, river, barren land, surface water, scrub forest, agriculture fallow land and dense vegetation. The dominating classes in land use land cover change for the year 2017 were dense vegetation (2972.12 sq. km), settlement (11.43 sq. km) and scrub forest (350.87 sq. km). The dominating classes in land use land cover change for the year 2007 were dense vegetation (3257.04 sq. km), settlement (06.24 sq. km) and scrub forest (233.71 sq. km). In the year 2017, settlement showed a major increase as a result of which, dense vegetation and light vegetation decreased rapidly and the surface water content decreased due to various factors. In the year 2007 the settlement was less as compared to the year 2017 as a result of which the forestland was greater in amount **(Figures 3 and 4)**.

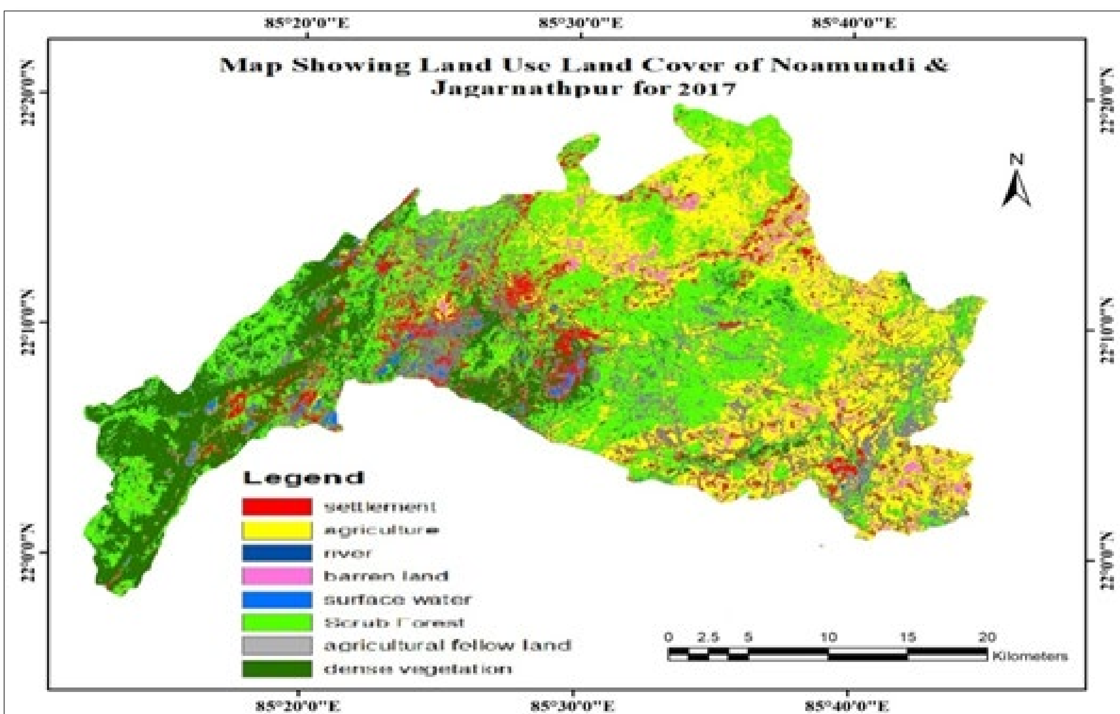

Figure 3. Map showing LULC of Noamundi and Jagarnathpur (West Singhbhum) for the year 2017.

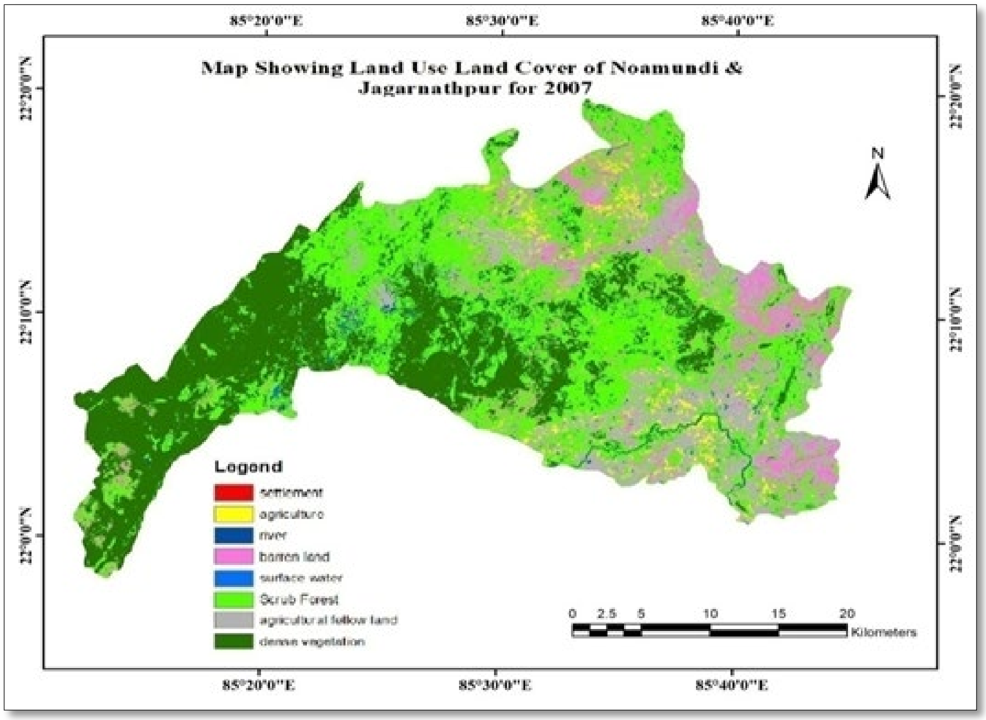

Figure 4. Map showing LULC of Noamundi and Jagarnathpur (West Singhbhum) for the year 2007.

Objective 2. Using forest canopy density model

- We have to take TIFF file where each band represents where it is downloaded from USGS.
- Total angle radiation and solar correction is applied.
- Now we are interested to determine the following indices that are used for calculating Forest Canopy Density.

Advance vegetation index

NDVI is unable to highlight subtle differences in canopy density. It has been found to be improved by using power degree of the infrared response. The calculated index has been termed as advanced vegetation index (AVI). It has been found to be more sensitive to forest density and physiognomic vegetation classes. For this reason, it is getting better by using power degree of the infrared response.

AVI = {(B4+1) (256-B3) (B4-B3)} 1/3

AVI = {(B5+1) (65536-B4) (B5-B4)} 1/3

The value AVI for a given pixel ranges from minus one (-1) to plus one (+1); however, no green leaf gives a value close to zero. A zero means no vegetation and close to +1 (0.6 to 0.8) indicate the highest possible density of green leaves and negative values mainly represent water and other non-vegetated surface.

Bare soil index

The bare soil areas, fallow lands, vegetation with marked background response are enhanced using this index. Similar to the concept of AVI, the bare soil index (BI) is a normalized index of the difference and the sums of two separating the vegetation with different background viz. completely bare, sparse canopy and dense canopy, etc. This index helps us to get a clear idea of vegetation from the surroundings. The range of BSI varies between 0 to 200. The reflectance spectra of the soil mainly depend on soil moisture and hydroxylions.IR region have low reflectance due to absorption by soil moisture (soil water).

BI= (Band 5 + Band 3) – (Band 4 + Band 1) / (Band 5 + Band 3) + (Band 4 + Band 1)

BI= (Band 6 + Band 4) – (Band 5 + Band 2) / (Band 6 + Band 4) + (Band 5 + Band 2)

Canopy shadow index

The crown arrangement in the forest stand leads to shadow pattern affecting the spectral responses. In the study area, matured even aged stands have high canopy shadow index (SI) compared to the young forest stands. The latter forest stands show flat and low spectral axis in comparison to that of the open area. The canopy shadow index is more for the year 2007 as compared to the year 2017. This index works out with a shadow pattern affecting the spectral response with the crown arrangement in any forest.

SI=√ (256-B2) (256-B3)

SI= ((65536 –B2)*(65536−B3)*(65536−B4)) 1/3

The range of BSI varies between 0 and 100. The even aged stands have high canopy shadow index (SI) compared to the young forest stands.

Thermal index

Two factors account for the relatively cool temperature inside a forest. One is the shielding effect of the forest canopy, which blocks and absorbs energy from the sun. The other is evaporation from the leaf surface, which mitigates warming. These two factors were found in both forest regions of Noamundi and Jagarnathpur. Formulation of the thermal index is based on this phenomenon. The source of thermal information is the infrared band of TM data.

$L=L_{min} + ((L_{max}-L_{min})/255)*Q$

T=K2/(ln (K1/L+1))

Where,

L: Value of radiance in thermal infrared

T: Ground temperature (k)

Q: Digital record

K1, K2: Calibration coefficients

K1=666.09 watts / (meter squared * ster* μm)

K2=1282.71 Kelvin

L_{min}= 0.1238 watts / (meter squared * ster* μm)

L_{max}= 1.500 watts / (meter squared * ster* μm)

The range of TI varies between 0 to 100. It is used to separate soil and non-tree shadow.

Forest canopy density model

VCD = VD (SSI + 1) 1/2 – 1

Where,

VD=Advanced Vegetation Index and Bare Soil Index

SSI=Canopy Shadow Index and Thermal Index

RESULTS AND DISCUSSION

By analyzing the above map we observe that the maximum dense forest is given by the FCD model, whereas other two techniques which were applied on Aster DEM, i.e., Aspect Map And Elevation Map give approximate extend of forest by interpretation, which is not as good as FCD model. The Landsat Imagery of 2007 and 2017 has been represented by Band combination of bands (True Colour Composite). These images were subjected to the PCA1 scaled and scaled SSI, following which Forest Canopy Density Maps were generated, where the overall accuracy for year 2007 was 84.25% and the overall accuracy for year 2017 was 80.06%, tested using the Kappa statistical methods generated from Erdas Imagine 10.3 tools **(Figures 5 and 6)**.

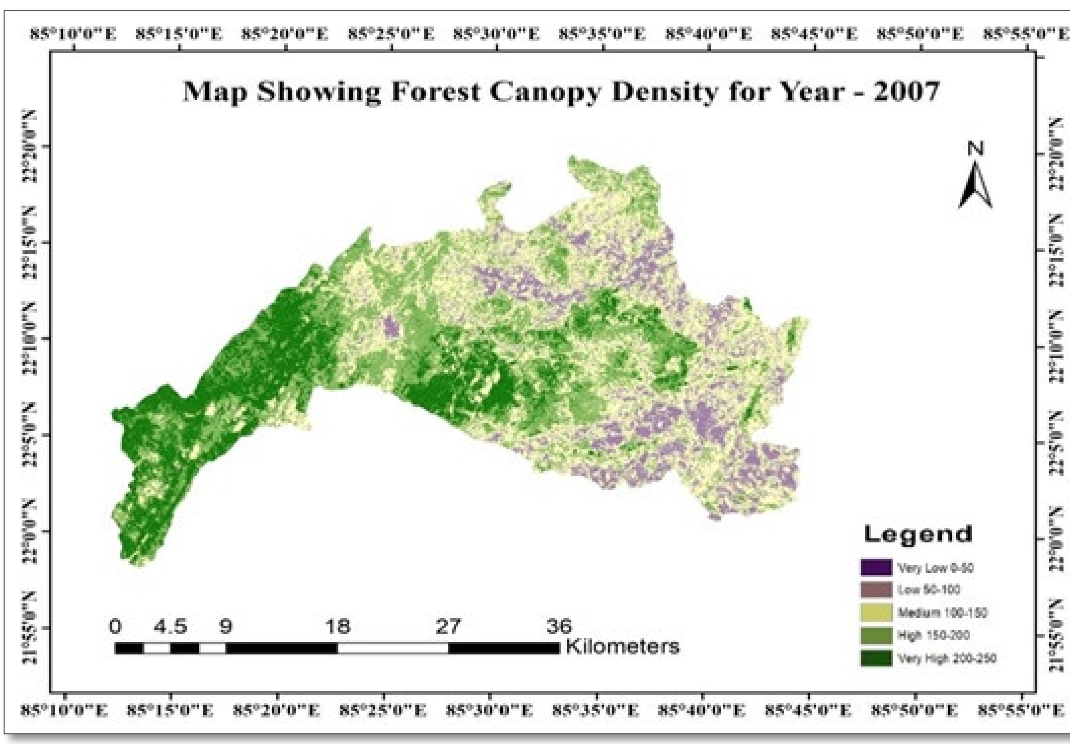

Figure 5. Map showing forest canopy density for the year 2007.

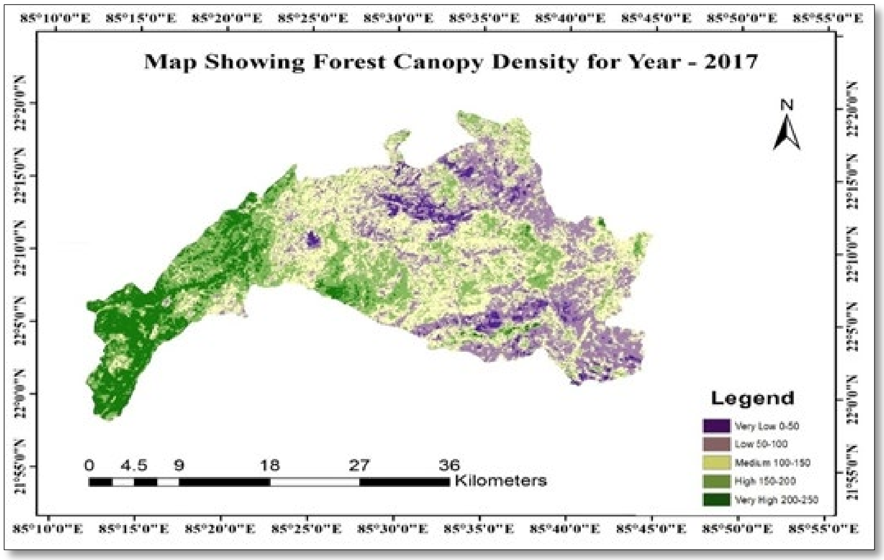

Figure 6. Map showing forest canopy density for the year 2017.

Chlorophyll estimation

Chlorophyll estimation is the method of estimating or measuring the chlorophyll content of leaves of a tree or plant. In this study the chlorophyll estimation was done by Off-field Chlorophyll Estimation.

Off-field chlorophyll estimation

The off-field chlorophyll estimation was performed on the satellite imagery by using empirical equation produced by Carmona. The empirical equation also involved the calculation of NAVI. The result assessed from that equation is shown on **Figure 7**.

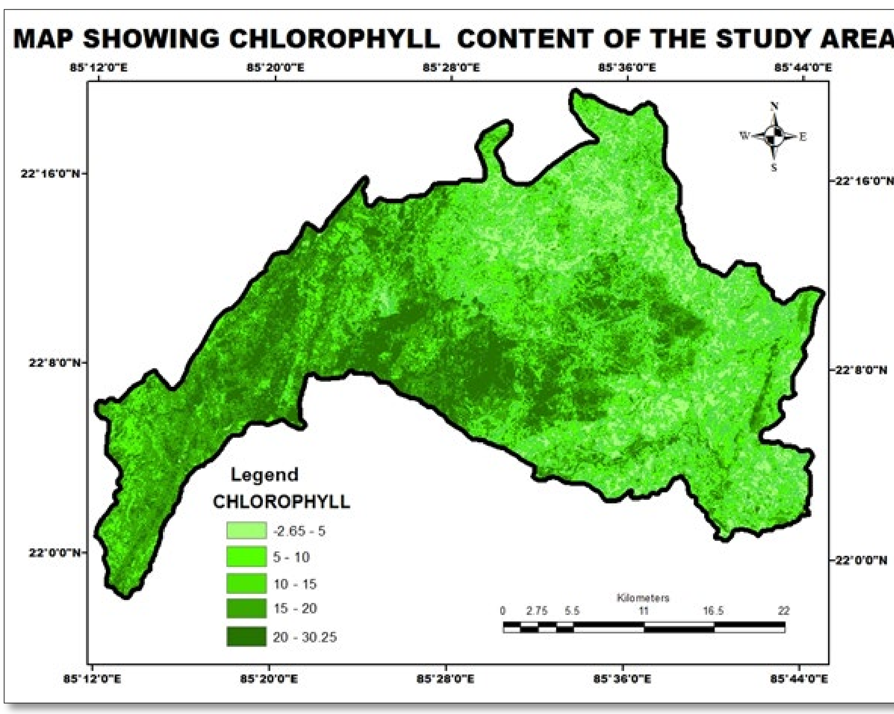

Figure 7. Map showing chlorophyll content.

The above shown image shows the variation in chlorophyll content extracted from the satellite imagery. The negative values near to the -2.65 shows features like water bodies, fallow land, etc., and all other features except vegetation. The green colors shows the high content of chlorophyll in the zone and the vice versa. The chlorophyll content shown in the map ranged between -2.6539 µg/cm^2 to 30.2564 µg/cm^2.

Field observation and validations

The field observation was done by measuring the chlorophyll content on the field by the help of DUOLEX SCIENTIF+ a proximal sensor for the measuring chlorophyll content from the tress of Shorea robusta. The table shown below displays species with its chlorophyll content first measured from the chlorophyll meter and next estimated from the satellite imagery **(Figure 8)**.

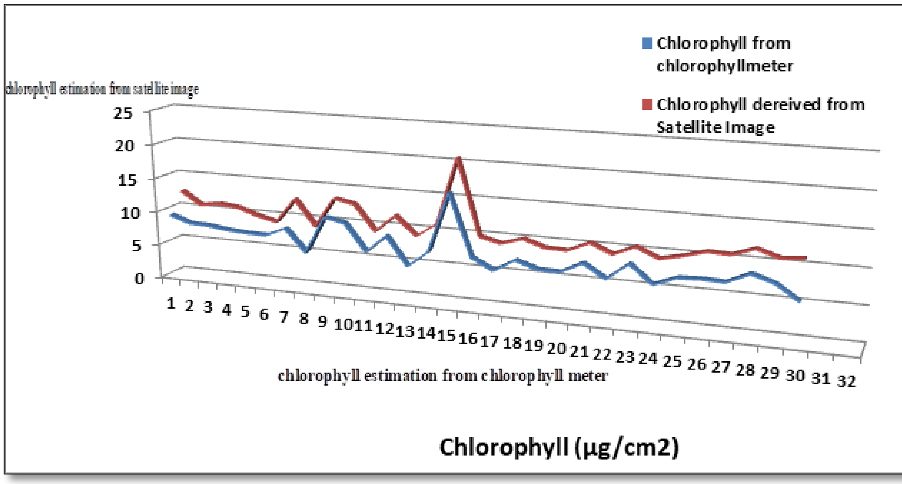

Figure 8. Figure showing variation of chlorophyll estimation from satellite image chlorophyll meter and Satellite image.

A significant deviation can easily be observed from the above table. Some deviation are like chlorophyll content of Sample 15 of Jagarnathpur forest region was found to be 20.569 µg/cm^2 when measured from chlorophyll meter and was 16.326 µg/cm^2 when estimated from satellite image. In the case of Noamundi when measured by chlorophyll meter it was 8.968 µg/cm^2 and it was 6.763 µg/cm^2 when estimated from the imagery. Similar trends are observed in all species. The trend of deviation which was being observed because the chlorophyll meter provided precise measurement for the chlorophyll species. On the hand the chlorophyll estimation from the satellite image gave result of 30 m * 30 m dimension of real ground plot, that plot contained several trees **(Figure 9)**.

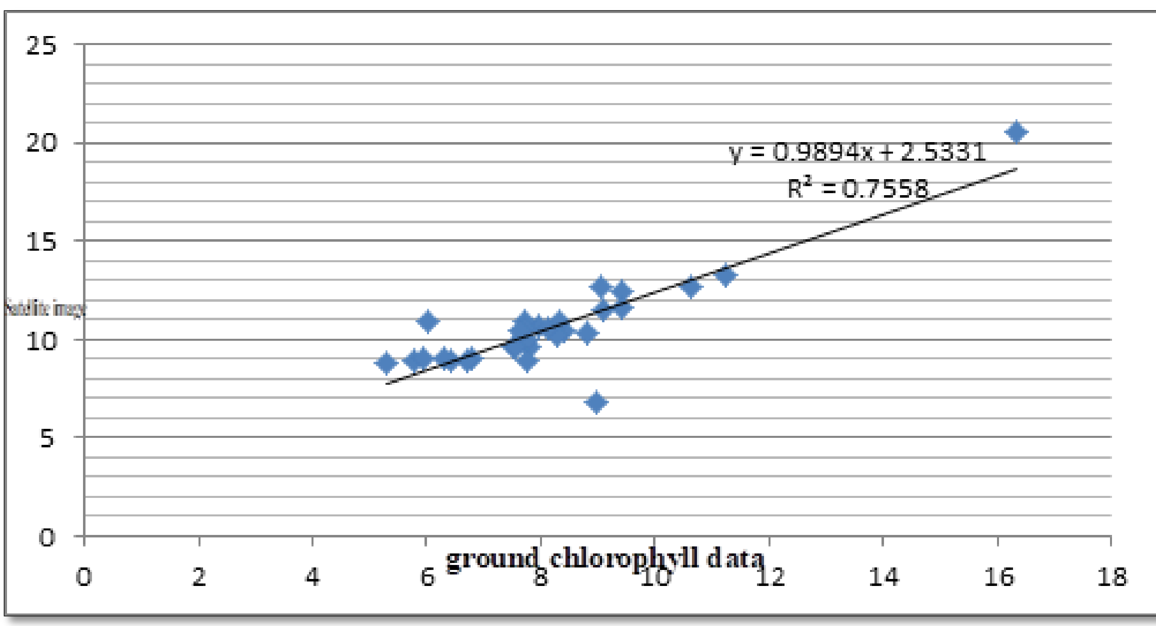

Figure 9. Figure showing R^2 relationship between the Satellite image and ground chlorophyll data.

In the present study the graph has been plotted using regression analysis techniques between satellite image and ground chlorophyll data in MS-Excel. Regression analysis has a great technique for estimating the satellite image and ground chlorophyll data The R^2 between the Satellite image and ground chlorophyll data is 0.755 which is good **(Figure 10)**.

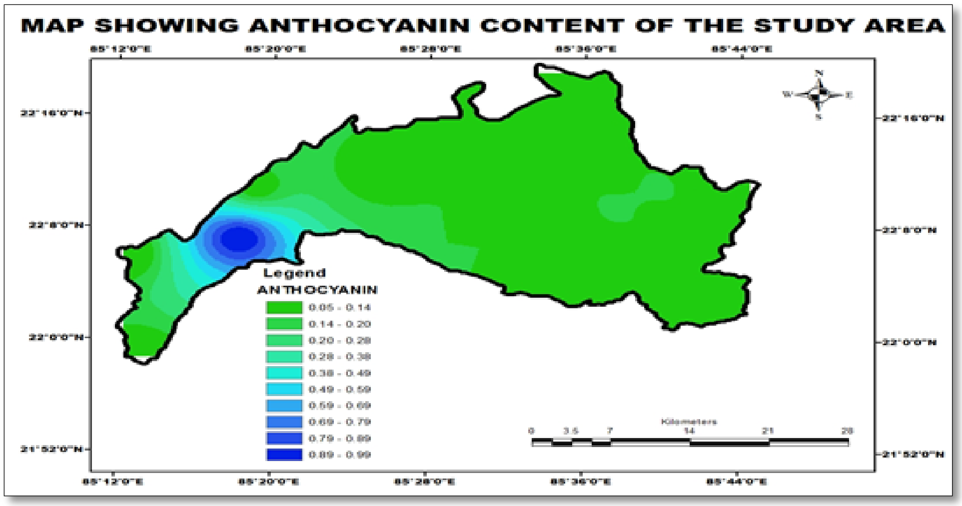

Figure 10. Map showing anthocyanin index of study area.

Anthocyanins belong to a parent class of molecules called flavonoids synthesized via the phenyl propanoid pathway. They occur in all tissues of higher plants, including leaves, stems, roots, flowers, and fruits. Anthocyanins may have a protective role in plants against extreme temperatures. Anthocyanins were observed in almost all combinations of every leaf tissue, but were most commonly located in the vacuoles of photosynthetic cells. As during the field based observation anthocyanins values was varying from one sample plot to another sample plot. By doing interpolation in my study area the value ranges from 0.05 to 0.99. These data indicate that anthocyanins are associated with photosynthesis, but do not serve an auxiliary phytoprotective role. They may serve to protect shade-adapted chloroplasts from brief exposure to high intensity sun flecks **(Figure 11)**.

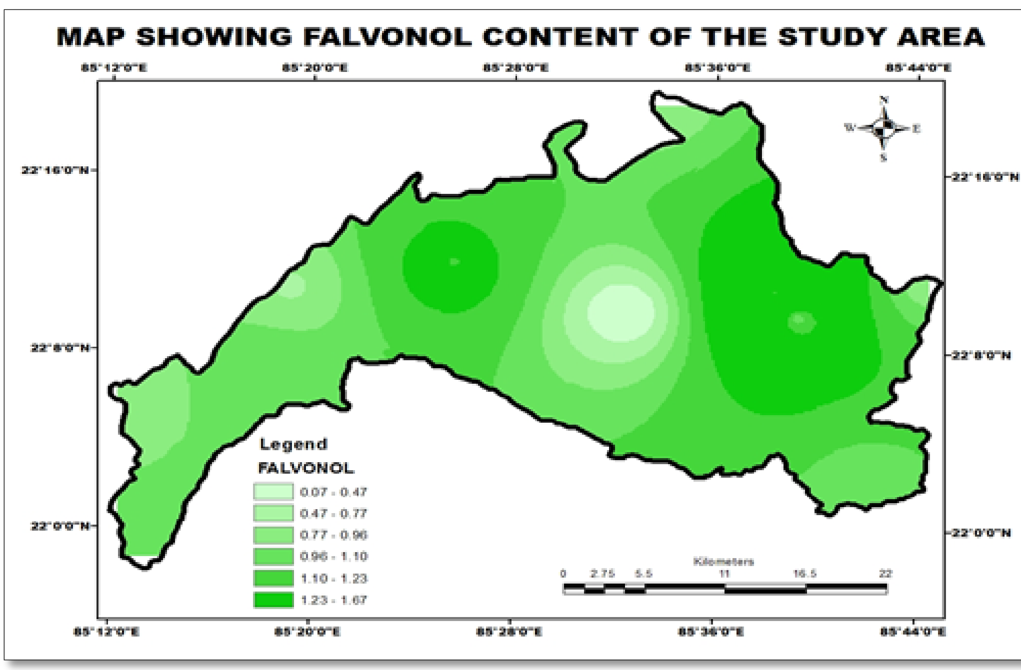

Figure 11. Map showing falvonol index of study area.

Flavonoids are a large group of polyphenolic compounds ubiquitous in fruits, vegetables and herbs; they have attracted much attention due to their potential antioxidant properties and probable role in the prevention of oxidative stress-associated diseases including atherosclerosis. Flavonoid is widely distributed in plants, fulfilling many functions. Flavonoid is the most important plant pigments for flower coloration, producing yellow or red or blue pigmentation in petals designed to attract pollinator animals. In higher plants, flavonoids are involved in UV filtration, symbiotic nitrogen fixation and floral pigmentation. As during the field based observation flavonol values was varying from one sample plot to another sample plot .By doing interpolation in my study area the value ranges from 0.07 to 1.67.

CONCLUSION

Conventional RS methodology, as generally applied in forestry is based on qualitative analysis of information derived from "training areas" (i.e., ground-truth). This has certain disadvantages in terms of the time and cost required for training area establishment, as well as to ensure a high accuracy. Unlike the conventional qualitative method, the FCD model indicates the growth phenomena of forests by means of qualitative analysis. The accuracy of methodology is checked in field test. FCD model is very useful for monitoring and management with less ground truth survey. The management and protection of forest resources play an extremely important role for the study area. Using GIS and remote sensing data, the achieved results have high reliability. Based on the physical properties and spectral reflection of the objects on the surface, the remote sensing images can provide much useful information in research. Geographic problems often require the analysis of many different factors. For instances, delineating the canopy density map, it needs different factors like Advanced vegetation index, Bare soil index, Canopy Shadow Index, and Thermal Index etc. It is possible to measure canopy density more accurately but it needs more parameters like DEM, Slope, Soil type and others values depending upon the environment of the study area. To fulfil the needs of these parameters Advance Indexes has been taken into consideration. The more parameters used the result will be more accurate. So it can be concluded that canopy density is the integrated result of the various parameters and thus can be found more accurate than normal classification scheme. Although higher Dense Forest regions can be located easily from FCD Model using satellite data further analysis could be carried out only when these data merged into Land use/land cover data and also more detailed analysis could be achieved. Chlorophyll estimation was conducted using on field chlorophyll estimation and off field chlorophyll estimation .On field chlorophyll estimation was performed by using Chlorophyll meter, which has inbuilt GPS present in it and provides Nitrogen status, Chlorophyll content, Flavonols and Anthocyanin. Off field chlorophyll estimation was conducted using the satellite imagery. From the imagery NAVI, i.e., Normalized Area Vegetation Index was calculated and thereafter by the NAVI value, Chlorophyll content is estimated. Hence from the on field and off field calculation, comparison study is performed. From the comparison study a significant deviation between the chlorophyll meters provided precise measurement for the chlorophyll species wise. On the other hand the chlorophyll estimation from the imagery gave result in a pixel of 30 m * 30 m dimensional of real ground plot, the plot contained same species and the result is generated by integrating the chlorophyll 56 content of the species. The variation is represented by plotting a line chart with both the values, chlorophyll content estimated by the satellite imagery and measured by the chlorophyll meter.

LIMITATIONS

In spite of using high resolution imagery, the chlorophyll was not satisfying as it provided result in plot of 30 m * 30 m which was proved to be coarser for this purpose. Performing field observation is really a time, labor and money consuming thing. As the study was performed in buffer region of the forest reaching and collecting observation from the core region could be more hazardous due to the dense vegetation of Sal trees.

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