Fraction of Vegetation Cover and Its Application in Vegetation Characterization in the Hazaribagh Wildlife Sanctuary, Jharkhand, India

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Fraction of Vegetation Cover and Its Application in Vegetation Characterization in the Hazaribagh Wildlife Sanctuary, Jharkhand, India

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Abstract The Vegetation Indices (VI) used for estimation of variations in vegetation cover in past decades. The Fraction of vegetation cover was calculated from pre-computed reflectance database based on inversion of PROSAIL model. It was found that the very low and low forest vegetation cover area was dominated with an area of about 104 Km² and 69.49 Km² respectively. The very high forest vegetation cover area is very low of about 24 Km². The high and medium vegetation cover forest shows intermediate dominance of about 51.74 Km² and 57 Km² in area respectively. The result indicates that NDVI, RVI and PSSRA value closely related to forest vegetation cover. Also, in the regression analysis the same was observed as the high relationship is found between FCOVER AND PSSRA (R² = 68%) followed by NDVI (R² = 66%) and RVI (R² = 65%). The low relationship is found in the relationship of FCOVER and MCARI (R² = 36.7%) followed by DVI (R² =53.7%) and IRECI (R² = 59%).

Keywords Fractional vegetation cover; Forest vegetation cover; Vegetation indices

1. Introduction

The fraction of vegetation cover (FCOVER) gives the information about the biophysical status of the forest. The FCOVER is an imperative variable for many spatial biophysical and biogeochemical models and used for the measurement of land cover change (Zhang, 2006). According to remote sensing techniques, FCOVER may be defined as the vegetated area which is directly visible from the sensor (Purevdor et al., 1998). Quantitative information on the vegetation cover is required in many studies for observing the global and local changes in forest landscapes.

With the advent of satellite imaging technology, it is much more common to use remote sensing techniques to monitor forest data, in particular, tropical deforestation. Remote sensing based methods for retrieving FCOVER have developed rapidly during the last few decades. The upcoming of Sentinel 2 satellites offer new open doors for a nonstop checking of the land and vegetation with regards to the climate change and global warming (POENARU, 2017).

Satellite sensors Sentinel-2 has the capability to forecast the forest activities and spectral resolution of 10 m at its red and NIR bands make it more reliable. It is ESA's mission to provide high-resolution imagery and enhanced data continuity for Landsat and SPOT (Drusch, 2012). The
several studies have been implemented that show the potential of Sentinel -2A for measuring many biophysical and biochemical parameters like FCOVER (Vander Meer, 2014).

Theoretical analyses and field studies have shown that VIs is near-linearly connected to the fraction of absorbed photosynthetic active radiation (fAPAR), a fraction of vegetation cover (FCOVER), roughness length for turbulent transfer, emissivity and albedo (Glenn, 2008). Remotely Sensed vegetation indices help to analyze vegetation parameters such as leaf area, biomass and physiological activities (Baret and Guyot, 1991; Verrelst et al., 2008). Spectral vegetation indices that are based on red and near-infrared reflections have the highest correlation with leaf area index and vegetation cover (Broge and Leblac, 2000). Spectral vegetation indices (VI) are very helpful in characterizing forest vegetation based on satellite data and spatially and temporally variables in vegetation conditions (Yang, 2017; Pricope, 2015). These Studies suggest the important relation of spectral indices to extract plant signal.

The present study utilizes the inversion of the PROSAIL radiative model which permitted us to recover vegetation biophysical variables (e.g. FCOVER) (Jacquemoud et al., 1995) from multispectral Sentinel 2A imagery. The proposed method was applied to monitor the forest vegetation cover in the Hazaribagh wildlife sanctuary, located in the eastern parts of India. The present study also utilizes scatter plot matrix which analyses the relationship between FCOVER and VIs. The scatter plot gives the linear relationship between the model output and the uncertain component using regression analysis (Srivastava et al., 2012).

Figure 1: Study area- Hazaribagh Wildlife Sanctuary
1.1. Study Area

This study was performed in the Hazaribagh wildlife sanctuary, Jharkhand, India (Figure 1). It lies between 24°45'22" N to 24°08'20"N latitude and 85°30'13" E to 85°21′58"E longitude and also includes bird Sanctuary and other biodiversity parks. The climate of the region is tropical having hot summers and chilly winters. In summer, greatest temperature rises to up to 41 degrees and low of 19 degrees. In winter, most extreme high and low temperature decreased are 19 degrees and 7 degrees respectively. The sanctuary has Sambhar, Deer, Bison and various mammalian fauna. The Cheetah, Kakar, Nilgai, Sambar and Wild Boar are among the most effective and frequently spotted creatures, especially close to the waterholes at the time of the sunset.

2. Methodology

The Figure 2 illustrates the flow chart of methodology used in the present study and its details is given according to it below. It involves the acquisition of sentinel 2A imagery and their processing for retrieving FCOVER, FCC and vegetation indices. The accuracy was done through the help of aerial map (Google Earth) and observing False Color Composite (FCC). The classification FCOVER and sample points to raster was converted by the use of Arc GIS software and further confusion matrix, overall accuracy estimation and kappa analysis were generated using QGIS software.

![Flow chart of methodology adopted in the present study](image-url)
2.1. Data and Software Used

In this study, Sentinel-2A optical satellite data were acquired from the USGS earth explorer (https://earthexplorer.usgs.gov/) for the period of February-2016 (Table 1). It contains 12 spectral bands with a spatial resolution of 10m, 20m, and 60m. This data is processed with SNAP software developed by ESA, which is excellent software for the processing of Sentinel satellite imagery. Q-GIS software was used for the DN to the reflectance conversion of the imagery and then the processed data was used for computation of various indices. The result obtained was used as an input parameter in SAGA GIS software for sensitive analysis between FCOVER and Vegetation Indices. Finally, all the results were exported using ArcGIS software.

Table 1: The satellite data used in the present study - Fractional of vegetation cover (FCOVER) estimation

| Sensor     | Date       | Id                                      | Processing Level | Product type |
|------------|------------|-----------------------------------------|-----------------|--------------|
| Sentinel2A | 2016-02-13 | 20160213T101928_A003362_T45QUG          | Level-1C        | S2MSI1C      |

Figure 3: Classification of FCOVER

The FCOVER is a canopy inherent variable that depends upon the structure of the canopy (LAI, Leaf angle and clumping) (Bacour, 2006). The FCOVER derived from the analysis of the PROSAIL model inversion technique of artificial neural network approach from multispectral Sentinel 2 data. In this perspective, the portion or fraction of vegetation cover in the forest area of the Hazaribagh wildlife sanctuary was calculated by using inversion of PROSAIL model embedded in the biophysical processor of the SNAP ESA Toolbox. It is already proven to be good at estimating FCOVER. It uses trained neural network algorithm having the input of 11 normalized data (B3, B4, B5, B6, B7, B8a, B11, B12, cos (Viewing Zenith), cos (Sun Zenith), cos (relative azimuth angle)) of the Sentinel-2A Sensor, one hidden layer with tangent sigmoid transfer function contains 5 neurons and an output layer with a linear transfer function (Vuolo et al., 2016). The training database contains canopy reflectance spectra with the corresponding output variables. The FCOVER obtains from the processing step of the artificial neural network and its inversion techniques, from the encoded coefficient computed during the training phase. The training process depends on the mean square error between the reflectance database and the output FCOVER. The network planning is determined by trials and errors, to get the optimal performances with minimum number of inputs layers and neurons. The
validation of the FCOVER was done through ground truthing during its training period. For the calculation of FCOVER the sentinel 2A bands firstly resample to 60m resolution, the resolution was chosen to ease the exporting task in Tiff format. Resampling is essential for converting each input bands into same resolution, as bands in sentinel 2A come in different resolution of 10m, 20m and 60m.

With the use of FCOVER, the forest vegetation cover area has been classified by thresholding it in ARC GIS (Figure 3). The value of the FCOVER between 0.23 to 0.52 considered as very high vegetation cover area, the value consisting 0.176 to 0.23 is considered as high vegetation area, the value between 0.12 to 0.176 is considered as a medium vegetation cover area, 0.069 to 0.12 as low vegetation cover area value of 0 to 0.069 as very low vegetation cover area and e statistical analysis was carried out in classified images of FCOVER, which gives area and percentage of classified FCOVER.

2.2. Atmospheric Correction

The estimation of radiometric vegetation indices depended on the reflectance properties of bands on Sentinel 2A satellite data. The bands require atmospheric correction before their use. For this reason, the raw satellite imagery of Sentinel 2A was first converted into reflectance. The DN (Digital Number) to reflectance conversion (Calibration) needs a header document given in the downloaded satellite imagery which contains all the necessary inputs like acquisition date, sun height, gain and bias for correcting the imagery (Lu, 2001). Then, the images were corrected by the dark object subtraction (DOS) to get real surface reflectance of the object. The DOS strategy is an image-based technique to counterbalance the haze component caused by additive scattering from remote sensing data (Chavez, 1988). For this purpose, QGIS software was utilized for the atmospheric correction of Sentinel 2A imagery. After these processing the bands were selected and mathematically operated in raster calculator in QGIS for the calculation of vegetation indices. The mathematical operation was accord to the vegetation index formula (table2) for the calculation of the selected vegetation indices for evaluating its performance in comparison to FCOVER and vegetation cover types.

2.3. Vegetation Indices

The six types of different vegetation indices were computed utilizing the mathematical operation on bands of satellite data to represent the amount and structure of vegetation (Figure 4). The most commonly used bands are RED and NIR because they are sensitive to the soil and vegetation reflectance respectively. The Difference Vegetation Index (DVI) is sensitive to the amount of vegetation and difference soil from vegetation. In DVI zero indicates bare soil, values less than zero indicate water, and those greater than zero indicate vegetation. The range of this index is theoretically very large, but if reflectance images are used, it tends to give values between 0 and 1. The Inverted Red-edge Chlorophyll Index (IRECI) needs four bands to estimate forest chlorophyll content. The red-edge is the region of vegetation spectra (680nm±740nm, red bands) that is sensitive to leaf scattering and chlorophyll absorption. The exact range value of it for vegetation and other land feature was not determined yet. The Ratio Vegetation Index (RVI) is high for vegetation and low for water, ice and soil. It indicates the amount of vegetation and reduces the atmospheric effects and topography. Note that the SR is not bounded; its values can increase far beyond 1. Generally, very high SR values are on the order of 30. Typical ranges are a little more than 1 for bare soil to more than 20 for dense vegetation. The Pigment Specific Simple Ratio (PSSRA) exhibits the linear relationship with the canopy concentration per unit area of chlorophyll and carotenoids. The exact range value of it for vegetation and other land feature was not determined yet. The Normalized Difference Vegetation Index (NDVI) is the most commonly used vegetation indices used in the analysis of vitality and
strength of vegetation. Data from vegetated areas will yield positive values for the NDVI due to high near-infrared and low red or visible reflectance. The NDVI increases in value up to nearly 1 as the amount of green vegetation increases in a pixel (picture element). In contrast, bare soil and rocks generally show similar reflectance in the near-infrared and red or visible, generating positive but lower NDVI values close to 0. The red or visible reflectance of water, clouds, and snow are larger than their near-infrared reflectance, so scenes containing these materials produce negative NDVIs. The typical range of actual values is about 0.1 to 0.2 for bare soils and 0.2 to 0.9 for vegetation. The Modified Chlorophyll Absorption Ratio Index (MCARI) used to observe the chlorophyll variation and ground reflectance. The exact range value of it for vegetation and other land feature was not determined yet.

![Figure 4: Spectral vegetation index used in the study area](image)

2.4. Regression Model

The scatter plot was preferred for the regression analysis between two raster variables. The variables here are rasters of vegetation indices and FCOVER. The potential of estimation of forest vegetation cover by indices is analyzed based on regression equation and R², which define mathematically the relation between two variables.

2.5. Accuracy Assessment

The validation of the result has been always a main criterion for the assessment of remote sensing based analysis. In general, validation for the most part refers to evaluating the uncertainties in remote sensing indirectly comes about by means of correlation with ground truth or between examination with
another option data that apparently speaks to the true condition of an object (Wang, 2016). In this paper, the validation was done through observing the false color composite (FCC) of imagery and the taking sample point of vegetation cover type from Google earth (sampling methods).

Table 2: Spectral vegetation indices and its formula for Sentinel-2 A bands

| Vegetation indices | Formula | References |
|--------------------|---------|------------|
| DVI | (B8-B4) | Richardson and Wiegand (1977) |
| IRECI | (B7-B4)/B5/B6 | Frampton et al. (2013) |
| RVI | B8/B4 | Birth and McVey (1968). |
| PSSRA | B7/B4 | Black burn, 1998 |
| NDVI | (B8−B4)/(B8 +B4) | Rouse et al. (1974) |
| MCARI | [(B5-B4)-0.2 * B5-B3] * B5/B4 | Daoughtry, et al. 2000 |

The accuracy assessment was done for the validation of the classified vegetation cover areas. These were assessed in two ways. Firstly, the classification was compared with the false color composite (8-4-3 bands) of the same sentinel imagery. The visual and color interpretation was done to observe the vegetation condition in the forest. Secondly, the training sample point was generated from the Google earth imagery. The point was taken by observing the different classes of vegetation cover according to classified FCOVER. Around 250 random sampling was done and then these points were converted to raster format in ARC GIS. These raster was taken as reference classified map for the accuracy assessment with the classified FCOVER. Then, the overall accuracy, confusion matrix and kappa coefficient were retrieved using QGIS software.

Figure 5: Fraction of vegetation cover (FCOVER) map of the wildlife sanctuary
3. Result and Discussion

3.1. Classification and Area Estimation of Vegetation Cover

The fraction of vegetation cover was used to estimate the vegetation cover in the forest (Figure 3). The value of FCOVER indicates the type of forest vegetation cover. Its value ranges from 0 to 1. In Figure 5, FCOVER of the study area is given; its high range is 0.52 whereas the low value is 0.0044. The classification can also be observed in the Figure that represents the classified FCOVER by natural breaks (Jenks) methods of classification in ARC GIS. Figure 6 indicates the classification of the forest vegetation covers according to FCOVER value. The statistics of an area and the percentage of FCOVER are given (Table 3). It is found that the very low and low forest vegetation cover was dominant, with the area of about 104 Km² and 69.49 Km² respectively, indicates deforestation and degradation in the part of the area. The very high forest vegetation cover area observed in small patches across the study area which contributing 24 Km². The high and medium vegetation covers forest shows intermediate dominance, about 51.73 Km² and 57 Km² in area respectively. In this study, we identified that forest vegetation monitoring with FCOVER is a best suited methodology and future change detection analysis can be possible. The Sentinel 2A is a new satellite and in the coming year, it can be helpful in change detection or seasonal change monitoring.

Map Showing Fractional Vegetation Cover in the study area

3.2. Accuracy Assessment

In the Figure 7, the false color composite of the sentinel 2A imagery is given, which indicates the true condition of vegetation and can be taken for validating the obtained result of classified FCOVER. In the FCC, the high vegetation cover area appears in dark red color. Sometimes it is misunderstood by the
shadow, as the forest canopy cover creates shadows depends upon the sun geometry. The more darkness in red found in the very high vegetation cover area and darkness decrease in the high vegetation cover followed by other medium and low vegetation cover area. The low and very low vegetation cover area looks pink and gray white respectively. Thus, the above validation for the obtained result is satisfactory.

In the Table 4, the accuracy assessment is given which gives the details about confusion matrix generated from reference map (sampling method) and classified FCOVER. The overall accuracy was observed 95.65% with kappa coefficient of 0.94.

Table 3: Area and percentage of forest vegetation classes based on FCOVER

| FCOVER | Forest vegetation cover | Percentage % | Area (Km²)  |
|--------|-------------------------|--------------|-------------|
| 0.5    | Very High               | 7.84         | 24.163200   |
| 0.4    | High                    | 16.79        | 51.735600   |
| 0.3    | Medium                  | 18.8         | 57.916800   |
| 0.2    | Low                     | 22.56        | 69.494400   |
| 0.1    | Very Low                | 33.9         | 104.731200  |

False color composite (bands 8-4-3) of sentinel 2 image in the study area

Figure 7: False color composite of Sentinel imagery
### Table 4: Accuracy assessment

| Vegetation cover > Reference | Very Low | Low | Medium | High | Very High | Total |
|-----------------------------|----------|-----|--------|------|-----------|-------|
| Very Low                    | 1047276  | 0   | 0      | 0    | 0         | 1047276 |
| Low                         | 0        | 694908 | 0     | 0    | 0         | 694908  |
| Medium                      | 0        | 46908 | 532260 | 0    | 0         | 579168  |
| High                        | 0        | 0    | 54144 | 430452 | 32760 | 517356 |
| Very High                   | 0        | 0    | 0     | 241632 | 241632 |       |
| Total                       | 1047276  | 741816 | 586404 | 430452 | 274392 | 3080376 |

Overall accuracy [%] = 95.6559848538
Kappa hat classification = 0.943128853533

### 3.3. Vegetation Indices Thresholding and Its Performance

The value of NDVI ranges from 0.81 to -0.15. The value of 0.6 to 0.82 indicates the very high vegetation cover area. The value from 0.47 to 0.6 is the high vegetation cover. The value that ranges from 0.33 to 0.47 is the medium vegetation cover area. Lastly, the value from 0.2 to 0.3 indicates a low vegetation cover and very low vegetation cover ranges from 0 to 0.2. The value that is close to zero indicates bare soil and the negative value indicates rocks and water bodies.

The value of DVI range is between 0.2588 to -0.021. The value closes to zero, indicate bare soil and the negative value indicate rocks and water bodies. The value above 0.116 is for very high vegetation cover. The value 0.116 to 0.098 indicates a high vegetation cover; the value of 0.098 indicates 0.076 medium vegetation cover and less than this indicates low and very low vegetation cover. There is difficulty in the classification of low and very low vegetation cover and the value of DVI indicating FCOVER based classification, doesn’t properly matched in all classes.

The range of RVI obtained is 0.9 to 0.72. The value that is greater than 0.395 indicates a very high vegetation cover. The value ranges from 3 to 3.95 indicates a high vegetation cover. The value ranges from 2 to 3 comprises medium vegetation cover. The value ranges from 1 to 2 consists of low vegetation cover and value less than 1 indicates very low vegetation cover. The RVI is somewhat well related to FCOVER based classification than DVI.

The PSSRA value ranges from 3.6 to 0.71. The value of 2 to 3.6 indicates a very high vegetation cover. The value ranges from 1.76 to 2 indicates a high vegetation cover. The value of the PSSRA from 1.48 to 1.76 indicates a medium vegetation cover and its value from 1.199 to 1.48 indicates low and very low vegetation cover jointly, means doesn’t able to categorize them. The value less than 1.199 indicates water and rocks.

The MCARI value ranges from 0.0035 to -0.00057. The value that retrieved is very low to define any forest vegetation cover classes. However, the indication is brought by effort to examine the forest vegetation classes in its smallest value. The value that ranges from 0.0007 to 0.0035 is the high vegetation cover area. The value ranges from 0.00044 to 0.0007 is the high vegetation cover. The value that ranges from 0.00018 to 0.00044 is the medium vegetation cover area. Lastly, the value that ranges from -0.000057 to 0.00018 indicates both low and very low vegetation cover areas jointly, means relationship of MCARI and vegetation cover is uncertain at these values to indicate classes properly.
The value of IRECl ranges from 0.51 to -0.042. The value that ranges from 0.1413 to 0.514 indicates higher vegetation cover area. The value ranges from 0.1077 to 0.14 is the high vegetation cover. The value that ranges from 0.074 to 0.1077 is the medium vegetation cover area. Lastly, the value that ranges from 0.007 to 0.074 indicates both low and very low vegetation cover areas jointly that is from difficulties in classification. The value that is close to zero indicates bare soil and the negative value indicates rocks and water bodies.

This analysis shows that they don’t totally good match with the vegetation cover types and these indices at a certain range show just an indication of vegetation types. However, NDVI, RVI and PSSRA show some potential in the classification that more relates to vegetation classification.

**Figure 8:** Scatter plot matrix for regression analysis of FCOVER with VIs; a) FCOVER vs NDVI, (b) FCOVER vs MCARI, (c) FCOVER vs IRECl, (d) FCOVER vs PSSRA, (e) FCOVER vs RVI and FCOVER vs DVI.
3.4. Regression Analysis

It is necessary to analyze the relationship of FCOVER with vegetation indices because the indices can be helpful for the estimation of forest biophysical variables indirectly, therefore helps in forest monitoring. Theoretical analysis and field study shows that the FCOVER is related to Vegetation indices. In Figure 8, the scatter plot is given which gives the relationship between various vegetation indices with the FCOVER. The regression analysis by using the scatter plot was done to observe the relationship of vegetation indices with FCOVER. The high relationship was found between FCOVER and PSSRA ($R^2 = 68\%$) followed by NDVI ($R^2 = 66\%$) and RVI ($R^2 = 65\%$). The low relationship was found in the relation of FCOVER and MCARI ($R^2 = 36.7\%$) followed by DVI ($R^2 = 53.7\%$) and IREC1 ($R^2 = 59\%$). The detail of the relationship between FCOVER and VIs is given (table4). The PSSRA, NDVI and RVI shows greater response toward FCOVER. Therefore, they show potential in forest monitoring activities.

| Y         | X   | Regression equation  | $R^2$ |
|-----------|-----|----------------------|-------|
| FCOVER    | NDVI| -0.05 + 0.41X        | 66.07%|
| FCOVER    | MCARI| 0.06 + 161.2X       | 36.7% |
| FCOVER    | IREC1| -0.02 + 1.41X       | 59.01%|
| FCOVER    | PSSRA| -0.2 + 0.19X        | 68.02%|
| FCOVER    | RVI  | -0.04 + 0.06X       | 65.26%|
| FCOVER    | DVI  | -0.09 + 2.35X       | 53.7% |

4. Conclusion

The present work uses FCOVER analysis to find the response of vegetation indices for vegetation cover monitoring; it is accurate and reliable because of its utilization and processes are easy to implement. In the study area, the lower level of FCOVER shows the condition of the forest is not good. FCOVER based classification of forest vegetation proved to be useful in defining several classes of forest vegetation cover. It requires less ground truth information for accuracy assessment. However, validation was done by the help of the FCC and Google imagery to observe the correctness of the obtained classification and found satisfactory. The overall accuracy was observed 95.65% with a kappa coefficient of 0.94.

The estimation of FCOVER works on pre-trained neural PROSAIL model which was pre-tested and proved to be efficient in a monitoring fraction of vegetation cover (FCOVER) in the forest.

The response of vegetation indices toward the vegetation cover was examined through the use of comparing the pixel value of classified vegetation cover types to VIs and from regression analysis of FCOVER and VIs. The FCOVER and VIs show positive and linear relationships among them, but NDVI and PSSRA show the high relationship both by observing the thresholds of VIs in vegetation cover and from regression analysis. The result indicates that NDVI, RVI and some PSSRA value ranges closely related to FCOVER based classification of forest vegetation cover. The NDVI, PSSRA and RVI can be used for monitoring forest vegetation and their quantifications.

The result reveals that the regression analysis and adopted thresholding of vegetation indices proves to be useful in the selection of potential indices for forest vegetation monitoring.
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