

Plant Species Diversity Index Mapping using Sentinel-2 Satellite Imagery in Western Part of Pathanamthitta District

Prithivi K¹, Nikhil P² and Radhakrishnan T³

¹Indian Institute of Information Technology and Management - Kerala, Thiruvananthapuram, India
Email: Prithivi.k@iiitm.ac.in

²⁻³Digital University of Kerala, Thiruvananthapuram, India Email: {Nikhil.p, rkrishna}@duk.ac.in

Abstract—Plant species and its diversity significantly influence the spectral reflectance of vegetation. Shannon diversity values of 84 sacred groves are located in the Pathanamthitta district is derived with Sentinel-2 satellite image using a validated biodivMapR algorithm. Sacred groves are classified as low, medium, and high plant species diversity based on the estimated results. It gives that most of the sacred groves of Pathanamthitta district belongs to high diversity classification. A patchwork of different crops on diverse surfaces has significantly more spectral diversity than a single surface type.

Index Terms— Sacred groves, Shannon diversity index, BiodivMapR, Principal component analysis.

I. INTRODUCTION

Since the 1990s, there has been an international acknowledgment of the importance of protecting natural capital and slowing the rapidly declining biodiversity seen over the previous 50 years [1]. The nature of plant species and species diversity are the biotic characteristics that largely determine the spectral reflectance of vegetation. Sacred groves (SG) or sacred forests are conserved environments that are preserved because of the indigenous communities' religious and cultural traditions. As a result, the plant species in the SGs able to sustain a desired environment. SGs are rich in species composition and studies shows diverse range of species and their overall number of plants is higher than other forests. SGs presently have a somewhat vulnerable situation, and rising threats to plant species diversity require innovative conservation strategies. Remote sensing (RS) technology has proved to be an effective tool for landscape characterization [2]. At different ranges, from local to regional to global, medium to high resolution data are widely employed to evaluate ecosystem processes [3]. Two popular techniques based on RS technologies is used to monitor species richness. Spatial and spectral resolution of RS data makes it possible to distinguish individual species from nearby pixels during direct species monitoring, and the associations of single species can be assessed based on the individual species [4]. Indirect species monitoring primarily uses RS data to map the important environmental parameters that link to species distribution in order to broaden the monitoring scope and evaluate more species or classes [5]. The capability of earth observation techniques to assist to spatially explicit tree diversity mapping and monitoring was once again altered with the launch of the Sentinel-2 (S-2) satellite into an implementation stage starting in 2015. With a spatial resolution of up to 10 m and multispectral data with a five-day revisit cycle, S-2 offers the chance to

include temporal seasonal data in the diversity modelling process [6]. The results of these analyses have shown that based on field-derived measurement data, RS satellite imagery may accurately estimate the species diversity. One of the primary components of the diversity prediction outputs is also the methodology and modelling strategies [7]. Indirect relationships between species richness and community composition have been found in satellite studies involving canopy brightness, topography, and other remotely sensed habitat indicators [8]. A number of widely used diversity metrics, including Shannon-Weiner index, is typically employed to measure the diversity of plant species in a given area. Estimation for plant species diversity is based on spectral variation hypothesis which assess spectral heterogeneity, as the spectral values of each pixels indicated the plant species spectral properties, and separable species occupying a spectral subspace of limited size defined by their chemical and structural properties within a community [10]. Spectral space corresponding to a landscape is a combination of subspaces related to one or several species sharing similar spectral signatures, and each of these subspaces are defined using an unsupervised approach to estimate Shannon index and variations in species composition [10]. Shannon index, Simpson index, and species richness-based RS imagery models' accuracy is influenced by the spectral and spatial resolutions of satellite imaging have a significant impact on the image accuracy [2]. However, it worked with fine spatial resolution images and S-2 is best equipped to predict diversity because of its medium spatial and spectral resolution [8]. RS-based technique can be used to evaluate species diversity in large, challenging-to-reach areas where field data collection is not practicable on a timely basis [9]. It offers new gateways as a result, consistently and regularly, over vast territories with a low-cost evaluation. The objective of this study is to classify the plant species diversity values of sacred groves using sentinel satellite image.

II. STUDY AREA AND DATASETS

To predict the plant species diversity, the chosen area must be diverse in plant species and richness. Pathanamthitta is such a district in Kerala state, situated near the western ghats with its vast stretches of forests. Forests cover the district's total land area to a greater than 50% extent. Many forest patches are seen throughout the district; some of them are protected landscapes with cultural practices and belief systems. These green patches are SGs and distinct in their biological diversity. The study focused on 84 selected SGs located on the western side of the district, from 9°6' to 9°22'N and 76°39' to 76°54'E (Fig. 1), having a total area of 30,572.19 m². The sacred groves were chosen because of the field data carried out on these groves. Sree Kalleli Oorali Appooppan Kavu is a SG having the highest land area (3535.64 m²) mapped for this study. The S-2 satellite's multi-spectral instrument captures 13 spectral bands with a spatial resolution of three bands at 60 metres, six bands at 20 metres, and four bands at 10 metres. In this study, a single S-2 dataset was collected on December 10th (2019) because the field work carried out on the same time period, was retrieved via the USGS portal (<https://earthexplorer.usgs.gov/>). It is a cloud free satellite image in the winter season to estimate the plant species diversity of SGs.

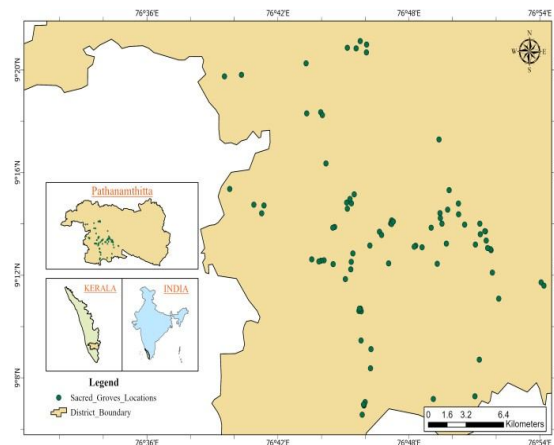


Fig. 1. Study area map of sacred groves in Pathanamthitta district

III. MATERIALS AND METHODS

Plant species diversity of SGs of an area using S-2 data is assessed through an unsupervised modeling procedure called the biodivMapR model. It was developed in R language to map diversity indicators using high-fidelity

satellite imaging spectroscopy. Estimating species diversity values based on the spatial heterogeneity of spectral information bands (spectral variation hypothesis) [8]. The biodivMapR model was tested and validated on tropical forests of the Amazon basin using a wide field study. Flow chart of the methodology is shown in Fig. 2. The downloaded S-2 images are layer stacked in the same order of bands of satellite data and clipped the raster by our study area. It is then converted into ENVI HDR format for the model requirements. BiodivMapR model installed using git repository on R studio software (1). Estimation of Shannon diversity mapping method is started with loading biodivMapR model with raster image in R studio.

`devtools::install_git('https://github.com/jbferet/biodivMapR.git')` (1)

Radiometric filtering done based on NDVI thresholding for the elimination of non-vegetated pixels and NIR thresholding used to eliminate shaded areas. Non vegetated areas are identified based on lower values of the NDVI, here we put the NDVI value as 2.5 based on the NDVI map derived before for the study area. Shaded areas are characterized by low overall reflectance. Based on the (near infra-red) NIR band information for the study area, pixels are identified below a threshold value of 1500.

The dimensionality reduction process is used to eliminate the spatial noise and sensor artifacts and pick the most useful spectral information in relation to spectral diversity. A continuum removal transformation is applied to the spectral data to suppress the effect of changes in illumination and followed by principal component analysis (PCA) to decrease spectral dimensionality [7]. PCA prepares for feature extraction to reduce noise in the image. It is performed on a random selection of pixels and PCA is computed based on this subset of pixels. Once PCA is defined for the subset, it is then applied to the entire continuum removed image [8].

Then the spectral species are defined on the selected PCA components based on the visual image interpretation techniques used on different PCA output images. Shannon diversity maps are computed from the spectral species raster to the distribution of clusters for a set of pixels defined by a window size of 2x2 pixels. The delineated boundary shape file of SGs opened on the Shannon map, and derived the Shannon diversity index for each of 84 SGs is listed.

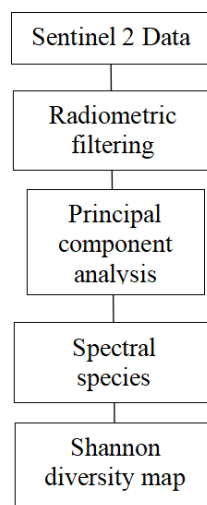


Fig. 2. Flow chart for the research methodology

IV. RESULTS AND DISCUSSION

The biodivMapR model's primary goal is to map the species diversity of vegetated regions; as a result, prior reduction of unnecessary pixels is essential to achieve the method's best results. Using radiometric filtering, non-vegetated areas are detected by applying a low NDVI threshold; pixels with NDVI values below this threshold are masked. Shaded areas identified by their lower total reflectance and removed by NIR thresholding; pixels that have NIR reflectance below this threshold are masked. Non-vegetated areas are masked out from the raster data as shows white color in the different PCA output images (Fig. 3).

When using reflectance data, a normalising method called continuum removal (CR) was provided. When applying a high spatial resolution imaging spectroscopy over tropical forests, this method removes multiplicative effects. It has proven to be reasonably effective in reducing the effect of variations in illumination within the individual tree canopies. It follows that these effects have a uniform impact on canopy reflectance across the entire spectrum and can be compared to applying a multiplicative factor to the canopy reflectance. To provide a

efficient computation for larger images, it was carried out on a randomly selected portion of the image. After doing CR, a random selection of pixels is made, and PCA is then calculated using this subset. PCA is first used for the entire continuum removed image after it had been computed for the subset. There are eight different PCA raster images created and shown in Fig 3. PCA transformation is based on computation from the covariance matrix, and the first band of PCA gives the maximum value of variations (Fig. 3). Based on the visual image interpretation over the final output of PCA images, for the estimation of species diversity values 1,2,4 and 6th bands of PCA datasets are obtained. PC selection's primary objective is to eliminate PCs that provide no relevant data related to vegetation or have artifacts that sensor characteristics could explain.

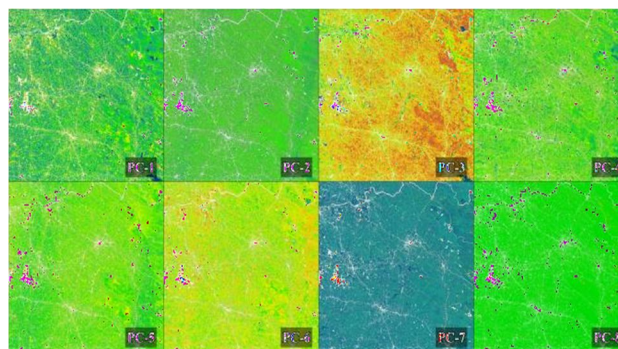


Fig. 3. Principal component images of the first eight bands of sentinel-2

The Shannon diversity index map (Fig. 4) for the Pathanamthitta area shows a range of diversity values with a maximum value is found to be 1.38. Most of the areas are highly diverse. Species diversity values between zero and 0.5 are classified as low diversity and comparatively low diversity values are found to be near or around the non-vegetated area. Species diversity values between 0.51 and 1.01 are classified as a medium diversity. Patches of medium diversity values are found on the eastern side of the map.

The lowest diversity value is found to be 0.27 for the SG named “Koyikkal Temple Kavū” and having an area of 176 sq.m. It is also the only SG found to be in low diversity. More than 80% of the selected SGs are high diversity in nature and the remaining fourteen SGs (Fig. 5) are medium diversity, values ranging from 0.51 to 1.01. A total of 72 SGs found to be greater than 1.00 Shannon diversity value. “Perumbral Kavū” is the smallest SG in the study, having an area of 10.57 sq. m. and a diversity value found to be 1.28. The largest SG having an area of 3535.64 sq.m. is found to be a 1.09 diversity value.

Most of the SGs in Pathanamthitta district is high diverse in nature, according to various field studies including the field work carried by us. Present analysis gives more than 80% of selected sacred groves are found to be high diversity in classification (Fig. 5) and validated with the results from field outputs. Species diversity of satellite derived and field studies are found relatively same.

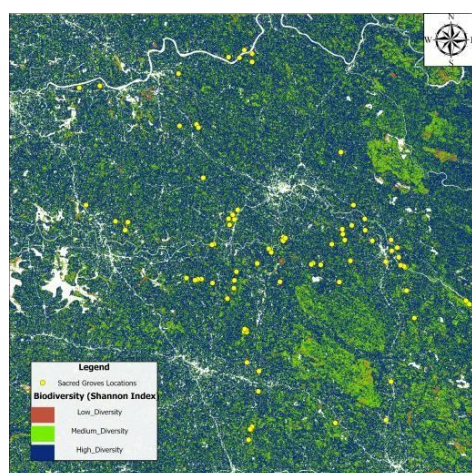


Fig. 4. Shannon diversity index map of the study area

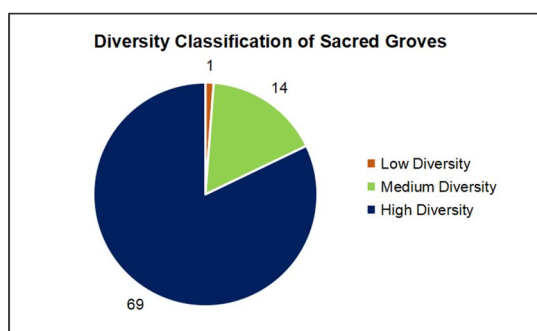


Fig. 5. Species diversity classification of sacred groves

V. CONCLUSION

Study provides a new entry point that give efficient, fast, and relatively inexpensive assessments over large areas using medium spatial resolution images with a validated mathematical algorithm for the plant species diversity classification. The biodivMapR model used in this study can also be used for complex surfaces, including diverse types such as forest, agriculture etc. Our study gives better results, but we are suggesting the use of hyper spectral satellite images for very much detailed classification. There was far more spectral diversity in a patchwork of different crops, than a single type of surface.

REFERENCES

- [1] J. Bongaarts, IPBES Summary for Policymakers of the Global Assessment Report on Biodiversity and Ecosystem Services; IPBES: Bonn, Germany, 2019.
- [2] D. Rocchini, D. S. Boyd, J. B. Féret, G. M. Foody, K. S. He, A. Lausch, N. Pettorelli, "Satellite remote sensing to monitor species diversity: Potential and pitfalls. Remote Sensing in Ecology and Conservation, vol. 2, pp. 25–36. 2016.
- [3] Chawla, A. Kumar, S. Rajkumar, R. D Singh, A. K Thukral, and P. S Ahuja, "Correlation of multispectral satellite data with plant species diversity vis-à-vis soil characteristics in a landscape of western himalayan region, India" App. Rem. Sen J., vol. 1, pp. 1-13, August 2010.
- [4] D. Rocchini, J. L. Hernández-Stefanoni, and K. S. He, "Advancing species diversity estimate by remotely sensed proxies: a conceptual review." Ecol Inf. Vol. 25, pp. 22–28. 2015.
- [5] H. Nagendra, "Using remote sensing to assess biodiversity." Int. J. Remote Sens., vol. 22, pp. 2377–2400, 2001.
- [6] I. Chrysafis, G. Korakis, A. P. Kyriazopoulos and G. Mallinis, "Predicting Tree Species Diversity Using Geodiversity and Sentinel-2 Multi-Seasonal Spectral Information" Sustainability, vol. 12, 2020.
- [7] J. B. Féret, and G. P. Asner, "Mapping tropical forest canopy diversity using high-fidelity imaging spectroscopy. Ecol. Appl. Vol. 24, pp. 1289-1296, 2014.
- [8] J. B. Féret, F. de Boissieu, "biodivMapR: An r package for α - and β -diversity mapping using remotely sensed images." Methods Ecol Evol. 2019.
- [9] S. Khare, H. Latifi and S. K. Ghosh, "Multi-scale assessment of invasive plant species diversity using Pléiades 1A, RapidEye and Landsat-8 data" Geocarto International, vol. 33, pp. 681-698, 2018.
- [10] G. P. Asner and R. E. Martin, "Airborne spectranomics: mapping canopy chemical and taxonomic diversity in tropical forests" Frontiers in Ecology and the Environment, vol. 7, pp. 269-276.