SPECTRAL ANALYSIS FOR THE SPECIES CHARACTERIZATION OF MANGROVES OF BHITARKANIKA NATIONAL PARK, ODISHA, INDIA USING HYPERSPECTRAL REMOTE SENSING

A Thesis submitted

in partial fulfillment for the Degree of

Doctor of Philosophy

by

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OCTOBER, 2016

ABSTRACT

Mangroves are salt tolerant woody halophytes usually thrives in the intertidal mudflats of tropical and subtropical coastlines. Globally mangroves are overexploited for the benefit of human needs such as conversion into aquaculture, agriculture, and logging for domestic and industrial purposes that resulted in a loss of 20% in the span of 1980 to 2005. Realizing its wide ecological and economic importance, as well as their ability to capture atmospheric carbon in the form of biomass and other associated organic matter, mangrove ecosystems are recognized as the critical habitat for protection, conservation, and management. Mapping and monitoring various dimensions of coastal zone are identified as preliminary steps for such conservation activities. For the past three decades, remote sensing technology has replaced the manual survey method and plays a major role in environmental resource monitoring and management activities from regional to micro-level. Recent advancement in remote sensing such as hyperspectral remote sensing becomes a reliable source of diversified information because of its high spectral resolution. High spectral resolution is the prerequisite for species level mapping as well as health monitoring of various natural ecosystems including mangroves.

Bhitarkanika National Park in Odisha is one of the major mangrove forests in India that covers nearly 145 sq. km and is recognized for its high species diversity. There are 76 mangrove species in which 30 are true species and 46 are associated species. This thesis aims at developing a methodological framework to spectrally characterize and map mangroves at the species level using hyperspectral remote sensing techniques.

Development of a spectral library is a prerequisite to map higher level vegetation classes using hyperspectral image analysis. Field survey is conducted in the study area to collect canopy level field spectra and leaf level laboratory spectra of 34 species (25 true and 9 associated mangroves) in the wavelength range of 400nm to 2500nm, using ASD Fieldspec® 3 spectroradiometer. Reflectance spectroscopy provides interoperable pure reflectance of feature of interest from its in-situ and laboratory measurements. The collected raw spectra are then undergone post-processing steps such as removal of water absorption bands, correction of thermal difference drifts, and smoothing of spectra for further utilization. The processed spectra are then compiled as a spectral library.

The main aim of developing such spectral database is to test their efficiency to uniquely identify the species in hyperspectral domain. Hence, the spectral data are analyzed using multiple statistical approaches followed by popular feature reduction methods such as Principal Component Analysis (PCA) and Stepwise Discriminant Analysis (SDA) to select optimal wavelengths for species discrimination. Initially, spectral signatures of eight mangrove species of *Rhizophoraceae* family are

analyzed using the proposed methodology since in earlier studies these species were reported as "less separable". First and second derivatives are derived for the reflectance spectra of eight species of *Rhizophoraceae* at first. Then spectral separability among species pairs are tested statistically using parametric and non-parametric statistical tests namely One-way Analysis of Variance along with Bonferroni post-hoc test and Kruskal Wallis test along with Mann-Whitney U test, respectively. Results show that non-parametric test provides better separability than parametric test especially in red edge (680nm to 720nm) and water absorption (around 1150nm and 1400nm) spectral regions.

To further explore the potential of hyperspectral region beyond 1400nm i.e., Short Wave Infra-Red (SWIR) region, spectral signatures in reflectance mode (RS) is transformed to (i) additive inverse of spectral reflectance (IS), (ii) continuum removal of reflectance spectra (CRRS), and (iii) continuum removal of inverse spectra (CRIS). When the four modes are analyzed using parametric and non-parametric tests, Continuum Removal of Inverse Spectra (CRIS) proposed in this study gives better result. CRIS utilizes the advantage of continuum removal in reflectance region beyond Near Infra-Red (NIR) which is often suppressed in Continuum Removal of Reflectance Spectra (CRRS). Later, PCA and SDA are performed on the transformed spectra to select optimal bands for spectral discrimination. Green (550nm), red edge (680nm to 720nm), and absorption region (1470nm and 1850nm) are found to be prominent wavelength region for species discrimination. Among *Rhizophoraceae* species, *Ceriops decandra* is found to be the most separable species.

The methodology is further extended to determine the spectral separability among all 34 species of the spectra developed in this study. To validate our results, the field and laboratory spectra of 34 species in CRRS and CRIS modes are classified using three supervised classification algorithms such as Maximum Likelihood Classification, Spectral Angle Mapper, and Support Vector Machines. Better classification accuracy is obtained using CRIS mode of field spectra and CRRS mode of laboratory spectra. This shows that CRIS has enhanced the separability in NIR and SWIR regions. Biophysical characteristics such as leaf area index, canopy structure, and leaf arrangement have potential contributions in these wavelengths when the spectra are collected in field condition rather than the simulated laboratory conditions. The same spectral transformation methodology is extended to classify the mangrove species using hyperspectral image of EO-1 Hyperion sensor.

To compare the potential of hyperspectral data, classification is also carried out using two widely used multispectral data namely Landsat-8 OLI and IRS-P6 LISS III. They are classified using ten base classifiers and their combination, the Multiple Classifier System (MCS). From the results, it is found that Support Vector Machine (SVM) algorithm gives maximum accuracy among base classifiers. Also, MCS increases the accuracy when compared to single best classifier in both multispectral images. In case of hyperspectral data (EO-1 Hyperion), it is transformed into four spectral modes mentioned earlier. The transformed images in four spectral modes are compiled together as separate dataset to utilize the complementary spectral information provided by each of the spectral modes for mangrove species classification. The transformed hyperspectral images in all five spectral modes are dimensionally reduced using three dimensionality reduction (DR) methods: Principal Component Analysis (PCA), Minimum Noise Fraction (MNF), and Independent Component Analysis (ICA). They are classified individually using ten base classifiers. On analyzing the results, MNF-SVM is identified as the best DR-Classifier combination. The decisive function values from ten base classifiers are combined to classify 11 mangrove species classes using MCS for all 5 spectral modes. Results show that among MCS results, combined spectral mode gives better accuracy (82.82%) than other four individual spectral modes.

WorldView-2 data, though it is multispectral, combination of additional narrow bands such as Yellow and Red edge bands with high spatial resolution is recently explored for biomass estimation of various tropical forests. The potential of such high resolution data is investigated to estimate biomass of heterogeneous mangrove forest in the present study area by regressing image derived parameters with plot biomass. Plot biomass is calculated from 40 stratified sample plots using species specific and common allometric equations, and field measured biophysical parameters such as tree height, diameter at breast height (DBH), etc. After preprocessing, 8 spectral reflectance bands, 28 simple band ratios, 12 vegetation indices, and 8 textural parameters for each of the preceding parameters are derived from the image and their relation with the plot biomass are investigated using multiple regression analysis. From the results, it is found that the textural parameters improve biomass estimation in simple reflectance bands and band ratios whereas in case of vegetation indices, there is no such improvement observed. When the textural parameters of all three inputs are combined and regressed, it improves the R^2 value (0.46) and reduces the error (RMSE of 169.28 t/ha) as compared with other biomass models developed in this study using different input parameters.

The potential of hyperspectral data and high resolution data are analyzed in this study to understand the spectral behavior of mangrove species and its biomass using various statistical, image transformations, and processing techniques. Hope that outcome of the study will be a stepping stone in the studies of Indian mangroves using hyperspectral and other remote sensing techniques.