DEVELOPING HYPERSPECTRAL SIGNATURES FOR TROPICAL TREE SPECIES GROWING IN SHOOLPANESHWAR WILDLIFE SANCTUARY, GUJARAT, INDIA

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Forests, one of the most important features in natural resources are fundamental to the healthy functioning of the biosphere and the main depositors of biodiversity. They are renewable, natural and valuable ecological resources of earth. Forests maintain ecological balance by providing environmental stability, carbon sequestration, soil moisture and conservation which is vital for preserving life supporting system of the globe. In an era of global concern about the sources and sinks of greenhouse gases, forests are seen as an important biome in the health of the planet. Forests are an important repository of carbon, an attribute that can be determined from knowledge of forest biomass. Multiple-use of forestry is aimed at achieving an appropriate balance between the various needs of society. Any interruption to this ecological balance brings the unimaginable miseries to life on earth. With regard to climate change, increases in global temperature and global land precipitation have been documented, both of which are expressed in spatial and temporal variations. Climate change is likely to cause increasing forest damage and tree mortality from direct and indirect causes.

Among different types of forests, tropical forests constitute about half of the world's forests and which are mostly occurring in developing country like India, Brazil, Burma, and Srilanka. Tropical forests cover approximately 17% of the terrestrial biosphere, yet they account for an essential 43% of global net primary productivity (NPP) and 27% of the carbon stored in forest soils. Tropical tree biomass represents major pool of terrestrial carbon. They harbor globally significant amounts of carbon both in the vegetation and in the soil, and they annually process vast amounts of carbon in photosynthesis and respiration. Changes in tropical forest carbon cycling can therefore affect the pace of climate change. One recent global scale study concluded that climate-change effects on tropical forests over the next 50 years may pose as much risk to species survival as deforestation. Hence there is a growing interest in quantifying habitat characteristics such as forest structure, floristic composition and plant species richness in intact and degraded forest fragments and forest landscapes.

India is the second most populous and the seventh largest country in the world. India is rich in biodiversity which possesses a rich flora of flowering plants (17,000 species) with a high degree of endemics (33.5%). India is one of the 12 mega diversity countries of the world. 12% of the world's recorded flora and about 7.3% of the world's recorded faunal species are in the Indian subcontinent. The increasing requirements of timber, estimated at 68,857 m tonnes in 1980, would rise to 181,270 m tonnes by 2025, is yet another area of concern. Further a lot of spatial and temporal variation in the values of species richness, composition and productivity. Hence the ecological status and the production capacity of these forests could not keep pace with exponential growth rate of human and livestock population and their requirements.

Monitoring changes in forest cover for efficient management has become an important aspect for forest department. Sustainable planning and management of forests requires vital information about forest resources, mapping and monitoring of existing natural resources and forecasting the future scenarios. The vegetation maps are the key for any planning, such as protected area management, sustainable development, social forestry, agroforestry, development without destruction, ecodevelopment, etc. This data can be obtained through monitoring, although access limitations may make the cost of direct monitoring prohibitive. Added to this our understanding for monitoring, conservation and management of tropical forests is greatly hindered by a lack of spatially and temporally extensive information of tree floristic composition, species richness and structure. There is an urgent need to develop a reliable database for forest cover of India. With remote sensing technology, one can produce independent and up to date estimates of both forest cover and cover change.

Remote sensing is a key tool for assessing vegetation condition periodically over larger areas, offering the possibility to analyze ecological issues at a wide range of spatial scales. Remotely sensed data also can be used as inputs in ecosystem models that are used to assess functional changes brought by climate variability and land use change. In addition to change measurements, remote sensing observations can be useful in revealing gradients in vegetation cover that can be further shown in relation to precipitation, groundwater, or edaphic factors across the landscape. It can be said that the remote sensing with broad band multi-spectral and multi-temporal data collection systems allows one to perform the work for different forest attributes more quickly and effectively. Multispectral imagery has demonstrated its strength in discriminating and mapping physical vegetation variables (biomass, LAI, cover) and in monitoring vegetation condition which has opened up new opportunities for conservation and sustainable use of forest resources. A major limitation of traditional broadband remote sensing products is that they use average spectral information over broadband widths resulting in loss of critical information available in specific narrowbands. In this process, narrow spectral features are lost or masked by other stronger features surrounding them. This makes them unable to explain a large proportion of the variability present in spectral reflectance of vegetation.

Plant species is the main building block of almost all ecosystems, and sustainable management of any ecosystem requires a comprehensive understanding of species composition and distribution. To reveal species composition and distribution by using remotely sensed data, species-level discrimination of plants is essential, which in turn can make it viable to recognize the succession process of the ecosystem. The importance of species-specific ecological interactions and potential consequences of changes in species distributions, reliable methods for remote sensing of forest composition at the species level would be a significant advancement towards understanding present dynamics. Given the additional spectral detail provided by imaging spectrometers, hyperspectral remote sensing has emerged as a potentially useful approach for distinguishing composition at the species level.

Hyperspectral imaging/Imaging spectroscopy is the study of the interaction between radiation and matter. Hyperspectral imaging/Imaging spectroscopy can best be described as a system that collects and provides a unique reflectance signature of many materials reflecting electromagnetic energy from the surface of the Earth in hundreds of bands with 10nm bandwidth. It is reported that the Hyperspectral images are spectrally over determined and so they provide ample spectral information to identify and distinguish spectrally unique materials. Hyperspectral imaging is a technology based on the phenomenon of electromagnetic spectrum and its underlying principles. Most natural objects have unique spectral signatures that distinguish them from others and many of these signatures occur in a very narrow wavelength region. The concept of Hyperspectral remote sensing has been used to detect and map a wide variety of materials having characteristic reflectance spectra. Vegetation analysts are using hyperspectral imagery to identify species, to study plant canopy chemistry and to detect vegetation stress. Hyperspectral images have a definite advantage over the conventional systems as they are capable of separating bare soil surfaces from senescent vegetation. They can also analyse biophysical and chemical information that is directly related to the quality of wildfire fuels, including fuel type, fuel moisture, green live biomass and fuel condition.

Vegetation reflectance spectra are often quite informative, containing information in the visible region, NIR (Near Infra Red) region, and in the MIR (Middle Infra Red) region of the electromagnetic spectrum. As ecological studies require the quantification of biochemical and biophysical attributes, the high spectral resolution of hyperspectral data is vital for yielding quality information about vegetation health, biomass and other physico-chemical properties. Moreover, hyperspectral data have made it possible to measure more accurately both the quantity and particularly the quality of the vegetation. The species can either be determined by the tree crown shape and size, or the crown can be classified using the digital counts of its spectral reflectance to determine which species it is. Many studies reported within species and among species variability due to difference in the pigment concentration, microclimates, soil characteristics, topography, stress factors such as air pollution, drought, foliage age and canopy position.

Almost all studies utilizing hyperspectral data require some form of data analysis techniques which are as follows:

- Reduction of data dimensionality
- Class separability
- Types of classifier/matching algorithm

Other ways of matching different spectra include distance functions, which calculate the relative fit of one spectrum vs. a reference spectrum and maximum likelihood classifiers (Supervised classification). Correspondingly classification algorithms such as ML (Maximum Likelihood), SAM (Spectral Angle Mapper), SCM (Spectral Correlation Mapper) and LDA (Linear Discriminant Analysis) have been optimized for distinguishing trees in temperate forests and also in tropical forests using airborne hyperspectral data. major advances in remote sensing research of boreal and temperate ecosystems, research on tropical systems currently is lacking the fundamental scientific understanding and potential for routine applications observed in other parts of the globe. This gap is due in part to the complexity of tropical forest ecosystems. Tropical vegetation has unique features as compared to temperate vegetation. Besides having larger diversity, the vegetal cover is not as uniform as is normally seen in temperate region. This makes the discrimination process more challenging. the current study was undertaken to look into the utility aspect of space-borne hyper data for spectral reflectance characteristics and species level classification of trees growing in a sanctuary in Gujarat, India.

To develop spectral signatures for selected/dominant tree species

To describe distinct absorption and reflectance pattern in the vegetation spectra of dry and post wet season imagery by applying continuum removal spectra

To look at within species variation based on size and topography

To look at the importance of uniformity/homogeneity in patch size & phenology of vegetal cover in affective accuracy assessment for wet and dry season data.

To highlight the potential of Hyperion data in deciphering floor cover characteristics from soil in dry season.

The study area, Shoolpaneshwar wildlife sanctuary (SWS), surveyed during the present research is situated in the hilly ranges of Narmada district in South Gujarat, INDIA. The SWS is an extension of old Dumkhal sloth Bear sanctuary falling in Dediapada and Nandod taluka of Narmada district. The forest ranges are Piplod, Sagai, Fulsar, Gora and Dediapada which covers an area of 675 sq. km. Latitude and longitude of the study area is 21^0 29'N - 21^0 52'N and 73^0 29'E - 73^0 54'E respectively.

Satellite path was selected to cover maximum area of the sanctuary with distinct features. This path represents the maximum vegetal cover with different levels of human disturbance compared to other areas of the sanctuary. On April 03, 2006 and on October 21, 2006, EO-1 (USGS, USA) collected hyperspectral data. These dates were selected to demarcate the vegetation by phenology. Selected dates reflect seasonal variability in the data sets. At the time of the satellite flight, the study area was showing < 25% cloud cover. In the month of April (dry season), vegetation was in different stages of senescence whereas in the month of October (wet season), vegetation was lush green due to seasonal change. Summer/Dry month (April) imagery is also useful to discriminate dry deciduous forest floor cover where litter acts as a load factor for forest fire. The study area has a total of 127 tree species. Selection of study species was done based on purity (% area occupancy) and density. This helped to focus present study on 7 tree species for which there were sufficient recordable individuals on ground. Selected 7 tree species represented both deciduous and evergreen types.

Atmospheric correction of satellite data is a major step in the retrieval of surface reflective properties. It involves removal of the effect of gaseous absorption as well as correcting for the effect of path radiance. In this study atmospheric correction was carried out using ACORN 1.5 pb for both the data sets. Atmospheric correction was done on 196 bands after excluding non-calibrated and over-lapped 46 bands. MNF transformation was applied to determine the presence of cross-track spectral smile, which appeared as a brightness gradient in visible near infrared bands. Destreaking was also applied to minimize the striping artifacts normally found in Hyperion data. The reflectance spectra so derived were compared with raw-data spectra.

Field visits were made to collect information on homogenous patches, including cover type, locality, slope, and signs of disturbance. Global positioning systems (GPS) (Magellan & Leica) have been used to collect Latitude /Longitude. Selected plot of the study area (128 sq km) was criss-crossed to locate homogenous cover of species. Like in any tropical area heterogeneity in species distribution is unique to the study area. Size of each quadrat laid down was 30mX30m. Phytosociological data such as dbh (diameter breast height), height, density, and spread of canopy were recorded from each quadrat. Distance between quadrats was dependent on the type and distribution of vegetal cover, non target area. The patchiness in the distribution of tree cover was an unique feature of the study area. This was major limitation for obtaining pure spectral signatures for most of the species. A total of 146 quadrats were established for species level discrimination. In forest floor study three major cover types were identified as *Tectona*, *Dendrocalamus* and other mixed dry deciduous species. Few spots of bare soil were also taken for discrimination. Selected plots were spread across an area of 112 hectares. A total of 77 observations were collected for 3 types of leaf litter cover and one of bare soil. Leaf litter thickness was recorded.

The study shows the importance of Hyperspectral data in understanding vegetation characteristics at species level. Hyperspectral imagery gave a better view to look into the differences of tropical forest vegetation. Tropical vegetation has unique features as compared to coniferous. Besides having larger diversity, the vegetal cover is not as uniform as is normally seen in coniferous. This makes the discrimination process more challenging. This study shows the advantages of using hyperspectral data of two different dates coming from different seasons. It reveals the usefulness of NASA's EO-I Hyperion data at species level discrimination of tropical vegetation at Shoolpaneshwar Wildlife Sanctuary (Gujarat, India) during dry season as well as at post wet season.

Typical vegetation signal pattern is seen in post wet season where the tree species have showed pronounced chlorophyll absorption at 680nm, maximum reflectance at NIR and low ligno-cellulose absorption in SWIR region, while in dry season species with different phenological conditions showed decreased chlorophyll absorption and increased ligno-cellulose absorption. This study concludes that phenological variation, size of canopy together with biochemical constituents alter the leaf reflectance. Species with different phenological conditions show different spectral signatures. Differences in leaf optical properties due to seasonality (wet/dry cycles) could be either beneficial or confusing to tree species identification. Temporal phenomena such as flowering, leaf flush, or senescence could also be looked into for developing spectral signatures.

Study reaffirms the findings of earlier scientists where tree species showed distinct absorption features in VIS region and reflectance features in SWIR-I & SWIR-II region of the continuum removal spectra. Continuum removal spectra clearly showed the pronounced biochemical features in dry condition using Hyperion data. In this study the continuum removed spectra showed several distinguishable absorption features in two different data sets. Study concludes that there is a considerable variation in the depth of absorption features which are likely due to differences in the chlorophyll concentration between selected species. Chlorophyll absorption features are stronger in wet season.

Variations in the reflectance values of *Tectona* due to physiognomy of trees and also for topographic change were recorded. Different stages of senescence in dry season are responsible for larger variations in different girth classes of *Tectona* as compared to post wet season. This indicates the usefulness of Hyperion data in discriminating a tree species based on their size. ANOVA performed showed that the differences seen amongst reflectance spectra of different girth classes are significant (α=.01) for both the data sets. There is a negative correlation between girth of the *Tectona* tree and corresponding reflectance spectra from dry season imagery whereas there is a positive correlation in post wet season imagery.

The study shows how to obtain a Descriptive spectrum from multiple observations of the same species. By comparing the Descriptive spectra of selected tree species using ANOVA and Distance measurements (D & θ) it is concluded that Hyperion data is useful for species level discrimination. Spectra were influenced by the phenological condition of the species. Red-edge position (REP) was calculated for all 7 species using linear-four point interpolation method to estimate phenological sensitivity. REP values are different for deciduous and evergreen species. First derivative spectra were used to select best bands for species level classification. The three bands selected for classification came from red edge region (701nm) and from SWIR region (1386nm, 1739nm). Reflectance data of these three bands was further used for species level classification of area of interest. A maximum likelihood algorithm with specific probability values for each species was used for classification. The resultant Hyperion map showed an overall accuracy of 60.7% and a Kappa statistic of 0.57. The results demonstrate that differences in phenological state may enhance the spectral separability of species in dry deciduous tropical forest. This study clearly shows the usefulness of Hyperion data at species level classification of tropical vegetation during dry/summer season. REP values showed the influence of phenological variations in the red-edge region. The results indicate importance of derivative spectra in picking up the best bands for species discrimination. The study is useful for effective management of tropical forest in fast developing countries.

Present study highlights the use of post wet season imagery to discriminate tropical tree species. Study shows the importance of Spectral Angle Mapper (SAM) to evaluate the spectral similarity of image spectra to the reference spectra. The study accentuates the use of Hyperion to classify tropical trees based on entire spectrum, spectrum partition analysis and spectra from MNF (Minimum Noise Fraction) bands using SAM (Spectral Angle Mapper) algorithm. MNF transformation followed by PPI enabled better endmember detection. SAM classification with 196bands (full-spectra) of Hyperion data gave 51% OAA for the 5 tropical trees selected. Obtained OAA is fairly-valued looking at the pattern of vegetal cover and also of the sensor used. Partition analysis of the spectrum indicated superiority of VIS-NIR region for classification. VIS-NIR region of spectra is more appropriate for classifying tropical trees with thick canopy. SWIR-I & II did not fare well because of the biophysical state of vegetal cover. Spectra from MNF bands equally did better in feature extraction. With the reported densities for *Tectona* and *Dendrocalamus*, Hyperion is found to be an appropriate sensor for monitoring. Results showed that the higher accuracy using MNF band combination indicated the potential of MNF transformation to increase classification accuracy of tropical trees by reducing data dimensionality. Present study highlights the importance of Homogeneity of vegetal cover as a critical aspect for classification in tropical areas. This study concludes that SAM is an appropriate method for classifying Hyperion data of tropics. It would be beneficial for forest managers in mensuration studies, monitoring and management.

A study was conducted to analyze high spectral reflectance data of floor cover of dry deciduous forest (Shoolpaneshwar wildlife sanctuary, Gujarat, India) during summer season. Variations in spectral characteristics of different types of leaf litter were seen. Spectral reflectance curves were different for different thicknesses of leaf litter. Altitude also had an impact on the reflectance curves. Spectra of bare soil is easily separable from the ones covered by litter. Descriptive spectra were extracted for 4 cover types such as *Tectona*, *Dendrocalamus*, mixed deciduous species and bare soil. Continuum removal spectra also were extracted for these 4 types. Sharp absorption features were seen in VIS and SWIR-II wavelengths which were absent in the spectra of bare soil, indicating the ability of Hyperion data to discriminate dry forest floor from bare soil. The three cover types also are distinctly separable. SWIR-II wavelengths are more sensitive to the type of floor cover indicating its distinctiveness. Results are discussed highlighting the potential of Hyperion data in deciphering floor cover characteristics in dry season.Using this forest department can easily monitor changes in litter load on the forest floor. This is to evaluate the potential of forest fire occurrence largely due to dry deciduous vegetation. This helps in developing a prewarning system for the prevention of forest fire. This is a very encouraging result, because it is difficult to distinguish dry vegetation and soil where dry vegetation is a critical component of fuel. This indicates that Hyperion data can be useful to discriminate floor cover types in dry season. This kind of information is very useful for forest fire studies where dry cover plays a major role.

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