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Analysis of Continuum Removed Hyper Spectral Reflectance Data of Capsicum Annum of Ground Truth Data

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Abstract

Recent studies have demonstrated the usefulness of optical indices from hyperspectral remote sensing in the assessment of vegetation biophysical variables both in forestry and agriculture. The spectral reflectance of the species varies at different stages of their growth. As the species differ the spectral reflectance also differs along with age and other different parameters which affect the reflectance values of the crop. In this study the spectral reflectance data collected at sri konda laxman Telangana state horticulture university Hyderabad, for the crop Capsicum annum at different stages of growth is analyzed using the continuum removal in the software ENVI (ENvironment for Visualizing Images), for analyzing the different of the reflectance values at different stages of growth of the species which is because of the difference in the amount of the chlorophyll and the pigment present in the species. In the continuum removed graph, at 410 nm the chlorophyll reflection is observed, 550nm a peak of reflection is observed due to Beta carotenoid, 760-940 nm dip is observed due to the presence of anthrocyanins. Thus using the reflectance library the stage of the species can be explored.

Keywords: Capsicum annum, spectroradiometer, continuum removal, hyperspectral remote sensing, chlorophyll, pigments, ENVI.

1. INTRODUCTION:

More specifically hyperspectral Remote Sensing, originally used for detecting and mapping minerals, is increasingly needed for to characterize, model, classify, and map agricultural crops and natural vegetation, specifically in study of species composition, vegetation or crop type, biophysical properties, biochemical properties, disease and stress, nutrients, moisture, light use efficiency, net primary productivity and so on, in order to increase accuracies and reduce uncertainties in these parameters the hyperspectral remote sensing data can be used. Hyper spectral data consists of hundreds or thousands of narrow-wave bands along the electromagnetic spectrum. It is important to have narrow bands that are contiguous for strict definition of hyperspectral data and not so much the number of bands alone. Hyperspectral data is fast emerging to provide practical solutions in characterizing, quantifying, modeling, and mapping natural vegetation and agricultural crops. The advantage of airborne, ground based and truck mounted sensors are that enable relatively cloud free acquisitions that can be acquired on demand anywhere. Hyperspectral narrow bands when compared with broad band's data can significantly improve in, discriminating or separating vegetation and crop types and their species, explaining greater variability in modeling vegetation and crop biophysical, yield, and biochemical characteristics, Increasing accuracies (reducing errors and uncertainties) in vegetation\land cover classification. Enabling the study of specific biophysical and biochemical properties from specific targeted portion of the spectrum. About 33 narrow bands, in 400-2500 nm, provide optimal information in vegetation studies. A nominal 3 to 5 nm wide bandwidth is recommended for all wavebands. In this study for the development of the spectral signatures the plant species of green chilies (Capsicum annum) is considered which is grown in Sri Konda Laxman Telangana State Horticultural University, Rajendranagar, Hyderabad, Telangana State, India.

2. REVIEW OF LITERATURE

Remote sensing technologies offer synoptic data to reduce the inherent sampling limitations of traditional ground-based methods and have the advantage of contributing information to a variety of closure criteria. Closure criteria are often site specific, but general measures, such as the creation of a stable land surface free of excessive soil erosion or sedimentation, botanical succession, low maintenance vegetation that 'blends in' with the surrounding environment, and a post-mining landscape that is non polluting, are common rehabilitation objectives that can be assessed over the mining lease with remotely sensed data.

According to Langley et al. 2001; Nordberg and Evertson 2003 the technology of remote sensing offers a practical and economical means to study vegetation cover changes, especially over large areas. Because of the potential capacity for systematic observations at various scales, remote sensing technology extends possible data archives from present time to over several decades back.

To obtain data of a higher spectral resolution compared to multispectral data, hyperspectral sensors on board satellites or airborne hyperspectral imagers are used (Smith, 2001b).Multispectral remote sensing systems use parallel sensor arrays that detect radiation in a small number of broad wavelength bands. According to Smith (2001a), most multispectral satellite systems measure between three and six spectral bands within the visible to middle infrared region of the electromagnetic spectrum. Multispectral remote sensing allows for the discrimination of different types of vegetation, rocks and soils, clear and turbid water, and selected man-made materials (Smith, 2001a).

Spectral reflectance is a ratio of the reflected energy to incident energy as a function of wavelength (Smith, 2001b). The graph of the spectral reflectance of an object as a function of wavelength is termed the spectral reflectance curve (Lillesand and Kiefer, 1999). The spectral reflectance signature illustrates a dramatic increase in the reflection for healthy vegetation at around 700 nm. In the NIR between 700 and 1300 nm, a plant leaf will typically reflect between 40 to 50%, the rest is transmitted, with only about 5% being adsorbed. Structural variability in leaves in this range allows one to differentiate between species, even though they might look the same in the visible region (Lillesand and Kiefer, 1999). Beyond 1300 nm the incident energy upon the vegetation is largely absorbed or reflected with very little transmittance of energy. Three strong water absorption bands are noted at 1400, 1900 and 2700 nm.

The spectral curve for bare soil shows far less variation in reflectance compared to that of green vegetation. This is due to the factors that affect soil reflectance acting over less specific spectral bands. Factors that affect soil reflectance include moisture content, soil texture, surface roughness, presence of iron oxide, and organic matter content. The factors that influence soil reflectance are complex, variable and interrelated (Lillesand and Kiefer, 1999)

Schlerf et al. (2005) investigated several narrow band and broad band vegetation indices in order to explore whether hyperspectral data may improve the estimation of biophysical variables such as LAI, canopy crown and crown volume when compared to multispectral analyses. Remote sensing data have been exploited to estimate canopy characteristics by using empirical approaches based on spectral indices (D'Urso et al., 2004; Schlerf et al., 2005). Analysis of hyperspectral remote sensing data has been carried out to estimate LAI for agricultural crops and forests

Several studies have derived band ratios or spectral indices which are useful for emphasizing certain physiological features, and can be used to distinguish between different vegetation within a mosaic of other land uses (Mc.Gwire et al., 2000; Underwood et al., 2003; Yamano et al., 2003; Galvao et al., 2005). Commonly used indices include normalized difference vegetation index, soil-adjusted vegetation index, and modified soil adjusted vegetation index (McGwire et al., 2000). Vegetation indices are also used to mask out vegetated areas from remote sensed imagery which are then used in the classification process (Underwood et al., 2003; Yamano et al., 2003; Koch et al., 2005). Similarly, principal component analysis (PCA) has been applied as a data enhancement method when analyzing remote sensing images to distinguish between vegetated and non-vegetation areas (Castro-Esau et al., 2004). These techniques facilitate the classification of vegetated areas, especially over large spatial scales where the landscape is unknown.

3. METHODOLOGY

The spectral signatures of C.annum is collected using the spectroradiometer and processed in ENVI software for the removal of continuum for the analysis of the spectral library is explain as below.

3.1 Collection of Ground truth data:

The ground truth data is collected for the species of capsicum annum, using the portable SVC HR-512i spectroradiometer which consists of the 512 bands and produces a hyperspectral signature of the object. Using this instrument the spectral signatures of the C.annum grown in Sri Konda Laxman horticultural university Rajendranagar Hyderabad, is collected at different stages of its growth and the libraries are developed at different stages.

Capsicum annuum is a species of the plant genus Capsicum native to southern North America and northern South America. This species is the most common and extensively cultivated of the five domesticated capsicums. The species encompasses a wide variety of shapes and sizes of peppers, both mild and hot. It is an attractive, upright shrub usually less than 1 m tall, with small, white, pendent flowers and elongated, yellow, orange or red fruits. It can be distinguished from other types of domesticated peppers by flowers that are solitary rather than in groups, and filaments that are not purple. The varieties and cultivars of Capsicum annuum are classified on the basis of their fruit shapes. The average life of a flower after the opening is 2-3 days, then attaches and become fruit or dries up and falls off. Flower drop is normal, especially with the high summer temperatures which may affect fruit set. An optimal temperature would be: 25°C daytime and night of 18°C. However, not all plants are the same, in general, the C. annuum better withstand the heat and attach more easily. The ground truth data collected on 6^{th} August, 16^{th} September, 4^{th} October, 14^{th} October, 22^{nd} October, 28^{th} October and 29^{th} November 2016 is used to analyze the spectral properties of the plant at different stages of its growth which shows the different stages of growth of the plant. The initial stage to the harvesting stage the spectral signature collected is analyzed.

3.2 Development of continuum removed spectral signatures:

After re-sampling the collected spectral signatures of the plant at different stages of growth, the spectral libraries are generated, and the continuum removed spectral signatures are developed in the ENVI software. For quantification of absorption features in spectra the overall concave shape of a spectrum should be removed. This normalization procedure is referred to continuum removal or convex-hull transform and allows comparison of spectra that are acquired by different instruments or under different light conditions. The continuum is a convex hull fit over the top of a spectrum using straight-line segments that connect local spectra maxima. The first and last spectral data values are on the hull; therefore, the first and last bands in the output continuum removed data file are equal to 1.0. The formula representing the continuum equation is as shown in equation 1.

$$S_{cr} = S / C \qquad \ldots (1)$$

S_{cr} = Continuum removed spectra

S = Original spectrum

C = Continuum curve

The resulting image spectrum is equal to 1.0 where the continuum and the spectra match, and less than 1.0 where absorption features occur. The resulting spectrum is analyzed for changes in the chlorophyll at different stages of the growth.

4. RESULTS AND DISCUSSIONS

The spectral signatures which are collected at the different stages of growth of the C.annum are analyzed in ENVI software. The Leaf reflectance in the visible spectrum is dominated by absorption features created by plant pigments, such as chlorophyll-a which is absorbed 410 -430 nm and 600 -690 nm, chlorophyll-b absorption is at 450-470 nm, carotenoid (e.g., β-carotene and lutein) peak absorption in wavebands less than 500 nm, anthrocyanins, lignin cellulose and protein have relatively low reflectance and strong absorption in SWIR bands. However, dry leaves do not have strong water absorption and reveal overlapping absorptions by carbon compounds, such as lignin and cellulose and other plant biochemical's, including protein nitrogen, starch, and sugars.

The reflectance collected in the initial stage of the growth of the C.annum the spectral library is generated. It is observed that the reflectance of the species showed the characteristics of the black soil with high moisture content. The C.annum reflectance is observed with the mixed reflection of the vegetation and the soil. This is because during the collection of the spectral signature during the initial growth i.e after transplantation the plant is flooded in water and during the collection the spectra the soil and the moisture content of the soil affected the reflectance of the species. This is shown in Figure 1 (a) which shows the reflectance of the soil and the species, Figure 1(b) shows the picture of the plant during the collection of the reflectance after transplantation.

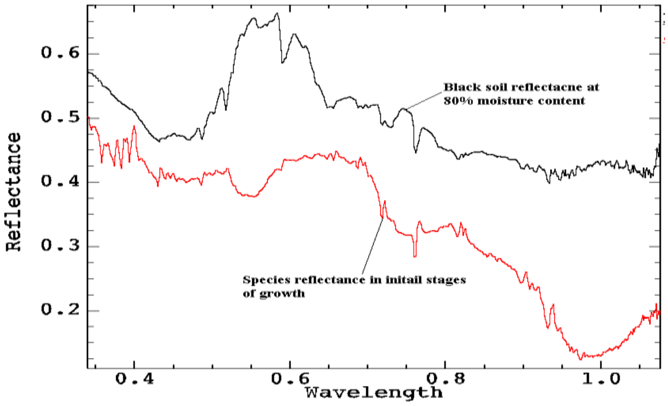

Figure 1: (a) Reflectance of the species in initial stages and black soil reflectance

Figure 1: (b) Plant in initial stage, flooded in water

After the initial stages of the growth, i.e. the flowering and the fruiting stages at low moisture conditions the reflectance of the species showed purely the vegetation characteristics. In which it was observed that the peaks and the troughs are observed at specific wave lengths.

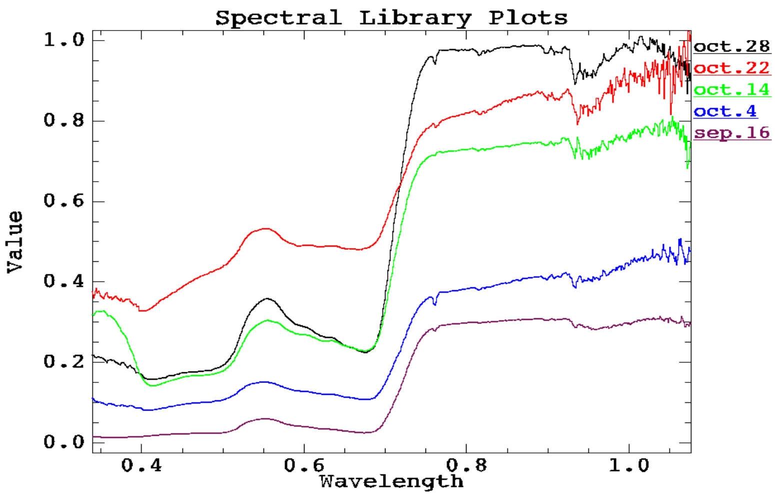

Figure 2: Spectral signatures of C.annum at different stages of the growth.

Figure 2 shows the reflectance of the species at different stages of the plant growth in which the gradual increase of the reflectance can be observed as the growth increases but the reflection shows some differences at certain stages. A trough and the peak can be seen in all the reflectance values at 410nm which purely indicates the chlorophyll a content in the plant. The reflectance on 16th September and the 4th October shows the slight increase in the reflectance values where in the reflectance collected on 14th October, 22nd October, 28th October shows the gradual increase of the reflectance which indicates the high content of the chlorophyll.

A sharp peak can be observed at the 550nm, which clearly explains the reflection due to beta carotenoids in the leaf content. The peak between 700-740 nm is the red edge, which locates between the strong chlorophyll absorption in the red and scattering in the NIR region. The reflection in the red edge region is different at the different stages of the growth of the species.

The sudden dip at 760 nm and 940 nm shows the absorption bands which is because of the anthrocyanins which are present in the leaf. All the above said features can be clearly seen figure 4 which is a continuum removed graph which clearly shows the absorption and the reflectance bands in detail where the troughs represent the absorption band and the peaks represent the reflection band. Figure 3 (a), (b) (c), (d) shows the photos of the different stages of the plant growth in which the greenness can be observed for which the reflection changes and the collection of the spectral signatures in the field.

(a)Initial stage (b) Flowering stage (c) Fruiting stage (d)Harvesting stage

Figure: 3 Different stages of the growth of the C.annum.

The Figure 3(d) shows the leafs turned to yellow color by which the reflectance changes suddenly due to low chlorophyll content, the reflectance graph during the harvesting stage of the species which is collected on 29th November has low reflection which is shown in Figure 4.

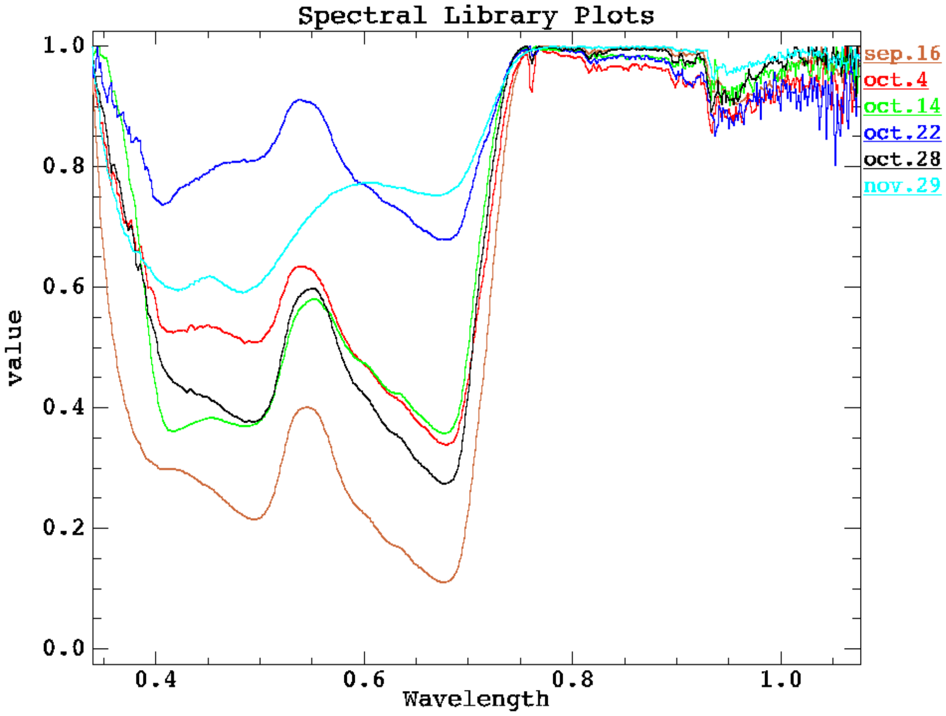

Figure 4: Spectral signatures of C.annum at different stages of the growth after continuum removed

Due to the low chlorophyll content and the less water content the graph during the harvesting stage reflects very low which also an indication of stress. So in any other stages of growth if the graph indicates so it can be understood that the crop is under stress.

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