Evaluation of Narrowband Vegetation Indices for Characterization of Crops Distinct Spectral Features from Hyperspectral Remote Sensing Data

[1]Rajesh K. Dhumal, [2]Amol D. Vibhute, [3]Ajay D. Nagne, [4]Karbhari V. Kale, [5]Suresh C. Mehrotra

[1]Research Scholar, [2]Professor, Department of Computer Science and Information Technology, Dr. BAM University, Aurangabad, Maharashtra, India.

[1]dhumal19@gmail.com

Abstract - In this work we focused on characterization of the distinct spectral features of cotton and maize crops from EO-1 Hyperion data extracted at canopy levels at the mature stage of their life cycle. Six Narrowband Vegetation Indices were examined. These indices are focuses on the reflectance at a wavelength which is sensitive to chlorophyll, carotenoid and anthocyanin pigments of crops. As both crops are of different internal pigment status and structure, Here we have analyzed the values of these indices obtained from EO-1 Hyperion data by using statistical t-test to highlights the differences within this groups, and found that there is significant difference in the response of PRI, SIPI, CRI-1 and ARI-2 whereas CRI-2 and ARI-1 gives slightly similar response for cotton and Maize crops.

***Keywords* —EO-1 Hyperion, Feature Extraction, Crop Classification, Leaf Pigments, NWBVI's, Remote Sensing.**

I. INTRODUCTION[1]

Identification of distinct spectral feature is one of the important issues while using hyper-spectral imagery for crop type classification. Here we focused on several narrowband vegetation indices which might be useful for giving distinct information of each crop. In literature various indices have been suggested for canopy level studies of the vegetation. The major objective of such research is to provide cost-effective way to monitor vegetation from a local to worldwide scale and the utilization of Earth Observation satellites. Satellites can give local to worldwide scope temporally. They likewise give data on remote territories where ground estimations are not possible all the time [1], [2], [3].

Various Narrowband vegetation indices used in this work is explained in this section these narrowband indices have been used to generate data which represents photosynthetic capability and status of Carotenoid and Anthocyanin pigments of cotton and maize crops. To improve vegetation signal from multispectral or hyperspectral data and provide an imprecise measure of green vegetation amount various indices reported in literature, which has been proposed by consolidating values from different bands into single esteem, some of them connected with biophysical attributes and others with biochemical qualities of the vegetation. Galvao et al. in their article has suggested light use efficiency indices (SIPI and PRI) for better crop discrimination [2],[3]. Here we have used Photochemical Reflectance Index (PRI), Structure Insensitive Pigment Index (SIPI), Carotenoid Reflectance Index-1 (CRI-I), Carotenoid Reflectance Index-2 (CRI-2), Anthocyanin Reflectance Index-1 (ARI-1) and Anthocyanin Reflectance Index-2 (ARI-2) which is most commonly used to highlight internal contents and their condition in the crops, equation for these indices are as given in table 1.

A. *Photochemical Reflectance Index (PRI)*

The Photochemical Reflectance Index (PRI) was proposed by Gamon et al. it was discovered as an indicator of photosynthetic radiation use efficiency of different species, it is derived from narrowband reflectance at 531 and 570 nm, It is significantly correlated with net carbon dioxide up take and radiation use efficiency measured by gas exchange [4]. Equation for PRI is as given in equation 1.

$$PRI = (\rho531 - \rho570)/(\rho531 + \rho570) \quad (1)$$

Where ρ are atmospherically corrected reflectance of the closest Hyperion bands (n, center in Nanometers) to the original wavelength formulations.

Table 1 Narrowband Vegetation Indices for Hyperion dataset used in this work

Sr. No.	Index	Equation	Reference
1	Photochemical Reflectance Index (PRI)	(ρ531 – ρ570)/(ρ531 + ρ570)	Gamon et.al.
2	Structure Insensitive pigment index (SIPI)	(ρ803 – ρ447)/(ρ803 – ρ 681)	Penuelus et.al
3	Carotenoid Reflectance Index-1(CRI-1)	(1/ρ508) –(1/ ρ548)	Gitelson et.al.
4	Carotenoid Reflectance Index-2 (CRI-2)	(1/ρ508) –(1/ ρ701)	Gitelson et.al.
5	Anthocyanin Reflectance Index-1(ARI-1)	(1/ρ548)-(1/ρ701)	Gitelson et.al.
6	Anthocyanin Reflectance Index-2(ARI-2)	ρ803[(1/ρ548)-(1/ρ701)]	Gitelson et.al.
Where ρ are atmospherically corrected reflectance of the closest Hyperion bands (n, center in Nanometers) to the original wavelength formulations.			

B. *Structure Insensitive pigment index (SIPI)*

As the ratio of carotenoid and chlorophyll *a* concentration (Car/Chl *a*) is the indicator of physiology and phenology of plants, and SIPI provides the best empirical estimation of the above ratio. SIPI minimizes the confounding effects of leaf surface and mesophyll structure the equation for this index is as given in eq. 2. This index is derived from the reflectance at 800 nm, 445 nm and 680 nm [5]

$$SIPI = (\rho800 - \rho\lambda1)/ (\rho800 - \rho\lambda2) \quad (2)$$

Where ρ is the reflectance at closest Hyperion band and $400<\lambda1<530$ nm and $600< \lambda2<700$ nm

C. Carotenoid Reflectance Index-1 & 2 (CRI-1 & CRI-2)

Carotenoid is one of the main pigments in the leaves of the plants, Reciprocal reflectance at 510 nm and 550 nm is very closely relevant to total pigment contents of the leaves whereas reciprocal reflectance at 510 nm is very sensitive to carotenoids and chlorophyll also, to extract the carotenoid it necessary to avoid the chlorophyll effect at 510 nm hence either reciprocal reflectance at 550 nm or reciprocal reflectance at 700 nm has been used. It was named as CRI-1 and CRI-2 respectively equation for this are as given bellow [6].

$$CRI\text{-}1= (1/\rho510) - (1/ \rho550) \quad (3)$$
$$CRI\text{-}2= (1/\rho508) - (1/ \rho700) \quad (4)$$

D. Anthocyanin Reflectance index 1 & 2 (ARI-1 & ARI-2)

Anthocyanin's are water soluble vacuolar pigments present in the plants, The anthocyanin contents in leaves provide important information about the physiological status of that plants. The main spectral features of Anthocyanin are found at peak around 550 nm to extract the perfect Anths features inverse spectral reflectance at 700 nm has been subtracted from inverse spectral reflectance at 550nm to avoid chlorophyll contribution (eq.5). This model has been suggested by Gitelson et.al. In 2001 further he has modified this by considering the reflectance at 800 nm (eq. 6) which is closely related to leaf scattering to make it independent on leaf thickness and density. [7], [8], [9].

$$ARI\text{-}1= (1/\rho550) - (1/ \rho700) \quad (5)$$
$$ARI\text{-}2= \rho800 \, [(1/\rho550) - (1/ \rho700)] \quad (6)$$

II. STUDY AREA

Study area covers Kanhori, Pimpalgaon Walan, Pal and Wanegaon Villages which comes under Phulambri Taluka in Aurangabad District of Maharashtra State, India. It is part of Marathwada region and Aurangabad Division. These villages are about 35 KM towards North from Aurangabad city. 5 KM from Phulambri and 350 KM from State capital Mumbai, and located at 20°07'13.5"N 75°23'05.3"E and surrounded by Khultabad and Kanand Taluka towards west, Aurangabad Taluka towards South, Sillod Taluka towards East [10].

III. DATASET AND FIELDWORK

The data utilized for conduction of this study was procured from Hyperion sensor of United States Geological Survey (USGS) Earth Observing-1 (EO-1) satellite. The Hyperion having 242 spectral bands with approximately 10 nm band width and 30 m spatial resolution, its swath is 7.75 km. The range of spectral bands of this data is from 400 nm to 2500 nm. This data was rectified to the Universal Transverse Mercator (UTM) zone 43 North and World Geodetic System (WGS)-84 datum. Ground truth points were collected by using GPS (Global Positioning System) enabled smartphone.

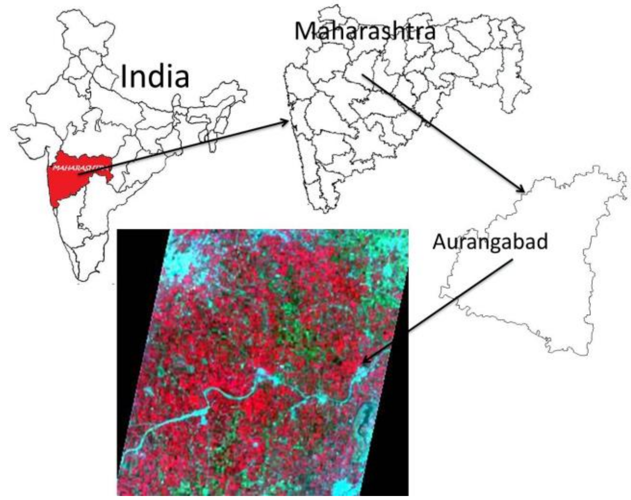

Figure 1: Study area shown by False Color composite of EO-1 Hyperion Subset

IV. METHODOLOGY

Procedure followed to meet these expectations incorporates several significant steps including preprocessing, Atmospheric corrections, computation of vegetation indices, Identification of pixels covering cotton and maize canopies using ground truth information and Google map. At last Investigation for assessed qualities about selected vegetation indices has been carried out.

A. Preprocessing

Preprocessing has been done firstly by evacuating bad bands out of 242, the Hyperion hyperspectral image has 44 bad bands and 43 water vapor bands[11], taking after 155 bands has been utilized for this study: Band 8 to 57, Band 79 and 83 to 119, Band 133 to 164, Band 183 and band 184, Band 188 to 220. Then subset of original Hyperion datasets were created, which covers the study area then for atmospheric correction QUAC (Quick Atmospheric Correction) tool in ENVI has been used.

B. Atmospheric corrections

The quick atmospheric correction (QUAC) model utilized for atmospheric correction of hyperspectral imagery in Visible, Near Infrared to Short Wave Infrared wavelength ranges. As compared to other methods it requires only approximate specification of sensor band locations or central wavelengths and their radiometric calibration; no other metadata is required. Quick atmospheric correction is a scene based empirical approach and based on the radiance values of the image used for the removal of atmospheric effects. It uses atmospheric compensation factors directly from the information contained within the image scene, without secondary information. It has relatively faster computational speed as compared to other methods. QUAC provides better repossession of reasonable reflectance spectra even if an image didn't have proper wavelength or radiometric calibration or solar illumination intensity is unknown. QUAC is applied in ENVI to perform atmospheric correction to hyperspectral imagery in Visible, NIR to SWIR wavelength ranges. QUAC will give enhanced results for further processing. QUAC does not involve first principles radiative-transfer calculations, QUAC is considerably faster than physics-based methods and it is also more fairly accurate [12], [13].

C. Computation of Vegetation Indices

After atmospheric correction above mentioned indices computed by using their appropriate formulae as given in Table 1 and finally identified the pixels representing cotton and Maize crops with reference to ground truth information and Google Map. Then used statistical T-test which gives corresponding value for each index to describe whether there is significant difference or not. Greater the magnitude of T means there is significant difference within the group means it is against the null hypothesis (There is no significant difference where t=0).

V. RESULTS AND DISCUSSION

As Hyperion Image utilized for this study is of 15th October 2014, at that time the life of cotton is about 15 to 20 Weeks, which would be the boll opening phase of cotton life cycle; likewise at the same time Maize is also well developed. After computing vegetation indices obtained layers are as shown in Figure 2, similarly the obtained statistics are given in Table 2

Table 2. Statistics obtained for given indices

Indices	*Cotton*		*Maize*		T-stat
	Mean	**Variance**	**Mean**	**Variance**	
PRI	-0.0260	0.00002	-0.0381	0.0011	1.5640
SIPI	1.0681	0.0039	1.1073	0.0082	-1.5047
CRI-1	0.6098	0.0121	0.5236	0.0247	1.8896
CRI-2	0.7343	0.0743	0.7186	0.0754	0.1722
ARI-1	0.1199	0.0884	0.0757	0.1078	0.4235
ARI-2	-0.1566	0.0285	-0.0503	0.0176	-2.1024

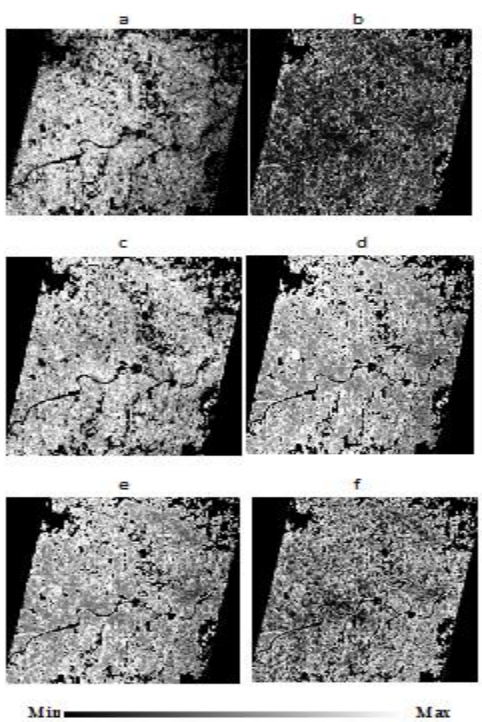

Figure 2: Indices Computed a) PRI, b) SIPI, c) CRI-1, d) CRI-2, e) ARI-1, f) ARI-2

As our objective is to study the distinct spectral features of identified crops, these obtained layers gives meaningful information in that direction. This kind of work is also beneficial for dimensionality reduction of hyperspectral data, because we are using only the several bands for characterization of distinct spectral features.

VI. CONCLUSION AND FUTURE WORK

As per our experiment work we conclude that, in pigment based indices CRI-1 and ARI-2 gives significantly different response for both identified crops. As ARI-2 is independent on leaf thickness and density this gives better distinctness among others. In case of Light use efficiency indices both PRI and SIPI also offers small difference in their mean for both the crops. Dataset used for this study is of October, the result may change in temporal datasets because phonological status of crops get changed throughout their life cycle, this study is very useful towards identifying unique spectral features at canopy level for knowledge based classification.

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