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

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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

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 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-1), 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.

\[ PRI = \frac{(\rho_{531} - \rho_{570})}{(\rho_{531} + \rho_{570})} \] (1)

Where \( \rho \) 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

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Index Description</th>
<th>Equation</th>
<th>Reference</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Photochemical Reflectance Index (PRI)</td>
<td>((\rho_{531} - \rho_{570})/(\rho_{531} + \rho_{570}))</td>
<td>Gamon et.al.</td>
</tr>
<tr>
<td>2</td>
<td>Structure Insensitive pigment index (SIPI)</td>
<td>((\rho_{803} - \rho_{447})/(\rho_{803} - \rho_{681}))</td>
<td>Penuelus et.al</td>
</tr>
<tr>
<td>3</td>
<td>Carotenoid Reflectance Index-1(CRI-1)</td>
<td>((1/\rho_{508})-(1/\rho_{548}))</td>
<td>Gitelson et.al</td>
</tr>
<tr>
<td>4</td>
<td>Carotenoid Reflectance Index-2 (CRI-2)</td>
<td>((1/\rho_{508})-(1/\rho_{701}))</td>
<td>Gitelson et.al</td>
</tr>
<tr>
<td>5</td>
<td>Anthocyanin Reflectance Index-1 (ARI-1)</td>
<td>((1/\rho_{548})-(1/\rho_{701}))</td>
<td>Gitelson et.al</td>
</tr>
<tr>
<td>6</td>
<td>Anthocyanin Reflectance Index-2 (ARI-2)</td>
<td>((p803/(1/p548)-(1/p701)))</td>
<td>Gitelson et.al</td>
</tr>
</tbody>
</table>

Where \( \rho \) 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

\[ SIPI = \frac{(1/\rho_{508})-(1/\rho_{548})}{(1/\rho_{701})} \]
is derived from the reflectance at 800 nm, 445 nm and 680 nm [5]
\[
\text{SIPI} = (p800 - p\lambda_1)/(p800 - p\lambda_2) \quad (2)
\]
Where \( p \) is the reflectance at closest Hyperion band and
400<\( \lambda_1 <530 \) nm and 600< \( \lambda_2 <700 \) 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].

\[
\text{CRI-1} = (1/p510) - (1/p550) \quad (3)
\]
\[
\text{CRI-2} = (1/p508) - (1/p700) \quad (4)
\]

**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].

\[
\text{ARI-1} = (1/p550) - (1/p700) \quad (5)
\]
\[
\text{ARI-2} = p800 \{[1/p550} - (1/p700)\} \quad (6)
\]

**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 Phulambi 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.

**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
radius 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
reasonoble 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

<table>
<thead>
<tr>
<th>Indices</th>
<th>Cotton</th>
<th>Maize</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Variance</td>
</tr>
<tr>
<td>PRI</td>
<td>-0.0260</td>
<td>0.0002</td>
</tr>
<tr>
<td>SIPI</td>
<td>1.0681</td>
<td>0.0039</td>
</tr>
<tr>
<td>CRI-1</td>
<td>0.6098</td>
<td>0.0121</td>
</tr>
<tr>
<td>CRI-2</td>
<td>0.7343</td>
<td>0.0743</td>
</tr>
<tr>
<td>ARI-1</td>
<td>0.1199</td>
<td>0.0884</td>
</tr>
<tr>
<td>ARI-2</td>
<td>-0.1566</td>
<td>0.0285</td>
</tr>
</tbody>
</table>

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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