

QUALITY ENHANCEMENT OF HYPERSPECTRAL IMAGE DATA THROUGH ATMOSPHERIC CORRECTION: A CASE STUDY OF HENRY AND LOTHIAN ISLANDS OF SUNDERBAN BIOSPHERE RESERVE, WEST BENGAL

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Abstract

Hyperspectral data finds wide applicability in species level mapping of forest cover in pure and mixed stands. The Sunderban Biosphere Reserve of West Bengal is an ideal locale where hyperspectral image data may be successfully utilized for accurate mapping of nearly 94 mangrove species that exist here. The present study is the first attempt in the Sunderban eco-geographic province to make species level discrimination of mangroves in a mixed stand. However, prior to data classification, several corrections are required to be made for meaningful interpretation of data. Atmospheric correction is one such crucial correction and pre-processing step which is done to minimize the effect of atmospheric agents that alters the actual radiance data that the sensor should represent. It therefore becomes essential to properly analyse, process and correct hyperspectral data by applying atmospheric correction techniques to reduce or remove the influence of atmospheric agents on the sensor captured data.

MODTRAN based FLAASH algorithm and scene based QUAC algorithm, both available in ENVI have been found to be effective in for atmospheric correction of data captured by the Hyperion sensor onboard the EO-1 satellite launched by NASA. In this paper the FLAASH and QUAC models have been applied on the Hyperion data and a comparative analysis carried out. The application of hyperspectral data is a unique attempt in the unexplored field of research for Indian mangroves in general and Sunderban mangroves in particular which is the world's largest single patch mangrove forest. This paper analyses the data processing steps for atmospheric correction of Hyperion data taken over the dense mangrove forest cover of the Henry and Lothian Islands of the Sunderban Delta of West Bengal. This data has been interpreted to understand the properties of mangroveforest cover and how they relate to the measurements actually made by the hyperspectral sensor.

Keywords: Hyperspectral data, FLAASH,QUAC,Sunderban

I. INTRODUCTION

The basic objective of remote sensing has been to characterize the properties of the objects through detection, registration and analysis of the radiant flow emitted or reflected by them. However, the mechanism of acquisition of this radiation is not ideal due to the presence of an extremely dynamic medium-the atmosphere- between the sensor and the earth surface. This atmosphere interacts with the electromagnetic radiation leading to significant alterations in the incoming radiant flow from the target.

These alterations are mainly a result of molecular scattering, scattering for aerosols and absorption by the atmospheric gaseswhich lead to erroneous sensor readings which pose a problem in accurate analysis of

data. The analysis many a time depends upon the spectral characteristics of the sensor and the atmospheric conditions at the date and hour of data acquisition.

The advent of hyperspectral sensors have made the acquisition of more than 100 simultaneous images of a same area possible and in producing a continuous reflectance spectrum for each pixel of the scene. Hence, it becomes a necessity to poise a larger emphasis on minimization of atmospheric influences on the acquired imagery through application of atmospheric correction algorithms (3).

The general objective of this study is to demonstrate the importance of atmospheric correction in hyperspectral image analysis with the dense

mangrove forest of Sunderbans as the target area for the study (5). Needless to mention, it is also the first attempt to focus on the application of hyperspectral imagery and test their efficacy in the Sunderban delta especially for mangrove mapping at species level. The FLAASH and QUAC algorithms have been applied for the atmospheric correction of hyperspectral images of the Henry and Lothian Islands of Sunderban Region, West Bengal. The dataset has been obtained from Hyperion sensor onboard the EO-1 (Earth Observatory-1) satellite launched by NASA.

II. STUDY AREA

As a case study, the pristine mangrove habitats of Henry island (approximately 10 sq. km. in area, extending between $21^{\circ}36'00''$ N to $21^{\circ}34'00''$ N latitude and $86^{\circ}16'30''$ E to $88^{\circ}18'30''$ E longitude) and Lothian island (approximately 38 sq. km. in area, extending between $21^{\circ}32'50''$ N to $21^{\circ}42'30''$ N latitude and $88^{\circ}18'10''$ E to $88^{\circ}21'30''$ E longitude) of the Sunderban Biosphere Reserve of West Bengal have been selected for study. The selection of the

study area is based considering the fact that Sunderban harbours a rich and bio-diverse mangrove community with a wide array of ecologically rare, endangered and endemic mangrove species.

III. HYPERION DATA ACQUISITION AND PROCESSING

A. Methodology: Data Acquisition

A Data Acquisition Request (DAR) for fresh acquisition of Hyperion data of Henry and Lothian Island of Sunderban region was sent to the USGS (EROS) Data Centre. Accordingly, cloud free data was acquired on 27th May, 2011 of the two islands of Sunderban and the Level 1R Hyperion data in HDF format has been downloaded for the study. The data files obtained are an image file (with L1R extension), image header file and a .met file. The .met file contains information on image acquisition date, time, latitude/longitude, etc. Figure 1.0 shows the browse overlay of the acquired Hyperion image over the Sunderban region. The metadata for the acquired imagery is given in Table 1.0.

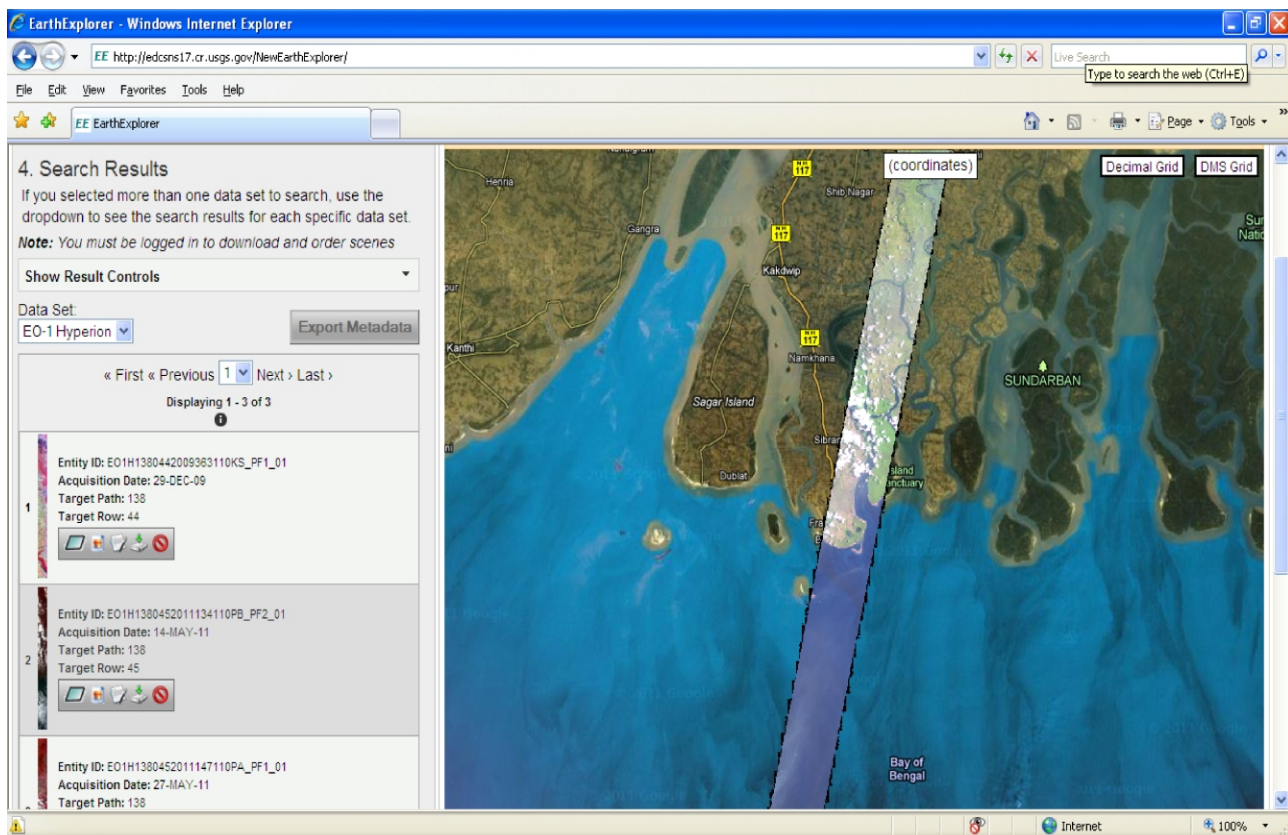


Fig. 1. Browse Overlay of Hyperion Image over Sunderban

Table 1.0 Meta Data of Acquired Imagery

Data Set Attribute	Attribute Value
Entity ID	EO1H1380452011147110PA_PF1_01
Acquisition Date	2011/05/27
NW Corner	22°00'41.99" N, 88°20'55.62" E
NE Corner	21°59'50.47" N, 88°25'10.02" E
SW Corner	21°09'48.92" N
SE Corner	21°08'57.60" N
Image Cloud Cover	30% to 39% Cloud Cover
Receiving Station	PF1
Scene Start Time	2011:147:04:18:06.243
Scene Stop Time	2011:147:04:18:21.243
Date Entered	2011/05/27
Target Path	138
Target Row	45
Orbit Path	138
Sun Azimuth	85.895254
Sun Elevation	65.396135
Satellite Inclination	98.08
Orbit Row	45
Look Angle	-2.1333
Browse Available	Y

Hyperion Data Cube

The acquired Hyperion image has the dimensions of $256 \times 3472 \times 242$. The first number represents the number of pixels that span the field of view. The total number of frames is represented by the second dimension and defines the swath length. The instantaneous field of view for each pixel and the frame rate, 223.4 Hz, define the dimensions of ground being imaged. Each pixel location images approximately a 30 m by 30 m region of the ground. The swath width for each focal plane is comprised of 256 pixel locations

corresponding to 7.7 km. The third dimension represents total number of bands acquired by the sensor.

Bands and spectral ranges for Hyperion data

The Level 1 data consists of 242 nominal bands covering the wavelengths from 356 nm to 2577 nm. The VNIR detector collects data in bands 1 to 70 and the SWIR detector collects data from bands 71 to 242. There is an overlap between the VNIR and SWIR regions. Some of the 242 spectral channels are not calibrated in the Level 1 data; these are channels that were not activated in the Hyperion arrays or some with low signal levels and some other channels which are duplicated in the VNIR-SWIR overlap region. The Level-1 data contains 200 calibrated channels of which 196 are unique. The digital values of the Level-1 product are 16-bit radiances and are stored as a 16-bit signed integer. The Level 1 product is only radiometrically corrected and is not geometrically resampled.

B. Data Processing

Band Combination for Images

A gray scale image of Band 40 has been displayed in Figure 2. (a). This band in the VNIR corresponds to 753 nm. The entire swath width of 7.7 km is displayed, but only a subset of the swath length showing the islands is presented in these images.

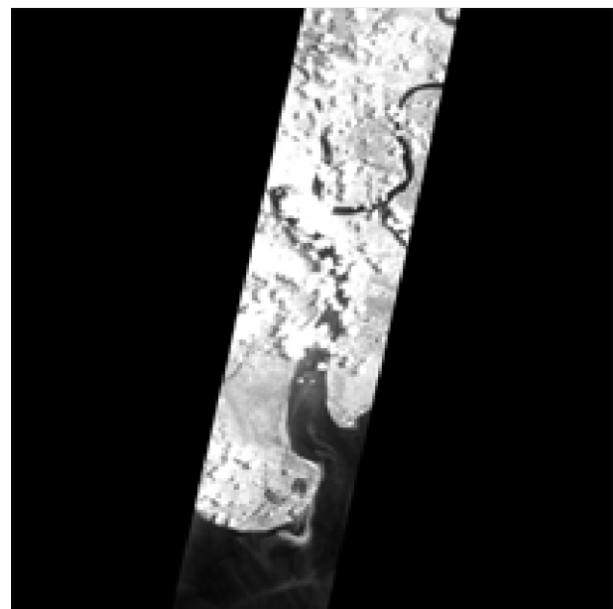


Fig. (a)



Fig. (b)

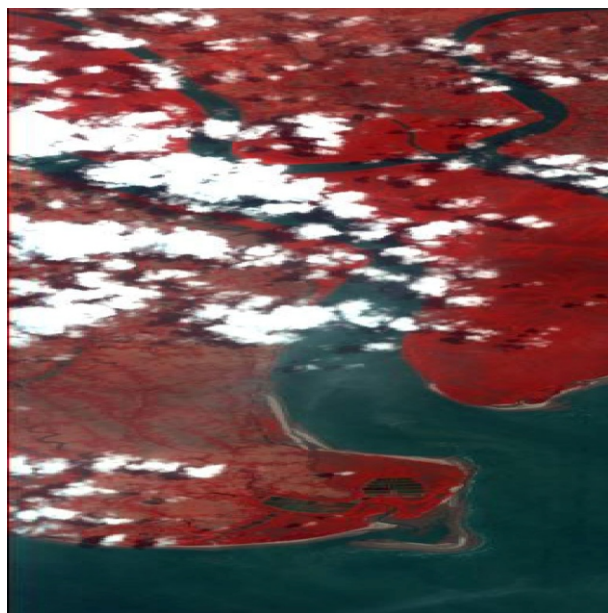


Fig. (c)

Fig. 2. Hyperion data of Henry and Lothian Islands, Sunderban Region

- (a) Band 40-VNIR (b) *Band-29:23:16-RGB*
 (c) *Vegetation RGB (Bands 50, 23 and 16)*

A true color image of the scene is represented in Figure 2.0 (b) by combination of bands 29:23:16 for R:G:B. This band combination corresponds to approximate wavelengths of 641 nm, 580 nm and 509 nm. Slight variation in the bands selected does not

noticeably affect the RGB image. Figure 2.0(c) shows a coloured image in which vegetation appears red. A combination of bands 50 (855 nm), 23(580 nm) and 16(509 nm) have been used.

Removing the absorption bands and bands having no information

It has been found that some bands are set to zero during Level-1 processing. The zeroed bands are 1-7, 58-76, 225-242. Bands 56-57 in the VNIR overlap with bands 77-78 in the SWIR region. Bands 77-78 have usually been found to be noisier than the corresponding bands in the VNIR. As the zero data bands and the VNIR-SWIR overlap (bands 56, 57 or 77, 78) are ignored, there are 196 unique calibrated bands (bands 8-57 and bands 79-224), which can be retained for processing. Within the 196 unique bands there a number of atmospheric water vapour bands that absorb most of the solar radiation. These have been identified by examining the radiance spectra. While analyzing the hyper-spectral images it has been found that the strongest water vapour bands occur between 1346 nm (band-120) - 1497 nm (band135), 1517 nm (band-137)-1537 nm (band-139), 1568 nm (band-142)-1578 nm (band-143), 1598 nm (band-145), 1669 nm (band-152)-1689 nm (band-154), 1709 nm (band-156)-2385 nm (band-213). Since these bands contain little or no information about the surface, they will be ignored for further processing (1).

However some atmospheric correction programs such as ENVI FLAASH do require bands centred near 1380 nm in the strong water vapour wavelengths for masking clouds (especially high altitude clouds). Therefore bands 123-125 (1376, 1386, and 1396 nm) has been retained in the image.

Ignoring the above strong water vapour bands along with the zeroed bands leaves subset of about 105 bands for atmospheric correction and further processing. The zeroed bands and strong water vapour bands will now be set as "bad" and will be ignored in further processing. This reduces the number of bands to 105 bands which will be used for further processing. This reduces the data volume and speeds up processing.

Removal of Bad Columns and Vertical Stripes

The level 1R product consists of the bands affected with vertical stripes which has been minimised by checking each band for the vertical stripe and

replacing the DN value of the affected column by the average of the DN values of the adjacent columns. This has been done for several image bands as these calibrated bands were seriously affected by these vertical stripes. In the present work, the bad columns have been identified visually in order to avoid imposing severe changes in the spectra. These bad columns once identified have been reduced by checking each band for the bad column, and replacing the DN value of the affected column by the average of the DN values of the adjacent columns.

C. Atmospheric Correction

The atmospheric correction is considered as a critical pre-processing step to achieve full spectral information from every pixel especially in case of hyper-spectral data. This paper investigates and tries to minimise the effect of atmospheric correction on the hyperspectral bands covering the study area. The Hyperion image for the study area is affected due to the time of acquisition i.e. 25th May, 2011. During this time of the year, the monsoon sets in and there are clouds and lot of water vapour in the atmosphere. Also, there is spectral variation in the vegetation of the region with the trees in its full vigour. Atmospheric correction for the Hyperion image is hence considered as a critical step in the present study. For atmospheric correction, FLAASH and QUAC models (Advanced Hyperspectral Analysis) have been used to convert the radiance values in the image to its reflectance values.

Quick Atmospheric Correction (QUAC)

This approach is based on the radiance values present in the image (i.e. scene), hence it is known as scene based empirical approach. QUAC is a visible-near infrared through shortwave infrared (VNIR-SWIR) atmospheric correction method for multispectral and hyperspectral imagery. It determines atmospheric compensation parameters directly from the information contained within the scene (observed pixel spectra), without ancillary information. QUAC is based on the empirical finding that the average reflectance of a collection of diverse material spectra, such as the endmember spectra in a scene, is essentially scene-independent.

Fast Line-of-Sight Atmospheric Analysis of Spectral Hypercubes (FLAASH)

FLAASH is an atmospheric correction tool that corrects wavelengths in the visible through near-

infrared and shortwave infrared regions, up to 3 μm . Unlike many other atmospheric correction programs that interpolate radiation transfer properties from a pre-calculated database of modelling results, FLAASH incorporates the MODTRAN 4 radiation transfer code. We can choose any of the standard MODTRAN model atmospheres and aerosol types to represent the scene; a unique MODTRAN solution is computed for each image. Water vapor and aerosol retrieval are only possible when the image contains bands in appropriate wavelength positions. In addition, FLAASH can correct images collected in either vertical (nadir) or slant-viewing (off-nadir) geometries.

IV. RESULTS

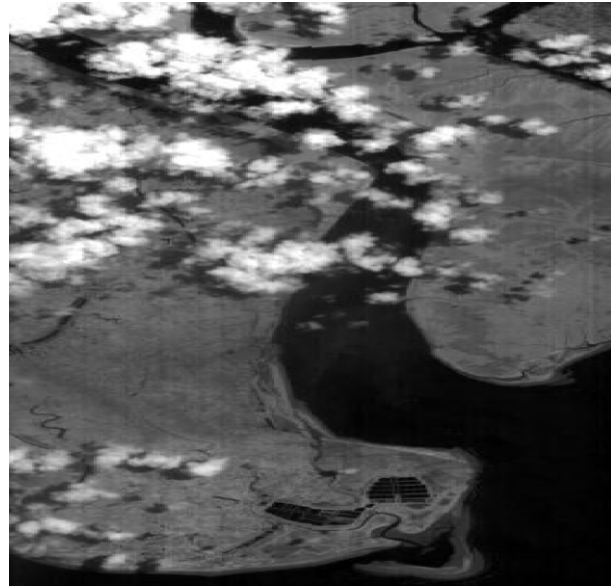
After the image bands have been resized to 105, the FLAASH and QUAC model is run on the images. The scene center location, sensor type, flight date, sensor altitude, average ground elevation of the scene, flight time has been used as input for processing of the radiance data. For more accurate correction, a tropical atmospheric model and a maritime aerosol model has been chosen and the water vapour content information extracted from Hyperion water absorption bands.

In Figure 3.0 we can trace out visually, the difference in the features seen before and after running the atmospheric correction model. After running FLAASH and QUAC model, the haziness in the image is minimised to a certain level and the features are sharpened with increased brightness.

This can be interpreted statistically also, by observing the spectral profile in Figure 4.0 (graphs showing the variation of wavelength vs reflectance value) of the feature before and after running FLAASH and QUAC. As our main area of focus are mangroves, we have taken the spectral profile of a forested segment. It has been observed that in the visible portion of the spectrum, the Chlorophyll in the plants absorbs the blue and red wavelengths more strongly than green, producing a characteristic small reflectance peak within the green wavelength range. This may be seen in Figure 4.0(b) after FLAASH correction. The reflectance then rises sharply across the boundary between red and near infrared wavelengths which is primarily due to interactions with the internal cellular structure of leaves.

From the above profile, one can observe the enhancement in the vegetation feature class after running both the models (4). We can well observe that the dips present in the profile between the wavelengths 875 to 975nm (approximated) and also at 1125-1145 range are reduced after the FLAASH atmospheric correction. Instead, we can see a rise in the value starting from the blue region and a steep slope in the atmospherically corrected profile. Also, we can observe in the profile of the atmospherically corrected image, the presence of a number of narrow contiguous peaks in the wavelength range of 750-1120 nm range.

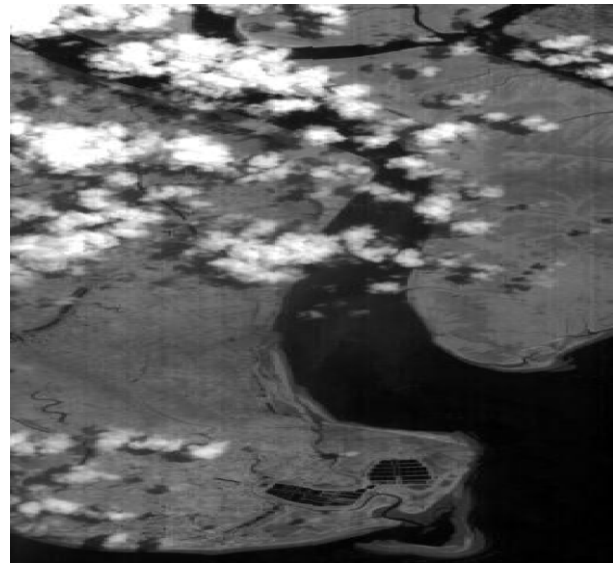
After application of QUAC model there has been an enhancement in the vegetation feature class as compared with the original Hyperion data. From the spectral profiles generated it is found that the correction achieved in the near infrared region seems to be better after QUAC correction than that of FLAASH.



(b)



(a)



(c)

Fig. 3 (a) Original Band (1030nm) (b) Band after FLAASH Correction (c) Band after QUAC Correction

V. CONCLUSION

The hyperspectral image bands have been corrected for the different errors like bad band removal, removal of absorption bands, removal of the non-calibrated bands and reduction of the vertical stripes. As a result, the 242 band image has been reduced to 105 bands after bad band removal. On

these resized bands, the FLAASH and QUAC atmospheric correction model has been applied.

After running FLAASH and QUAC model, the haziness in the image is minimised to a certain extent and the features are sharpened with increased brightness. It is evident from the spectral profiles after correction that the strong absorption bands near the

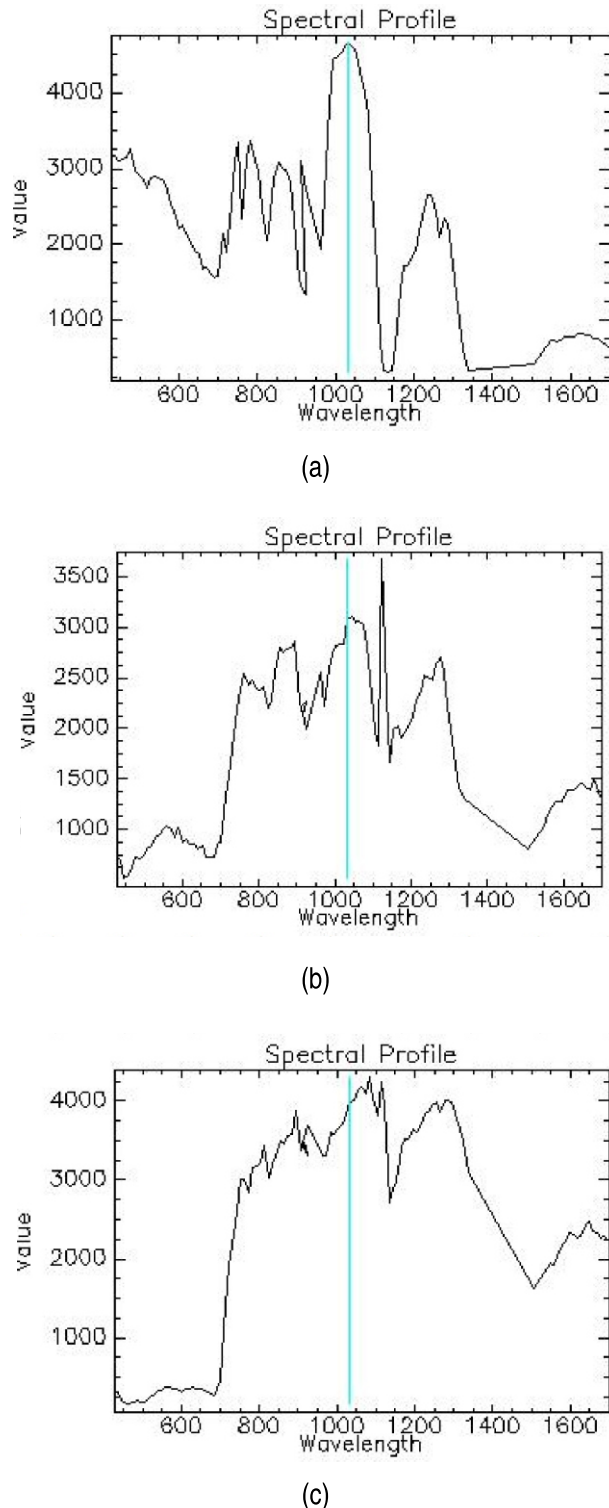


Fig. 4. Spectral Profile of the mangrove forest area
 (a) Original data (b) after FLAASH Correction
 (c) after QUAC Correction

VNIR and SWIR regions of the original spectra have been compensated and corrected to a large extent.

It has been observed that there is slight difference in the spectral profile obtained after QUAC and FLAASH corrections. FLAASH is normally expected to give better correction results than QUAC but it requires full knowledge of the atmospheric conditions of the study area at the time of acquisition which was not available. QUAC performs a good approximate atmospheric correction to FLAASH. In this study QUAC has been found to give better correction results than FLAASH. The execution time of QUAC is also faster than FLAASH as it needs less data for processing and performs well for atmospheric corrections of areas whose details are not known. The atmospheric corrected reflectance image can now be used for geo-referencing and further classification.

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