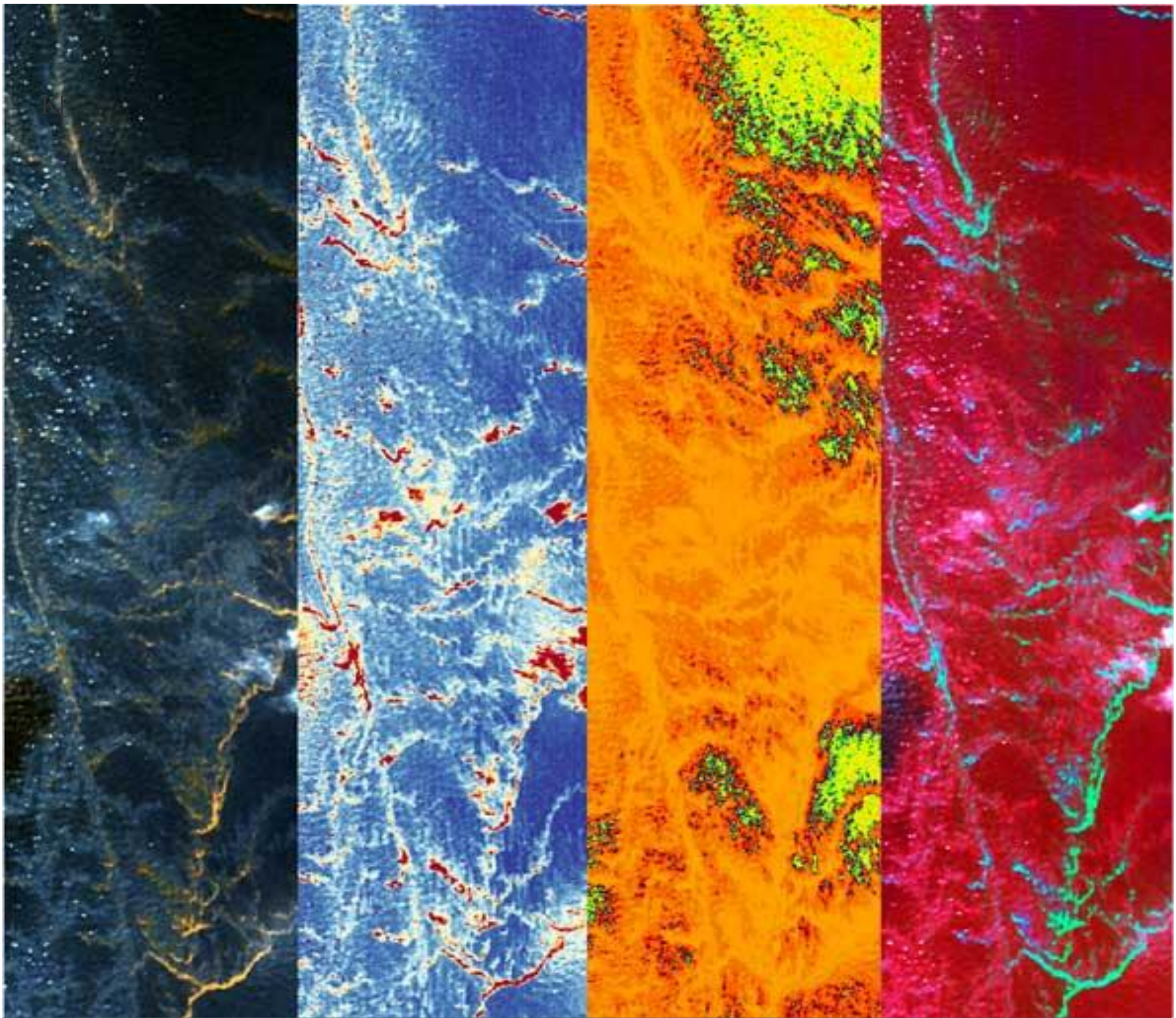

Hyperspectral Image Processing

Results & Analysis

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6/1/20

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1. Data Description and Pre-processing:

Hyperion is a high-resolution hyperspectral imager producing 242 unique spectral channels ranging from 0.357 to 2.576 micrometers with a 10-nm bandwidth. The instrument operates in a pushbroom fashion, with a spatial resolution of 30 meters for all bands and a standard scene width of 7.7 kilometers.[1]

In the current task, Level 1Gst dataset is used, which is terrain corrected and provided in 16-bit radiance values. The data is available in Geographic Tagged Image-File Format (GeoTIFF). Out of these 242 spectral bands, few are uncalibrated, and some return no data. Hyperion level L1Gst data has 242 bands, out of which, only 198 are nonzero, i.e., a few were intentionally left unused (bands 1 to 7 and 225 to 242) and others fall in the overlap region of the two spectrometers (bands 58 to 76). Among the nonzero bands, four bands are still in the overlap region of the two spectrometers, i.e., bands 56, 57, and 77, 78; out of which, bands 77 and 78 were eliminated because of the higher noise levels present in those bands. Then, there are water vapor absorption bands which need to be eliminated and are identified as bands120 to 132 (1,346 to 1,467 nm), bands 165–182 (1,800 to 1,971 nm), and bands 221 (above 2,356) and higher. Water vapor absorption bands absorb all the incident solar energy and can be easily identified visually [2], [3]. The list of bad bands which are eliminated is given in Table 1 below.

S.No.	Bad Bands	Reason
1	1-7	Non-illuminated
2	58-76	Overlap Region
3	120-132	Water vapor absorption
4	165-182	Water vapor absorption
5	221-224	Water vapor absorption
7	225-242	Non-illuminated

Table 1: List of Eliminated Bands

After the removal of bad bands, atmospheric correction is done for which radiance image is obtained by performing radiometric calibration on the data using the gains and offsets for each band available in the metadata. The Hyperion documentation recommends using FLAASH or ACORN to convert radiance to reflectance[4]. The Atmospheric Correction module in ENVI provides two atmospheric correction modelling tools for retrieving spectral reflectance from multispectral and hyperspectral radiance images, namely Quick Atmospheric Correction (QUAC) and Fast Line-of-sight Atmospheric Analysis of Spectral Hypercubes(FLAASH).QUAC is based on the empirical finding that the average reflectance of a collection of diverse material spectra, such as the end member spectra in a scene, is essentially scene-independent. This results in significantly faster computational speed compared to the FLAASH or any physics-based first-principles methods. Hence, in the current task, QUAC model is used to obtain the reflectance data.[5]

2. Level 1 Image Processing:

Figure 1 shows the RGB composite of atmospherically corrected Hyperion Data (Tile: EO1H1480472016328110PZ_1GST) using band 30, band 20 and band 10.

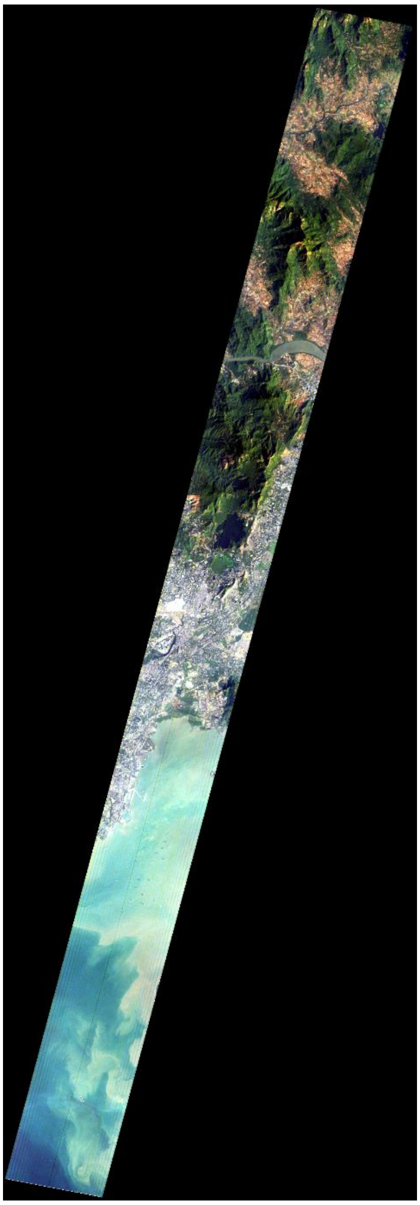


Figure 1: RGB Image (Band30:Band20:Band10)

3. Level 2 Image Processing:

The atmospherically corrected data with 163 bands is processed further by reducing bands using band averaging method. The table below (Table 2) shows the number of bands used for averaging and resultant number of bands in final image.

No. of bands averaged	Total number of bands in final image
3	54
5	32
7	23
11	14
15	11

Table 2: Reduced number of bands in Level 2 data

4. Level 3 Image Processing:

The signal-to-noise ratio (SNR), the ratio of signal power to the noise power, is a key parameter in satellite remote sensing. It quantifies how much the signal has been corrupted by noise. Users require data and images with high SNRs to better serve their analysis needs. Moving average method and the Savitzky Golay filter are commonly used for signal smoothening.

In this task, Savitzky Golay filter (commonly known as Savgol filter), which is a particular type of low-pass filter has been adapted for data smoothing. The following table shows the spectrum of a random pixel for atmospherically corrected image and smoothened images with different window length and polynomial order. It is observed that with increase in window length, much smoother spectrum was achieved, but after some point, the trend starts dissolving. It is also observed that with increase in polyorder the noise increases (Figure 2). Hence, the choice of window length and polyorder play an important role. For further analysis, the image filtered using window length 19 and polyorder 2, has been considered.

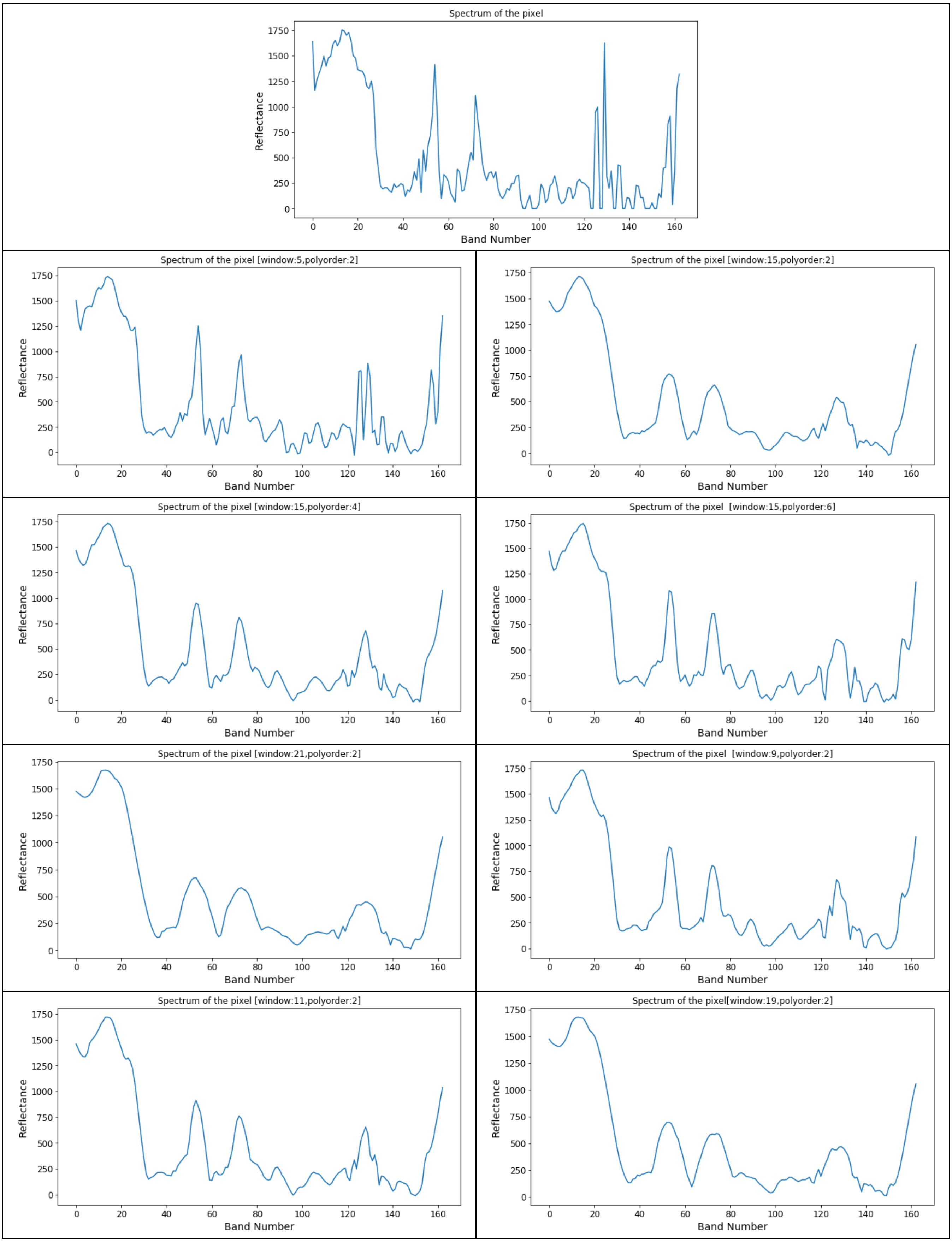
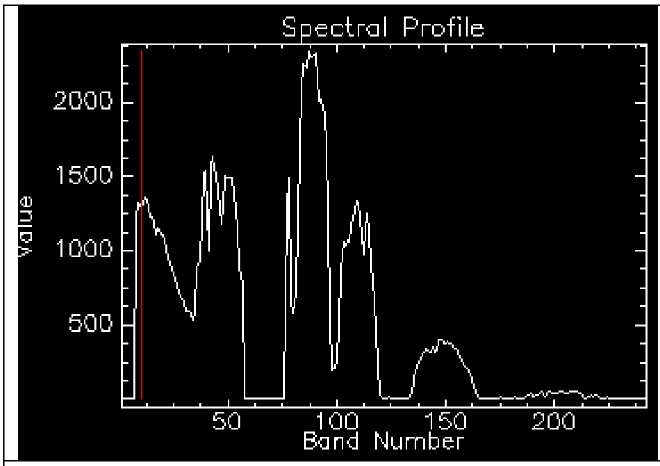


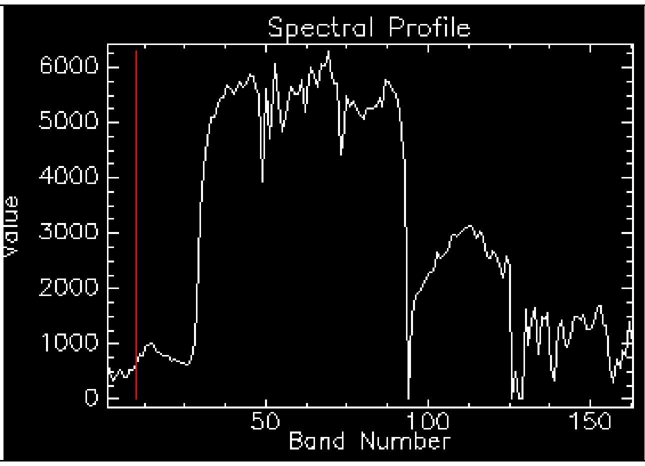
Figure 2: Spectrum of a random pixel obtained for different window length and polynomial order in level 3 data

5. Spectrum of a pixel in Level 1, Level 2 and Level 3 data

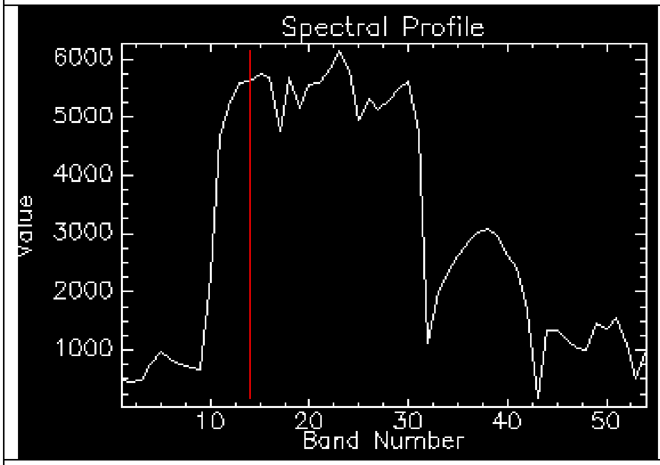
The following figure 3, shows the spectral profile of a vegetation pixel in all the level images.



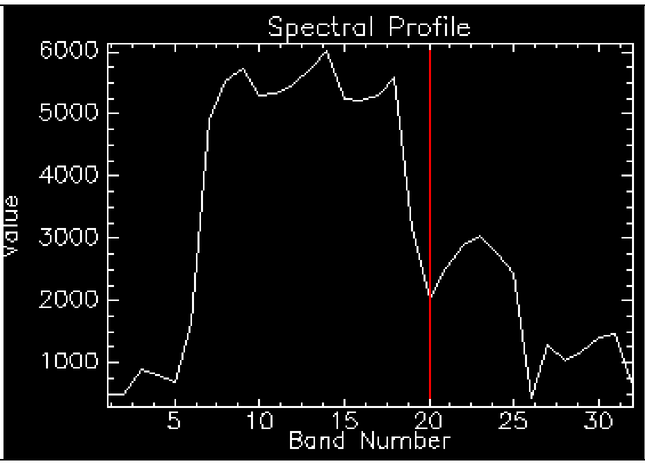
Original Image (242 bands)



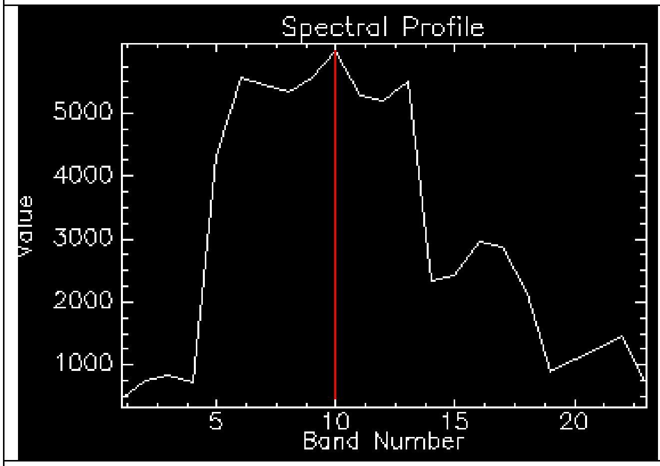
Level 1 : QUAC Reflectance Image (163 bands)



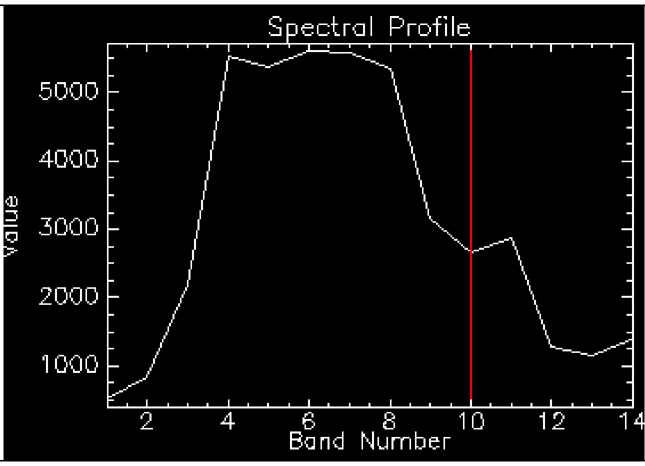
Level 2: Three Band Average Image (54 bands)



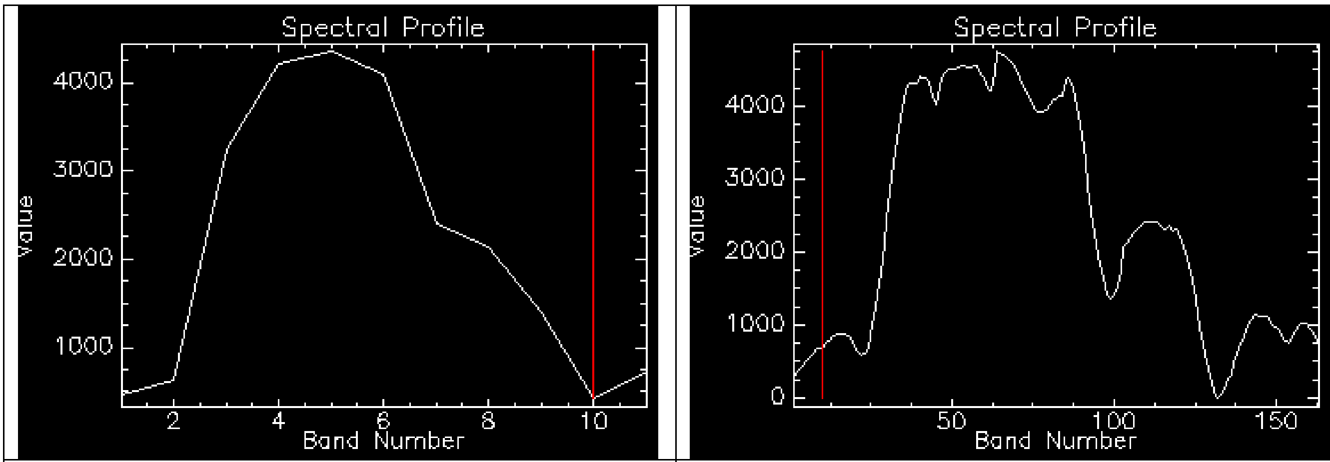
Level 2: Five Band Average Image (32 bands)



Level 2: Seven Band Average Image (23 bands)



Level 2: Eleven Band Average Image (54 bands)



Level 2: Fifteen Band Average Image (54 bands)	Level 3: Savgol filtered Image (163 bands)

Figure 3: Spectrum of a vegetation pixel obtained for different level images

The spectral profile of the pixel in the original image shows bands where there is no response. The spectral profile of the pixel after removing the bad bands and atmospheric correction, can be seen showing higher reflectance in the near-infrared region. Drops can be observed at the end of visible region, near band number 100,135 due to water absorption. A lot of noise can be observed in the spectrum. The averaging of the bands reduces the noise in the spectral signature. As the bands start combining the finer variations within the bands aren't visible. With the increase in the number of bands to 15 ,only the drop between visible and NIR regions, peak of higher reflectance in the NIR region, and drop at SWIR regions at water absorption band is visble. Level 3 image has a smoother spectral profile with no noise. All the variations in the profile in visible , NIR and SWIR region can be observed properly.

6. Classification of Level 1, Level 2 and Level 3 data

The images are classified into four classes: 1) Vegetation, 2) Water, 3) Barren Land and 4) Settlement. The classification is done using reference spectrums obtained from Region of Interest (ROI)s of each class. Random Forest classifier algorithm is implemented to classify the images. The number of trees used for classification is 10, which is kept constant for classification of all the images. Random forest is a very popular and widely used estimator that fits a number of decision tree classifiers on various sub-samples of the dataset and uses averaging to improve the predictive accuracy and control over-fitting. After, training the model, probability matrix is calculated. The class with highest probability and at the same time more than 0.6 is assigned to the pixel, otherwise left unclassified. For validation purpose, NDVI image has been generated using the atmospherically corrected data. Using thresholds (NDVI>0.2 for vegetation and -1>NDVI>-0.1 for Water) the NDVI image is classified into two classes and compared with classified images to determine the percentage of correctly classified vegetation and water pixels using Confusion matrix.

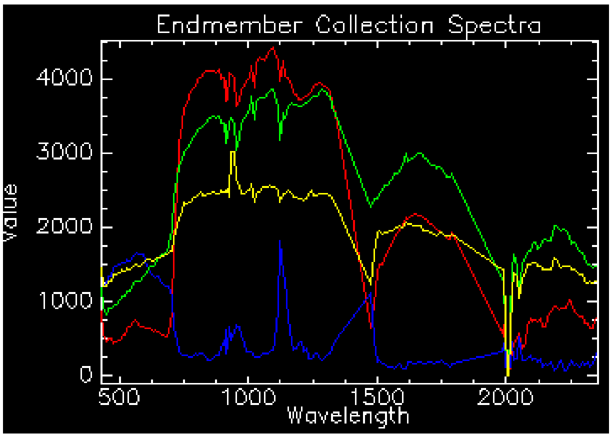


Figure 4: Reference mean Spectra obtained for Level 1 Image (Water: Blue, Barren: Green, Vegetation: Red, Settlement: Yellow)

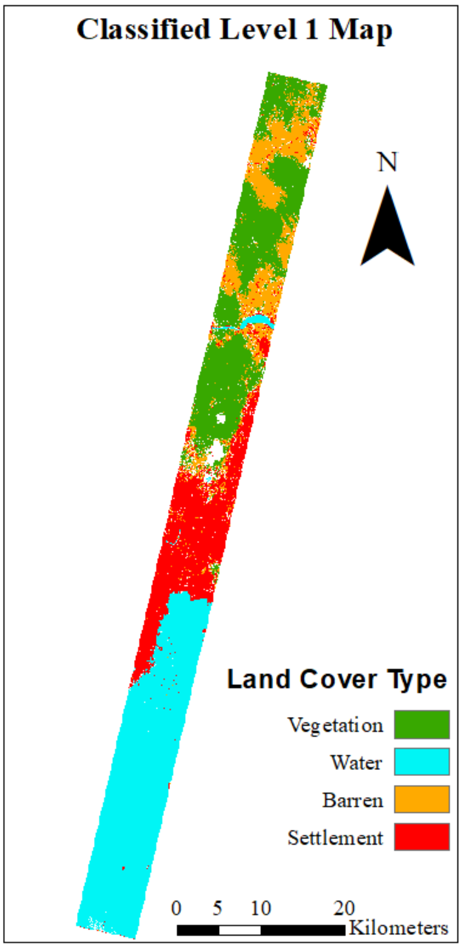


Figure 5: Classified map of atmospherically corrected image

Figure 5 shows the classification of radiometrically corrected data with 163 bands. It is observed that few water pixels are unclassified, because of probability lesser than 0.6 . The confusion matrix obtained between the predicated image and NDVI image are as follows (Table 3):

	Predicted		
Actual	No Class	Vegetation	Water
No Class	2780430	14	395
Vegetation	218246	222018	0
Water	17636	0	315362

Table 3: Confusion Matrix between level 1 classified map and NDVI map

Classified images (Figure 6) with 5 band averaging and 11 band averaging, had maximum correctly classified water pixels than others. Vegetation class was however, similar with approximately 50% classification accuracy. The confusion matrix for all the level 2 images are shown below (Table 4-8).

	Predicted		
Actual	No Class	Vegetation	Water
No Class	2780421	23	395
Vegetation	219982	220282	0
Water	14055	0	318943

Table 4: Confusion Matrix between level 2 (3 band average) classified map and NDVI map

	Predicted		
Actual	No Class	Vegetation	Water
No Class	2779785	42	1012
Vegetation	220496	219746	22
Water	7946	1	325051

Table 5: Confusion Matrix between level 2 (5 band average) classified map and NDVI map

	Predicted		
Actual	No Class	Vegetation	Water
No Class	2780279	56	504
Vegetation	218845	221418	1
Water	19523	9	313466

Table 6: Confusion Matrix between level 2 (7 band average) classified map and NDVI map

	Predicted		
Actual	No Class	Vegetation	Water
No Class	2779755	62	1022
Vegetation	218723	221509	32
Water	7059	10	325929

Table 7: Confusion Matrix between level 2 (11 band average) classified map and NDVI map

	Predicted		
Actual	No Class	Vegetation	Water
No Class	2780042	163	634
Vegetation	218567	221693	4
Water	10702	260	322036

Table 8: Confusion Matrix between level 2 (15 band average) classified map and NDVI map

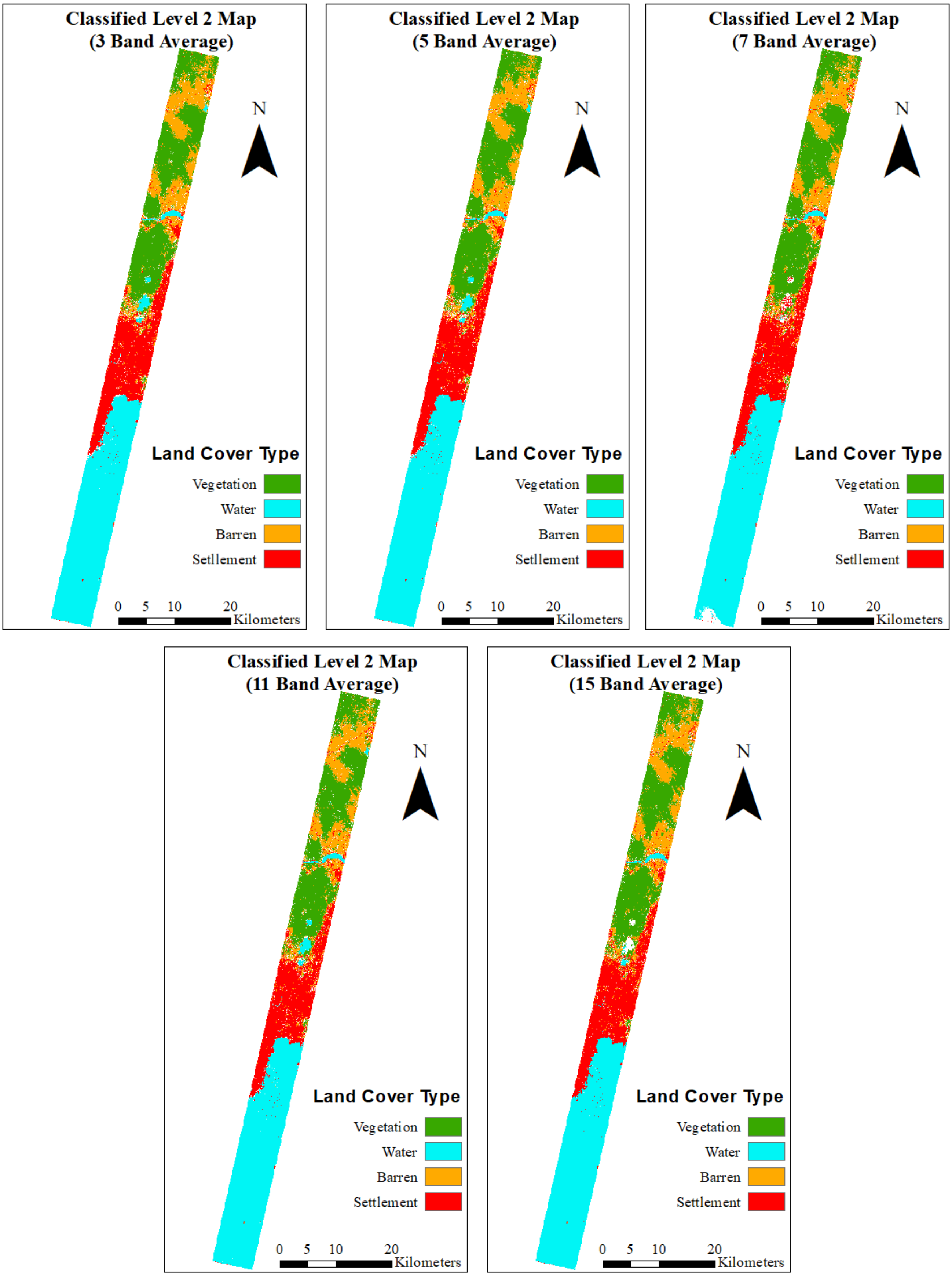


Figure 6: Classified Maps of images obtained by averaging bands.

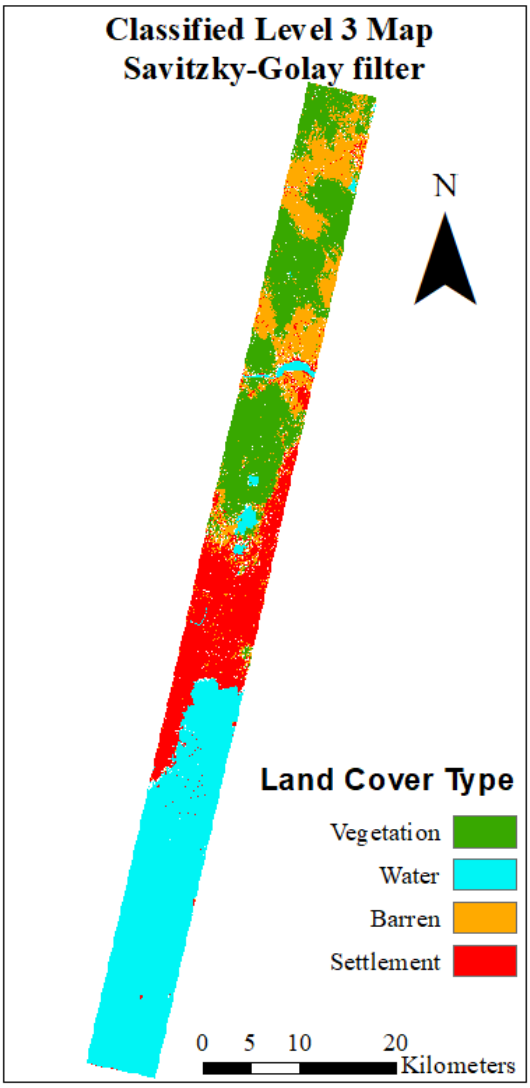


Figure 7: Classified image after applying Savitzky Golay Filter with window length 19 and polynomial order 2

The classification accuracy, for both the classes among all the classified images was found highest in Level 3 classification map (Figure7), i.e. after applying the Savgol low pass filter for signal smoothening. The confusion matrix for the same is shown below (Table 9).

		Predicted		
Actual		No Class	Vegetation	Water
	No Class	2873343	1140	1098
	Vegetation	126109	219302	111
	Water	8002	13	324983

Table 9: Confusion Matrix between level 3 classified map and NDVI map

The classification accuracy in percentage for each class obtained for various classified maps is given in the table 10 below.

Classified Map	Vegetation (%)	Water (%)
Level 1	50.43	94.70
Level 2 (3 bands average)	50.03	95.78
Level 2 (5 bands average)	49.91	97.61
Level 2 (7 bands average)	50.29	94.13
Level 2 (11 bands average)	50.31	97.88
Level 2 (15 bands average)	50.35	96.71
Level 3 (savgol filter)	63.47	97.59

Table 10: Percentage accuracy in classifying classes

Table 11 shows the random forest classifier accuracy obtained for classification of different level maps.

Classified Map	Prediction Score(%)
Level 1	97.98
Level 2 (3 bands average)	98.06
Level 2 (5 bands average)	97.95
Level 2 (7 bands average)	97.54
Level 2 (11 bands average)	96.94
Level 2 (15 bands average)	96.89
Level 3 (savgol filter)	98.55

Table 11: Percentage accuracy of Random Forest classifier.

All the codes and results are available on https://github.com/Sumana18/Hyperspectral-Data-Processing/

References:

[1] USGS, "USGS EROS Archive - Earth Observing One (EO-1) - Hyperion." [Online]. Available: https://www.usgs.gov/centers/eros/science/usgs-eros-archive-earth-observing-one-eo-1-hyperion?qt-science_center_objects=0#qt-science_center_objects. [Accessed: 31-May-2020].

[2] B. P. Ganesh, S. Aravindan, S. Raja, and A. Thirunavukkarasu, "Hyperspectral satellite data (Hyperion) preprocessing-a case study on banded magnetite quartzite in Godumalai Hill, Salem, Tamil Nadu, India," *Arab. J. Geosci.*, vol. 6, no. 9, pp. 3249–3256, 2013, doi: 10.1007/s12517-012-0584-8.

[3] B. Datt, T. R. McVicar, T. G. Van Niel, D. L. B. Jupp, and J. S. Pearlman, "Preprocessing EO-1 Hyperion hyperspectral data to support the application of agricultural indexes," *IEEE Trans.*

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[4] A. Land, I. Ali, and T. Beckmann, “Advanced Land Imager (Ali) Level 1G (L1G) Product Output Files Data Format Control Book (Dfcb),” 2005.

[5] ENVI, “ENVI Atmospheric Correction Module: QUAC and FLAASH user’s guide,” *Modul. Version*, p. 44, 2009.