CHAPTER 5

Chapter 5
Summary and Conclusions

5.1 INHERENT & EXPERIMENTAL ISSUES

When the hyperspectral data is studied for the issues that affect the overall quality of the results pertaining to vegetation assessment, the much needed clarity and the need for systematic data analysis came into being. The conclusions derived from this analysis are discussed in the following section.

The thorough analysis of the hyperspectral data revealed the following points:

i. For vegetation, the shift in bands is of higher significance especially in the VNIR range. On account of it, wrong identification of the vegetation type and its condition could be made. Thus, it should be checked every time before using hyperspectral data as no two datasets have same level of smile. Smile effect can be present in variable proportions across the hyperspectral image. Since, deviation from the ostensible band positions on account of it, can be positive as well as negative, so, no simple bias correction can be done. Also, the deviation does not follow any particular order. This poses limitation on fitting of empirical model to rectify these wavelength shifts. However, it can be rectified at processing level. And, it changes across track but along the image it remains the same.

ii. The pattern and magnitude of radiance/reflectance values in spectral plots provide a key to the normal functioning of the sensor and the associated data processing techniques. In addition to this, presence of out of band response in the spectrum causes shielding or concealing of the relevant peaks and dips and thus must be reported. The analysis of these factors can help in improving the response of the sensors. AIMS is an example of it.

iii. Many a times, band-to-band mis-registration is not visible from the naked eye. For such cases, quantitative assessment has to be done. As a consequence of band-to-band mis-registration, the most affected pixels are the boundary pixels in a classified image.

iv. Sometimes, the presence of noise in hyperspectral data is visible through the presence of stripes. But, many times, the noise is not visible from the image but it interferes with the analysis. In such cases, computation of scene SNR becomes important. Based on scene SNR, the noisy bands are removed at pre-processing levels. Removal of noisy bands based on this method helped in improving upon the classification accuracy from 62% to 79% in AIMS data.

v. The selection of optimum exposure time is important for the collection of sufficient amount of energy in each band without causing image blur. By studying the spectral profile of vegetation, this analysis yielded exposure time of 10ms as an optimum value.

vi. As regards to optimum number of samples required for generating spectral profile, representative of a particular species, it is found that 7-10 samples are sufficient as they address the diversity well. Beyond 10 samples, the change in spectra is insignificant.

vii. The spectral profile of a single leaf is significantly different from a stack of even two leaves. As the number of leaves in a stack increases, the magnitude of the spectra increases. However, the change in reflectance is comparatively low between a stack of 2 leaves and 7. Associated ground information is also necessary while labelling the target vegetation in the image.

viii. The spectral plot for the mature leaf is the standard one and is usually found on ground as well as in spectral library. The spectrum of young leaf does not resemble the typical reflectance curve as is shown in the example of *Madhuca indica*. If this signature is used for training purpose, the resulting classification would be erroneous. This is an example where spectra interpretation can introduce huge conflict. Thus, knowledge of phenological stage of the vegetation is of utmost importance before using the spectra for further analysis.

ix. The varieties of a particular crop are easily discernable by their typical absorption features captured in the hyperspectral data. The same holds true for the species type. Thus, owing to the species as well as variety, the spectral profiles look different which may cause wrong identification of the target of interest. These factors should be borne in mind while labelling the target in the image. Also, while developing spectral library, these details should also be tagged.

x. Choice of Saturation Radiance should be carefully made because same DN value corresponds to variable radiance with change in SR.

xi. Field Spectroradiometers generally measure a much smaller area, therefore, sampling complete area of interest becomes difficult. So, appropriate sampling strategy has to be adopted. To avoid stray reflectance, the observer must avoid wearing bright cloths and keep himself away from the camera's Field of View (FOV). Tripod should be used for repeated observations so in order to avoid changes in reflectance with hand shiver. Any change in environmental conditions calls for recollection of reference spectra. Instrument should be properly warmed up before starting measurements. The height of data acquisition should be carefully considered and should be in concurrence with the FOV of the instrument.

xii. For hyperspectral image validation, viewing geometry similar to the sensor is required. For developing spectral library, usually, nadir view in direct sunlight is required. Care should be taken to avoid diffuse sunlight.

5.2 ISSUES OF ATMOSPHERIC CORRECTION, DATA REDUNDANCY AND IMAGE CLASSIFICATION

i. While analyzing remote sensing data in order to derive meaningful interpretation, atmospheric correction and image classification form the two essential steps. However, when the data is hyperspectral data, one more step becomes essential and that is removal of redundant bands.

ii. Radiance plot of vegetation in the above image shows a large number of prominent dips corresponding to atmospheric constituents. When these dips are flattened after atmospheric correction, the reflectance image is generated. The spectra from this image resembles the spectra obtained through standard spectral libraries which helps in identifying the target as well as its status. As regards to data redundancy, feature extraction as well as reduction techniques exist but their success is measured through the improvement in classification accuracy owed to them. Furthermore, due to very large number of bands conventional classifiers are not suitable, so hyperspectral-centric classifiers are required. This has led to the identification of the feature extraction/reduction method and classifier which yield the best classification accuracy while using hyperspectral data in various domains of vegetation assessment.

iii. Relative methods of atmospheric correction may give 'vegetation like spectra' where the pseudo reflectance values don't owe any real significance but they do emphasize upon the important absorption features. Secondly, the inflection point of red edge is apparent in addition to difference in magnitude between visible and NIR regions, although the spectra is very different from the real spectra. These methods may help in objectives like classification, where absolute atmospheric correction is generally not needed but are not suitable for quantitative studies like biochemical parameter estimation.

iv. In using absolute methods of atmospheric correction, water vapor retrieval through one of the water vapor absorption channel is important in improving atmospheric correction. The reflectance values obtained from Spectroradiometer and through 6S code match closely with each other but vary significantly from both the absolute as well as relative methods of atmospheric correction. The use of either of the inbuilt atmospheric models in FLAASH doesn't affect the reflectance values greatly.

v. The effect of change in zenith angle on retrieving surface radiance from Phytoplankton colonies is studied. Here, the surface radiance increases by 4-5 times with increase in zenith angle. This calls for taking into account this effect before any inference is made from the data.

vi. Step-wise Discriminant Analysis is suitable for analyzing the data when the input is in the form of spectral plots and not images. It is suitable for discrimination between vegetation types, varieties, growth stage and crop residue.

vii. Image texture is a good means to address the issue of band redundancy in hyperspectral data. Here, a novel technique of band extraction using image texture is developed.

viii. Both MNF based band extraction and image texture based band extraction were investigated for providing better classification accuracy using hyperspectral-centric classifiers as well as classifiers for multispectral data. The combination of image texture based band extraction along with SVM classifier outperformed all other combinations for discriminating tropical tree species and mangrove tree specie

5.3 OPTIMUM SPATIAL & SPECTRAL RESOLUTION

Even with the same spatial resolution, the sensor having better spectral resolution outperforms the other. Thus, the choice for optimum spectral resolution is important keeping in mind the application planned. At the same time, spatial resolution should be so selected so that the contrast of the image is not compromised. In these contexts, the studies were conducted which yielded the following understanding:

i. Beyond 10nm, species level identification of vegetation is not possible. Also, if there exists a band shift, the unique peaks would be lost. For discriminating crop residue from other farm components, the optimum spectral resolution is 10nm although spectral resolution up to 100nm can work. In case of Phytoplankton too, spectral resolution of 10nm is found suitable.

ii. There is a continuous decrease in the contrast ratio as the resolution advances indicating mixing of pixels resulting in lesser information. Beyond 60m, the contrast ratio declines sharply for Hyperion while it declines sharply at 16m for AIMS. From this analysis, it may be concluded that for targeting different objects different resolutions are required which depends on object size and characteristics to be retrieved.

iii. The dynamic range of the sensors should be wide enough to capture the low as well as high albedo targets. But, in both the cases the SNR should be separately defined.

5.4 FUTURE DIRECTIONS

Hyperspectral data is very promising due to the presence of a very large number of closely spaced bands. But, as discussed in the preceding sections and chapters, the hyperspectral data involves a complex set of lot of intermingling factors involving the sensor design and underlying physics, processing models and software, experiment design, understanding of the influence of one factor over another and the expertise in data assessment. Since, this study is mainly concentrated on understanding of hyperspectral data quality issues with regards to vegetation assessment, similar kinds of studies are needed for geological observations also, so that a sensor is designed in totality covering all applications. Although, this study involves marine single celled autorophs, the phytoplankton, but, is mainly concentrated on terrestrial vegetation. The reflected signal attenuates largely in water and at the same time, the phytoplanktons vary in quantity and spatial abundance diurnally also, which is in great contrast to the terrestrial observations. Thus, the analyses as well as the sensor specifications change in marine vegetation studies quite significantly from the terrestrial vegetation. Thus, similar kind of study is much needed precisely for marine vegetation also. Based upon the understanding derived from this study regarding issues that affect the quality of hyperspectral data analysis and results, the future studies also hold scope for intensive and extensive use of hyperspectral data in addressing the problems of the society.