CHAPTER 5

SUMMARY AND CONCLUSIONS

5.1 INTRODUCTION

This chapter summarizes the contents of the thesis and the results of the experiments carried out to explore the applicability of hyperspectral radiometry in the VNIR-SWIR regions, to estimate certain index properties of a variety of soils. Section 5.2 presents a summary the work carried out during the process of this research work. Section 5.3 lists the conclusions to the thesis as a whole. Finally, suggestions for further research are listed in section 5.4

At the outset of the thesis, it was noted that index properties such as texture, water content, OMC, mineralogy and clay content influence the spectra of soils in the VNIR and SWIR regions. Further it is also observed that the influence of these index properties is manifested in the form of reflectance or absorption at narrow wavelength regions, thereby necessitating the use of hyperspectral radiometry.

5.2 SUMMARY

Chapter 1 of this thesis presented an introduction to the index properties of soils and the conventional techniques used to estimate these properties. The limitations of the conventional techniques and the advantages of hyperspectral radiometry has also been presented. The need for the use of hyperspectral radiometry and the aims and objectives of this research has also been listed in chapter 1.

Chapter 2 reviewed the literature related to the estimation of soil properties using conventional methods, remote sensing application to soil studies, the role of hyperspectral remote sensing in estimating soil properties, laboratory based spectral studies of soils and its current status. Such a review has helped in formulating the aim, objectives and the methodology for this research.

Chapter 3 discussed in detail, the methodology and experimental set-up for this study. This chapter involved the description of the standardization of the instrument (spectro-radiometer), sample preparation, the procedure of obtaining spectra, spectral curve analysis and modelling.

Chapter 4 presented the observations of spectro-radiometric experiments carried out using several soil types collected from various locations in Tamilnadu state, south India. Observations include those related to spectral parameters (overall reflectance, Area under the Curve, slope of the curve at given wavelength regions, depth of absorption at given wavelength regions, spectral separability etc). Observations are also related to textural characteristics, mineralogy, Liquid Limit, Plastic Limit, OMC, water content etc. Discussion on these observations and their significance is also presented in this chapter. Based on the observation, results and discussion, certain conclusions were drawn. These conclusions are listed in section 5.3 of this chapter.

Thus the various ways in which hyperspectral radiometry could be used to estimate certain index properties of soil has been presented in this thesis.

5.3 CONCLUSIONS

5.3.1 Texture

In general, the overall reflectance increases when the grain size decreases. This statement, however, applies only to soils which have uniform colour and mineralogy (from coarse soil to fine soil).

Spectral parameters typical of the visible region were observed and it is seen that the slope of the spectral curve in the 350-800nm region relates very well (R^2=0.9114) to the texture.

Spectral response in the entire region (350-2500nm) is governed by soil texture for uniform soils.

NIR region is well suited for soil textural analysis for non uniform soils.

The results of the average spectral analysis results of different types of soil clearly shown that beach sand and river sand textural analysis can be done using the parameter, 'Slope at 1000-1400nm region'. Since it gives the good correlation result compared to other parameters.

"Area under the curve" is the best suited parameter to estimate the soil texture of red and black soils.

5.3.2 Water Content

When the soil moisture content increases, the overall reflectance increases. However, this statement is not suited when the saturation limit of a soil sample is exceeded. The interaction of soil and the energy in the 1400nm region is fully governed by soil water content.

Depth at 1400nm is best suited parameter for analysing water content in soils even beyond saturation limit

5.3.3 Organic Matter Content

Colour of the soil is highly influenced by its organic content. The spectral response of soils in the visible region is governed by organic matter.

- According to the results of spectral parameter analysis, the spectra is highly influenced by SOM in visible region.
- AUC at visible region is best suited parameter for SOM identification.

5.3.4 Mineralogy

Calcium carbonate rich soils have high reflectance in the visible, NIR and the SWIR regions.

- Beach sand with heavy minerals shows the good relationship for a parameter ‘Slope at 350nm region’.

Certain well defined narrow, wavelength regions characterise a few minerals or their groups. These include:

- Calcium carbonate : Absorption at 2350nm
- Clay minerals : 2200nm absorption
- Hydroxyl ions in soil and H_2O absorption bands : Depth at 1950 & 2200nm
- OH group in soil - Absorption at 2200nm
- Silica - High reflection in NIR and SWIR regions

- Iron content in soil – Absorption at 900nm
- Iron oxide : Reflection in Visible (red) and NIR absorption
- Titanium : Strong absorption in visible region (in soils associated with Rutile).
- Kaolinite : Doublets at 1400nm.

5.3.5 Other Soil Properties

- Clay content in soil can be characterised due to its characteristics spectra in the 450-1100nm region.
- Density of soil influences the spectra in the entire VNIR-SWIR region.
- Liquid limit and plastic limit do not portray any defined relationship with the spectral parameters.

5.3.5.1 Clay Content

- Clayey and non-clayey soils can be differentiated due to their highly separable spectra.
- Salinity in clayey soils has a profound influence on the NIR and MIR spectra.
- The optimal region for discriminating non-clay and clayey soils is 450-1100nm region, because in wavelength regions less than 450nm and greater than 1100 nm, the seperability decreases due to absorption of energy.

- Red clayey soil and its composition can be very well characterised by analysing the NIR absorption-trough for such soils.
- The spectra of the mixtures are more sensitive to the proportion of sand in a mixture rather than the proportion of kaolin clay in the same mixture.
- The 350-800nm region is well suited to characterise mixtures of kaolin and sand.due to the higher spectral seperability in this region.
- The abundance of clay in mixtures containing sand, kaolin, ball clay and red clay can be accurately estimated using the ‘Depth at 1400nm’ as a parameter, since it is highly correlated with the clay content (R^2= 0.83 for sand + kaolin, R^2=0.93 for sand + ball clay, R^2= 0.89 for sand + red clay).
- Sand content in black clay can be estimated correctly using ‘Radius of Curvature at 2250nm’ as an effective parameter.

5.4 SCOPE FOR FURTHER WORK

Though this work has been carried out in an extensive manner, there is adequate scope for further work to be done. A few of these are:

- ➢ Only five to seven varieties of soil have been taken into account in this study. However, many more soil types could have been selected for this study.
- ➢ Field / in situ measurements could have been done instead of laboratory based measurements. This could have been more closer to the ideal situation.

- This work could be extended to the image scale, ie spectral curves could have been derived from an hyperspectral image such as Hyperion and the index properties could have been derived from such spectral curves.