CHAPTER 8

SUMMARY AND CONCLUSION

8.1 SUMMARY

This chapter summarizes the contents of the thesis and the results of the experiments carried out to explore the applicability of moderate resolution multi-spectral satellite images to map and monitor the water-spread area and the capacity of large multi-purpose reservoirs. Section 8.2 summarizes the principal results of the various experiments carried out and presented in chapters 4, 5 and 6. Section 8.3 provides a brief conclusion to the thesis as a whole. Finally, suggestions for further research are outlined in section 8.4.

At the outset of the thesis, it was noted that erosion in the upper reaches and in the catchment area, followed by transportation and deposition in the reservoirs, is often the primary cause of reduction in the volume of the reservoirs. This has prompted the hydrologists and reservoir managers to shift their focus from conventional time consuming and error prone capacity estimation techniques to rapid, inexpensive, easy and accurate remote sensing based approaches to capacity estimation. It has also prompted the present study to map the reservoir water-spread area and reservoir capacity in three large multi-purpose reservoirs of south India, using multi-spectral satellite images and spectro-radiometry.

Chapter 1 introduced the broader concepts of catchment erosion, its causes, the threats faced and the consequent reduction in reservoir capacity. The various conventional techniques and the importance of remote sensing techniques in estimating area and volume of the reservoir was also discussed in the chapter.
In chapter 2, the literature available on the significance of erosion in the catchment area, reduction in capacity of the reservoir due to the deposition of eroded material, the role of field based conventional surveys and mathematical based techniques, the role of remote sensing based approaches which includes per-pixel and sub-pixel techniques, the spectral studies of landcover components. Based on the literature review the gaps in research related to remote sensing applications were identified and accordingly the broad aims of this thesis, were enumerated in chapter 2.

Chapter 3 presented a description of three study reservoirs (Nagarjunsagar, Singoor and Vaigai) chosen to test the applicability of remote sensing techniques. The chapter also described the various image data sets acquired and used in this study, placing emphasis on the water year, cloud-free nature and the availability of contemporaneous high resolution data.

The methodology of the first set of experiments carried out using the per-pixel classification approach is described in chapter 4. These experiments included selection of training classes from the images of three reservoirs, analysis of the spectral seperability and the analysis of classification accuracy. Based on the results of per-pixel classifier, water-spread area and the capacity estimates were arrived at for the three reservoirs at different water levels. The significance and implications of the errors in the per-pixel approach have also been discussed in this chapter.

Chapter 5 listed the limitations of per-pixel approach and the justifications for advocating sub-pixel approach are given. This is followed by estimation of sub- pixel parameters of the peripheral pixels of the reservoir by means of the linear mixture model. Selection of the inputs of the model, namely the end-members, description of the out puts of the models namely, fraction images and estimation of water-spread area from the water fraction image is also described in this chapter. This is followed by the validation of water-spread area using high resolution image data and estimation of capacity of the reservoir from the fraction images.
Chapter 6 analyzed the results of laboratory based spectro-radiometry carried out on various mixtures of materials that represent the components of the peripheral pixels of a the multi-purpose reservoir. The influence of the individual and mixed components on the DN value of pixels in the image of the reservoir system is also discussed.

The three experiments related to image analysis and spectro-radiometric study of the reservoirs culminated in certain observations and findings, whose significance is discussed in chapter 7. Thus, the various ways in which remote sensing data and information extraction techniques could be used to accurately estimate the water-spread area and the capacity of reservoirs have been presented in this thesis. The principal results of these applications are summarized in the following sections.

8.2 SUMMARY OF PRINCIPAL RESULTS

It is observed that hard/per-pixel classification of multi-spectral satellite image data of multi-purpose reservoirs results in inaccurate estimates of water-spread area and reservoir capacity. Sub-pixel classification may be useful in accurately estimating these parameters. Thus, as an alternative to the hard/per-pixel classification techniques, linear mixture model is a promising tool that can be used to extract accurate information on reservoir water-spread area and capacity.

8.3 CONCLUSIONS

The multi-temporal image data sets pertaining to different water levels of the three reservoir sites have offered adequate information about the spectral characteristics of the reservoir water and the water in the peripheral areas, in the visible and NIR wavelengths. While water in the central portions of the reservoir have strong absorption in the visible and NIR wavelengths, the water in the peripheral pixels of the reservoir have moderate to high spectral response in the visible and NIR wavelengths. This leads us to conclude that the peripheral pixels and pixels in the central portion of the reservoir can be discriminated by using the
visible and NIR bands. However, the moderate to high response in the VNIR band of the water peripheral pixels implies that there could be inaccuracies while classifying these pixels as water.

The seperability measures such as Euclidean Distance and Transformed Divergence values provided the opportunities to examine the quality of the training sets used for the image classification, apart from indicating the possibility of spectral overlap. It was learnt that there is spectral overlap between the peripheral pixels containing water and other pixels containing soil and vegetation adjacent to the peripheral pixels.

It is therefore opined that use of an image data, where spectral overlap exists, might result in alarming inaccuracies in computation of water spread area, perhaps due to per-pixel allocation by the ML classifier and possibly due to the ‘coarse’ resolution of the image data.

A note-worthy observation from the spectra for the set of mixtures is that when water fraction is more than 60% in any of the mixture, the spectral seperability is almost nil in the visible region (450 to 700 nm), whatever be the fraction of soil present in the mixture.

It was also observed, that there is appreciably higher NIR spectral seperability for mixtures with low amounts of water (10 to 40%), than for mixtures containing high amount of water (> 60%). That is, the estimation of water fraction by sub-pixel approach in the peripheral pixels of a reservoir with low abundance of vegetation will be more accurate than for the peripheral pixels which have high abundance of vegetation.

The decrease in spectral seperability for high-vegetation and low-water mixtures could result in erroneous estimates of vegetation and water fraction while performing sub-pixel classification of images of reservoirs that are bounded by dense vegetation.
In addition, the spectral curves also indicated that vegetation fraction above 40% can be estimated with greater accuracy using slope of the curve in the 765 to 950 nm region as a parameter. This study has lead to the inference that the estimation of water/vegetation/soil fractions by sub-pixel classification will be accurate for pixels which have up to 40% vegetation in them.

If a pixel contains highly turbid water, it is likely that the sub-pixel classifier may calculate and assign high values for soil fraction and low values for water fraction. Thereby, it is possible that a pixel fully occupied by turbid water may not be assigned 100% of water as its value, which is a erroneous computation.

High spatial-resolution image data enables accurate mapping of the terrain features. The use of high spatial resolution satellite image data, however, is constrained by factors such as cost and less area coverage by the sensor. Hence, the use of the commonly available medium-resolution image data becomes imminent. The processing of such data using the sub-pixel approach is recommended.

The validation shows that the application of sub-pixel approach produced very less error (1.08) than the per-pixel (3.14) based approach. Relatively lesser error shown by the sub-pixel approach presents a case for potential use of the technology for estimation of capacity of other reservoirs with acceptable accuracy.

8.4 SCOPE FOR FURTHER RESEARCH

Addition of higher temporal resolution may yield better results. However, the economical usage of temporal resolution image data may be ascertained for every reservoir to yield better results.

The sub-pixel classifier produces more accurate results with hyperspectral images. Hence the use of hyperspectral image data with higher spatial resolution would have yield better results.

Multi-sensor image fusion, followed by classification of the image data may produce good results.
Non-linear spectral unmixing technique can be applied to produce better results.

Shortwave could have also been included both in image analysis and spectro-radiometry to obtain better results.