CHAPTER 8

SUMMARY AND CONCLUSION

8.1 SUMMARY

This chapter presents the summary of the work done and the conclusions drawn from the experiments carried out as a part of this work. Chapter 1 introduces the problems of the coastal zone, the need for mapping the coast, problems in mapping the complex coastal features and the concept of remote sensing and its applications. This chapter also lists the aim of this study, which is to realise the potential of certain recent and emerging image processing techniques applied to multi-sensor satellite image data for mapping coastal features of Tamil Nadu State.

To have a understanding of the various researches carried out in the field of coastal mapping and remote sensing applications, a number of research articles, journals, conference proceedings and websites were referred to, and the literature thus gathered was reviewed and described in Chapter 2. Such a review aided in developing the methodology to be adopted for this study and also in identifying the limitations of such a methodology.

Three coastal sites were chosen for this study. These sites (Pitchavaram, Vedaranniyam and Rameswaram) are geomorphologically and ecologically important and spatially complex in nature. It is believed that mapping such complex environments using remotely sensed data is less expensive and more information can be extracted. Hence, many satellite image data such as those acquired by IRS-1C/1D LISS-III, PAN, Landsat-TM (including thermal) and ERS-2 SAR sensor were used, because these multi-sensor images could provide more information of such complex
coastal features. The characteristics of these images were described and listed in Chapter 3.

As enhancing the quality of the above mentioned images is one of the objectives in this thesis to bring out more informations about the coastal features, various conventional and recent image enhancement techniques were attempted and reported in Chapter 4. The results obtained from the conventional techniques did not bring out much information about coastal features of the study sites. Hence, a recently evolved enhancement technique, namely image fusion was attempted with multi-sensor image data to bring out better information about the various coastal features. Fusion of LISS-III and PAN image data using wavelet transform brings out detailed information about different coastal features of Pitchavaram and Vedaranniyam study sites. Similarly, fusion of thermal (Landsat-TM band6) and Landsat-TM band 542 using wavelet transform brings out better information about soil moisture, coral reef and other vegetation communities of Rameswaram study site. This study also attempts to fuse optical and radar data for enhancing certain coastal features, which are otherwise not clear in a single sensor data. LISS-III and speckle filtered SAR image data of Pitchavaram and Vedaranniyam were then fused, and the results were compared with the original image data. Among all the techniques used in this study, it is seen that fusion using brovey transform has brought out enhanced information about aquaculture and different mangrove species such as *Rhizophora apiculata* and *Avicennia marina* in the Pitchavaram study site. In the Vedaranniyam study site, dry and wet mudflats, reclaimed mudflat, submerged mudflat and sandy areas were clearly brought out in the fused images.

For mapping coastal features of the three study sites, image classification was attempted in Chapters 5 and 6. Image classification using unsupervised and supervised techniques to derive the information classes from IRS-1C/1D LISS-III and Landsat-TM image data of the study sites was attempted and reported in chapter-5. It was observed that the unsupervised classification using ISODATA classifier produced
broad coastal land cover classes. When compared with manual delineations from the imagery (hard copy), it is seen that this automated method gave more information about certain coastal features such as marsh, scrub, mangroves, forest, plantation, mudflat, salt pan, sand dune/sandy areas and water of the study sites. Since moderate level of accuracy was achieved in using unsupervised classification, supervised classification (Maximum Likelihood Classifier) was attempted to generate better and accurate coastal land cover maps of the three study sites.

As a first step to supervised classification, Transformed Divergence and Jeffries-Matusita separability measures were computed and analysed to evaluate the training signatures and to perform better classification. There were four groups of class types (5, 10, 15, and 20 classes) produced in each image of the three study sites. The accuracy of the information classes was analysed in terms of overall and kappa accuracy. The results obtained from supervised classification technique reveal that the overall accuracy decreases when the number of classes increases. This is mainly due to the 'coarse' spatial resolution and occurrence of 'mixed pixels' in IRS-1C/1D LISS-III and Landsat-TM image data. Thus, per-pixel classifier (Maximum Likelihood Classifier) results in misclassification, and accordingly less accuracy in labelling several classes is observed. Realising these problems, spectral unmixing to derive sub-pixel level coastal information for the three study sites was attempted in Chapter 6.

Spectral unmixing is an excellent approximation for calculating the abundance or fraction of an end-member in an image pixel. It assumes that the measured reflectance of a pixel is the linear sum of the reflectance of the mixture components that make up that pixel. As spectral unmixing is a procedure that requires spectra of end-members, Principal Component Analysis, Minimum Noise Fraction and Pixel Purity Index techniques were attempted to collect spectrally distinct end-members. Spectral unmixing was then performed and the fraction images for each end member (soil, vegetation and water) were derived. Validation of unmixed proportions of soil and vegetation was carried out by comparison of the fraction images and NDVI
values. NDVI and the vegetation fractions obtained by spectral unmixing are well correlated and the $R^2$ values are above 0.90 in all the study sites, thus indicating the validity of the unmixing model.

Good correlation was also observed between ground derived moisture fraction and image derived moisture fraction; and between ground derived soil fraction and image derived soil fraction in the Muthupet lagoon area of Vedaranniyam study site. The $R^2$ value for the relationship between actual and computed moisture fraction is 0.82 while $R^2$ value for the relationship between actual and computed soil fractions is 0.90.

The results of spectral unmixing were also compared with the results of supervised classification. This comparative results reveal that the spectral unmixing has good potential in bringing out sub-pixel coastal informations at greater accuracy compared to the supervised classification.

Thus the applicability of certain recent image enhancement and image classification techniques for improved coastal classification was demonstrated in this thesis.

8.2 CONCLUSION

In general, it may be concluded that this study demonstrated the application potential of image enhancement and classification techniques applied to multi-sensor image data to bring out detailed and accurate informations about coastal features.

The specific conclusion drawn from this research work are as follows:-

- Contrast stretching is a technique, that suits well to enhance marsh, mangroves, scrub, plantation, mudflat, aquaculture and lagoons. Histogram
equalization is better than the other enhancement techniques to highlight sand dunes and sandy areas in all the three study sites. Band ratioing enhances marsh, mangroves, agricultural vegetation and mudflat in Pitchavaram and Vedaranniyyam study sites. PCA is better than other techniques to bring out mangroves, plantation, scrub and other vegetation communities in the study sites. Density slicing is less potential in discriminating the coastal features accurately while filtering tends to smoothen the various coastal features in all the three study sites.

Multi-sensor image fusion enhances coastal land cover informations in a better manner. For optical data fusion (LISS-III+PAN), wavelet transform technique appears to be good to derive spatial information for dense and sparse mangroves, degraded mangrove, marsh, dense and open forest, mudflat, reclaimed mudflat, salt pan, sandy areas and lagoon in the Pitchavaram and Vedaranniyyam study sites. While fusing Landsat-TM bands 542 and TM- band 6 (thermal) of Rameswaram study site, wavelet transform technique is better than the other fusion techniques to bring to coral reef, soil moisture, scrub, plantation and agricultural vegetation. Brovey transform is better than the other fusion techniques in fusing LISS-III and SAR image data for Pitchavaram and Vedaranniyyam study sites. Brovey transform highlights different mangroves (*Rhizophora apiculata* and *Avicennia marina*) and aquaculture ponds in Pitchavaram study site, while highlighting wet and dry mudflat, reclaimed mudflat, submerged mudflat, salt pan and lagoons in Vedaranniyyam study site.

Unsupervised classification gave only broad picture of the coastal land cover features of the three study sites. Higher accuracies were achieved only when few classes were used. Supervised classification gave similar results, i.e., as number of classes increased the overall accuracy decreased. This is due to (i) spectral confusion/overlap among certain classes such as
mudflat and fallow, marsh and mudflat, mudflat and lagoon water, sandy areas and fallow land, mangrove and agricultural vegetation, plantation and agricultural vegetation, (ii) inadequate spatial resolution of the sensor and hence the occurrence of mixed pixels. However, supervised classification is better than unsupervised classification in terms of classification accuracy.

Spectral unmixing is a reliable method to resolve the mixed pixel problem. It gave proportions of various coastal land cover features present within a pixel rather than labelling the entire pixel as belonging to one class. Accuracy of the spectral unmixing model for the relationship between NDVI and vegetation fraction is above 0.9 in all the images of the three study sites. The accuracy of the spectral unmixing model is upto 90.6% for moisture fraction while it is 80.6% for soil fraction. Based on the comparative results of spectral unmixing and supervised classification, spectral unmixing produced accurate estimates of coastal land cover features at sub-pixel level.

8.3 SCOPE FOR FURTHER RESEARCH

- All the enhancement and classification techniques reported in this research may be attempted on the hyperspectral data sets and multi-band and multi-polarization radar images to achieve better results.

- Intensive field spectro-radiometry and validation using more field data is necessary to obtain more accurate results.