CHAPTER 7: SPECTRAL BEHAVIOUR OF DOMINANT MANGROVE COMMUNITIES

Remote sensing plays an important role in the study of the biosphere through its ability to make repeatable measurements of vegetation characteristics at global scales (Gao, 1999). Data from different wavebands (often visible and near-infrared wavelengths) have been combined to produce spectral signatures of the component vegetation. Spectral response in visible wavelengths is affected by leaf pigmentation, in near-infrared region (NIR) due to internal structure of leaves and due to leaf stacking and in middle-infrared (short wave-infrared or SWIR) regions due to leaf water (moisture content). The entire spectral response of mangroves is induced by the chlorophyll content (density and structure of the ecosystem) and by humidity gradient in soils related to tidal levels (Blasco and Aizpuru 2002).

Mangrove terrain is extremely difficult to traverse and a standard set of signatures if available would help in minimizing the ground data collection and will go a long way in accurately identifying species using satellite data. The study using satellite data has a distinct advantage over aerial data and conventional data due to its much lower cost and reaching to areas that are otherwise inaccessible. Spectral studies would not only be extremely useful in assessing the phyto-diversity of the habitat but also productivity, as determination of photosynthetic pigments reflect the physiological status of plants, plants in stress, healthy communities, etc.

There are few studies on spectral behavior of mangrove communities/species in the optical domain, with most of them using ground spectro-radiometers to establish signatures. In recent times airborne hyper spectral sensors such as HYMAP and CASI have been used as they are flown at low altitudes and are capable of collecting image data at sub-meter resolutions. Thus the task of mapping the 'spectral diversity' in highly diverse forests (50 types or more species per hectare) has become feasible and detailed vegetation mapping using hyperspectral sensors have been evaluated with some success in recent years (Held, 2001b). In the microwave region while radar signatures have been established for biomass estimation to some extent, they have not been established for the different mangrove species or communities (Proisy *et al.* 1996, 2001). ***Spectral signatures of mangroves in the optical domain using space-based sensors have not been established.***

7.1 Mangrove species radiometry:

Using ground-based Exotech spectro-radiometer in MSS, TM and IRS bands, for Pichavaram mangroves in Tamil Nadu, Ramachandran *et al.* (1998) showed that all the mangrove species showed similar radiance pattern with variations in intensity of radiance. *Rhizophora lamarckii* showed highest radiance values in 0.5-0.6 µm, 0.6-0.7 µm and 0.7-0.8 µm wavelengths, *R. apiculata* peaked at 0.8-1.1µm and *Avicennia marina* showed higher values in 0.7-0.8 µm and 0.8-1.1µm wavelengths. Sato *et al.* (1992) carried out spectral studies of mangroves using ground-based spectro-radiometer for a few mangrove species at the river mouth of Kesaji river in the northern part of Okinawa Island in Japan. Krishnamoorthy *et al.* (1994, 1996) used the Exotech radiometer with MSS bands and Multi-band Ground-Truth radiometer with MSS, TM and IRS LISS II bands, at Ennore, Adyar and Pichavaram and the spectral radiance of major mangrove species were measured and the results showed similar radiance patterns with variations in intensity of spectral radiance. *R. lamarckii* showed highest radiance values in green, red and NIR bands and *R. apiculata* peaked in SWIR band. *A. marina* showed higher values in NIR and SWIR bands than *R. mucronata*. They also used band ratios of all the six bands of TM (except thermal band) for separating *Avicennia* and *Rhizophora* communities of Pichavaram along with their densities (best results were obtained from the ratio of 4/7 bands). Loubersac (1991) using a helicopter borne HRS (High spectral resolution) radiometer studied the spectral responses of important mangrove communities like *Bruguiera*, *Avicennia* and *Rhiozphora* and concluded that *Bruguiera* had the highest reflectance in the infrared region. Herz (1991) studied the spectral behavior of the *Avicennia*, *Rhizophora* and *Laguncularia* communities using an airborne radiometer and concluded that leaf reflectances alone would not permit the precise discrimination of mangrove communities. Both of the above studies however did not include the middle infrared reflection, which is very important in mangrove community zonation.

A study by Ramsey III and Jensen (1996) using an airborne radiometer with 252 bands (400-1170 nm) concluded that the difference in the reflectance between the *Rhizophora* and the *Avicennia* communities was less than the variance in between the communities.

It is therefore attempted in the present study to establish signatures of major mangrove communities of the study area using purely space-borne sensors (LISS III). Ground evaluation of the sensors were carried out

7.2 Characteristics of mangroves of the study area

Low tide pre-monsoon LISS III data of March 2000 has been used to study the spectral signatures of the mangrove community of the area. The data was converted to apparent reflectance (exo-atmospheric reflectance) and then studied for spectral behaviour. This has been evaluated only at the genus level and where this was not possible, it has been evaluated at the community level.

Pure and homogeneous *Avicennia* is the major community of the study area. The Avicennia community comprises *A. marina* var *marina* (70-80% occupancy) *A. marina* var *acutissma*, *A. officinalis* and *A. alba*. *Ceriops tagal* is also found in pure and homogenous patches and constitutes the second most common genus in the area in terms of extent. *Rhizophora mucronata* is another pure and homogenous community appearing in the study area along with *Ceriops tagal.* Though *Ceriops tagal* and *Rhizophora mucronata* occupied different microhabitats in the region they could not be separated spectrally and that is the reason why this community has been named the *Ceriops-Rhizophora* community. The height of the *Ceriops* plants rarely goes above 2 m. The height of the *Rhizophora* plants is upto 3.5 m. At a small patch in Baga Belan the height of the *Rhizophora* plants was estimated to be above 5 m.

7.3 Spectral behaviour of major mangrove communities:

The spectral radiance values for the major mangrove communities for march 2000 have been given in the table 8.1. The difference in the spectral behavior of the two dense mangrove communities of the study area and its mixed community is clearly evident from the spectral curves (Fig.7.1). The spectral curves for the other communities in the study area have been given in the figure 7.2. As compared to *Avicennia* community, the *Ceriops-Rhizophora* shows lower reflectance values in all the four bands. Ramsey III and Jensen (1996) also obtained results in which the reflectance from the black mangrove (*Avicennia germinans*) tended to be higher than the red mangrove (*Rhizophora mangale*).

Table 7.1 Apparent reflectance values for major mangrove communities

(Values in percentage)

Mangrove Community	Green (520 – 590 nm)	Red (620 – 680 nm)	NIR (770 – 860 nm)	SWIR (1550 – 1750 nm)
Avicennia Dense	15.1346 ± 0.4902	15.2866 ± 1.0118	30.0565 ± 2.2274	9.8388 ± 0.3194
Avicennia Sparse	16.2459 ± 0.6349	18.6224 ± 1.2141	22.5120 ± 0.7652	10.1347 ± 0.2136
Ceriops-Rhizophora Dense	13.7509 ± 0.4983	14.4796 ± 0.8799	23.2540 ± 0.9244	7.7143 ± 0.4102
Ceriops-Rhizophora Sparse	15.1562 ± 0.5288	17.1890 ± 0.8535	20.5542 ± 0.5337	8.2853 ± 0.3686
Mixed Dense	14.5789 ± 0.3950	14.8175 ± 0.4847	26.5442 ± 1.0590	9.1699 ± 0.3268
Mixed Sparse	15.3575 ± 0.4316	17.2958 ± 0.7159	21.5571 ± 1.1204	9.2232 ± 0.1724
Transtional Mangrove	18.1114 ± 0.8327	22.1794 ± 1.5005	21.6756 ± 0.6503	11.1946 ± 0.2011
Degraded Mangrove	17.9097 ± 0.5579	22.4080 ± 1.0877	19.0477 ± 0.4687	11.8667 ± 0.1637
Standing Dead	17.5290 ± 0.3362	22.0340 ± 0.5550	18.0175 ± 0.4500	11.0575 ± 0.1742
Marsh	16.6169 ± 0.5331	19.9684 ± 0.8962	18.4189 ± 0.5819	9.8711 ± 0.2118

Vegetation reflectance in the visible region of the electromagnetic spectrum is dependent on the photosynthetic pigments present in them. The dominant photosynthetic pigment in land plants is chlorophyll a and chlorophyll b. Both of them have absorption maxima in the blue and red regions.

Lower reflectance in the red band indicated higher concentration of photosynthetic pigments. Oswin and Kathiresan (1994) have mentioned that photosynthetic pigments are high in species of *Rhizophora* and low in *Avicennia*. Increase in the amount of photosynthetic pigments lead to a decrease in the reflectance in the red region (Gausmann *et al. 1970).* The leaves of *Avicennia* are bright green and small with canopy being globose and irregularly branched and showing medium leaf stacking. The leaves of *Rhizophora* are also darker in colour (indicating greater pigmentation), thicker and broader than *Avicennia* leaves.

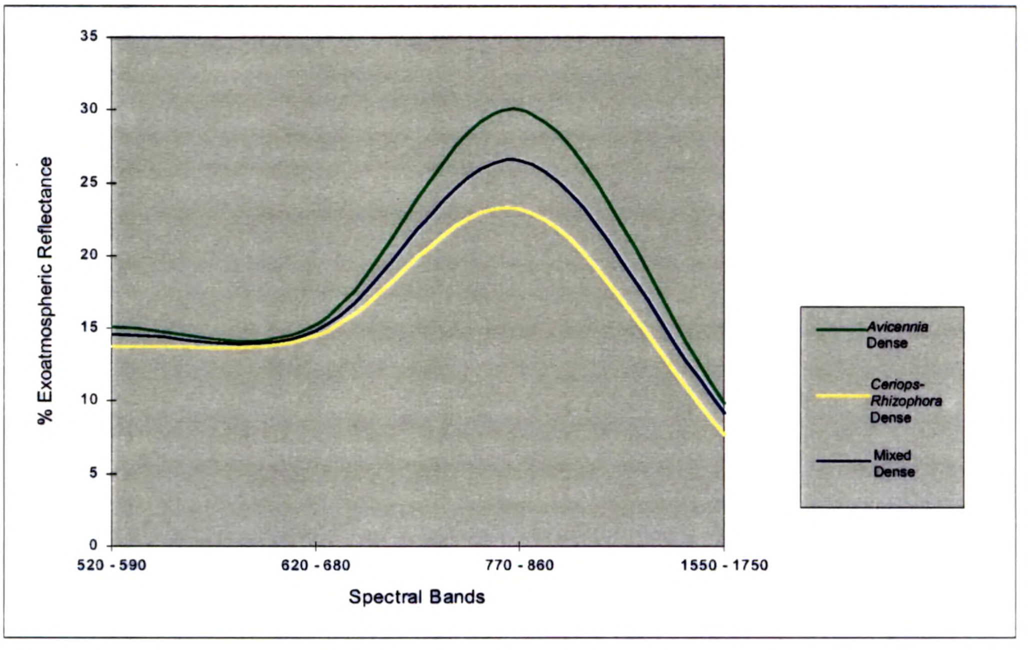

Fig 7.1 Spectral curves for major dense mangrove communities

Reflectance values in the NIR are indicative of the density of the vegetation. The high reflectance of vegetation in this region is due to the additive reflectance of leaves. Plants having a canopy several layers thick will have higher reflectance values in this region. The leaves of *Avicennia* are small and light passing through this plant has to pass through several layers of leaves. On the other hand leaves of *Rhizophora* and *Ceriops* are large and thick, but they are restricted to the upper regions of the plant and that is why they have less reflectance in the NIR region.

Reflectance values in the SWIR band are indicative of the water content of the vegetation. They have proved to be the most important in the discrimination of different mangrove communities. This importance of the SWIR can be seen in fig 7.2 and fig. 7.3. It is clearly seen that while the dense and sparse components of *Avicennia*, *Ceriops-Rhizophora* and the mixed communities have different reflectances in the other bands, they have almost similar reflectances in the SWIR band. The leaves of *Ceriops-Rhizophora* are much thicker than the

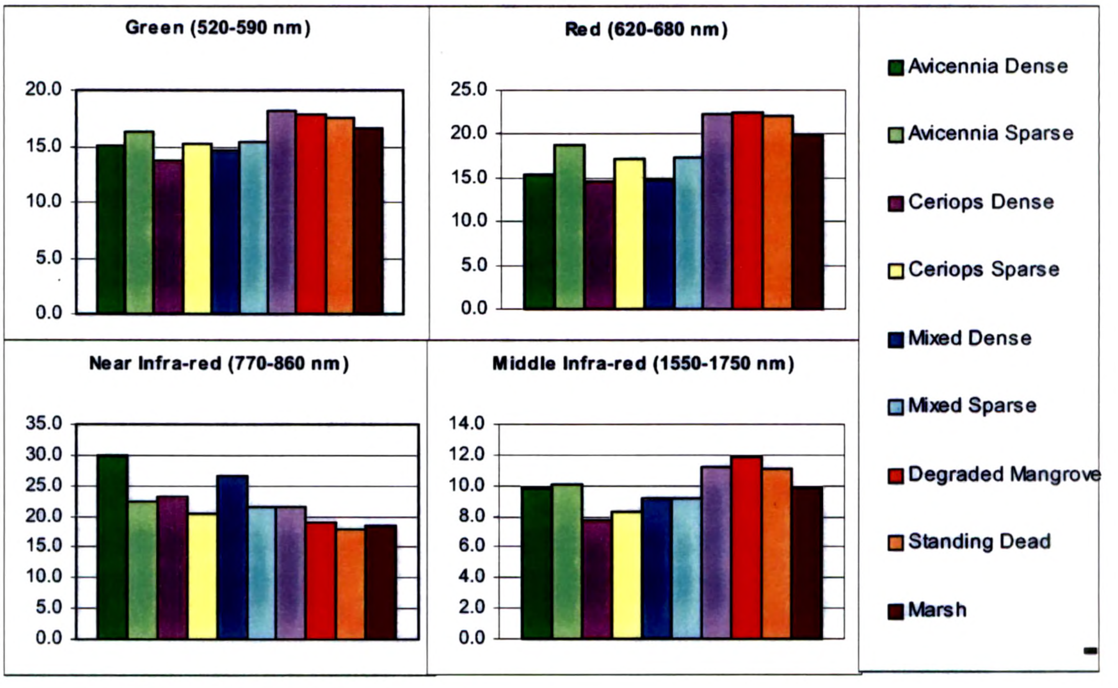

Fig 7.2 Apparent reflectance (%) for the major mangrove communities

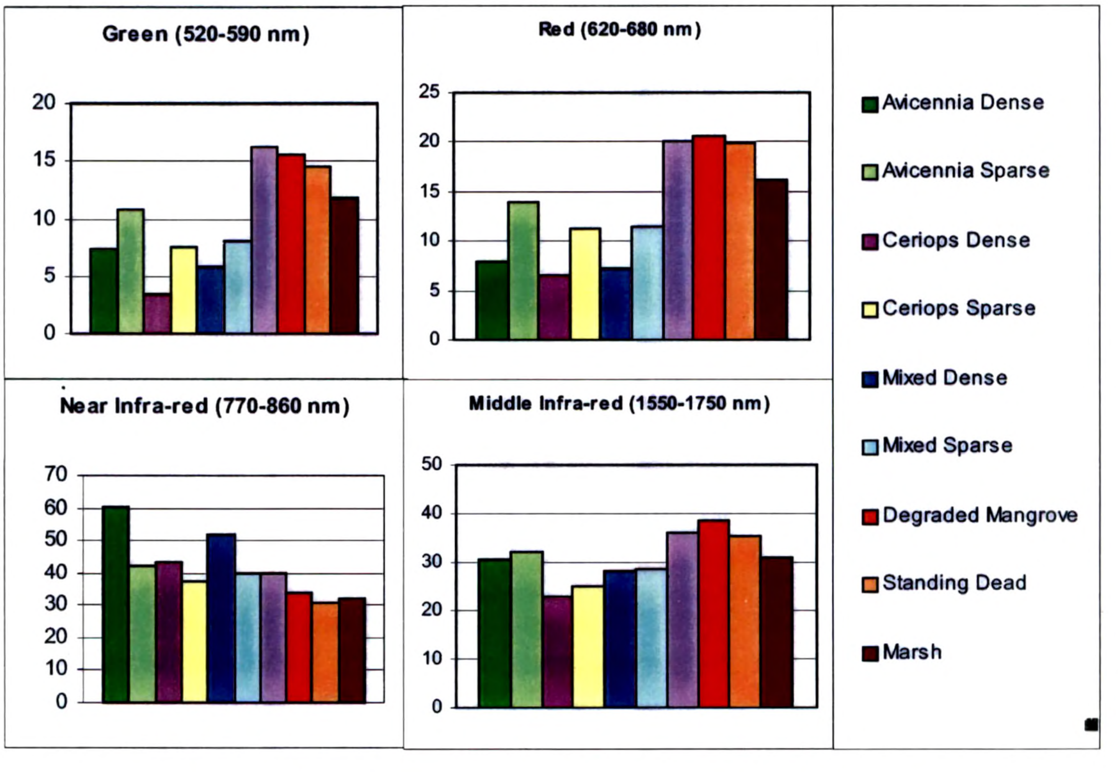

Fig 7.3 Relative apparent reflectance (%) for the major mangrove communities

Avicennia leaves. This leads to higher water content in the leaves and hence lower reflectance values in the SWIR band, The Mixed dense community has intermediate values for all the four bands, which is expected as it is composed of elements of both the above mangrove communities. The sparse density *Avicennia* shows high reflectance values in red and middle-infrared bands and lower value in the near-infrared as compared to its dense counterpart. This is indicative of the community being in stress or sparse in density with more open canopy and more space in between two plants The higher values in the SWIR can be explained by the fact that this community is at a higher elevation compared to the dense community and has comparatively less water in the soil as compared to its dense counterpart. Also, as the canopy is sparse, soil reflectance plays a bigger role in reflection than in denser canopies.

The sparse communities of *Avicennia*, *Ceriops-Rhizophora* and the mixed mangroves follow the same relation seen in their dense counterparts. They have higher values in the green, red and the middle-infrared bands and lower values in the near-infrared band as compared to their dense counterparts. The degraded mangroves have a higher reflectance in the green, red and the m-infrared as compared to the sparse mangroves. It is also seen that the standing dead mangroves and the degraded mangroves have similar spectral behaviors in almost all the bands except in the near-infrared band where the degraded mangroves have a relatively higher value. This is probably due to the fact, that the degraded mangroves have comparatively more vegetative cover than the standing dead mangroves, which have negligible vegetative cover. Also the degraded mangroves as well as the standing dead mangrove community have largely come into existence due to an unexplained event (most possibly an oil spill) that severely degraded the pre-existing mangroves in the region. The degraded mangroves are composed of such areas where the condition of the mangrove is deteriorating or areas where the condition of the mangrove is improving from the standing dead category. The marsh community has comparatively less reflectance in the red and the middle-infrared than the degraded as well as the standing dead communities. The marsh vegetation in the region is mostly composed of species of *Suaeda* that have a low height of up to 20-30 cm. They are found in large as well as small patches and are never found in very dense patches. The lower values in the red can be explained by the fact that they have higher photosynthetic pigments that absorb the radiation in this band. Also they have a very low height due to which only a few layers of leaves are present and this reduces the characteristic additive reflectance by vegetation in the near-infrared region resulting in lower reflection in the region. The lower reflection in the middle-infrared region could be due to the more amount of water that is stored in the *Suaeda* marsh communities due to its succulent nature.

Due it is unique physiognomy, the above spectral behavior of the major mangrove communities is specific to this region though broad similarities exist with other mangrove regions of India. Roberts et al (1999) has specifically recommended that spectral libraries developed for the purpose of species identification should be regionally based to account for the inherent variability in the spectral signatures between regions.