CHAPTER 5: REMOTE SENSING OF MANGROVES

The main difference between mapping mangroves and other coastal habitats such as reefs and sea grass is that mangrove foliage is terrestrial. No compensation has to be made for variation in water depth and colour. In addition, infrared portion of the electromagnetic spectrum can be used. Mangrove areas, especially, the interior of mangrove stands, are often difficult to access. Remote sensing allows information to be gathered from areas that are otherwise very difficult to survey.

A variety of sensors (both air-borne and space-borne) and image processing methods have been used in studying mangroves. The first aerial photographic surveys of mangroves were made in the 1920s. A review of the literature shows that though aerial photographs have been available for at least 80 years it is difficult to obtain an overview of aerial photography for the assessment of mangroves as published accounts are rare. There is no doubt about the utility of aerial photos for mangrove studies but this condition has probably resulted by low emphasis that governmental departments and consultants place on the publication of results in scientific literature.

The use of remote sensing for mangrove study broadly covers three major mangrove applications,

1. Resource inventory and mapping
    a. Mangrove extent mapping
    b. Mangrove community mapping (Community zonation)
    c. Measurement of mangrove biophysical properties
2. Change detection
3. Aquaculture site management.

Most of the remote sensing work on mangroves has been restricted to resource inventory and mapping

5.1 Resource inventory and mapping – Global Scenario

The major work on mangrove remote sensing has been accomplished using sensors in the optical domain. Several studies have been conducted in which both optical and microwave data has been used and such studies have been more in regions where availability of data in the optical region has been hampered by consistent cloud cover. Major authors that have reviewed mangrove remote sensing in the optical and the combined optical-microwave domain have been given in table 5.1 while the list of the studies outside India has been given in table 5.2

Several authors have reviewed the use of remote sensing for mangrove studies. Aschbacher *et al.* (1995) compared data from several sensors for a study site in Thailand and concluded that the best results were obtained when optical and radar data were merged. Spot data with its high spatial resolution had the second best results. Blasco *et al.* (1998) has also reviewed the work on remote sensing of mangroves. Studying the spectral characteristics of different mangrove species he concluded that with presently available sensors it is impossible to spectrally differentiate all the sixty mangrove species and that most of the work on spectral differentiation of mangroves centers on the *Avicennia* and *Rhizophora* communities, which are dominant in most of the mangrove areas. He has also advocated the combination of optical and radar data for the best mangrove differentiation.

Table 5.1 Major reviews on the remote sensing of mangroves

Sr. No.	Author	Year
1.	Aschbacher *et al.*	1995
2.	Blasco	1998
3.	Green *et al.*	1998
4.	Gao, J.	1999
5.	Dahdouh-Guebas, F.,	2002
6.	Ozesmi, S. L., & Bauer, M. E.,	2002

Green *et al.* (1998) have reviewed the various sensors used in the remote sensing as well as the management applications of the different studies.. He has also remarked on the use of aerial photographs for mangrove studies and the lack of published scientific literature on studies using them. He has also made an assessment on the accuracy assessment of various studies and found that a very small percentage of all studies have any sort of accuracy assessment. Gao (1999) compared the spatial and spectral resolutions of optical data for mangrove mapping in New Zealand. He concluded that a spatial resolution of 30m was appropriate for mapping the mangroves of the area and that higher spectral resolutions allowed more accurate classification of different vegetation types. Dahdouh-Guebas (2002) has reviewed the state of the art and application of remote sensing and GIS in tropical coastal zones, and illustrated their relevance in sustainable development. It has highlighted a selected number of remote sensing case-studies on land cover patterns, population structure and dynamics, and stand characteristics from South-East Asia, Africa and South-America, with a particular emphasis on mangroves. It showed how remote sensing technology and other scientific tools can be integrated in long-term studies, both retrospective and predictive, in order to anticipate degradation and to take mitigating measures at an early stage. He highlighted the guidelines for sustainable management that can result from remote sensing and GIS studies, and identified existent gaps and research priorities. Ozesmi & Bauer (2002) have reviewed the literature on satellite remote sensing of wetlands (both coastal and inland), including what classification techniques were most successful in identifying wetlands and separating them from other land cover types. He has concluded that the most commonly used computer classification method to map wetlands is unsupervised classification or clustering and maximum likelihood is the most common supervised classification method. He advocates the use of multi-temporal data as well as using ancillary data such as soil data, elevation or topography data to improve the classification of wetlands. He has also compared classified satellite imagery and maps derived from aerial photography and has come to the conclusion that they offer different but complimentary information.

According to him the combination of radar and optical data provide the most promise for improving wetland classification.

Table 5.2 Studies on the remote sensing of mangroves in optical and optical-microwave combined region (World)

Sr. No.	Authors	Satellite / Sensor	Method	Level of Discrimination
1.	Bina, R .T. *et al.* (1978)	Landsat TM	Supervised Classification	Mangrove identification
2.	Lorenzo *et al.* (1979)	Landsat TM	Supervised Classification	Separated mangrove from non mangrove
3.	Bina *et al.* (1980)	LANDSAT MSS, MOS-1 MESSR	Supervised Classification	Separated mangrove from non mangrove
4.	Peterson & Rehder (1985)	Aerial Photo	Visual Interpretation	Five classes labeled after dominant species or association of species
5.	Blasco *et al.* (1986)	SPOT	Vegetation index image	Two classes of mangroves
6.	Chaudhury, M. U. (1986)	Landsat MSS	Supervised and Unsupevised Classification	Two mangrove classes based on dominant species were obtained
7.	Ishaq Mirza, M. *et al.* (1986)	Landsat	VI and unsupervised classification	Three classes of mangroves based on density were delineated
8.	Ratansermpong, S. (1986)	Landsat MSS	Supervised Classification	Separated Mangrove from non mangrove vegetation
9.	Ranganath *et al.* (1989)	Landsat TM	Band ratioing	Separated mangrove from non mangrove
10.	Chaudhury 1990	Landsat TM	Vegetation index image, Unsupervised Classification	Two-four classes labeled after dominant species or association of species
11.	Dutrieux *et al.* (1990)	SPOT XS	Supervised Classification	Four classes labeled after dominant species or association of species
12.	Gray *et al.* (1990)	Landsat TM	Band ratioing	Three height classes of mangroves
13.	Vibulsresth *et al.* (1990)	Landsat TM, SPOT XS,	Supervised Classification	Six classes labeled after dominant species or association of species
14.	Jensen *et al.* (1991)	SPOT XS	Vegetation index image	Percentage canopy closure
15.	Kay *et al.* (1991)	Landsat TM	Band ratioing	Separated mangrove from non mangrove

(Table 5.2 Cont ...)

Sr. No.	Authors	Satellite / Sensor	Method	Level of Discrimination
16.	Populus & Lantieri (1991)	Landsat TM, SPOT XS	Band ratioing	Two classes of mangroves based on density
17.	Woodfine (1991)	Landsat TM	Unsupervised , Supervised Classification	Five classes of mangroves
18.	Eong *et al.* (1992)	Landsat TM	Supervised Classification	Two classes labeled after dominant species or association of species
19.	Gang & Agastiva (1992)	SPOT XS	Visual Interpretation	Five classes labeled after dominant species or association of species
20.	Loo *et al.*(1992)	Landsat TM, SPOT XS	Unsupervised Classification	Three classes, dense, less dense and cleared
21.	Mohamed *et al.* (1992)	Landsat MSS	Supervised Classification	Two classes of wetland vegetation
22.	Palaganas (1992)	SPOT XS	Supervised Classification	Two classes, primary and secondary mangroves
23.	Long *et al.* (1994)	Landsat TM	Band ratioing	Separated mangrove from non mangrove
24.	Sery *et al.* (1995)	SPOT, ERS-1, JERS-1, AIRSAR	Supervised Classification	8-10 classes of mangroves were delineated
25.	Vits and Tack (1995)	SPOT XS Landsat TM	Unsupervised , Supervised Classification	Four classes, 2 fringing, mixed, shrub
26.	Ramsey, E W & Jensen, J R, (1996)	Field Data	Field Data	The variation within and between mangrove spectral reflectance of different species has been compared
27.	Green, E. P. *et al.* (1997)	Landsat TM. SPOT XS	Band Ratioing followed by PRA and Visual Interpretation	Modelling the relationship between LAI and NDVI
28.	Tam *et al.* (1997)	Aerial Photgraphs	Visual	Mangrove Class mapping only.
29.	Gao, J. (1998)	SPOT	Hybrid - MLC	Mangrove habitat mapping. Has worked out major mangrove types in the area with one mangrove species. Tried out various combinations

(Table 5.2 Cont ...)

Sr. No.	Authors	Satellite / Sensor	Method	Level of Discrimination
30.	Held, A (1998)	CASI and AIRSAR	Classification	Optical and radar data were used simultaneously to get better mangrove classification
31.	Ramirez-Garcia *et al.* (1998)	Landsat TM	Supervised Classification	Two classes based on dominant species
32.	Rosolofoharinoro, M. *et al.* (1998)	SPOT	VI and Supervised Classification - Hybrid	Mangrove habitat mapping with aerial surveys as GT and use of Visual interpretation for supervised classification
33.	Pasqualini, *et al.* (1999)	SPOT-XS, SIR-C	Supervised classification, Vegetation index,	Four classes of mangroves based on morphology
34.	Held, A (2001)	CASI, HYMAP	DTC	Three classes of mangroves based on species
35.	Hosking *et al.* (2001)	Landsat TM, ETM	Vegetation Index	Change on Mangrove cover.
36.	Blasco, F & Aizpuru, M. (2002)	SPOT, RESURS	Supervised Classification	The paper studies the present ecological state of mangrove ecosystem along the coast of Bay of Bengal.
37.	Sulong *et al.* (2002)	Landsat TM, Aerial Photographs	Supervised Classification, Visual	Seven classes in TM and 14 classes in Aerial
38.	Verheyden *et al.* (2002)	Aerial Photographs	Visual Interpretation	Six to seven classes based on dominant species or species assemblages
39.	Cohen, M. C. L., & Lara, R. J. (2003)	Landsat TM, Airborbe Radar (X-band),	Visual Interpretation	Change in mangrove area
40.	Manson *et al.* (2003)	Aerial Photographs	Visual Interpretation	14 classes labeled after dominant species or assemblage of species.

There have been few studies on mangrove remote sensing using microwave data alone and most of them have dealt with the measurement of structural parameters of mangrove vegetation. A list of such studies has been given in table 5.3

Table 5.3 Studies on remote sensing of mangroves using microwave data only

Sr. No.	Authors	Satellite / Sensor	Method	Remarks
1.	Proisy *et al.* (1996)	ERS-1, JERS-1, SIR-C, AIRSAR	Correlation of polarimetric signatures with mangrove structural parameters	HV-polarized bands have high correlation with structural parameters and above ground biomass
2.	Mougin (1999)	AIRSAR	Correlation of polarimetric signatures with mangrove structural parameters	L-HV and P-HV bands have high correlation with structural parameters and above ground biomass
3.	Proisy *et al.* (2001)	AIRSAR	Analysis of polarimatric signatures and backscatter coefficients	Quantitative biomass estimation for homogenous communities

5.2 Mangrove resource inventory and mapping – Indian Scenario

Narain & Jadhav (1982) used Landsat MSS data to study the coastal and marine ecosystem in the Gulf of Kachchh. They mapped the extent of coral reefs but they could not distinguish between marsh and mangrove vegetation. Untawale *et al.* (1982) used aerial photographs to study the mangroves along the estuaries of Goa, they were successful in delineating mangrove species classes. Nayak *et al.* (1985) used Landsat TM and MSS data to map wetlands in Gujarat using several enhancement techniques like contrast stretching, Principal component analysis as well as band ratios. Good distinction between mangroves, marsh vegetation and swamps was obtained using the band ratioing technique. Nayak *et al.* (1989a, 1989b) and Pandeya *et al.* (1989) were able to classify mangroves into two density based classes for the Gulf of Kachchh. Ranganath *et al.* (1989) used band ratioing to separate mangrove from non-mangrove vegetation in the middle Andamans. Roy (1989) using KATE-140 and MKF-6 data from the Salyut-7 mission mapped the mangroves of the Mahanadi-Brahamani-Bhaitrani delta complex in Orissa and differentiated seven mangrove classes based on dominant species or associations of species.

Remote sensing data was used for the first time to generate information at density level for the entire country's coastline in 1992. The entire Indian coast al habitats including mangroves were mapped using medium resolution data (IRS LISS II, Landsat TM, SPOT) at 1:2,50,000, 1:50,000 and 1:25,000 (Nayak *et al*, 1992; Nayak and Bahuguna, 2001). Attempts were made to classify tree and shrub mangroves using IRS LISS III data (Nayak *et al.*, 1996). Classification of mangroves at the community level was attempted using IRS LISS III data for Bhitarkanika (Orissa) by Bahuguna & Nayak (1996) in which seven communities of mangroves were differentiated. Satyanarayana *et al.* (2001) tried to correlate ground based biophysical parameters with IRS LISS III data and was able to discriminate two major classes of mangroves. Blasco, F. & Aizpuru, M. (2002) using SPOT 'Quick Look', HRV and RESURS data, have classified the mangroves of the Bay of Bengal into six major classes based on land cover.

There have been few uses of radar data for the mapping and monitoring of mangroves. Krishnamurthy *et al.* (1996a) and Kushwaha *et. al.* (2000) have used ERS-1 SAR data in Tamil Nadu and Sundarbans respectively. They study by the latter was not mangrove specific and mainly involved the delineation of wetlands. Krishnamurthy, *et al.* (1996b) used ground based radiometers and studied the spectral properties of the mangrove species found in Tamil Nadu. The summary of mangrove studies in India using remote sensing has been given in table 5.4.

It is apparent from the table that there have been few studies dealing with diversity of mangroves at the community level, though this information would be of vital importance in the management of mangrove areas. Such information does also not exist for the mangrove community in the Gulf of Kachchh.

Table 5.4 Studies on remote sensing of mangroves in India

Sr. No.	Authors	Area	Satellite / Sensor	Aspect of Mangrove Research	Method	Level of Discrimination
1.	Narain, A & Jadhav, R. N (1982)	Gulf of Kachchh	Landsat	Coastal mapping	Visual Interpretation	Marsh and Mangrove vegetation mixing
2.	Untawale, A.G., Wafar, S. and Jagtap, T (1982)	Goa,	Aerial Photos	Mangrove Mapping	Visual Interpretation	Mangrove distribution along the estuaries
3.	Nayak, S. R., Gupta, M. C., & Chauhan , H. B. (1985)	Gujarat	Landsat TM & MSS	Wetland Mapping	Visual Interpretation, Band ratios, PC	Distinction between marsh and mangroves in band ratioing technique
4.	Nayak, *et al.* (1989a)	Gulf of Kachchh	Landsat TM & MSS	Coastal mapping	Visual Interpretation	Two classes of mangroves based on density
5.	Nayak *et al.* (1989b)	Gujarat, Karnataka	LISS II, Landsat TM	Coastal Mapping	Visual Interpretation	Two classes of mangroves based on density
6.	Pandeya *et al.* (1989)	Gulf of Kachchh		Mangrove Mapping	Visual interpretation	Two classes of mangroves based on density
7.	Ranganath *et al.* (1989)	Middle Andamans	Landsat TM	Mangrove Mapping	Band ratioing	Separated mangrove from non mangrove
8.	Roy (1989)	Bhitarkanika, Orissa	MKF-6, KATE-140	Species zonation	Visual Interpretation	Seven classes labeled after dominant species or association of species
9.	Nayak *et al.* (1992)	All India	Landsat TM, LISS II	Coastal Mapping	Visual Interpretation	Two classes of mangroves based on density
10.	Jagtap, T. *et al.* (1994)	Maharashtra, India	LANDSAT TM, Aerial Photo (B/W)	Mangrove mapping	Visual Interpretation	Mangrove extent along major rivers and creeks along the coast of Maharshatra have been delineated.
11.	Bahuguna, A., Chauhan, H. B. & Nayak, S. (1995)	Andaman and Nicobar Islands	LISS II	Aquaculture Management	Visual Interpretation	Mangrove delineation and aquaculture site selection

(Table 5.4 Cont ...)

12.	Bahuguna, A & Nayak, S. (1996)	Bhitarkanika, Orissa	LISS III	Mangrove species mapping	Supervised Classification	Seven classes labeled after dominant species or association of species
13.	Krishnamurthy *et al.* (1996a)	Tamil Nadu, India	LANDSAT TM, LISS II, ERS-1 SAR	Mangrove Mapping	Visual Interpretation, Fuzzy and MLC classification	Comparision of optical and radar data for suitability as well as different classification techniques
14.	Krishnamurthy, R. *et al.* (1996b)	Tamil Nadu	Field Data	Species Zonation	Field Based Study	The spectral properties of Mangrove species is measured.
15.	Nayak *et al.* (1996)	Western Mangroves	LISS III	Mangrove Mapping	Visual Interpretation	Two height classes of mangroves delineated
16.	Kushwaha, S. P. S. *et. al.* (2000)	Sundarbans	ERS-I SAR, LISS II	Wetland Mapping	Classification, SAR – LISS II merged	Delineation of wetlands using SAR and not mangrove specific
17.	Sudhakar, S. (2000)	Sundarbans	LISS III	Mangrove Mapping	Supervised Classification	Prepared community maps for a compartment in Sundarbans
18.	Vijaykumari, N *et al.* (2001)	Andhrapradesh	LANDSAT MSS, LISS I & LISS II	Mangrove Mapping and Change detection	Classification using MLC	Change in the mangrove area from 1973 to 1997 was attempted
19.	Krishnamurthy, R. & Ramchandran, S. (2001)	Tamil Nadu,	LANDSAT, Aerial	Mangrove mapping		A general review of mangrove remote sensing
20.	Nayak, S & Bahuguna, A. (2001)	India	LISS III	Mangrove Species Mapping	Supervised Classification using MLC	Mangrove zonation for several regions of India
21.	Satyanarayana *et al.* (2001)	Coringa, Andhra Pradesh	LISS III	Mangrove Species Mapping	Supervised Classification	Two classes of mangroves
22.	Blasco, F. & Aizpuru, M. (2002)	Bay of Bengal	SPOT HRV, RESURS	Mangrove Mapping	Supervised Classification	Six mangrove classes based on land cover