April 25th, 2:00 PM - 5:00 PM


G. Bashir-Ud-Din  
Department of Space Science, University of the Punjab

Muhammad Ali

Moshin Jamil Butt

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1. Abstract

This paper presents a study on mapping and area estimation of the Mangrove and Riverine forests in Sind, using Remote Sensing techniques. Landsat 5 False Colour Composite and Black & White Prints have been used for manual interpretation. A Mangrove forest map and a Riverine forest map have been prepared on 1:250,000 and 1:1,000,000 scales respectively.

From these maps, area estimates have been carried out Mangrove forests have been estimated to be on about 0.52 million acres whereas Riverine forests have been estimated to be on about 0.66 million acres.

Results indicate that Remote Sensing techniques can be effectively used for mapping and area estimation of Mangrove and Riverine.
2. Introduction

Mangroves, generally the name for tropical and subtropical forests, represents dense thickets along tidal estuaries in salt marshes and on muddy coasts. They are chiefly composed of shrubs or small trees which produce prop roots. In Pakistan Mangrove forests have developed in the vicinity of Indus delta. Riverine forests, on the other hand, are floodplain forests. They depend upon annual floods to provide the water necessary for their growth and regeneration. Examples of these forests are found along the Chenab, Jhelum and Ravi rivers, but mostly along the Indus. Both Mangrove and Riverine forests provide firewood and serve as a vast grazing ground for cattle, camels etc. However, its worthy to mention that the prevailing ground survey techniques are costly and time consuming to estimate the area under these forests.

The Remote Sensing technology is a powerful technique for surveying, mapping and monitoring of earth resources. This technique has become indispensible and increasingly more meaningful because of synoptic coverage of satellite data over large areas rendering it cost and the time effective. Further, in areas which are different to reach, the technique is perhaps the only method of obtaining the required data speedily.

Keeping in view the above mentioned points, this paper aims at mapping and area estimation of Mangrove and Riverine forests using Remote Sensing techniques. For this purpose Landsat 5 False Colour Composed and Black & White Prints have been used.

3. Geographic Location Of Study Area

Supporting Mangrove and Riverine forests, the study area is located in Sind which extends form latitude 23°35' to 28°30' and longitude 66°42' to 71°10'. Sind is bounded on the west by the province of Baluchistan, on the north by the province of Punjab, on the east by India, and on the south-west by the Arabian Sea.
4. **Methodology**

The study has been based upon manual interpretation of LANDSAT Multispectral Scanner (MSS) data both in the form of False Colour Composite and Black & White Prints. Manual interpretation were carried out with the help of overhead projector, illuminated tracing table, glass magnifier etc.

4.1 **Analysis Of False Colour Composite**

Landsat False Colour Composite on 1:1,000,000 scale was utilized for the identification of mangrove forests and other landuse classes in the Indus deltaic region. False Colour Composite of March 5, 1990 was enlarged (1:250,000 scale) to study the extent of mangrove forests and other landuse classes. Following are the different landuse classes which were identified in the study area.

Dense mangrove forests were identified by their bright pink tone and irregular patchy shape in the imagery. For example dense mangrove forest patches were found along the coast Karachi and near Korangi creek. One such patch is visible in the lower right corner of the image.

Normal mangrove forests were recognized by their pink tone and irregular patchy shape in the imagery. Most of the normal mangrove patches were found lie between Korangi and Dabbo creek. Some of the normal mangrove forest patches were also visible on the bottom right of the imagery.

Sparse mangrove forests were identified by their light pink tone and irregular patchy shape on the imagery. Most of the sparse mangrove forest patches also were found between Korangi and Dabbo creek. Sparse mangrove forest patches were also visible on the bottom right of the imagery. The decrease in density of mangrove forest may be due to the pollutions brought by the river, or due to the cutting of trees for fuel purposes.

Riverine forests were identified by their brownish tone and irregular patchy shape on the satellite imagery. These forests were visible in the form of patches on either banks of the Indus river.

Deep water gave a dark blue tone while shallow water gave a light blue tone. For example, light blue tone in creeks and river manifested the presence of shallow water whereas dark blue
tone of lakes and see water revealed the presence of deep water.

Sand was identified by its bright tone, smooth undulating texture on the imagery. For example sandbanks of Indus river and sandby beaches. Hills showed a bright tone and rough texture with a variety of drainage patterns. Indus river showed light blue tone due to the pressure of shallow water and meandering pattern on the image. Lakes were identified by their dark blue tone and irregular closed shape on the image. The dark blue tone was due to the presence of deep water in lakes. Halaji Lake, Hudero Lake, Makarwari Lake were identified under this class. The canal was identified by its linear shape and light blue tone. The light blue tone revealed the existence of shallow water.

4.2 Analysis Of Black & White Prints

Landsat MSS band 5 black & white prints on 1:1,000,000 scale were utilized for the identification of riverine the forests and other landuse classes in Sindh. A mosaic was formed from four prints of different dates namely August 9, 1989, September 3, 1989, February 17, 1990 and March 5, 1990. Another mosaic was formed using Landsat MSS band 7 images of above mentioned dates for use in land water boundary delineation. Following are the different landuse classes which were identified in the study area.

With a smooth and mottled texture the riverine forests were found to be patchy with a variety of shapes and sizes. Their tone is usually white in band 5 imagery. The riverine forests along Indus river course above Sukkur barrage and below Mancher Lake were particularly prominent. The density of the riverine forests was found to be varying widely probably depending upon the soil and the climatic conditions of the area.

Thar desert in the eastern side of the Indus river was determined by a smooth texture with dark tone in band 5 imagery. Sand banks along the Indus river course depicted dark grey tone in the band 5 imagery.

Sand banks along the Indus river course depicted black tone in the band 7 imagery. Thar desert appeared to be having smooth and undulating texture with a black tone.

The images showed rugged hilly terrain on the western side of the river. With a variety of drainage patterns and tones the hills were found with a rough texture.
Marshy areas have been determined by their light grey tone in the imagery. The presence of water channels or creeks also revealed their existence. The marshy areas provide ideal conditions for the growth of mangrove forests. On the band 5 imagery, these forests appeared to be having a white tone with a mottled texture. Most of the mangrove forest patches were found in Indus deltaic region areas on the western side of the river. A few mangrove forest patches were found on the eastern side of the river.

Water was found to be having a variety of tones ranging from white to grey. The deep water in lakes and in the Arabian Sea depicted a white tone whereas comparatively shallow water in Indus river manifested a grey tone in band 5 imagery. On the other hand, in band 7 imagery, the tone of both deep and shallow waters was white. The tone of turbid water in creeks was grey.

Lakes were identified by their white tone, smooth texture and irregular closed shape. The white tone indicated the presence of deep water. The features have identified under this class are Manchar Lake, Kinghar Lake, Hub Dam and Halaji Lake

Diagonally running across the image, the Indus river manifested a meandering pattern and grey tone. However, in band 7 image, the tone of river was white. A light grey tone and a linear shape helped in the identification of Nara and Rohri canals. The shape of canals in band 7 image was also linear, however, their tone was white. Water channels were recognized by their subdentritic pattern associated with mud flats. Their tone was grey associated with turbid water. They were identified by their cusp like shapes and white & grey tones.

4.3 Delineation Of Interpreted Data

Having identified different landuse classes on Landsat. False Colour Composite and Black & White Prints, two base maps were prepared. Ammonia prints were then obtained from these base maps. On these ammonia prints, different colours were assigned to different landuse classes. This gave us the required mangrove forests map on 1:1,250,000 (as per attached map-1) scale and riverine forests map on 1:1,000,000 (as per attached map-2) scale respectively.

4.4 Area Estimation

Now using millimeter grid, the required information regarding the total area of mangrove
Forrests and percentage of area under each class of mangrove forests was calculated. Similarly, the area under riverine forests was also calculated.

4. Results

The total area under Mangrove forests has been estimated to be about 0.52 million acres (210,700 ha). A further classification of Mangrove forests shows that dense Mangrove forests cover an area of 0.03 million acres, normal Mangrove forests are on about 0.16 million acres and sparses Mangrove forests are found on an area of 0.33 million acres. These are shown below in Table.

The area under Riverine forests has been estimated to be about 0.66 million acres (268,200 hectares).

6. Table

Area under Mangrove and Riverine Forests in Sind (in million acres)

<table>
<thead>
<tr>
<th>Sr.No.</th>
<th>Landuse Class</th>
<th>Area</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>MANGROVE FORESTS</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Dense</td>
<td>0.03</td>
<td>05.8</td>
</tr>
<tr>
<td></td>
<td>Normal</td>
<td>0.16</td>
<td>30.8</td>
</tr>
<tr>
<td></td>
<td>Sparse</td>
<td>0.33</td>
<td>63.4</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>0.52</td>
<td>100.0</td>
</tr>
<tr>
<td>2</td>
<td>RIVERINE FORESTS</td>
<td>0.66</td>
<td></td>
</tr>
</tbody>
</table>
7. **Conclusions**

Forest mapping using Landsat data has been a unique exercise for three major reasons. First, it has served to highlight the special merits of Landsat data for forest mapping. Secondly, it has been synergistic in developing operational methodologies for manual interpretation. And finally, completion of the mapping in a very short time has enthused a particular sense of accomplishment and rendered a high degree of confidence to tackle similar projects of national importance. Overall, it can be concluded that Remote Sensing techniques have come of age in Pakistan in providing a viable, authentic and cost effective means for mapping and area estimation of Mangrove and Riverine forests.

8. **Acknowledgement**

I pay my heartiest thank to Dr. Muhammad Ishaq Mirza Member Space Research SUPARCO, for taking keen interest in the completion of my paper despite his routine commitments.

9. **References**

- Curran, P.J., (1982), Principles of Remote Sensing
- Seth, S.K., & Khattak, G.M., (1965), Forest Types of Pakistan
**BRIEF BIOGRAPHY OF THE RESEARCHER**

The researcher was born at Faisalabad on June 6, 1968. He did his B.Sc. in Space Science from the Department of Space Science University of the Punjab, Lahore-Pakistan. Then he completed his M.Sc. degree course in Space Science from the same institution. He is presently a lecturer in the Department Of Space Science, University Of the Punjab, Lahore - Pakistan.