BIOME LEVEL CLASSIFICATION OF VEGETATION IN WESTERN INDIA - AN APPLICATION OF WIDE FIELD VIEW SENSOR (WiFS)

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ABSTRACT
Timely and accurate information on natural resources are pre-requisite for optimum and effective management of natural resources. Remote sensing technology is now established and widely accepted all over the world. Subsequent improvements in the spatial and spectral resolution and better temporal resolution help not only in mapping and monitoring natural resources and environmental degradation at regional and local scales but also provide database for newer area of application. The successful launch of the Indian Remote Sensing Satellites (IRS) series and application in natural resource management and other studies is a new milestone in the development of potential of land cover mapping and estimation in the world over. Coarse resolution satellite data as of NOAA-AVHRR are widely used for vegetation characterisation at regional level. The IRS - 1C/1D - WiFS data have an advantage of covering large area in single instant field of view (IFOV) avoiding any illumination differences and having good spectral and spatial resolution and recommended temporal resolution for optimum land cover studies. Biome or ecosystem level zonation provides information as per biogeographical map, essential for understanding subsequent eco-physiological processes. An attempt has been made for regional level classification of arid zone in Western part of India using WiFS data, keeping in view the national development needs vis-à-vis advancement expected in the future indigenous and international remote sensing missions. The forest of Western India mainly consists of dry and moist deciduous forest of Tectona grandis, Anogeissus latifolia and associated species and thorn forest of Acacia species, Prosopis juliflora etc. Mangrove vegetation occurs along the coastal mud flats. Phenological variability and multidate data have been found very useful in characterising vegetation at biome level through various enhancement methods and classification algorithms. The study conforms to the earlier biogeographical zoning and suggests further subdivision of tropical thorn forests in Kachchh and Kathiawad peninsulas based on the floral & faunal diversity, land cover and land use pattern.

KEYWORDS: Biome, Phenology, Remote Sensing, IRS-WiFS, NDVI, Classification, Gujarat, India

1. INTRODUCTION
Multitemporal remote sensing data are widely acknowledged as having significant advantages over single date imagery (Townshend et al.,1985). Mapping of land cover can be improved by using variations in phenological patterns of the vegetation, forests in particular and so also the cropping pattern at a regional level. In a dynamic ecosystem the single date data may not express full mapping potential. In this study an attempt has been made to map land cover/land use in desert climate. Phenologically the area has been found to be very variable. IRS-WiFS data has been used to map the biomes in Gujarat state.

Conventional inventory practices are having several inherent limitations. An alternative method to derive such information, at the acceptable spatial scales, is to use remotely sensed data, particularly acquired by satellites having large instantaneous field of view (IFOV). The use of aerospace technology to monitor land surface features has increased with near daily coverage of the Earth by the NOAA series of satellites (Tucker et al.,1985 and Tucker et al.,1986b; Andres et al.,1994; Azzali and Menenti,1996). In spite of having a very good temporal resolution of one day NOAA-Advanced Very High Resolution Radiometer (AVHRR) has coarse spatial resolution as compared to Landsat Multispectral Scanner (MSS) or Thematic Mapper (TM), the System Probaloire Observation de la Terre (SPOT) (Justice, et al., 1985) or Indian Remote Sensing Satellites (IRS LISS II, LISS III and PAN).

NOVA-AVHRR data have been widely used world over for mapping at regional and continental level for green coverage, productivity, early warning, environmental monitoring etc.(Tucker et al., 1986a;
Fung et al., 1987; Townshend, 1992; Benedetti et al., 1994; De Fries and Townshend, 1994) in spite of coarser resolution. India launched its second generation of remote sensing satellites viz., IRS-1C, IRS-1D, IRS-P3 in December 28, 1995, September 29, 1997 and March 21, 1996 respectively with Panchromatic (PAN), Linear Imaging Self Scanning Sensor (LISS-III) and Wide Field Sensor (WiFS) camera onboard. High spatial resolution LISS III data (in G, R, NIR and SWIR bands) is comparable to SPOT (XLS) and Landsat (TM) satellites, whereas PAN, with one band, has better spatial resolution (6 m) than SPOT (PAN). IRS-WiFS meets the requirement of medium scale data for better regional and continental level applications. WiFS has two spectral bands, red (0.62-0.68 µm) and near infrared (0.77-0.86 µm), and is specifically designed for vegetation monitoring application. IRS with its repetitive coverage of 25 days has revisit capability of 3-5 days for WiFS and PAN (steering) and 25 days for LISS III (Anonymous, 1997b). Medium level of spatial resolution of 188 m and swath coverage of about 812 km makes it more useful for mapping and monitoring growth parameters throughout the year. The WiFS data offer advantage in spatial resolution in comparison to NOAA-AVHRR 1.1 km (local coverage) for vegetation/forest mapping and monitoring at global/regional level with similar required band combination for vegetation studies. The temporal resolution provided by WiFS is adequate to monitor the phenological variability in the vegetation with 3-7 days. NOAA data has been widely used for regional and global vegetation change studies. A comparison is done to assess the capabilities of WiFS with respect to NOAA for vegetation studies (Table 1).

This paper intends to demonstrate the usefulness of WiFS data for regional vegetation mapping at biome levels. An attempt has been made to use WiFS data for regional level classification of arid zone in Western part of India, keeping in view the national development needs vis-à-vis advancement expected in the future indigenous and international remote sensing missions. Characterisation of vegetation has been attempted using various phenological stages. This variability has been derived from temporal remote sensing data of seven months. Phenological variability provided further insight into the sensitivity towards climatic fluctuations. An assessment has been made on the capability of WiFS data for regional studies considering growth profiles of different type of vegetation. WiFS multivariate data have been used to provide biome or ecosystem level zonation of Gujarat in Western India.

<table>
<thead>
<tr>
<th>Parameters</th>
<th>IRS-WiFS</th>
<th>NOAA-AVHRR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spectral Band(s)</td>
<td>0.62-0.68 µm</td>
<td>0.55-0.9 µm</td>
</tr>
<tr>
<td></td>
<td>0.77-0.86 µm</td>
<td>0.725-1.1 µm</td>
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<td>3.55-3.93 µm</td>
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<td></td>
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<td>10.5-11.5 µm</td>
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<td>Radiometric Resolution</td>
<td>2&quot;</td>
<td>2’&quot;</td>
</tr>
<tr>
<td>Spatial Resolution</td>
<td>188 m</td>
<td>1.1 km (local coverage)</td>
</tr>
<tr>
<td>Swath</td>
<td>812 x 812 km</td>
<td>2400 x 2400 km</td>
</tr>
<tr>
<td>Repeat Cycle</td>
<td>3-5 days</td>
<td>Twice a day</td>
</tr>
</tbody>
</table>

Table 1. Comparison of payloads of IRS-WiFS and NOAA-AVHRR

2. DATA SET

Data set comprising of multidate data of IRS WiFS covering various phenological stages of seven months, has been analysed. Data set of growing season (May and October), maturity (December, January, February), senescent (March) and leaf fall (April and May) were available to us for the year 1998. October data was discarded because of cloud cover.

3. STUDY AREA

Gujarat, an insular maritime state of Western India is bounded in the west by Arabian Sea and in north by Great Indian Thar Desert of the Indus Plains. State astride Tropic of Cancer and is located in the Western part of the sub-continent occupying the sub-tropical high-pressure location. The state has 4 national parks and 21 wildlife sanctuaries. Floristically area falls in to two regions (Good, 1974): (a) western and north-western fall under the African-Indian Region (number 9) spread over Rann of Kachchh and (b) eastern and south-eastern part belongs to the Eastern Indian region (number 17). Climatically, most part of the state falls in sub-humid and semi-arid climates merging in arid zone in the northern and north western extremities (Anonymous, 1987). Champion & Seth (1968) categorised the region into four forest-groups viz., tropical moist deciduous forest, tropical dry deciduous...
forest, tropical thorn forest and littoral & swamp forests. Rodgers & Panwar (1988) divided the area into five biogeographic zones viz., western ghats (Malabar Plains), western ghats (Western Ghats mountains), semi-arid (Gujarat Rajputana), desert (Kachchh) and coasts (West Coast).

Predominant vegetation is thorny with dry deciduous in the northern and western region, and moist deciduous forests of *Tectona grandis*, Acacias and bamboo in the eastern and southern regions. There are three floristically distinct hill ranges occurring in the eastern and southern region called Saurashtra viz.,

(a) Aravali Ranges, with open low density tropical dry forests of mainly *Anogeissus latifolia*, *Boswellia serrata*, *Acacia catechu* and *Lannea grandis* community;
(b) Vindhyan Range, medium to low density tropical dry deciduous forests of mainly *Tectona grandis* and *Diospyros melanoxylon* community on isolated hill ranges;
(c) Dissected plateau of Satpura Ranges, with very dense tropical moist deciduous forests of mainly *Tectona grandis*, *Terminalia tomentosa* and mixture of several other species.

Region around Rann of Kachchh is marshy or mud flats are inundated during monsoon and only salt tolerant species grow there, whereas Kachchh region has very degraded forests of *Acacia arabica*, *Prosopis juliflora* etc. intermixed with grasslands. This region is formed by the delta of Indus and Sarswati rivers. The most characteristic feature of the coastal vegetation is the conversion of salt marshes into salt pans. Wide spread grasslands/grazing lands occur throughout the dry western part of the state in Kachchh, Kathiawad and Gir ranges. Gir National Park has dry deciduous forests of *Tectona grandis*, *Acacia catechu* and other species growing in moist areas along the drainage. Kachchh has vast tracts of grasslands and greatly supports the cattle population and other wildlife. This tract is saline and does not support anything else. These grasslands have patches of scrub vegetation. However, recent land use practices like uncontrolled propagation of *Prosopis juliflora*, once introduced for afforestation purpose now naturalised and is encroaching grasslands (Puri, 1960; Puri *et al.*, 1989) and industries like salt, petroleum, mining etc.

Grasslands, habitat for wild ass, have decreased considerably. Due to high biotic pressure Kathiawad region has scrubby vegetation, but better than Kachchh. Mangrove forests, the only source of fuel wood and fodder, found in narrow belts along the coastal region are mostly open and scrubby (Khan, 1959). Good quality forest is in the eastern and southern region where high moisture supports good growth of broad leaved deciduous forests, this is the northern most extension of Western Ghats ranges. Northern part of Gujarat is having only 19,393 km² recorded forest and 12,578 km² actual forest which is 6.4% of the geographical area (Anonymous, 1997a), much below the optimum forest cover.

4. METHODOLOGY-- Data Pre-processing

Additive effects on satellite data due to atmospheric scattering were rectified using dark pixel subtraction technique, assuming that there is a high probability that there are at least a few dark pixels either belonging to deep water or shadow within an image which should be black (0% reflectance). Because of the atmospheric scattering the imaging system records a non-zero DN value at this supposedly dark-shadowed pixel location. This represents the DN value that must be subtracted from a particular spectral band to remove the first order scattering component. The data set was geometrically corrected to first level using ground control points (GCPs) and co-registered.

5. RESULTS AND DISCUSSION

Analysis of the satellite data has been carried out using various digital analytical procedures. In view of the high seasonal variability in land use and vegetation phenology, multivariate data have been subjected to enhancement procedures like vegetation indices and principal component analysis. Hybrid approach was adopted to classify the area. One of the simplest and easiest methods to highlight and discriminate vegetation types is to perform normalised difference vegetation index (NDVI) on different season (winter, spring and summer) data. Vegetation mapping using NDVI of each month was put to grey level scaling and poor separation among forest types was observed. In order to tap information on phenological variability entire data set was used to derive maximum NDVI and then grey level scaling was performed to segregate vegetation types and land uses. Even though the vegetation was highlighted, it was found that the discrimination among
vegetation types, forest and agricultural crops was lacking. This could be attributed to the closeness of the ratio values in forest and other vegetation types. Cotton and tobacco are cultivated very extensively in this area and NDVI values these areas were very similar. It was when none of the vegetation indices looked potential; the entire data set was compressed into three principal components. Although the contrast between forest and agriculture areas was high, discrimination among forest types was reduced. Vegetation information was represented in second component. Colour composite of three components showed distinct zones of cropped areas. With an assumption that vegetation information could be brought out by using data set, comprising second principal component (containing vegetation information), maximum NDVI and NIR band of February month, supervised classification was performed on this data set. There was no significant gain in the discrimination of forest types, however agriculture areas were better discriminated Boundary between forest and non-forest areas sharpened. Another data set comprising maximum NDVI, NIR and R band data of February months was also tested but there was not much gain and a lot of intermixing occurred. It is clear from the above observations that various combinations of data set were useful only to a certain extent. Another data set of maximum NDVI, minimum NDVI and NDVI amplitude were subjected to unsupervised (isodata clustering) classification but there was no advantage in forest type discrimination in the study area. Having tested the hypothesis in vain through various approaches we then considered the hybrid approach. Six months raw data set was used for supervised and unsupervised classification scheme. Forest areas and water bodies were given 125 training sites and were then masked out after supervised classification. Remaining data was put to isodata clustering. Since data contained year around variability it was noticed that less number of clusters led to the mixing of classes, and discrimination improved on increasing the number of clusters to 125 or more. Supervised and unsupervised classified outputs were merged together to get classified output (Fig.1). This approach was useful in discriminating the moist deciduous, two types dry deciduous, thorn, mangrove forests, scrub and grasslands. Moist deciduous forests are in the southern part of the state on the plateau of Satpura ranges. Dry deciduous forests of *Tectona grandis* and *Diospyros* are mapped on the Vindhyan range and Gir National Park, these in the transition zone between very dry deciduous and moist deciduous forests. Very Dry deciduous forests of mixed Acacias are in the northern part, adjacent to Thar Desert. Thorny scrub Jungle of Kachchh has dense growth of shrubs and climbers. These thorny formations have been mapped and it is observed that these species are spreading towards Little Rann of Kachchh and leading to the decrease in grassland, the only habitat of wild ass and several birds (Puri, 1960; Prasad et al., 1994). Kachchh has been facing the problem of grassland conversion to woodlands of Acacias and *Prosopis juliflora*. Grasslands are seasonal and form small patches in agriculture areas to large patches in forest and Rann of Kachchh. Because of high biotic pressure quite a bit of area has scrubby vegetation. Scrubby vegetation of Dwarka has common elements with Mediterranean flora and forms the eastern most limits.

The present effort using medium resolution WiFS data has brought out very clearly the broad cropping patterns in the state. The southern part mostly has irrigated double cropped agriculture and orchards whereas northern part has irrigated agriculture of different cropping patterns. Rain-fed agriculture forms the major portion in the Kathiawad and Rann of Kachchh areas in the western region. The region is close to seashore and has vast salt pans. Marshy lands are confined in the Rann of Kachchh. A large part of the study area specially Kachchh region is very dry, hot and receives very less rainfall and supports either grasslands or scrubby vegetation. Salt pans and barren land occupy the most in this region. All these features have been mapped.

It is possible to infer from an overview of the land cover and land use map that the region can be clearly divided into various zones and hypothetical lines can be drawn to delineate biomes like (a) tropical moist deciduous around Satpura Ranges, (b) tropical dry deciduous around Aravali and Vindhyan Ranges, (c) tidal swamp around Rann of Kachchh (d) tropical thorn around Kachchh and Kathiawad regions (e) Mangrove along the coasts of Kachchh, Kathiawad and Saurashtra. This has been explained by phenology and type of vegetation/forest, and land use practices using six date data set, which are manifestations of climatic factors like rainfall, temperature, humidity, altitude, latitude, salinity, physiography, human use etc.
The present study conforms to the delineation drawn by Champion & Seth (1968). However, the study has also brought out additional sites of swamp forests. Analysis also suggests that thorn forest biome can be further characterised into:

(a) Flood plain region of Indus characterised by thorn forests, extensive swampy mud flats, salt pans inundated by sea water and habitat of the wild ass, flamingos, waterfowl and wolf;
(b) Kathiawad peninsula with *Tectona grandis* and thorn forests without swampy mud flats and salt pans and habitat of Asiatic lion, deer, great Indian bustard, migratory cranes etc.

### 6. CONCLUSION

Advantage of a sensor lies in its suitable spatial and spectral resolutions for regional level, competitive band combination for vegetation studies and temporal resolution for vegetation dynamics. The use of WiFS data for land cover and land use mapping at mesoscale for regional level assessment and monitoring receives significant support from the present study. It offers wider coverage for comparison of regional or continent level studies. Its effectiveness is in discrimination of forest types and major crops and other land cover and uses. The accuracy of medium resolution WiFS data for land cover classification is comparable to medium resolution data in regions dominant with uniform features.

Phenological variability though highlighted in each NDVI did not offer much in this area simply because of the similarities or closeness of the ratio values with other crops and orchards. Hybrid approach of classification proved to be more useful than other approaches. Profiles of various features further give evidence for usefulness of the data in discriminating features. Pattern of land cover and land use map supports earlier biogeographical/botanical zoning based on ground observations. WiFS data have been found to be satisfactorily to do biome level mapping and delineation. Present study suggests further subdivision of tropical thorn forests.

### 7. REFERENCES

Anonymous, 1997a, State of Forest Report, Forest Survey of India, Dehradun, India.


Figure 1: Land Cover / Land Use Classification of Gujarat (India)