CHAPTER VII

METHODOLOGY
CHAPTER VII

METHODOLOGY

In the present thesis various aspects of grassland mapping methodology using remote sensing technique are described. Various steps involved in such a methodology are:

i. Classification adopted

ii. Data used

iii. Data selection

iv. Mapping levels

v. Instruments/materials used

vi. Ground truth data collection

vii. Data interpretation

viii. Mapping accuracy

ix. Area calculation

7.1 CLASSIFICATION ADOPTED

Some of the classifications for grasslands are reported in earlier section. They are either climatic classification or based on soil or those, taking into consideration various levels of details. Before finalizing the legend for grassland mapping using multitemporal remotely sensed data, many points were considered. These were:
a) Scale of data  
b) Spatial resolution  
c) Spectral bands  
d) Mapping instruments  
e) Mapping level needs  

Considering the vastness of the study area, 1:50 000 scale was finalized. This being a grazingland, palatable and salt-tolerant grasses must be differentiated. Also, salinity and Prosopis should also be classified. Thus, legend for grassland mapping comprised of the following:

i. Palatable grass G1

These are areas having pure patches of palatable grasses like Dicanthium, Cenchrus and Sporobolus.

ii. Salt-tolerant grass G2

Salt resistant dominating spp. are Suaeda, Cressa and Cyperus spp. They appear dull red to brown in tone, in a normal IRS-LISS II FCC.

iii. Prosopis juliflora P1

It grows gregariously in Banni. It can be either in pure stands which appear bright red and coarse in texture or it can be mixed with palatable grasses (P+G). Sometimes, where salinity has advanced there are
patches of dried or dying Prosopis (P2).

iv. Salt-affected areas

These appear bright white to light bluish in tone (subject to encrustation site, amount of moisture, etc.). Such areas are divided into severely saline (S1), moderately saline (S2) and saline areas (S3).

v. Waterbodies and waterlogged (WL/WB) areas -

These are seen as black, light of dark blue in tone. They vary in size and shapes.

vi. Blanks (B)

They are, seen as dull coarse, whitish, tiny patches, usually near palatable grass zones.

7.2 MAPPING CRITERION

Mapping the vegetation is a very effective method to present the disorder in an ecological set-up. This is so, because only on a map, geographical location, extent and distribution of a plant community can be shown objectively and in a really meaningful manner. (Kuchler, A.W. 1984).

Before finalizing mapping strategy, two important questions should be answered:
i. What type of mapping is needed?

ii. What level of mapping is needed?

Type of mapping is, already answered during finalisation of legend (classification). Level of mapping is a very delicate issue. If useful and application-oriented information is to be supplied, it should be at a level, which is the smallest management unit. The vastness of Banni grassland shows that mapping at 1:250,000 scale would provide a quick-look type of information. Thus, 1:50,000 scale would be an ideal scale for mapping which can be used by planners.

7.3 DATA USED

Data selection has been described in earlier chapter. After selection of the right kind of data, various types of data were used during the course of this study. Data used can be mainly divided into two groups:

a) Remotely sensed data
b) Other data

7.3.1 Remotely Sensed Data

Different remote sensing data used during the present study are shown in Table 7.
Table 7:

<table>
<thead>
<tr>
<th>Sr.No.</th>
<th>Satellite</th>
<th>Path</th>
<th>Row</th>
<th>Date of pass</th>
<th>Product</th>
<th>Spectral bands</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Landsat MSS</td>
<td>162</td>
<td>44</td>
<td>FCC</td>
<td>B/W Transparency</td>
<td>124</td>
</tr>
<tr>
<td>2.</td>
<td>Landsat MSS</td>
<td>151</td>
<td>44</td>
<td>26.10.85</td>
<td>B/W Transparency</td>
<td>234</td>
</tr>
<tr>
<td>3.</td>
<td>Landsat TM</td>
<td>150</td>
<td>44</td>
<td>6.12.85</td>
<td>FCC</td>
<td>234</td>
</tr>
<tr>
<td>4.</td>
<td>IRS-1A LISS II</td>
<td>34</td>
<td>51A2</td>
<td>5.10.88</td>
<td>FCC &amp; CCT</td>
<td>234</td>
</tr>
<tr>
<td>5.</td>
<td>IRS-1A LISS II</td>
<td>35</td>
<td>51B1</td>
<td>6.10.88</td>
<td>-do-</td>
<td>-do-</td>
</tr>
<tr>
<td>6.</td>
<td>IRS-1A LISS II</td>
<td>35</td>
<td>51B2</td>
<td>6.10.88</td>
<td>-do-</td>
<td>-do-</td>
</tr>
</tbody>
</table>

Landsat Data

An advance in multispectral sensing is, the use of such systems which record the spectral reflectance by photoelectrical means, (rather than by photo chemical means as in multispectral photography) simultaneously, in several individual wavelengths within the visible and near infrared portion of the EM spectrum (0.47 to 1.1 um). Such instruments, which were being used in aircrafts since early 1960 are now being used in the Earth Resources Technology Satellite (ERTS) launched in 1972.
Optical sensors for the various frequency bands sweep across the underlying terrain in a plane perpendicular to the flight direction of the satellite. They record energy from the individual areas on the ground. The smallest individual area distinguished by the scanner is called picture element or pixel. A separate spectral reflectance is recorded in analog or digital form for each pixel. A pixel covers about 1/2 acre (0.4 ha. or 4047 m²) of the earth’s surface in case of the ERTS (now renamed as Landsat). Each Landsat image comprises of 7,50,000 pixels (or 185 x 185 km. area).

The Landsat series of satellites have been in orbit since July 1972. The satellite takes 103 min. to complete one orbit and is continuously drifting westwards over the earth, taking 18 days to reappear over the same spot. India is scanned in 250 scenes by this satellite. Landsat scanner are available in two formates. They are in 23 cm (effective image size is 18.5 cm.) at 1:1 million scale or/and 70 cm. (effective image size is 55 mm) at 1:3,339 million scale.

Landsat series of satellites has till now provided 3 types of data acquisition systems. They are:

i) Multispectral Scanner (MSS)
ii) Return Beam idicon (RBV)
iii) Thematic Mapper (TM)
For the present study MSS and TM data have been used.

MSS

In the MSS, during the operation, mirror scans an area 185 km. wide normal to the orbit path. Image data, which are acquired continuously along the orbit path are transmitted to a ground receiving station for recording on magnetic tapes. The tapes are then processed to produce images. In the processing method, there is a 10% forward overlap between successive images.

When sunlight is reflected from an object, it is separated into 4 spectral bands. There are 6 detectors for each spectral band in the MSS. Thus, for each sweep of mirrors six scanlines are generated simultaneously for each of the four spectral bands. The energy sensed by the detectors is converted into an electrical signal for recording and transmission as image data (Sabnis, 1978). Fig. 18 shows Landsat MSS and Fig. 19 shows a typical Landsat MSS black and white transparency of Banni.

**LANDSAT MSS BANDS**

<table>
<thead>
<tr>
<th>MSS band</th>
<th>Wavelength (nm)</th>
<th>MMR region</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>500-600</td>
<td>Green</td>
</tr>
<tr>
<td>5</td>
<td>600-700</td>
<td>Red</td>
</tr>
<tr>
<td>6</td>
<td>700-800</td>
<td>Photo IR</td>
</tr>
<tr>
<td>7</td>
<td>800-1100</td>
<td>Photo IR</td>
</tr>
</tbody>
</table>

Fig. 18 Landsat multispectral scanner system

(Source: NASA, Data User Handbook)
Fig. 19 Typical Landsat MSS B/W transparency of Banni
THEMATIC MAPPER (TM)

The TM on boared Landsat 4 and 5 is an advanced scanner. It has 7 spectral bands, all of which are chosen after detailed studies for various themes and hence are more theme specific. TM has 3 visible, 3 solar IR and one thermal scanner band. The spatial resolution is 30 mts. The details of TM spectral bands and various themes which can be better attempted through these spectral bands are shown in Table 8.

Indian Remote Sensing Satellite (IRS)

It was launched on 17th March 1988 from Cosmodrome, USSR. The 1st satellite of IRS series, it is named as IRS-1A (Fig. 20). It is the largest satellite developed by India. It spans 11 mts. with both its solar panels deployed and weighted 975 kg. at launch. Its planned life was 3 years which it successfully completed. IRS-1B which is similar to IRS-1A was launched on 29th August 1991. Table 9 shows some salient features of IRS-1A.

The payloads

IRS-1A and IRS-1B comprises of sensor payloads which have 2 push broom cameras LISS II having 36.5 m. resolution and one camera LISS I having 72.5 m. resolution. Each of the camera systems images in 4 spectral bands in the visible and
near IR region using 4 separate lens assemblies each with a CLD detector array of 2048 elements. The push broom scan mode operates in such a way that the linear detector array is used to image the scene in the cross-track direction of the spacecraft motion.

Table 8: Thematic Mapper Bands

<table>
<thead>
<tr>
<th>Band No.</th>
<th>Spectral band (um)</th>
<th>Application</th>
</tr>
</thead>
<tbody>
<tr>
<td>TM1</td>
<td>0.45-0.52</td>
<td>Sensitivity to chlorophyll carotinoid concentration</td>
</tr>
<tr>
<td>TM2</td>
<td>0.52-0.60</td>
<td>Slight sensitive to chlorophyll plus green region characteristics</td>
</tr>
<tr>
<td>TM3</td>
<td>0.63-0.69</td>
<td>Sensitive to chlorophyll</td>
</tr>
<tr>
<td>TM4</td>
<td>0.76-0.90</td>
<td>Sensitive to vegetational density or biome</td>
</tr>
<tr>
<td>TM5</td>
<td>1.55-1.75</td>
<td>Sensitive to water in plant leaves</td>
</tr>
<tr>
<td>TM6</td>
<td>2.08-2.35</td>
<td>Sensitivity to water plant leaves</td>
</tr>
<tr>
<td>TM7</td>
<td>10.4-12.5</td>
<td>Thermal properlies</td>
</tr>
</tbody>
</table>

Table 9: Salient features of IRS-1A

Ground resolution 36.25 m LISS II
Spectral bands

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>0.45-0.52 microns</td>
</tr>
<tr>
<td>2</td>
<td>0.52-0.59 microns</td>
</tr>
<tr>
<td>3</td>
<td>0.62-0.68 microns</td>
</tr>
<tr>
<td>4</td>
<td>0.77-0.86 microns</td>
</tr>
</tbody>
</table>
Quantization 128 gray levels
Band to band registration ± .25 pixel
Swath

<p>| |</p>
<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>148 km. LISS I</td>
</tr>
<tr>
<td>146.5 km. LISS II</td>
</tr>
<tr>
<td>A&amp;B combined</td>
</tr>
</tbody>
</table>
Data rate

<p>| |</p>
<table>
<thead>
<tr>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>5.2 mbps LISS I</td>
</tr>
<tr>
<td>2x10.4 mbps LISS II</td>
</tr>
</tbody>
</table>

---

Mission Control

The IRS-1A mission control rests with the spacecraft control centre (SCC) and its associated Telemetry Tracking and Command Centre (TTC) at Bangalore. The SCC is connected with all participating stations and centers by voice links or data lines and teleprinters. The Overseas Communications Services (OCS) provides connection to external TTC stations.
Data Reception

National Remote Sensing Agency, Hyderabad controls data reception recording of payload data and also, further processing and distribution of standard special products.

The ground station at Shadnagar, NRSA, comprises of Data Acquisition System, Real Time Quick Look System and Communication links.

A 10m. dia Antenna receives LISS I and LISS II data in S&Y bands respectively Records it on High Density Digital Tape Recorders.

The IRS Data Products System (DPS) provides for operational generation of photographic and digital products of IRS-1A data and dissemination to users catalogues of all data acquired are generated routinely according to IRS-1A image referencing scheme. The facilities are located at 3 work centers, viz. Data Reception System at Shadnagar, NRSA, Hyderabad, DPS at Balaner NRSA, Hyderabad and at Space Applications Centre, Ahmedabad. Fig. 21 shows path-rows covering Banni and Fig. 22 shows a typical IRS-1A False Colour Composite of Banni.
Fig. 22 Typical IRS-1A FCC showing a part of Qanni.
Data Products

Photographic Products

<table>
<thead>
<tr>
<th>Type</th>
<th>Scale</th>
<th>Location accuracy</th>
<th>Turn around time</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>LISS I</td>
<td>LISS II</td>
<td></td>
</tr>
<tr>
<td>1. Std (B/W, FCC)</td>
<td>1 million 500 thousand ± 2.2 km</td>
<td>± 2.2 km</td>
<td>7 days</td>
</tr>
<tr>
<td>2. Precession (B/W, FCC)</td>
<td>&quot;</td>
<td>100 m.</td>
<td>15 days</td>
</tr>
<tr>
<td>3. Special (Enhanced, B&amp;W colour)</td>
<td>&quot;</td>
<td>&quot;</td>
<td>&quot;</td>
</tr>
</tbody>
</table>

In precision products, the corrections for standard products as well as corrections using Ground Control Points are incorporated to improve position accuracy and reduce internal distortion.

There are also special products like Natural Colour Products which incorporate additional digital processing such as grey level modification, edge detection, rationing and principal component transformation.

FORMATES

All products are available on 240 mm format. In addition to these, spectral products can also be obtained in 70 mm chips on request.
ENLARGEMENTS

Enlargements to standard nominal scales are also available on request.

DIGITAL PRODUCTS

Computer compatible tapes or CCTs, as they are called, are available in 1600 BIP (Band Interlived Pixel) for standard precision and special products.

SPOT

It is a French satellite that has special resolution
10 m - Panchromatic
20 m - Multispectral
but IRS-1C with similar orbital would prove to be equally useful.

7.3.2 OTHER DATA

During the course of studies, data from various other sources have also been used. They are:

i) Forest Atlas (F.A.) of India NATMO

In 1976, National Atlas and Thematic Map Organisation brought out F.A. of India in which, maps are at 1:1 M, 1:2 M, and 1:6 M scales. The present study area of
Banni has been shown in plate no. 3, Rajkot plate, on 1:1,000,000 scale. Most of it is shown as a wasteland and only some western most part is shown as scrub and grass.

ii) Survey of India Toposheets

Banni grassland is covered by 41 E and 41 I quarter inch or 1:250,000 scale, of Survey of India toposheets. In 1:50,000 scale it is covered in 12 SOI toposheets numbered 41 E/1, E/2, E/5, E/6, E/9, E/10, E/11, E/13, E/14, E/15 and 41 I/2, 41 I/3.

iii) Animal Husbandry

Notes, status papers, reports etc. produced by Dept. of Animal Husbandry, Gujarat, has been a good help for my reference. These helped mainly to learn temporal statistics pertaining to live stock in Banni, rainfall, human population, village area, etc. Also discussions held with concerned officers has helped a lot in understanding Banni area set up and problems.

7.4 INTERPRETATION INSTRUMENTS

Different interpretation instruments used during the course of Banni grassland mapping are shown in Table 10. These were developed indigenously at SAC, Ahmedabad at low
cost are:

7.4.1 LIGHT TABLE

It is a simple instrument which aids quick look analysis. Different multispectral diapositives can be observed at the same time on the light table and this essentially helps to select the suitable data product for mapping.

7.4.2 HIGH MAGNIFICATION ENLARGER (HME)

It is an optical projection device for wide ranging image enlargements developed under low cost interpretation aids project of Indian Remote Sensing Satellite Utilisation Programme (IRS-UP). The instrument features direct projection on table top. The magnification range of HME has been optimized such that it suffices for various interpretation inputs.

HME works on the principle of optical projection (Habell and Lox 1971). It uses Kohler system of illumination which provides best efficiency. Fig. 23 shows HME. Following are its salient features:
SPECIFICATION OF HME

Film Capacity 24 cm format satellite/aerial image (B/W or colour)

Projected Film Gate 50 x 50 mm, 30 x 30 mm and 20 x 20 mm selected by sliding baffle

Magnification range 3.5x - 45x continuously variable

Mode of scanning Motorised/manual X-Y translation of film holder by + 90 mm

Illuminance Centre illuminance of 150 lux at 20 x magnification and 500 lux at 10 x magnification for 50 mm lens

Uniformity Less than 50 % fall off at extreme image corners

Resolution Better than 20 lp/mm throughout the magnification range

Scale Variation 0.5 % RMS for all lens-magnification combination with maximum value of +1%

Overall Dimensions 230 (II) x 145 (W) x 85 (D) cm

Weight 180 kg. approx.

Power requirement 230 volts AC/5 Amps.
Fig. 23 Schematic view of HME

(Source: Scientific Note on HME by Dubey and Mallick, 1986)
LARGE FORMAT OPTICAL ENLARGER (LFOE)

The design of LFOE is aimed at getting proper image imminence with high degree of format. LFOE consists of a light source, condenser unit, object holder, projection lens and screen. It uses 500 watts/120 v projection lamp as the light source. The condenser unit comprises of 2 fresnel lenses corrected for spherical aberration. The projection lens forms the image of the transparency or FCC on a Formica top table which serves as the screen. A step-down transformer in conjunction with a solid state light dimmer provides power to the lamp (Sahai et al., 1980). The specification of LFOE are as follows:

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Film capacity</td>
<td>Single 23 cm format imagery or 4 chips in 70 mm format</td>
</tr>
<tr>
<td>2. Magnification</td>
<td>Fixed at 4X</td>
</tr>
<tr>
<td>3. Condenser lens</td>
<td>Two (f 0.8/317.5 mm) fresnel lenses</td>
</tr>
<tr>
<td>4. Projection lens</td>
<td>Jena lens Tessar (f 4.5/210 mm)</td>
</tr>
<tr>
<td>5. Dimensions</td>
<td></td>
</tr>
<tr>
<td>5.1. Housing</td>
<td>750 x 505 x 513 mm</td>
</tr>
<tr>
<td>5.2. M.S. angle frame</td>
<td>1980 x 1120 x 1120 mm</td>
</tr>
<tr>
<td>5.3. Table</td>
<td>Area 1100 x 1100 mm</td>
</tr>
<tr>
<td>6. Power</td>
<td>230 volts, 100 watt for fans, 120 volts for lamp, 500 watt</td>
</tr>
</tbody>
</table>
7.5 MULTITEMPORAL DATA

It is very crucial to understand the changes in grazing land cover in order to manage them properly. In the recent years monitoring of vegetation change using remotely sensed data has received attention (Singh, 1986; Houghton, 1990; Sader, et al., 1990, and Jadhav et al, 1991).

In the present study, I have aimed to observe the changes that have occurred in the Banni grassland during the last decade i.e. from 1980-1990. This would highlight all the positive and negative changes that have occurred during the said time.

Multitemporal satellite data of the years 1980, 1985 and 1988 was studied. The status of grassland spread or degradation, invasion of Prosopis juliflora and salinity ingress was critically observed.

It is apparent from rainfall that 1980 and 1988 can be considered as very good years as they received about 500 mm rainfall whereas 1985 was a drought year with only 123 mm.
rainfall. Figs. 24 and 25 show the grassland status in different years, and Fig. 26 shows the flow chart of overall approach for grassland mapping.

7.6 PRELIMINARY ANALYSIS

The flow chart of methodology adopted during preliminary visual analysis is shown in Fig. 27.

After quick-look analysis whereby different season imageries were scanned, suitable season i.e. September/October was identified, since, the imageries of this season showed right differentiation of grassland, salinity, *Prosopis* and other areas.

A Reconnaissance Study of the study area was done in April 1989 with Survey of India (SOI) topographical maps and temporal satellite data. This helped to identify certain permanent features which are called Ground Control Points (GCPs). The reconnaissance survey helps to formulate an interpretation key based on data collected on different soil and vegetation types.

From SOI toposheets, a base map, showing major ground features like road, waterbodies and village boundaries, was prepared at 1: 50,000 scale.
Fig. 24 Histogram showing vegetation status during different rainfall years in Banni
Fig. 25 Changes observed in Banni region during 1980-85, 1985-88 and 1980-88 time frame
GRASSLAND MAPPING
METHODOLOGY

Cloud Free
Drought (D), Normal (N), Excess (E)
Rainfall Year Satellite Data (Landsat/IRS)

Digital Enhancement

Hybrid Technique

Visual Analysis Technique of D, N, E Data

Digital Analysis Technique of D, N, E Data

Accuracy Estimation & Cost Benefit Analysis

Selection of Most Suitable Methodology

Fig. 26 Flow chart showing overall approach for grassland Mapping
GRASSLAND MAPPING METHODOLOGY
VISUAL ANALYSIS

DATA NEEDS

RS DATA
- MULTI SEASON
- DROUGHT. NORMAL
- EXCESS RAINFALL
YEAR

• SOI TOPOSHEET
• BANNI DEV. OFFICE MAP
• FOREST DEPT. MAP
• CDO/WRD MAPS

DIGITAL ENH.

GROUND
TRUTH

QUICK LOOK ANALYSIS

SELECTION OF SEASON

PRELIM. ANALYSIS

MULTI TEMP. DATA

FINAL ANALYSIS OF
T1 T2 & T3

CURRENT STATUS &
CHANGE DETECTION

INFERENCES

FIELD CHECK

ACCURACY

Fig. 27 Flow diagram for grassland mapping (visual analysis)
Since the study constituted analysis of multitemporal data, many copies of the base map were prepared on the ammonia printer.

In IRS-1A, LISS II Banni was covered in 3 FCCs 34-51 A2, 35-51 B1 and 35-51 B2. In Landsat TM and MSS the path-rows for Banni are 151-44 and 150-44. Each FCC or black and white transparency was individually loaded on the LFOE, developed in SAC, for

Table 10: Interpretation instruments used during the course of Banni grassland mapping

<table>
<thead>
<tr>
<th>Analysis Phase</th>
<th>Instrument</th>
<th>Magnification</th>
<th>Format</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quick Look</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Analysis</td>
<td>Light Table</td>
<td>Nil</td>
<td>23 cm</td>
</tr>
<tr>
<td>Visual</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Analysis</td>
<td>LFOE</td>
<td>4x</td>
<td>23 cm</td>
</tr>
<tr>
<td>Final</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Analysis</td>
<td>HME</td>
<td>3.5x - 45x</td>
<td>23-24 cm</td>
</tr>
</tbody>
</table>
preliminary analysis on 1: 250 000 scale. This was essential before switching over to final mapping at 1: 50 000 scale which was done using HME (High Magnification Enlarger). Its specifications are already given.

In HME, the imagery was loaded and enlarged so as to superimpose on the base map. At this time GCPs help in correct superimposing. After proper alignment, palatable and salt-tolerant grasses, Prosopis, saline areas, etc. were delineated and mapped taking into consideration their tone, size, shape, pattern, texture, location, etc.

7.7 HYBRID ANALYSIS

This procedure is a typical mixture of visual and digital analysis. A standard product, (FCC) with its specific look-up table, does not provide sufficient contrast to discriminate various thematic features of interest. Therefore, to facilitate the correctness of interpretation, various digital enhancements were generated for Landsat Thematic Mapper data and IRS-1A LISS II data. A flow chart describing the various steps involved in the hybrid methodology is shown in Fig. 28.
GRASSLAND MAPPING METHODOLOGY
HYBRID ANALYSIS

Fig. 28 Flow diagram showing steps involved in hybrid technique for satellite data analysis

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7.7.1 IMAGE ENHANCEMENTS

Image enhancements are basically employed to improve the appearance of an image for visual analysis or subsequent machine analysis. A particular type of enhancement may not hold true over a large area as soil background and many other factors may change. Moreover, it cannot be categorically stated that a particular enhancement is better than the other, as, it is a subjective judgment of an interpreter. Some special data products can be obtained from the data centers, however, it may not be possible for a user to go for the bulk purchase of such data because of the cost factor and the time involved in the processing. Moreover, it may not be exactly suitable to the user's application. Regional Remote Sensing Service Centers (RRSSCs) under National Natural Resources Management System, have been set up, to cater to the precise need of the user. Here he has possibility to attempt several enhancement techniques and select the best one for his further use.

After season selection which was carried out using browse and available FCCs, various digital enhancements were generated at the VIPS-32 systems at RRSSC, Dehradun and Jodhpur. The enhanced products were critically examined with respect to identifying the classes of interest and the most suitable one for grassland mapping of Banni were written as
Human eyes employ three primary colours to perceive any object, whereas, both IRS and TM collect data in more than three bands giving scope for the choice of the best three (Oza, 1990). Sensors record reflected and emitted radiant flux from different objects on the earth. Different objects would reflect differently in different regions of the EM spectrum. The results in 'contrast' between the two objects. Unfortunately, different materials often reflect similar amounts of radiant flux throughout the visible and near IR portion of the electromagnetic spectrum, resulting in a relatively low contrast image. It is, therefore, necessary to select a particular digital enhancement which ensures higher contrast amongst the objects of interest for better interpretability.

Apart from the generation of the standard FCC using bands 2,3,4 with blue, green and red filters respectively, other enhancements attempted were

1. Linear Contrast Enhancement
2. Principal Component Analysis
3. Histogram Equalization/Modification
4. Normalized Difference Vegetation Image (NDVI)
5. Greenness Vegetation Index (GVI)
6. Greenness Above Bare Soil (GRABS)
1. LINEAR CONTRAST ENHANCEMENT

A contrast enhancement expands the original input brightness values to make use of the total range or sensitivity of the output device. In case of IRS and Landsat MSS where data lies between the gray level range (0-127) there is a definite scope of enhancement by a factor of 2, however, in case of TM also, where the quantification levels are 256, there is a possibility of using this technique since the actual data does not occupy the entire range in practice. In such cases, one determines the minimum and maximum gray levels by taking the histogram of the image and computes the output brightness values according to the equation

\[
BV = \frac{BV_{in} - BV_{min}}{BV_{max} - BV_{min}} \times BV_r
\]

where

- BV_{in} = input brightness value (to be modified)
- BV_{min} = minimum brightness value in the input image
- BV_{max} = maximum brightness value in the input image
- BV_r = range of the brightness values in the output device
- BV_{out} = output brightness value
In the event when the histogram of an image is not Gaussian in nature (i.e. bi-modal or tri-modal etc.), it is advisable to use the piece-wise linear stretching. In this case the analyst identifies the ranges of the modes and uses the linear stretching formula repeatedly for all the ranges. This gives scope of enhancement for all the classes. If the analyst is interested only in a particular class, the others can be set to 0 or 255 giving maximum scope of discrimination for the class of interest.

2. PRINCIPAL COMPONENT ANALYSIS

Principal component analysis is a proven spatial transformation in the analysis of remotely sensed digital data. Principal component images are often more interpretable compared to the raw images. PCA is also used to compress the information content of a number of bands of imagery into just two or three transformed principal component images. This proves to be very economical. The application of the transformation to the correlated remote sensing data will result in an uncorrelated multispectral data set that has certain ordered radiance properties.
3. HISTOGRAM EQUALIZATION/MODIFICATION

When the contrast in a certain image is too low, one resorts to nonlinear contrast enhancement techniques. Histogram equalization is one of the most useful technique of this sort. In this approach image values are assigned to display levels on the basis of their frequencies of occurrence. For spatial analysis specific feature may be analyzed in greater radiometric detail by assigning display range exclusively to a particular range of image values by a method called special stretching e.g. if grass area is represented by a narrow range of values in a scene, further distinction within grasses could be enhanced by stretching this small range to the full display range.

4. NORMALIZED DIFFERENCE VEGETATION INDEX (NDVI)

Sometimes the differences in brightness values from similar objects are caused by topographic conditions, shadows, or seasonal changes in sunlight illumination angle and intensity. These conditions may hamper the ability of an interpreter or classification algorithm to correctly classify the surface features in a remotely sensed image. Ratio transformations, in certain cases, can be applied to reduce the effects of such environmental conditions. NDVI is nothing but a normalized ratio of the difference and
combination of the red/infrared bands. The main goal of carrying out NDVI is to reduce the four to seven bands of IRS, MSS or TM data to a single number per pixel that predicts or assesses canopy characteristics such as biomass, productivity, leaf area and/or percent vegetative ground cover. Most vegetation indices are based on the fact that different vegetations have typical separability in different bands. Two most important bands, red and infrared, in the ranges of 0.63 um to 0.69 um and 0.76 um to 0.90 um that are sensitive to chlorophyll and vegetational density or bio-mass respectively, are used in NDVI. This procedure was developed by Rouse et al. (1973) for monitoring vegetation. They computed the normalized difference of brightness value by using MSS bands 7 and 5 and called it normalized difference index. It is given by

\[
\text{Normalized Difference Index (NDI)} = \frac{\text{MSS 7} - \text{MSS 5}}{\text{MSS 7} + \text{MSS 5}}
\]

(in case of other sensors corresponding bands are to be considered).

5. GVI AND GRABS

One of the most important vegetation indices is the tassled cap transformation developed by Kauth and Thomas.
It is based on Gram-Schmidt sequential orthogonalization techniques that produce an orthogonal transformation of the original four channel data space to a new four dimensional space. It is called the tassled cap transformation because of its cap shape. The transformation identifies four new axes including Soil Brightness Index (SBI), the Green Vegetation Index (GVI), the Yellow Vegetation Index (YVI) and a Non-such Index (NSI) associated with atmospheric effects. Greenness is an orthogonal deviation from the mean soil line and is used as a measure of a green vegetation present. The further the distance perpendicular to the soil line, the greater the amount of vegetation present within the field of view of a pixel. A GVI image is created by multiplying each of the four original brightness values for each pixel by corresponding tassled cap coefficients.

Another vegetation index called Greenness Above Bare Soil (GRABS) was tested by Hay et. al. (1979). It is computed using the Kauth-Thomas transformation on the data which is corrected for sun-angle effects and atmospheric haze:

\[
GRABS = GVI - (0.09178 \times SBI) + 5.58959
\]

(SBI : Soil Brightness Index)
6. **BAND COMBINATIONS**

The four spectral bands of IRS-1A are comparable to first four bands of Thematic Mapper data. However, TM data has additional three bands in the ranges of 1.55 - 175 μm, 2.08 - 2.35 μm and 10.4 - 12.5 μm. These bands are useful because of their sensitivity to water in plant leaves. Therefore, various combinations of these bands were tried and FCCs were generated to observe whether these bands are providing any better or additional information on grasslands.

It is well known that strongly correlated bands generally make a poorly coloured picture compared to weakly correlated bands (Gillespies et. al. 1987). The commonly used measures of information content in a statistical sense are the total variance and the generalized variance. The use of maximum determinant value was recommended by Sheffield (1985). Oza (1989) has used for IRS data, the maximum determinant criterion on five different scenes. He found out that band 3 (0.62-0.68 μm) and band 4 (0.76-0.86 μm) have more information content than band 1 (0.45-0.52 μm) and band 2 (0.52-0.59 μm). Moreover, band 4 is generally better than other bands and band 2 comes out as the least favoured one. The values of Optimum Index Factor (OIF) were worked out and it was observed that OIF value for bands 1, 3 and 4 are
higher in majority cases. After selecting band combination next step was to assign colours to the selected bands. Since human eye is sensitive to green, this colour was assigned to band 4, red to band 3 and blue was assigned to band 1.

These findings were again tested during the studies of grasslands mapping in Banni region of Kachchh district.

Various digital enhancements tried for IRS-1A LISS II and Landsat TM data have been shown in Figs. 29 and 30.

Two best suitable enhancements from each kind of data were singled out and later transferred on as diapositives by film writing system FIRE. The FIRE written transparencies were used for mapping grassland at 1: 50 000 scale using visual analysis procedure mentioned earlier. The accuracy of the interpreted maps was then checked on ground. Table 13 and 14 show the qualitative assessment of various enhancement techniques applied on TM data as well as IRS-1A data. The confusion matrices of the same are shown in Table 15 a and b.
Fig. 29 Various digital enhancement from IRS-1A LISS II data
Fig. 30 Various digital enhancement from Landsat TM data
7.8 DIGITAL ANALYSIS

There are certain thresholds beyond which the human interpreter can not detect just noticeable differences in the imagery (Jensen, 1986). Human interpretation can be affected by tiredness or bias and what more, it is seldom repeatable with the same results. Digital analysis can overcome this obstacle, but then digital image processing uses only tone/colour parameters and not others like texture, shape, size, pattern, shadow etc. Attempts are being made to use these other parameters too, in digital processing, but this has still not reached operational level.

7.8.1 MULTISPECTRAL CLASSIFICATION

The process of multispectral classification is carried out using supervised or unsupervised classification procedures. Out of these the former procedure was used during grassland mapping of Banni, as the area is accessible and it is possible to get information on various features of interest.

During supervised classification an analyst attempts to locate specific sites in the remotely sensed data selects homogenous samples of known cover types. These areas are
commonly referred to as "training sites", because the special characteristics of these known areas are used to train the classifier to map the remainder of the image. Multivariate statistical parameters (mean, standard deviations, variance covariances, correlation matrix etc.) are calculated for each training site. Every pixel, both within and outside these training sites are then evaluated and assigned to a class of which it has the highest likelihood of being a member. However, care has to be taken to identify, distinguish and level information classes and spectral classes. Information classes are those which man defines whereas spectral classes are those that use inherent properties in the remote sensor data. It is necessary to translate spectral classes into information classes to fulfill the objective of the study.

7.8.2 TRAINING SITE SELECTION

Banni area is covered by various grass types, Prosopis and saline areas. Hence the following classification scheme was adopted:

1) Grass-palatable
2) Grass-salt tolerant
3) Prosopis-wet
4) Saline soil
5) Saline soil (moderate)
6) Saline soil (severe)
7) Agriculture
8) Waterbodies/waterlogged
9) Blanks
10) Scrub

After the finalisation of classification scheme, training sites were selected. A detailed ground truth data collection was carried out and various classes were precisely marked on map (Survey of India topographical sheet) and image (FCC prints at 1: 50,000 scale). The image co-ordinates of these sites were identified and used to generate the signatures for each of these areas.

7.8.3 CLASSIFICATION ALGORITHMS

It is generally observed that the pixels within a particular theme or class do not have identical spectral values. Rather these are scattered in the form of a cluster. This cluster of points represents spectral response pattern of a particular class. Though many a pixels in an image with value close to the mean can be easily classified, others falling in the peripheral region need application of a statistically good algorithm (RRSSC, 1988). There are various classification statistics to assign a pixel of unidentified cover type of an appropriate class.
The most simple classification algorithm is based on "Minimum Distance to Means" classifier. During the process the mean spectral value in each band for each category is determined. These values comprise the mean vector for each category. This classifier is mathematically simple and computationally efficient but it is insensitive to different degrees of variance in the spectral response data.

Another method used is "Parallelepiped Classifier". Here sensitivity to category variance can be introduced by considering the range of values in each category training set. The range is usually defined by highest and lowest digital value in each band, and appears as a rectangular area in the two channel scatter diagram.

Yet another method is that of "Maximum Likelihood Classifier". An unknown pixel is classified according to the category range, or decision region, in which it lies, or as unknown if it lies outside all regions. This method takes care of variance but not of covariance. In the presence of covariance, the rectangular decision regions fit the category training data very poorly. In essence, the maximum likelihood classifier delineates ellipsoidal equiprobability contours. In the scatter diagram, the shape of equiprobability contours expresses the sensitivity of the likelihood classifier to covariance.
Taking above mentioned facts into consideration maximum likelihood classification was adopted during grassland mapping of Banni region.

7.8.4 DATA USED

The following data was used:

<table>
<thead>
<tr>
<th>Sr.No.</th>
<th>Sensor</th>
<th>Season</th>
<th>Data product</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>IRS-1A LISS II</td>
<td>Oct. 1989</td>
<td>CCT</td>
</tr>
<tr>
<td>2.</td>
<td>Landsat MSS</td>
<td>Nov. 1986</td>
<td>CCT</td>
</tr>
</tbody>
</table>

7.8.5 METHODOLOGY

The methodology as shown in the flow chart (Fig. 31) involved GCPs selection, creating map to image transformation model, digitisation of Banni boundary, digital overlay of village boundaries, mask creation, rectification, training set selection and classification using maximum likelihood algorithm. Smoothing was also applied on the classified image. Details of these steps are as follows:

1) Extraction of Administrative Boundaries
   Banni area is characterized by waterlogging during October season. Keeping this in mind, about 25 Ground
Control Points (GCPs) were selected, majority of them from road intersections or bands. The GCPs were located on the image as well as 1: 50 000 topographical maps.

After digitizing GCPs, their coordinates in the form of latitudes and longitude were obtained. Image coordinates along with latitude and longitude were used to obtain first order map-image affine transformation. West Banni boundaries were digitized and the mask was created. Finally the mask and boundaries of roads and villages were digititionally overlayed.

2) Generation of Training Sets and Classification

Ground truth sites pertaining to grasses (both palatable and salt-tolerant, Prosopis (wet and dry) saline area (with varying degrees of salinity) and other land use categories were identified from the image displayed on pericolour monitor. Several training windows were selected for each class, on the basis of spectral signatures, histogram of the gray values and the spectral separability. Then, based on separability evaluation, final classification was performed using Maximum Likelihood classifier (MXL). Landsat MSS data pertaining to 1986 was also classified in addition to October 1988 IRS-1A LISS II data.
Fig. 31 Methodology flow chart for grassland mapping using digital analysis technique
A ground truth design was made to check classification accuracy. This was tested on a sample basis assuming binomial distribution for the probability of success/failure of the sample. A confusion matrix was generated after field check, which is shown in table.

7.9 GROUND TRUTH (GT) DESIGN AND SAMPLING METHOD

The true description (qualitative and/or quantitative) of any object or phenomenon can be learnt from 'Ground Truth' (GT). The ground truth data collection is needed for 3 reasons:

1) for calibration of sensors
2) for the preparation of final image interpretation key and
3) checking interpretation accuracy (Sahai, 1979).

A GT design map at 1:50 000 scale was prepared for verification of classified categories accuracy (Fig. 32).

Keeping in mind, the accessibility of a point and also the fact that no category got left out, many points were plotted on the map on random bars. Some doubtful areas were especially marked. Since accuracy checking should be done in the same season as that of the analyzed imagery, GT survey was done in October 1990. This being the post-monsoonal
Fig. 32 GT design of a part of Banni

X - sampling sites.
time, some areas were inaccessible due to complete waterlogging.

Upon reaching the sample point, field details were entered directly on the GT map for the post ground truth verification as well for mid course corrections, if any.

Other details like floristic composition were also noted. In all 35 samples were verified in the grassland, *Prosopis juliflora* and salinity categories.

Salt samples from the sites of each category were collected to learn about their pH and electrical conductivity. A graph of pH versus electrical conductivity is shown in Fig. 7.

7.10 FINAL INTERPRETATION KEY

After the GT survey, a final interpretation key was prepared as shown in Table 11.
### Table 11: Interpretation key for use with IRS-1A LISS II NORMAL FCC data

<table>
<thead>
<tr>
<th>Grazing Image characteristics</th>
<th>Land cover</th>
<th>Tone</th>
<th>Texture</th>
<th>Association</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Grassland</strong></td>
<td>Light red to brown</td>
<td>Coarse to mottled</td>
<td>Palatable &amp; salt tolerant grasses</td>
<td></td>
</tr>
<tr>
<td><strong>Palatable</strong></td>
<td>Light red</td>
<td>-do-</td>
<td>Dicanthium, Cenchrus.</td>
<td></td>
</tr>
<tr>
<td><strong>Salt tolerant</strong></td>
<td>Dull red tint to brown</td>
<td>-do-</td>
<td>Suaeda, Cyperus &amp; Cressa spp.</td>
<td></td>
</tr>
<tr>
<td><strong>Prosopis mixed grass</strong></td>
<td>Medium red &amp; reddish tint appear in dots &amp; patches</td>
<td>Coarse to smooth</td>
<td>Prosopis spp., Aristida, Cyperus, Cenchrus spp.</td>
<td></td>
</tr>
<tr>
<td><strong>Prosopis</strong></td>
<td>Dark red to light red</td>
<td>Smooth texture</td>
<td>Prosopis juliflora</td>
<td></td>
</tr>
<tr>
<td><strong>Salinity</strong></td>
<td>Bright white to bluish</td>
<td>Smooth to mottled</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Salinity 1</strong></td>
<td>Bright white to medium bluish</td>
<td>-do-</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Salinity 2</strong></td>
<td>White to yellowish bluish</td>
<td>-do-</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Salinity 3</strong></td>
<td>Dull bluish to blackish brown</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

In the normal FCC of IRS-1A LISS II dominating palatable grasses viz. Dicanthium annulatum, Cenchrus biflorus, Sporobolus helvolus and Aristida sp. appear light...
red and smooth in texture whereas salt tolerant dominant spp. like *Suaeda*, *Cyperus* and *Cressa* sp. appear dull red to brownish in tone. They have a slightly mottled texture.

*P. juliflora* which grows gregariously in Banni, either grows in pure form or is mixed with palatable grass. Wherever, salinity occurs, *Prosopis* dries out. The pure patches of *P. juliflora* appear dark red or orangish red in colour with coarse texture, depending upon the foliage cover, stage of growth and moisture availability.

Ecotonal areas having both, palatable and salt tolerant grasses look light yellow to greenish blue in tone.

Saline or salt-affected land appears bright white to light blue in tone (subject to encrustation site and amount of moisture, etc.). Salt affected areas have been divided into severe, moderate and saline areas on the basis of tone and textural variation.

Waterbodies and waterlogged areas are seen in light to dark blue tone and they vary in size. They have irregular shape.

Small blank patches appear as dull white patches, generally where palatable grass occurs.
7.11 CLASSIFICATION ACCURACY

Interpretation key and accuracy checking, both were done in the same ground truth survey trip. Total 35 samples were checked in all categories, based on random sampling. Commission and omission errors were worked out through the confusion matrix generated.

Confusion matrix is the verified and tabulated results of ground truth survey. The accuracy of each classified category is calculated and thus accuracy of the map prepared is verified.

7.12 AREA CALCULATION

After preparing a final interpretation map from ground truth results, area calculation was done using dot grid method, where

12 cm = 16 dot grids (Fig. 33).

Some other methods for area calculation are -

i) Polar planimeter

ii) MM graph sheet

iii) Electronic planimeter

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Fig. 33 Using transparent dot grid and m.m. graph sheet for area calculation