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LAND USE MAPPING WITH LANDSAT-1 IMAGERY AND CC TAPES IN TAMIL NADU, SOUTH INDIA

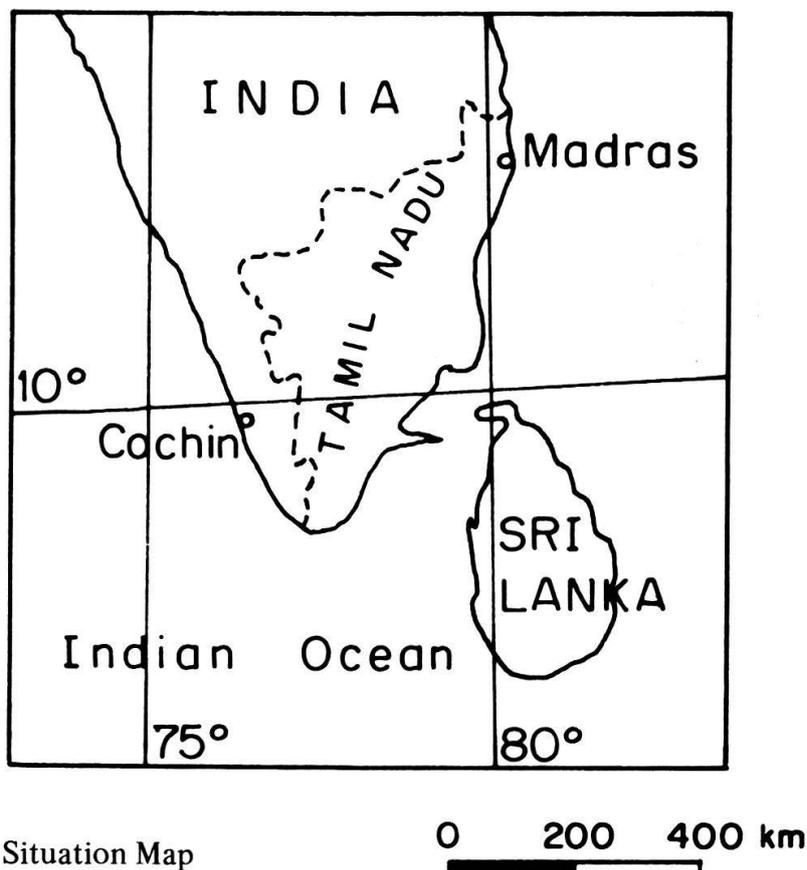
by R. KRUMMENACHER *)

with 8 figures in the text

1. INTRODUCTION

In a recent United Nations/FAO water resources Project in Tamil Nadu, South India (fig. 1), large areas of the State were photomapped and some thematic maps were produced. An updated information on water distribution (water map), vegetation, irrigated

Fig. 1



land, dry farming and percentage of bare land was made available. In this paper, these maps are compared with the information retrieved from data collections made aboard the international satellite LANDSAT-1 (formerly ERTS-1) which flew over the Tamil Nadu State in 1972/73, using remote sensing techniques.

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1.1. Remote sensing

Remote sensing is the acquisition of information about specific objects by an information and gathering device not in intimate contact with the subject under investigation (1). This represents the technology of looking at the Earth's surface from an aircraft or spacecraft, manned or unmanned, and acquiring data about the resources on the Earth's surface, land and sea and occasionally few meters below the surface also. These documents taken from satellites usually represent the logic extension of existing mapping methods over large areas. But it can also represent a completely new approach capable of many useful variations (2). The devices used on board satellites sense the Earth's surface in different bands in the visible spectrum (what our eye can see) or in the infrared (sensing temperature variations). Fortunately, the atmosphere is transparent to most of these bands when cloudfree.

1.2. Origin of LANDSAT-1

This satellite was launched July 23, 1972 and it has been flying in a circular orbit 570 miles (920 km) above the Earth's surface. It circled the Earth every 103 minutes, or roughly 14 times per day. The orbital pass was from North to South. From such vantage point, the LANDSAT covered the entire globe with repetitive coverage every 18 days. A unique feature is that it viewed the Earth at the same local time, around 9:30 a.m. at the Equator and covered on each pass an area 185 km wide with, laterally, an 18 km overlap.

The Tamil Nadu State is covered with 10 LANDSAT scenes, each having a near-square shape 185 km wide. They are of good quality with only few areas covered with clouds.

1.3. Performances of LANDSAT

LANDSAT data are recorded at various wavelengths of both visible and infrared light. The sensors on board the spacecraft convert the energy received to electric signals which are transmitted to N.A.S.A. receiving stations on the ground. These signals are stored on magnetic tapes and can be later converted to photo-like images (LANDSAT imagery) or computer compatible tapes (CCT) data. These CCT are used to produce maps printed out on a computer printer at the attractive 1:25 000 scale.

The image sensor on the satellite LANDSAT is called a multispectral scanner (MSS). It views the area in four bands, the blue-green (band 4), the red (band 5), the near infrared (bands 6 and 7). These wavelengths were chosen with specific goals in mind. Band 4 appears in green on the image produced. Water is transparent and the sediments are visible when in suspension. The depth and/or turbidity of a body of water can commonly be discerned. Band 5 shows a good contrast between types of vegetation, soils. On bands 6 and 7, water appears black because it totally absorbs the radiant energy at these wavelengths. The limits between land and water are therefore very good, and flowing rivers, water tanks, moisture content of soils can be mapped. In these 2 bands, structural features and lineaments are well recognized. These lineaments, usually not visible on conventional photos are useful to understand the geological set-up of an area. They are also good for mineral exploration. In short, the devices on board LANDSAT satellites can sense many ground features useful in many disciplines (3), (4), (5), (6), (7).

2. OPTICAL INTERPRETATION

Except when associated with other bands for color composition or used for coastline mapping, the optical interpretation of MSS band 4 on mainland is rather limited. MSS

bands 5, 6 and 7 black/white images at a 1:500 000 scale were used. They cover part of the Indian Peninsula, from latitude 14° N southward.

We had also the corresponding series of positive transparencies at a 1:1 000 000 scale. Enlargements on paper were made from the imagery with which tone contrasts can be improved. Some details are lost, but main land units are better seen.

Enlargements at a 1:63 000 scale were found convenient. It is the scale of previous aerial surveys. Topographical sheets printed at the same scale were often consulted, as well as Taluk maps (Taluk = District).

35 mm chips of transparencies were projected at various scales to appreciate the size of the features to map and the edge effects.

2.1. *Image resolution*

The difficulty with LANDSAT imagery is the lack of fine detail, caused by the size of each resolution cell. The size of a single record in any of the four MSS bands is approximately a circular cell 79 meters in diameter. At a 1:63 000 scale, it is about 1.3 mm wide and it can be seen individually. But its tone has been averaged in with the adjacent cells. This automatic effect does not bring in a sharp definition of the features. Moreover, in our area, land boundaries are irregular, and the fragmentation is such that field dimensions are often under the 79 m definition limit (8). Only linear features with a sharp reflectivity contrast with adjacent surfaces can be observed, even when less than 79 m wide.

2.2. *Interpretation*

Interpretation principles are the same as for aerial photos interpretation. An additional skill is required to differentiate the grey tones and classify them. One should recognize different textures, for example a coarse texture for irrigated land, a finer one for dense shrubs or thicket, when both have the same average tones.

Color composites certainly help classify land units quicker. In turn, close examination of black/white scenes gives a better understanding of the phenomena detected, reflectivity or absorption, on natural surfaces.

The interpretation of the Elathur test area *on band 5* was a bit laborious. The image is mainly a combination of small scale features and relatively coarse textures. The temperature in the Tamil Nadu plains never goes down as much as to prevent vegetation from growing continuously. Thus reflected tones express essentially vegetation and cultivation growing stages and density. The very coarse texture of irrigated lands reflects a high subdivision of the area. Limit between cultivated and non-cultivated patches are not easy to draw. Bare soil and stream channel are well defined. Suspended particules in tank water produce higher reflectivity levels, but limits of the water bodies are no more accurate.

On band 6, flowing rivers can be seen when equal or more than 120 m wide. Small bodies of muddy water are not shown. Geological structures and outcrops are easily mapped. Ranges of grey tones must indicate various vegetation densities. When this image was recorded, 75 mm of rain have been collected at the nearest rainfall station (Cheyyar Anicut) four days ago, and fresh new grass was probably growing on otherwise bare ground. Two clearly different tones were mapped, one reflecting little or no vegetation, the other reflecting dense cultivation, leaving an intermediate class of average cultivation density.

On band 7, river courses can be located when equal or more than 70 m wide. Limit of tank water is excellent. Tones of grey are principally soil moisture features. Areas of irrigated land are dark grey and have a coarse texture. Uncultivated subcrops have a light grey tone with a fine homogeneous texture. Outcrops are highly reflective, surrounding weathered rocks and pediments are light in tone and have a very fine texture.

Band 7 is used in sedimentary rocks areas to define discharge (darker tones) from re-

charge zones (lighter tones) (9). In turn, in Tamil Nadu, where natural discharges have been known for centuries, band 7 is very useful to draw water maps (10), (11). Darker tones feature water at the surface (river, water tanks, irrigated fields) or near the surface (intense cultivation). Lighter tones feature water deeper into the ground or not yet extracted (subcrops, empty tanks, non-cultivated land).

An engorgement of band 7 image of the Elathur area is shown on fig. 2, and its interpretation on fig. 3.

2.3. *Superposition*

Positive transparencies can be superposed and tones added. This procedure can accentuate certain features, average others. We had the following results:

Band 6 + 7: — give a very good contrast helping define irrigated land from rainfed fields.
— enhance the contrast between different degrees of soil moisture.

Band 5 + 7: — depict well flowing rivers in their channel.
— in sedimentary coastal areas give a better definition of discharge and recharge zones.
— contrast between bare land, rainfed fields, irrigation land is marked, but not so well as with bands 6 + 7.

Band 5 + 6: — no additional information.

2.4. *Combined interpretation*

Interpretation of band 5, 6 and 7 were combined into one map. When superposing the drawings, boundaries sometimes do not coincide. Therefore we had to determine in which band individual features were best seen. In our area, these are:

Water tanks: 7, flowing river: 7, irrigated land: 7, 6, irrigation density: 6, geological features: 6, subcrops: 6, pediments: 5, 7, non-irrigated area: 5, 6, natural vegetation: 5, washes and alkali soils: 5.

By carefully comparing our interpretation with the land use map, we decided on an acceptable mapping procedure which is:

- start with band 7. Map outcrops, weathered rocks and pediments, water tanks, flowing rivers, irrigated land.
- take band 6. Subdivide area left blank into cultivated subcrops (dry farming) and non-cultivated area. Subdivide irrigated land into areas of two different densities.
- take band 5. Map area of little cultivation within dry farming area. Map washes and alkali soils within non-cultivated area. Superpose high vegetation onto outcrops and pediments. Trace river channels.

Fig. 4 shows a combined interpretation of the same test area.

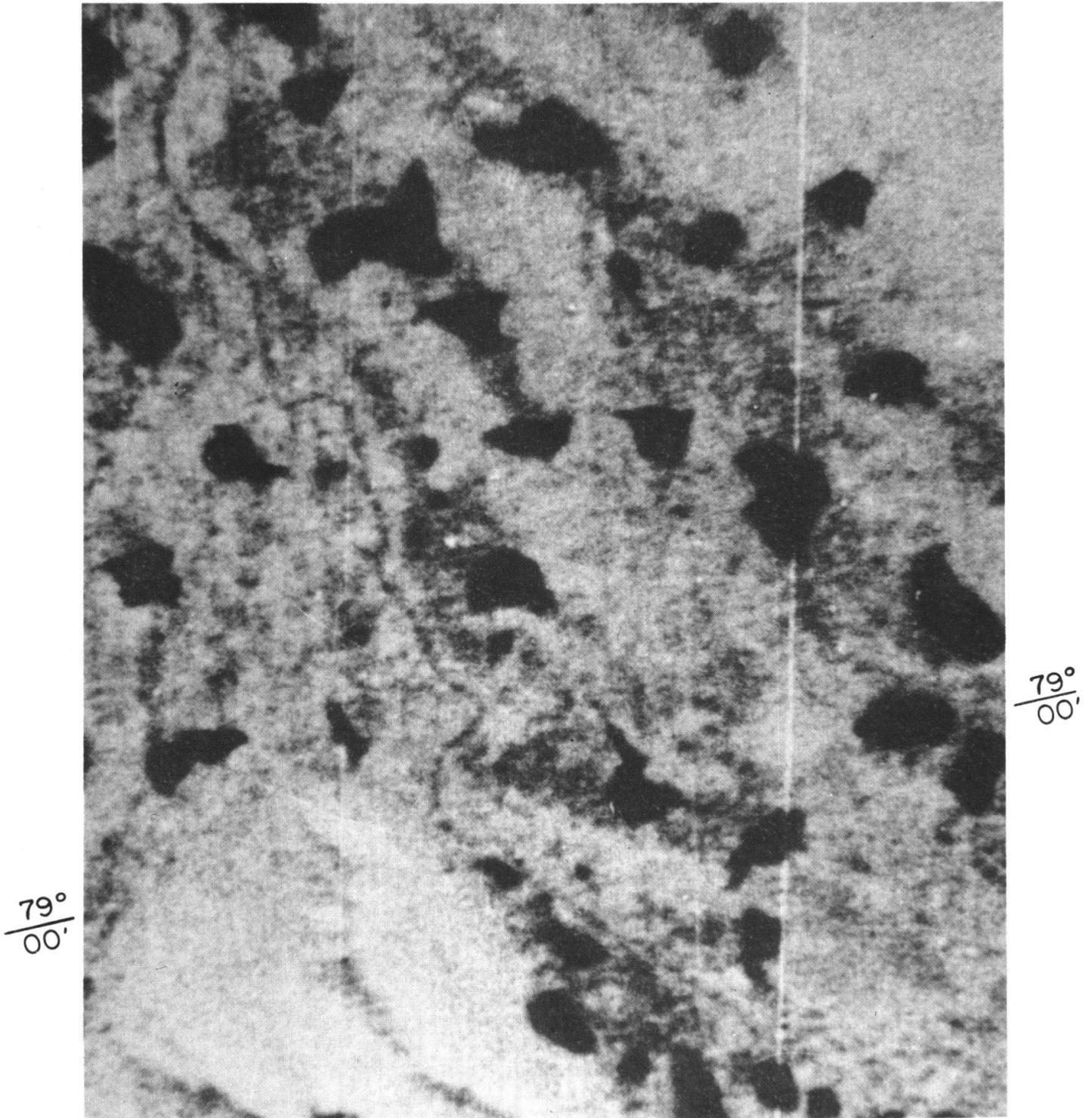
This manual work allows the mapping of main land and water features. Unfortunately, villages and roads, narrow and sinuous cannot be seen. A lot more could be performed on soil and vegetation species with suitable field checks. Rather, the optical interpretation of LANDSAT imagery is a good introduction to the analysis performed with computer compatible tapes.

3. MAPPING WITH COMPUTER COMPATIBLE TAPE

The mapping of hydrologic and agricultural features can be performed using computer compatible tapes (CCT). The print-outs come at a scale near 1:25 000 on the IBM/370 printer of the Indian Institute of Technology, Madras.

12°/25'

Fig. 2



79°
00'

79°
00'

|



Enlargement of scene

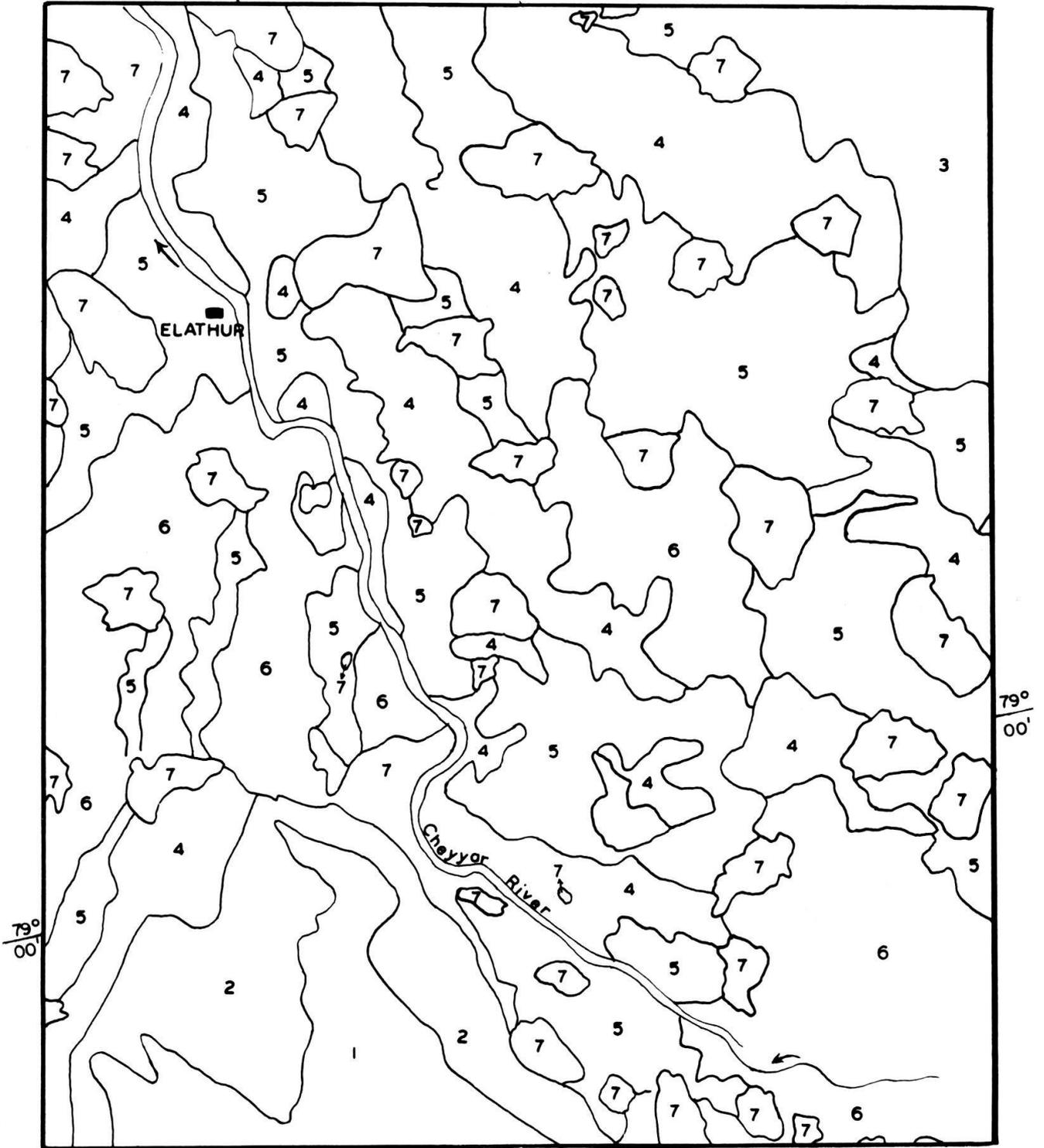
81110043325A000

Elathur area.

0 1 2 km
scale

12° 25'

Fig. 3



- 1. OUTCROPS.
- 2. WEATHERED ROCKS, PEDIMENTS.
- 3. UNCULTIVATED SUBCROPS.
- 4. LITTLE CULTIVATION.
- 5. IRRIGATED LAND.
- 6. MIXED 4 AND 5 FEATURES.
- 7. FLOWING RIVER, WATER TANK.

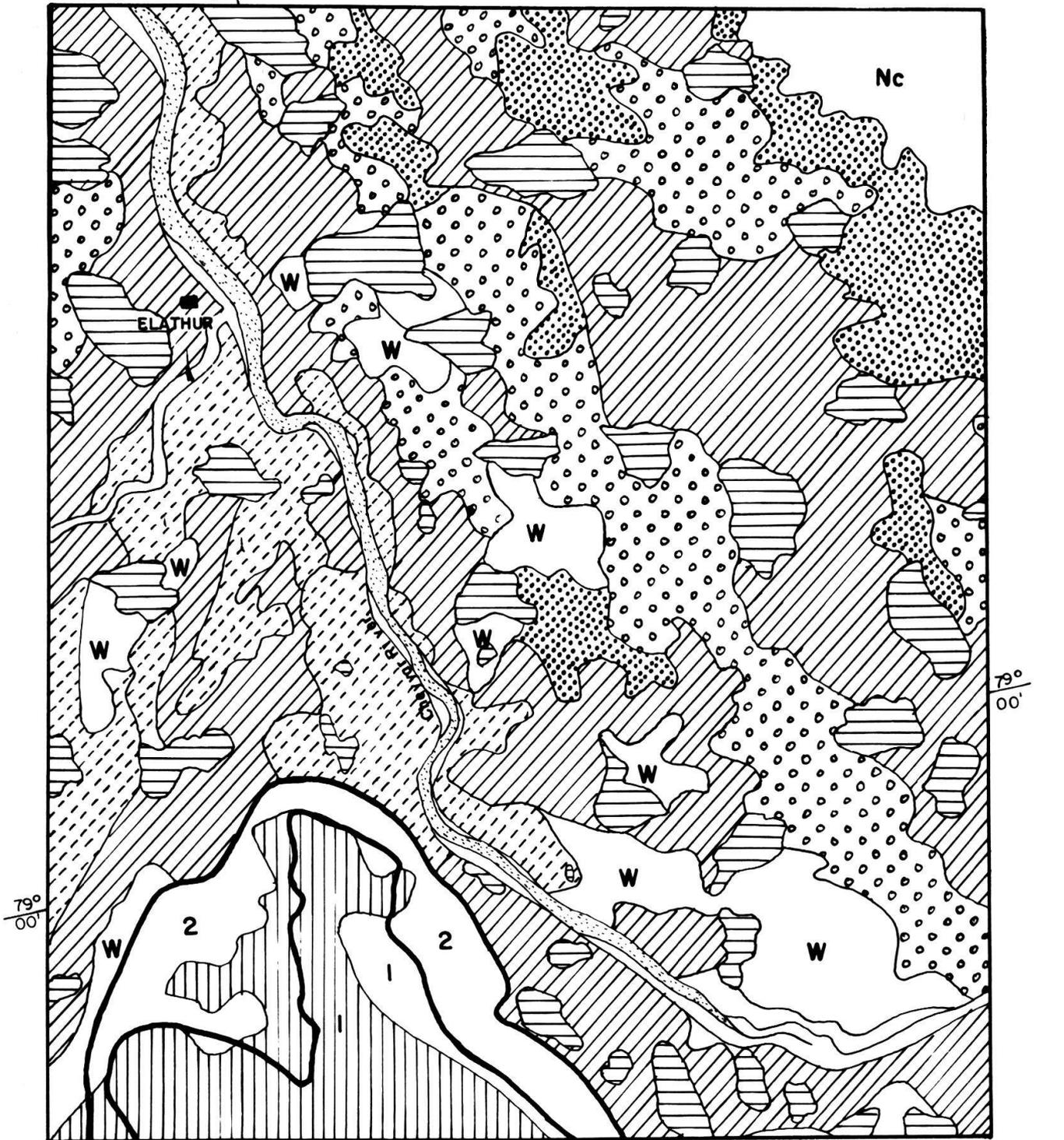


0 1 2 Km.

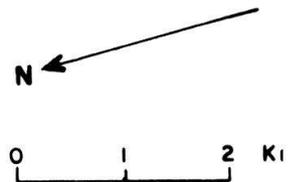
INTERPRETATION OF BAND 7

12° 25'

Fig. 4



- | | | | |
|---|-----------------------------|---|----------------------------------|
|  | OUTCROPS. |  | LITTLE CULTIVATION. |
|  | WEATHERED ROCKS, PEDIMENTS. |  | HIGH VEGETATION. |
|  | WATER TANK. |  | NON - CULTIVATED. |
|  | IRRIGATED LAND. |  | WASHES. |
|  | PARTLY IRRIGATED LAND. |  | FLOWING RIVER AND RIVER CHANNEL. |
|  | DRY FARMING AREA. | | |



COMBINED INTERPRETATION WITH ALL BANDS

3.1. *The Madras frame*

The Madras image contains 2 340 scanlines each having 3 240 pixel values. At the end of each scanline, there is an additional space for calibration information (56 bytes).

The distance covered by a scanline varies with the altitude of the spacecraft. Experience has shown that variations have resulted in scanline changes of approximately 4 km in the worst case (12). At nominal altitude, 918.592 km, the scanline is 185 km. The data of the Madras scene is stored on two tapes containing two separate files 46.25 km wide.

The radiometric data of each pixel in the four separate bands are interleaved with the data of the next pixel. Given pixel A and B, and MSS bands b1, b2, b3, b4 the bytes on the tape will be: . . . b1A, b1B, b2B, b3A, b3B, b4A, b4B, . . . The 40-byte Identification ID record is the first record on the tape. It appears only once per tape. It contains the data on the day, hour, minute and tens of seconds since launching time. The second record of the tape is the Annotation record, which also occurs once per tape. It contains 624 characters. A first block contains the human-readable annotation allowing user interpretation of the imagery. A second block contains the image location data, describing the tick marks that associate the scene with latitude and longitude.

3.2. *Processing the tapes*

LANDSAT data are analysed using supervised methods, or unsupervised methods. The *supervised methods* include checking the print-out results in the field, on aerial photos or on land use maps. Skill of the photointerpreter is most appreciated when readjusting the signatures or ranges of signatures. The classification obtained has no strict statistical background but the method has been proved of acceptable accuracy in the Madras frame.

The *unsupervised methods* exclude a priori comparison with ground truth. They are the equivalent of sorting out clouds of data into families, classes, ranges, in other words finding specific grouping of single signature values. A Cluster Analysis can be performed, with either a distance matrix or a correlation matrix. Principal Components or Factor Analysis are also used, in R-mode (investigating interrelations in a matrix of correlations between variables, i.e. pixel values) or in Q-mode (investigating interrelations in a matrix of correlations between samples, i.e. test areas).

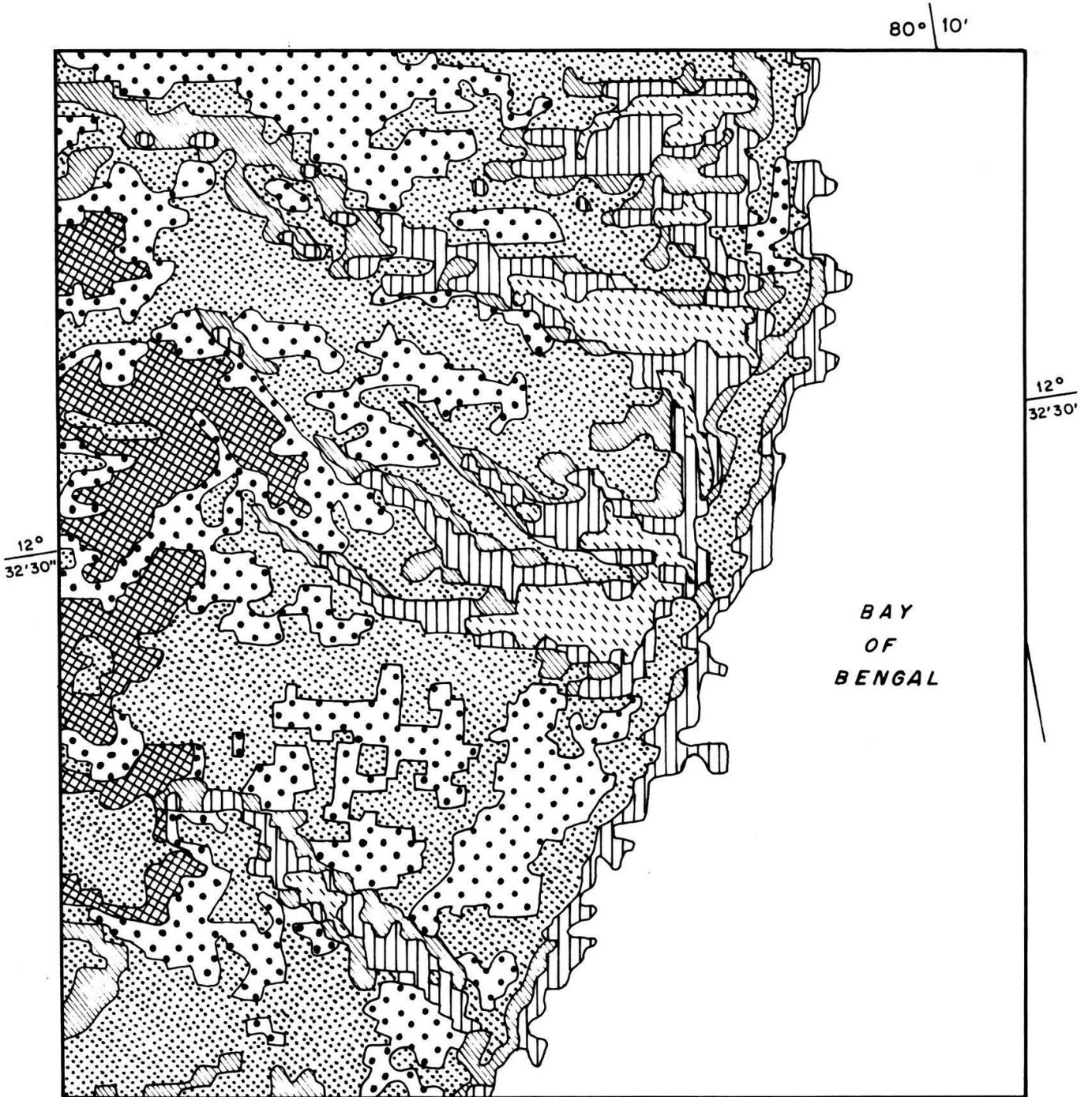
In tape processing, one should remember that there is no direct access to a test site feature for signature extraction since there is no direct way to assure the location of that feature in the imagery (13). Moreover pattern recognition needs recognition of textures. The concept of texture is concerned with the spatial distribution of grey tones. Although texture is quite easy for humans to recognise and describe, it is subjective in nature and extremely difficult to precisely analyse by digital computers (14), (15).

3.3. *Supervised methods*

The work with CCT has been conducted the following way:

- a) Locate on the tape known topographical references. A first orientation is made in mapping water bodies in band 7, using grey-level ranges 0–2 (deeper water) and 3–8 (shallow water). Square temple tanks, when large enough, are good landmarks.
- b) On the land use map, select a window including only a few well defined land features and compute histograms of grey level frequency distribution in the four spectral bands.
- c) Repeat experience to obtain suitable classification table exhibiting ranges of grey. Their frequency distributions are assumed to be normal and it is up to the user to appreciate a range of grey levels by \pm one standard deviation around the mean.
- d) Apply the result in mapping ranges preferably with band 5 and 7. Compare result with ground truth.

Fig. 6



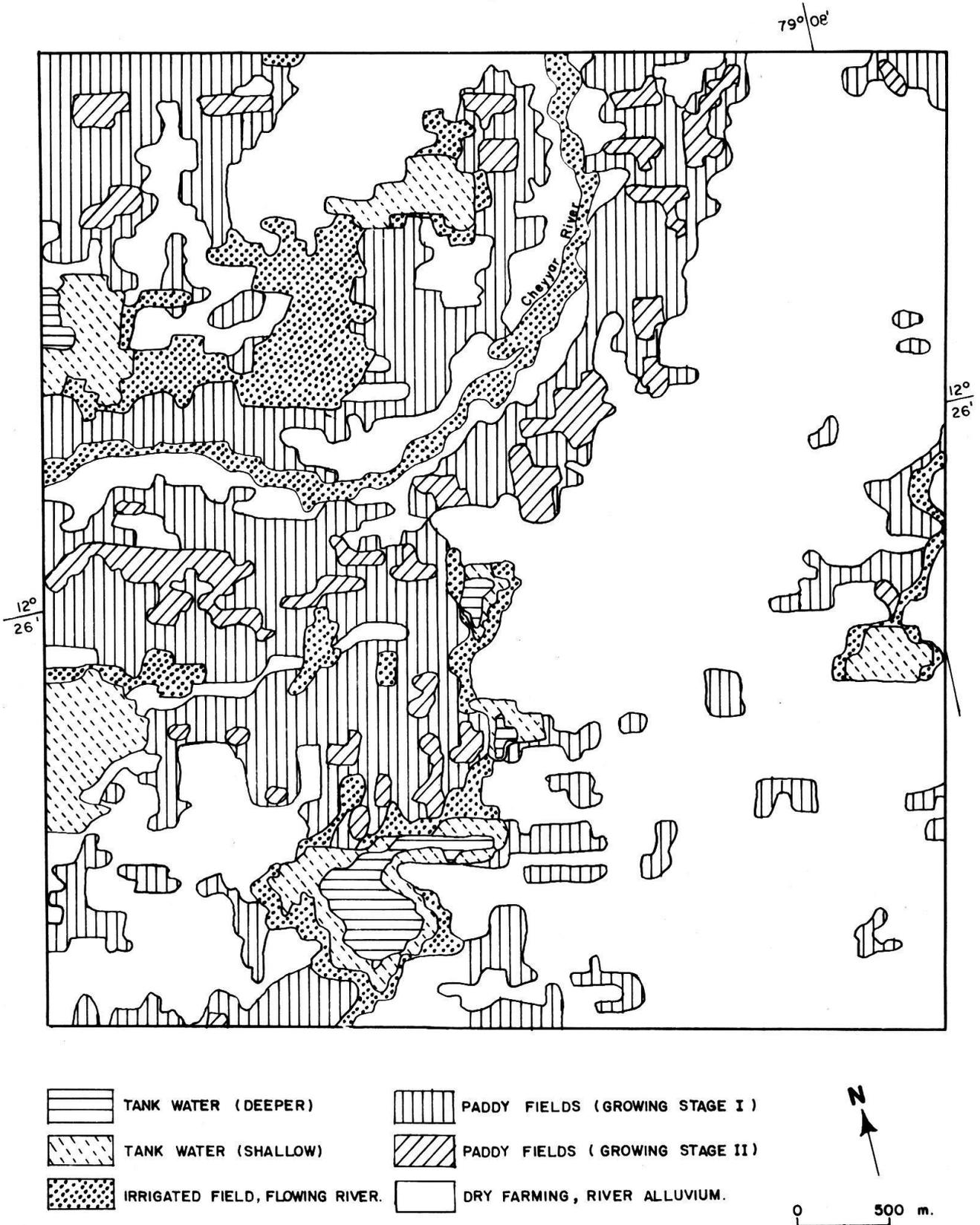
- | | |
|--|---|
|  Deeper water. |  Fine clean sand. |
|  Shallower water. |  Sand with probably a thin reflective crust. |
|  Shallow water - Coastal water with suspended particules. |  Open sea. |
|  Sandy soil with some evaporitic content. | |

0 500 m.



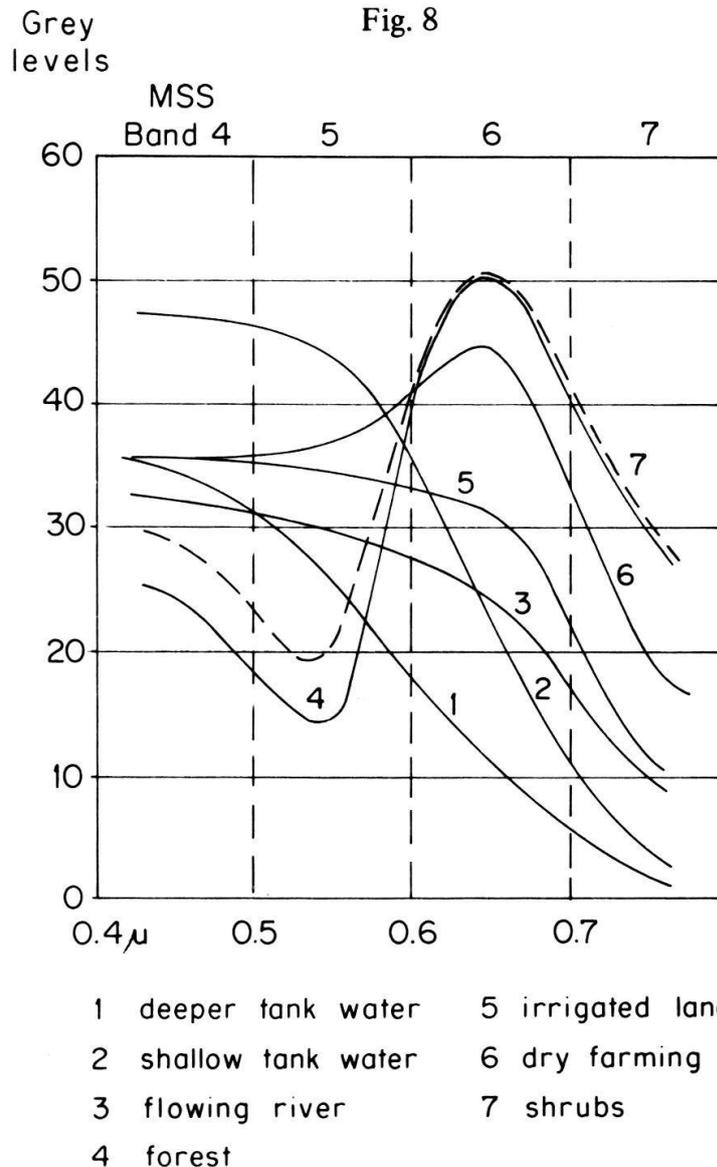
INTERPRETATION OF COMPUTER PRINT-OUT BAND 7, PALAR DELTA

Fig. 7



COMBINED INTERPRETATION WITH COMPUTER
PRINT-OUTS, BANDS 5 AND 7

The land features mapped with the Madras frame CCT are: water (three water depths) turbid coastal waters, sand flats and dry river channels, flowing river, high forest, shrubs and thickest, irrigated fields, bare land (two classes), outcrops, outcrop shadows. Clouds are best defined on band 5 (grey level > 45). Fig. 8 shows variations of grey levels for some of these features. These levels were obtained in finding out mean vectors of well defined windows.



Skewing of the picture is also incorporated in the programs and the choice of skew is given to the user. The skewing used is as follows: jump 1 character to the left each 16 scanlines 5 times, then once after 15 scanlines.

Processing time with the mapping program, including 8 land features in one band is $10^{-3} \times 5$ sec/pixel.

3.4. Other methods used

3.4.1. Grey programs

These programs output a grey level picture of a window of CCT frame in a particular band. The number of grey levels is optional and the user can choose it to be 8, 16 or 32. The program finds out the minimum and maximum values of pixels occurring in the window and subdivides the interval in 8, 16 or 32 classes of grey.

3.4.2 Maximum likelihood

This method of classification which has been worked out at the Canada Centre for Remote Sensing (16), (17), is using discriminant functions for optimum classifiers. This method is meant to become a fast, economic and accurate productive tool. A test was performed in the Elathur area but no satisfactory results could be obtained.

3.4.3. The ORSER system

This system has been developed at the Pennsylvania State University and contains an attractive hybrid approach. After going through some preliminary procedures such as defining size of training areas, indentifying clouds, it can analyse and printout an interesting series of thematic maps the quality of which can be constantly improved with the collaboration of the protointerpreter. Within a short time, satisfactory classification criteria should be obtained and larger areas mapped with good reliability. In this analysis, more weight is put on cluster analysis, but specific statistics can also be utilized such as the principal components analysis (18).

The supervised programs of the system use principally normalized vectors and the angle of separation. Normalized random vectors are compared with normalized vectors of known ground features. The angle of separation between the two is the criterion variable used for classification. If the angle is greater than the critical angle, the pixel is not classified. If the critical angle is not specified, it is equal to $30^\circ/n$ (n = the number of categories).

The unsupervised programs of the system develop their own sets of spectral signatures using various algorithms. The ACLUS program uses a clustering algorithm. The first scanline is used to compute initial centroids. The first two vectors Z_{11} and Z_{12} are taken and normalized. If the angle is smaller than the critical angle, the mean vector C_1 is calculated to become the initial centroid. If the angle is greater, $C_1 = Z_{11}$ and $C_2 = Z_{12}$. The following vectors are assigned to whichever centroid with which it makes the smallest angle, unless this angle is greater than the critical angle and a new centroid is formed. The centroid is recomputed with each additional observation, and a "moving" angular standard deviation is also computed.

When this first computation is over, overlapping by one standard deviation is controled and centroid samples which are too small are dropped until 10 classes remain.

On the digital map, all vectors outside any cluster with allocated multiple of the angular standard deviation is assigned a blank character.

4. DISCUSSION AND CONCLUSIONS

The maps closest to ground truth were obtained using the supervised methods described under 3.3. The reason probably is that the land under study is highly fragmented. Most of the cultivated land units are under the 79 m definition limit. Natural vegetation and soils are best mapped with one particular band. Water bodies, their depth and sediments load are most accurately mapped with band 7.

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