https://ntrs.nasa.gov/search.jsp?R=19840005563 2020-03-21T01:48:09+00:00Z

View metadata, citation and similar papers at core.ac.uk

brought to you by CORE

provided by NASA Technical Reports Server

General Disclaimer

One or more of the Following Statements may affect this Document

- This document has been reproduced from the best copy furnished by the organizational source. It is being released in the interest of making available as much information as possible.

- This document may contain data, which exceeds the sheet parameters. It was furnished in this condition by the organizational source and is the best copy available.

- This document may contain tone-on-tone or color graphs, charts and/or pictures, which have been reproduced in black and white.

- This document is paginated as submitted by the original source.

- Portions of this document are not fully legible due to the historical nature of some of the material. However, it is the best reproduction available from the original submission.

Produced by the NASA Center for Aerospace Information (CASI)

"Made available under NASA sponsorship
In the interest of early and wide dissemination of Earth Resources Survey
Program information and without liability
for any use made thereof."

E84-10038
CR-174590

DEC 1983
RECEIVED
NASA STI FACILITY
ACCESS DEPT.

LANDSAT 4 PROGRAM

Investigator Number F-01

THE USE OF THEMATIC MAPPER DATA FOR LAND COVER DISCRIMINATION - PRELIMINARY RESULTS FROM THE UK SATMaP PROGRAMME

M.J. Jackson,
J. R. Baker,

Natural Environment Research Council, UK.

J.R.G. Townshend,
J.E. Gayler,
J.R. Hardy

Reading University, UK.

Original photography may be pu[illegible]
from EROS Data Center
Sioux Falls, SD 57198

(E84-10038) THE USE OF THEMATIC MAPPER DATA FOR LAND COVER DISCRIMINATION: PRELIMINARY RESULTS FROM THE UK SATMAP PROGRAMME (Natural Environment Research Council) 17 p HC A02/MF A01 CSCL 08B G3/43
N84-13631
Unclas 00038

THE USE OF THEMATIC MAPPER DATA FOR LAND COVER DISCRIMINATION – PRELIMINARY RESULTS FROM THE UK SATMaP PROGRAMME

1. SUMMARY

The principal objectives of the UK SATMaP programme are to determine Thematic Mapper (TM) performance with particular reference to spatial resolution properties and geometric characteristics of the data. Since no data of the UK test sites have been received so far, analysis has been restricted to images from the U.S. and has concentrated on spectral and radiometric properties. The results indicate that the data are inherently three dimensional compared with the two dimensional character of MSS data. Preliminary classification results indicate the importance of the near infrared band (TM 4), at least one middle infrared band (TM 5 or TM 6) and at least one of the visible bands (preferably either TM 3 or TM 1). The thermal infrared also appears to have discriminatory ability despite its coarser spatial resolution. For band 4 the forward and reverse scans show somewhat different spectral responses in one scene but this effect is absent in the other analysed. From examination of the histograms it would appear that the full 8-bit quantization is not being effectively utilised for all the bands.

2. THE SATMaP PROPOSAL

The objective of the SATMaP proposal (Spatial Analysis of Thematic Mapper Products) proposal is to parameterise the Thematic Mapper (TM) performance with respect to its spatial resolution properties and its geometric characteristics. This assessment will be made in relation to the TM's absolute performance and by comparing results with those obtained from the Multispectral Scanner System (MSS). Three different types of measure of spatial resolving capability will be estimated these being the modulation transfer function and frequency response of the Thematic Mapper, the size of the effective resolution element, and the minimum classifiable area for typical land cover types.

The geometric accuracy tests will be undertaken using large scale (1:1250 and 1:2500) Ordnance Survey Maps along with aerial imagery and ground map to spectral band, band to band, and scene to scene accuracy.

3. PROGRESS-TO-DATE

Much of the detailed investigation of both the spatial and geometric properties of TM data will require imagery of the UK test sites. This should become available from NASA following the launch of the first Tracking and Data Relay Satellite System (TDRSS) and from the European Space Agency. Preliminary work has been possible, however, based on the availability of TM data for Arkansas (Path 23, Row 35, 8-22-82 ID: 40037-16031) and Detroit (Path 20, Row 31, 7-25-82 ID: 40009-15413) and also using data from an 11 channel airborne scanner hired from Daedalus. This scanner, which provides the opportunity of simulating all seven of the TM channels, was flown over the proposed UK test sites in September 1982 and plans exist to coordinate future flights with overpasses of Landsat-4. The analysis has concentrated on an examination of the histograms of subscenes, on within band variations of spectral response, on interrelationships between the bands, on the differing spectral responses of certain cover types, and on the separability of these cover types.

4. DATA PROCESSING

The analysis of the data was undertaken on I^2S System 101 Model 70 linked to an HP3000 mini-computer. An Optronics C4300 was used for direct colour output. The large block size (28k bytes)* generated by storing three lines of imagery per record is difficult to handle on mini-systems and the first stage of processing was to reformat the data. Additional basic work included setting up sequences on the I^2S which displayed the seven channels and selected three band combinations in a loop mode. Similar loops were set-up for displaying two dimensional histograms and for moving from viewing the full TM image in a subsampled mode to small areas under the zoom option.

5. HISTOGRAMS OF SPECTRAL BANDS

Histograms of selected areas for both scenes were examined. Examples of these histograms are shown in figure 1 and represent a 512 x 512 area centred approximately on New Madrid. This area includes a loop of the Mississippi River, a small urban area, agricultural land, and woodland and is thus typical of much of the full scene. It is notable that the visible bands display a narrow range of digital values; for example, for band 2 over 95% of the pixels are found within 25 out of 255 digital counts. The histograms are better balanced for bands 4, 5 and 6. For example for band 4 the 95% limits cover 120 digital counts. For classification purposes it is not considered that the eight-bit quantization available is being effectively utilised even if one takes into account the fact that only a single image is being examined. Finally it is of interest to note that the data distributed in the near and middle infrared bands is tri-modal but only bi-modal in the visible bands indicating the importance of the former channels for classification purposes.

*This varies slightly between the B, A and P CCT's.

ORIGINAL PAGE IS
OF POOR QUALITY

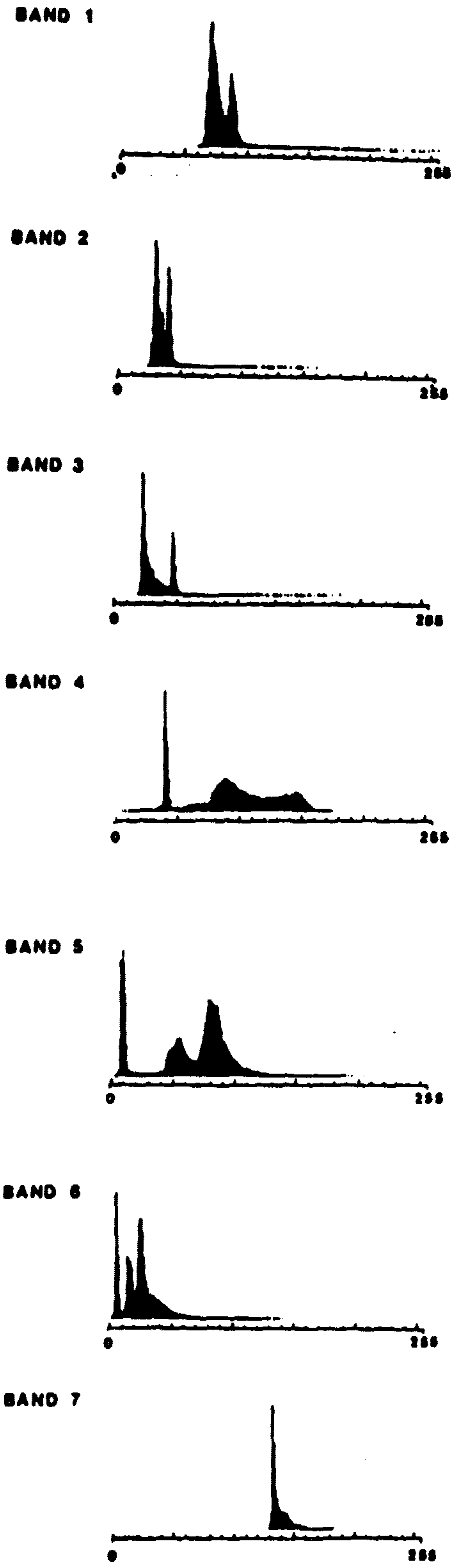

Fig.1 Histograms For Each Spectral Band For Sub-scene 1. Note that band 7 is the thermal band.

6. WITHIN BAND VARIATION IN SPECTRAL RESPONSE

In assessing the accuracy of classification techniques for Thematic Mapper data the consistency of the detector-to-detector response is critical. Preliminary studies were undertaken, therefore, to assess the significance of this factor for the TM. The approach taken has been to examine the spectral response of water bodies where spectral frequency responses are generally low and where for wavebands longer than 0.7um reflectance is both very low and stable. The results obtained suggest the existence of anomalies especially in band 4 for the Detroit scene. Figure 2 shows a profile of band 4 data over Lake Erie. The striping is related to differences in forward and backward scans of the sensor. The average difference is approximately two digital counts and is clearly present from the eastern edge of the Detroit scene to the lake shore near the centre of the image. Examination of Reelfoot Lake in the eastern portion of the Arkansas scene fails to reveal a similar response, nor is it apparent in any part of the Mississippi. Either a change in response of the sensor or a difference in the data processing is therefore indicated.

7. INTER-RELATIONSHIPS BETWEEN BANDS

The correlations between the thematic bands are shown in Table 1 for three sub-scenes. The first two are from the Arkansas scene. The first sub-scene is the one described above , and the latter includes an agricultural area and a large region of woodland. The 512 x 512 sub-scene from the Detroit scene is centered on Toledo, and includes a wide diversity of urban land cover types, agricultural land and a portion of Lake Erie. At the time the latter was imaged the cooled detectors (for bands 5, 6 and 7) were not operating. For all three sub-scenes there are strong correlations between the three visible bands, the coefficients exceeding 0.9 in all cases. Of the other band combinations only bands 4 and 5, 5 and 6, and 6 and 7 show any strong relationships. Negative correlations are found consistently between band 4 in the near infrared and the visible bands 3 though as Table 1 shows, the strength of these relationships varies substantially between the sub-scenes. The overall structure of the relationships can be examined by principal component analysis, the Eigenvalues for the three sub-scenes being shown in Table 2. For the first two sub-scenes there are apparently three basic dimensions of variability whereas for the third, this is reduced to two dimensions, since bands 5, 6 and 7 are missing.

8. CHARACTERISTICS OF INDIVIDUAL LAND COVER CATEGORIES

In order to examine the utility of the Thematic Mapper data more carefully, six different land cover classes at approximately Anderson level 1 were selected from the first sub-scene. These included an area of water from the sediment-laden Mississippi, woodland, agricult-

ORIGINAL PAGE IS
OF POOR QUALITY

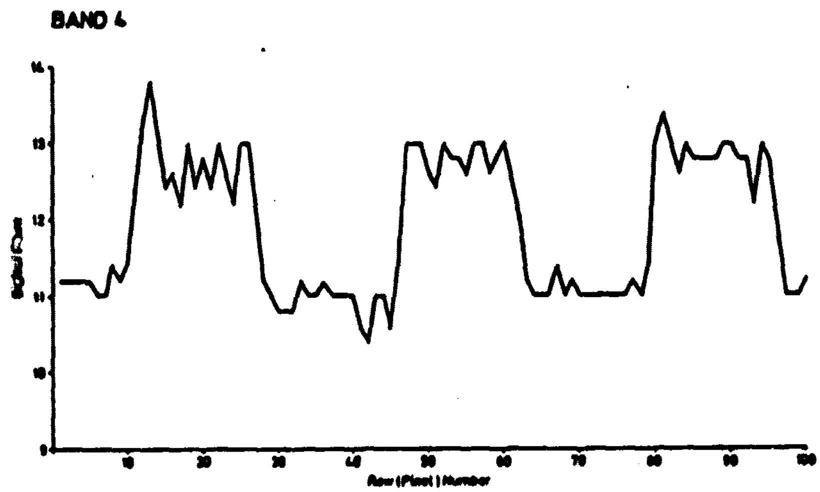

Fig.2 Spectral Response For Band 4 Across Lake Erie (P Tape).

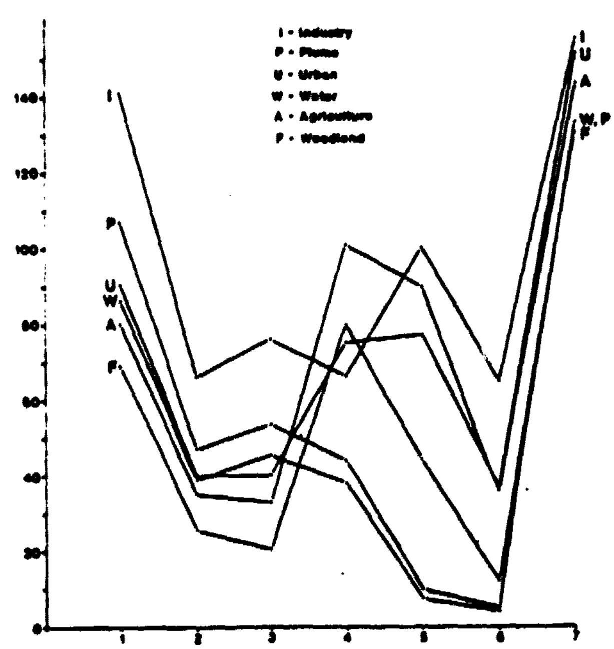

Fig. 3 Spectral Response Of Selected Cover Types From Sub-scene 1
Note that band 7 is the thermal band.

Table 1

CORRELATION ON MATRICES FOR SELECTED LANDSAT 4 THEMATIC MAPPER SUB-SCENES

Correlation Matrix For Sub-scene 1

	1	2	3	4	5	6
1	1.00					
2	.967	1.00				
3	.953	.957	1.00			
4	-.512	-.473	-.631	1.00		
5	-.136	.067	-.245	.713	1.00	
6	.244	.310	.166	.362	.883	1.00
7*	.347	.391	.298	.008	.567	.745

Correlation Matrix For Sub-scene 2

	1	2	3	4	5	6
1	1.00					
2	.950	1.00				
3	.935	.904	1.00			
4	-.148	-.029	-.166	1.00		
5	.089	.207	.088	.849	1.00	
6	.353	.431	.361	592	.904	1.00
7*	.477	.485	.455	.076	.452	.674

Correlation Matrix For Sub-scene 3

	1	2	3
1	1.00		
2	.923	1.00	
3	.989	.948	1.00
4	-.386	-.330	-.210

Note band 7 is the thermal band*

ORIGINAL PAGE IS
OF POOR QUALITY

Table 2

EIGENVALUES FOR SELECTED SUB-SCENES

Sub-scene 1

Eigenvalue	1	2	3	4	5	6	7
	.745	.204	.042	.004	.002	.001	.000

Sub-scene 2

Eigenvalue	1	2	3	4	5	6	7
	.868	.099	.025	.003	.001	.001	.000

Sub-scene 3

Eigenvalue	1	2	3	4
	.822	.175	.003	.000

Note that band 7 is the thermal band.

ral land and urban land. A "plume" class was also selected which includes the plume of smoke emanating from the power station and drifting over the Mississipi river. The means and standard deviations for this class are shown in Table 3 and the spectral response of each class is summarised in Figure 3. For the first three bands the overall form of the spectral response is remarkably similar, whereas for the near and middle infrared bands considerable differences in overall response are found. For the thermal infrared band, the means of the classes are closely clustered but it is worth noting from Table 3 that the standard deviations are also very low suggesting this band may have some discriminatory power.

9. CORRELATION STRUCTURE OF INDIVIDUAL COVER CATEGORIES

Table 4 shows the correlation between the TM bands for the individual cover categories. Considerable differences can be seen between their correlation structures and that of the whole sub-scene (Table 1). For example for water and woodland the correlations between the three visible bands are much weaker; the usual weak to moderate negative relationship between the visible bands and the near infrared band 4 is replaced by strong positive correlations for the industrial and plume categories. For the agricultural land and urban land categories bands 5 and 6 have moderate to strong relationships with the other bands except for band 4, whereas the first two sub-scenes as a whole (Table 1) and the water and woodland classes of sub-scene 1 show much weaker relationships.

The underlying structure of the relationships is shown in Table 5 for each of the categories. Except for the water and plume categories the eigenvalues are similar to those of the complete sub-scenes indicating that there are three basic dimensions. For the plume category there are only two dimensions and for the water category apparently as many as seven. The latter may simply stem from a near spherical distribution of points of this category in the residual sub-space. If the eigenvectors of the first two principal components are examined (Table 6), it is apparent that although the dimensionality of the data is similar for the whole sub-scene and several of the individual land cover categories, the principal components are orientated very differently within the seven dimensional feature space. In other words different bands contribute to very varying degrees to these first two components. Relatively speaking bands 2 and 3 contribute least to the first two principal components, and bands 4, 1 and 5 the most. These results strongly suggest that although there may be only three basic dimensions within the data, if we wish to depict the variability within as well as between broad cover categories then more than three spectral bands will have to be used.

ORIGINAL PAGE IS
OF POOR QUALITY

Table 3

MEANS AND STANDARD DEVIATIONS OF COVER CLASSES FROM SUB-SCENE 1

	1	2	3	4	5	6	7
WATER							
Mean	87.4	38.8	45.4	38.0	7.5	4.4	133.0
Standard Deviation	(1.8)	(1.0)	(1.2)	(2.0)	(1.4)	(1.3)	(.8)
WOODLAND							
Mean	69.7	26.9	21.1	82.4	51.0	14.8	131.5
Standard Deviation	(2.2)	(1.1)	(1.1)	(5.0)	(7.6)	(2.7)	(1.8)
AGRICULTURAL LAND							
Mean	79.2	34.6	31.6	112.5	87.5	32.1	140.0
Standard Deviation	(17.9)	(11.0)	(14.7)	(23.7)	(10.2)	(9.3)	(4.0)
URBAN							
Mean	90.1	39.6	40.0	75.5	76.6	35.9	150.0
Standard Deviation	(11.4)	(7.1)	(10.6)	(12.2)	(13.1)	(10.2)	(4.0)
PLUME							
Mean	111.4	48.9	55.0	45.0	9.5	5.4	133.0
Standard Deviation	(8.5)	(3.7)	(3.6)	(2.2)	(1.0)	(1.1)	(1.4)
INDUSTRIAL							
Mean	144.8	67.3	77.6	68.5	104.9	67.9	153.9
Standard Deviation	(34.0)	(18.5)	(23.1)	(17.2)	(24.4)	(18.2)	(6.6)

Note that band 7 is the thermal band

ORIGINAL PAGE IS
OF POOR QUALITY

Table 4

CORRELATION STRUCTURE OF COVER CATEGORIES

WATER	1	2	3	4	5	6
2	.4					
3	.5	.6				
4	-.4	-.3	-.2			
5	.3	.4	.4	-.1		
6	.3	.2	.3	-.1	.5	
7	.0	-.1	-.2	.1	-.2	-.1

WOODLAND	1	2	3	4	5	6
2	.4					
3	.5	.7				
4	-.1	.1	-.1			
5	-.2	.3	.1	.6		
6	-.2	.3	.2	.5	.9	
7	-.2	.2	.1	.5	.8	.8

AGRICULTURAL LAND	1	2	3	4	5	6
2	.9+					
3	.9+	.9+				
4	-.2	-.2	-.3			
5	.5	.5	.6	-.1		
6	.7	.7	.8	-.4	.8	
7	.5	.5	.5	-.7	.3	.6

URBAN	1	2	3	4	5	6
2	.9+					
3	.9+	.9+				
4	-.2	-.1	-.2			
5	.7	.7	.7	.3		
6	.8	.8	.9	-.2	.8	
7	.5	.4	.5	-.6	.1	.4

PLUME	1	2	3	4	5	6
2	.9					
3	.9	.9				
4	.9	.9	.9			
5	.5	.5	.5	.5		
6	.1	.1	.1	.1	.3	
7	-.3	-.4	-.3	-.3	-.2	-.1

INDUSTRIAL	1	2	3	4	5	6
2	.9+					
3	.9+	.9+				
4	.8	.8	.9			
5	.7	.7	.7	.7		
6	.6	.6	.6	.4	.9	
7	-.2.	-.2	-.2	-.1.	-.4	-.4

+ indicates correlation above 0.95

Table 5

EIGENVALUES FOR INDIVIDUAL LAND COVER CATEGORIES

	1	2	3	4	5	6	7
WATER	.40	.25	.13	.08	.06	.04	.03
WOODLAND	.77	.14	.06	.01	.01	.01	.00
AGRI LAND	.59	.33	.06	.01	.00	.00	.00
URBAN	.66	.25	.06	.02	.01	.00	.00
PLUME	.94	.02	.01	.01	.01	.01	.00
INDUSTRIAL	.82	.12	.04	.01	.00	.00	.00

Note that band 7 is the thermal band.

ORIGINAL PAGE IS
OF POOR QUALITY

Table 6

FIRST 2 EIGENVECTOR/BAND LOADINGS FOR EACH COVER CATEGORY
(Absolute values above 0.5 are underlined)

Band number

Eigenvector		1	2	3	4	5	6	7
WATER	1	.56	.29	.36	-.53	.35	.25	-.00
	2	-.39	-.04	-.14	-.82	-.29	-.21	.12
WOODLAND	1	.06	-.03	-.01	-.42	-.85	-.27	-.16
	2	.03	-.05	-.05	.90	-.37	-.15	-.15
AGRICULTURAL LAND	1	-.53	-.33	-.46	.52	-.19	-.26	-.06
	2	.38	.23	.25	.84	.17	.05	-.06
URBAN	1	-.48	-.30	-.46	.03	-.52	-.44	-.05
	2	.14	.05	.14	-.89	.39	.05	.13
PLUME	1	-.84	-.36	-.34	-.20	-.05	-.01	.00
	2	-.20	.21	.22	.06	.09	-.04	-.92
INDUSTRIAL	1	-.63	-.35	-.43	-.28	-.39	-.26	.00
	2	-.35	-.18	-.21	-.12	.67	.57	-.05
WHOLE SUB-IMAGE	1	-.12	-.06	-.14	.72	.63	.21	-.00
	2	-.26	-.2	-.33	.50	-.54	-.48	-.12

Note that band 7 is the thermal band.

10. DISCRIMINATION BETWEEN COVER CATEGORIES

The classificatory potential of the Thematic Mapper bands may be examined by calculating the divergence between the classes[1]. Table 7 shows the four best bands from the seven TM bands in discriminating between any one class from any of the other classes and the four best bands in simultaneously distinguishing between the classes. It is notable that except for band 2 all the bands are indicated as having significant discriminatory potential for at least two of the classes. Overall the results indicate the particular significance of bands 3, 4 and 5 in discrimination between the classes.

Additionally it is interesting that the thermal band, band 7, is of independent value in discrimination despite its low spatial resolution and a less than optimal time for sensing of this band.

11. IMPACTS ON LAND COVER CLASSIFICATION

Whilst the above comments have naturally stressed the anomalies and error factors associated with the TM it should be clearly stated that the overall performance is considered to be excellent. Considerable potential exists with the TM data for improved classification performance over that available from MSS. This is due not only to the improved spatial resolving capability but to the greater real dimensionality of the data.

The improved land cover classification accuracy will not be achieved, however, merely by applying the traditonal per-pixel classifiers so frequently used with MSS data. In fact in some circumstances such procedures could result in reduced accuracy[2]. Attention is therefore being given to improved techniques and procedure for classification of TM data. The Thematic Information Services (TIS) of NERC incorporates the Experimental Cartography Unit (ECU) which over the last 15 years has acquired large quantities of digital vector data and developed a large body of software for manipulating and overlaying vector/polygon data sets. Software has now been written to allow any of these data contained within the cartographic data-base to be imported and registered with the satellite data[3]. In addition the airborne scanner data acquired in September 1982 is seen as the first acquisition of a regular programme of flying and again the imagery is being input and registered with the map and satellite data. The opportunity therefore exists to apply classification techniques which exploit per-pixel, textural and contextual algorithms within the framework of a probabilistic tree classifier and an integrated multi-level and multi-parameter data set. As for the characterisation of the TM geometry and spatial resolving properties significant further progress awaits TM data of the UK but preliminary results using the airborne Daedelas and MSS data are promising and are being applied in a number of studies ranging from ecology to epidemiology.

Table 7

DIVERGENCE BETWEEN CLASSES: BEST FOUR BANDS FOR DISCRIMINATING BETWEEN CLASSES

	1	2	3	4	5	6	7
Water			X	X	X	X	
Agricultural Land	X		X	X	X		
Woodland	X		X	X	X		
Urband			X	X	X		X
Plume			X	X	X		X
Industry			X		X	X	X
All classes			X	X	X		X

Note that band 7 is the thermal band.

12. PRELIMINARY ANALYSIS OF THE FIRST UK SCENE

The first TM image of the UK was obtained in January 1983. This image was received via X-band transmission at Fucino, Italy and processed at ESRIN, Frascati. Unfortunately the scene includes neither of our UK test areas but does include the towns within which our two research institutes are found. At present only a single, TM band 4 image has been received but some preliminary evaluation is possible. Two obvious defects are found in the image. The first relates to shifts due to a lack of registration between forward and reverse scans. The strength of the shift is up eight pixels though normally it is three or less. This shift apparently arises because precise orbital data have not been used in image processing so that corrections for minor changes in satellite orientation have not been included. A number of drop-outs can be seen thoughout the image. Their origin is not currently understood. Currently steps are being taken to correct these minor defects. These have digital counts between 50 and 80 rather than zero. It should be emphasised, however, that ESA released this scene to European PI's at the earliest possible time with the knowledge that these problems existed. In terms of information content this image represents a very substantial improvement on Landsat MSS data in terms of the detectability of ground targets especially in rural areas. In the upper and lower parts of the scene, it is apparent that individual fields are readily detectable, see figure 4 which certainly was not true in this area with MSS data. In several places narrow hedgerows can be seen which are less than 6m across and most of which are less than 3m across.

The River Thames can be seen meandering across the northern half of the image. The large black areas are gravel pits, now filled with water. The main through route in the area (the M4) can be seen in the southern part of the . age. Whereas the image is significantly better in rural areas than the MSS, in the urban areas the improvements are much less marked. The urban area is represented by the mottled dark tones across the full width of the central part of the image. Compared with images of urban areas in the US such as Detroit and Washington D.C., the results are apparently rather disappointing. However it must be noted that the density of urban development is in general much higher in English than American cities and hence much less ground detail will be detectable. For resolution of the details of urban structure of cities like Reading, spatial resolutions of 20m or better will be required.

ORIGINAL PAGE
BLACK AND WHITE PHOTOGRAPH

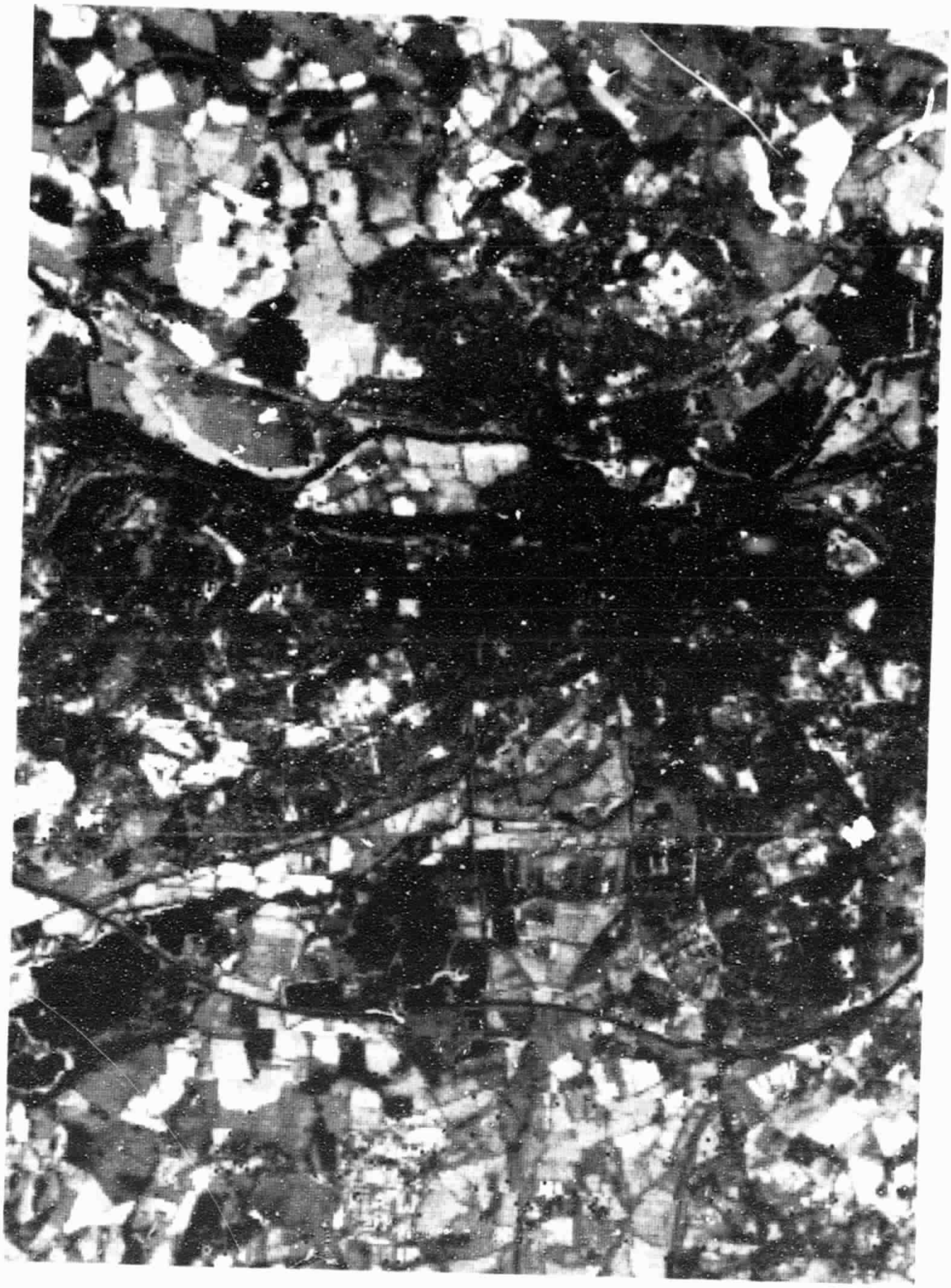

Fig. 4 Preliminary TM band 4 sub-scene of Reading UK. Scale is approximately 1:65,000.

ORIGINAL PAGE IS
OF POOR QUALITY

REFERENCES

1. P.H. Swain, and S.M. Davis, Remote sensing: the quantitative approach New York: McGraw-Hill, 1978.

2. J.R.G. Townshend, The spatial resolving power of Earth resources satellites: A review. NASA Technical Memorandum. 82020, 1980.

3. M.J. Jackson and J.F. Drummond, The NERC System for the combined analysis of raster remotely sensed image data and vector digital cartographic data. Proceedings of 17th Congress of the International Federation of Surveyors, Sofia, Bulgaria, July 1983 (Preprint).