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Delineating Salt-affected Soils in the Ganges Plain, India, by Digital Analysis of Landsat Data

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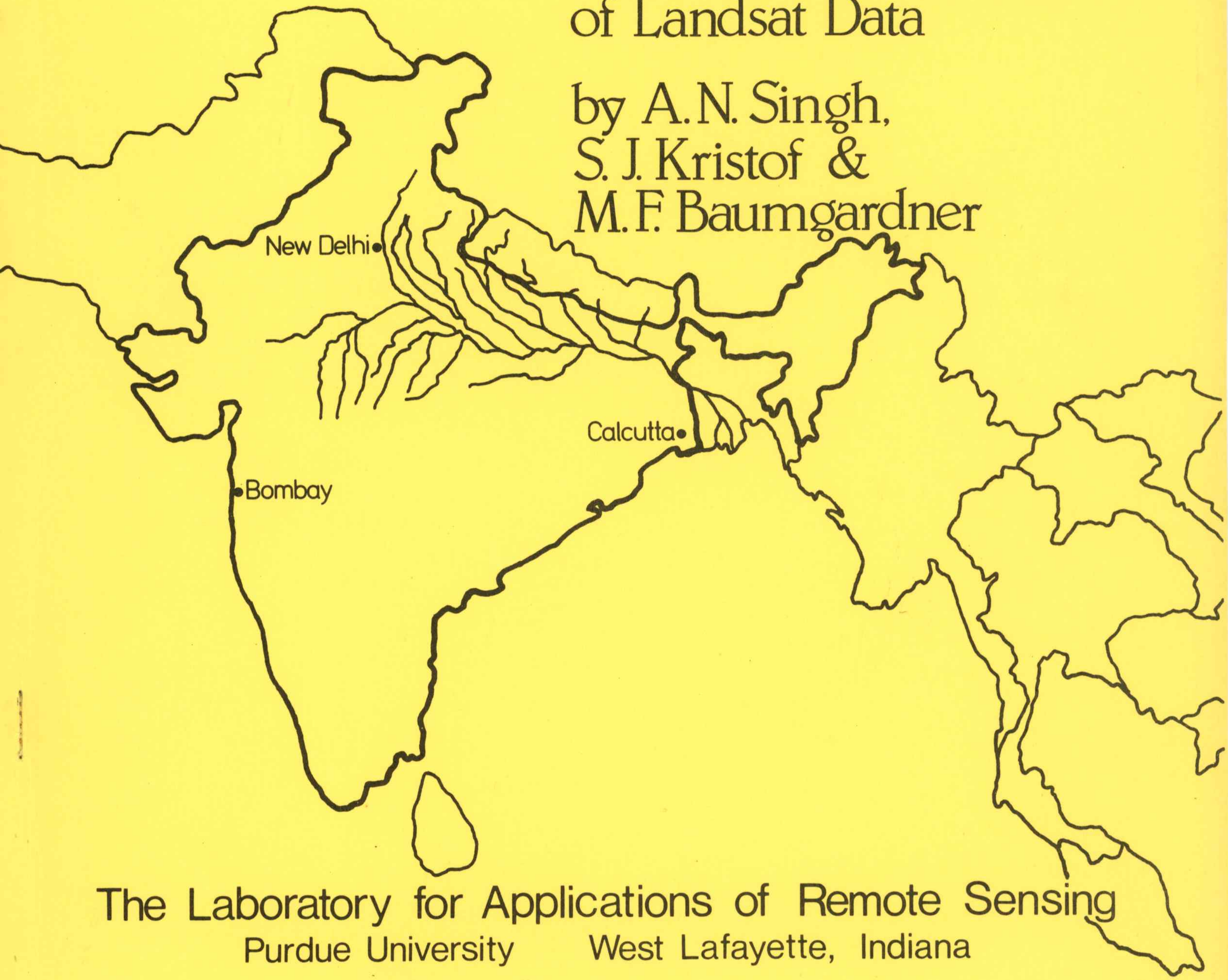

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DELINEATING SALT-AFFECTED SOILS IN THE GANGES PLAIN, INDIA BY DIGITAL ANALYSIS OF LANDSAT DATA

ABSTRACT

A study was conducted to determine the feasibility of delineating salt-affected soils using computer-aided analysis of Landsat-1 data in an area of the Ganges Plain, Meerut district, India. The multispectral scanner data were obtained on the 2 December 1972 Landsat pass. Both supervised and unsupervised classification techniques were used. Four spectral classes of salt-affected soils were separated. The results indicate that Landsat data can be successfully used for differentiating salt-affected soils.

INTRODUCTION

An estimated 7 million hectares of land in India are affected with the menace of salt and sodium accumulation. With increasing pressure of population on land, it has become necessary to reclaim and manage these areas properly. Recent maps showing exact location and characteristics of salt-affected soils are not available for most of the areas because of the time consuming method of soil survey. Computer-aided analysis of Landsat multispectral data has been found to be useful for delineating soils, with higher efficiency and reasonable accuracy by various workers (Kristof, et al., 1977; Weismiller, et al., 1977). The Indo Gangetic plain has the largest portion of salt-affected lands in India. The present study was, therefore, undertaken to determine the feasibility of using digital analysis of Landsat data for delineating salt-affected lands in the Ganges Plains of Uttar Pradesh.

STUDY AREA

The study area is situated in the central part of the Ganges-Yamuna Doab (land between the rivers). It extends approximately between latitudes 29°00'-29°20' North and longitudes 77°30'-78°00' East in Meerut district of Uttar Pradesh, India. The total area covers approximately 2060 km^2.

The soils in the area have been formed from the material transported by the rivers Ganges and Yamuna. The Ganges river has built up an alluvial cone, the bouldery deposits of which are away from the centre and are gradually covered with sub-recent silty and clayey river alluvium. The younger deposits, which are partially flooded during the monsoon, do not show any soil development. The soils developed in the old river alluvium show argillation. Salinization and alkalization in this alluvial plain have been developed primarily due to natural conditions such as geology, hydrology, relief and climate; and secondarily due to human influence by introducing irrigation without adequate drainage. In the study area, south of Meerut, natural conditions have played a more important role (Hilwig, 1976).

METHODOLOGY

Landsat-1 data collected over the area on 2 December 1972 was used for this study. The scene ID is 81132-04515. The sun angle is 33^{o} and azimuth 150^{o}. The data were reformatted and geometrically corrected.

The scene was displayed on the digital image display and a sub-area was selected for further analysis. This particular area was chosen because a generalized landscape map was available for comparison with the computer-classified output. The selected area was then displayed using GDATA processing function of the LARSYS software (Phillips, 1973). This function produces a gray scale printout using an electrostatic printer/plotter in the form of quasi-photographic images. Figures 1, 2, and 3 show the study area in bands 4, 5, and 7 on this output. CLUSTER analysis was then done for the entire area. This algorithm groups sample points of similar spectral characteristics. The cluster output included a cluster map showing 18 spectrally separable classes and a punched output of field description cards for each of the cluster classes. The field description cards were input into a statistics processor to obtain the mean spectral response and covariance matrices of each cluster class in all four Landsat bands. The magnitude of response of each class was obtained by totaling the mean relative spectral responses. The RATIO function was used to calculate the ratio of visible (V) and infrared (IR) spectral response [V/IR, where V represents the sum of reflectance in both visible bands (4 and 5) and IR in both infrared bands (6 and 7)]. Differences in the magnitude and ratio values were used to group the cluster classes into 3 major classes--vegetated, non-vegetated, and water. The covariance matrix and mean vector statistics of these classes were input into a maximum likelihood algorithm which classified the entire area. The classification results were obtained in alphanumeric form. An output with 6 major classes--3 bare soil, 2 vegetation and water--was also obtained by regrouping the original 18 cluster classes according to differences in magnitude and ratio.

An available landscape soil map (Figure 8) was used to obtain a supervised classification output with 4 soil classes mapped in the area and 4 non-soil classes (two vegetation, one township/built-up area class and one water). These classes were identified on the cluster map and training fields were submitted for classification. Evaluation of the classification results was done using the general landscape map since no other detailed map was available during the study. The four landscape units mapped in the portion falling in the study area and their soil composition are described in Table 1.

Table 1. Soils mapped in the study area (Karale and Venugopal, 1970).

Symbol	Physiography	Soil Composition
US	Salt-affected lowlands	Clayey Typic Natrustalfs
UP	Alluvial Plains	Fine loamy to clayey Typic and Udic Haplustalfs
UL	Levees	Fine loamy Udic Haplustalfs and coarse loamy Arenic Udic Haplustalfs
UC	Old channels	Clayey Aquic Haplustalfs and Aeric Ochraqualfs

RESULTS AND DISCUSSION

A visual study of images in bands 4, 5, and 7 (Figures 1, 2, and 3) show that Meerut city (a) is clearly seen in band 7 and can be recognized in band 4 but not in band 5. The floodplain of the Ganges River (b) is more clearly differentiated in bands 4 and 5 whereas in band 7 it is not because the vegetation grown in the river floodplain reflects very high and adjoining areas also have similar reflection. The Ganges canal (c) can be seen clearly in all the three bands. Salt-affected lands (d) are easily differentiated in both the visible bands but not in the infrared bands because of low contrast. Productive agricultural lands (e) can be clearly seen in bands 4 and 5.

Unsupervised Classification

Eighteen spectrally separable classes were recognized in the area. The magnitude (sum of relative spectral reflectance in all the four bands) and ratio of V/IR reflectance showed that out of 18 spectral classes, 4 represent vegetation, 1 water and 13 non-vegetated areas. An output for a portion of the area showing the 13 non-vegetated classes, the 2 classes of vegetation, and one class of water is presented in Figure 6. Figure 4 shows the same area using 3 classes--vegetated, non-vegetated, and water. A study of these two outputs shows that, whereas Figure 4 does not show any "informational soil class", Figure 6 shows many more classes than desired or identified with the present ground observation data available. A grouping was made of these 13 non-vegetated spectral classes into 3 classes on the basis of magnitude of reflectance into 3 levels--high reflection, medium reflection and low reflection. This regrouping resulted in 6 classes--3 classes of non-vegetated areas, 2 classes of vegetated areas and one class of water. The computer output with 6 spectral classes for the same area as in Figure 4 has been presented in Figure 5. A comparison of this output with the ground observation map (Figure 8) shows that the areas of high magnitude of relative spectral reflectance on this output could be recognized as salt-affected lowlands (clayey, Typic Natrustalfs). Though this group represents 4 spectrally separable classes on the cluster map, further delineation of salt-affected areas into sub-categories could not be tried due to insufficient ground data. Table 2 shows the statistics of these four classes identified within salt-affected lands. They represent four levels of salt accumulation but further ground observations and chemical analysis data of these soils are needed to sub-categorize them spectrally. The areas with medium magnitude of relative spectral reflectance were recognized as Levees and Old channels on the ground observation map. However, these two units were not distinctly separable on the computer classification. The areas with low magnitude of relative spectral reflectance were recognized as Upper Alluvial Plain.

Table 2. Statistics of four spectral classes identified within salt-affected lowlands.

	Response in					
Class	Chan 1	Chan 2	Chan 3	Chan 4	Magnitude	V/IR
US/1	53.2	52.0	45.34	17.86	168	1.67
2	45.4	44.0	39.24	15.74	144	1.63
3	36.4	37.4	38.91	17.29	130	1.31
4	39.7	35.8	32.04	12.88	120	1.68

Supervised Classification

The results of supervised classification of the area into 8 classes have been presented in Figure 7&9. The 8 classes are: four soil classes mapped in the area, namely i) Soil UP, ii) Soil UL, iii) Soil UC and iv) Soil US; and four non-soil classes, v) Vegetation A, vi) Vegetation B, vii) Township/ built-up area, and viii) Water. These classes were given for better separation of salt-affected soil unit (Soil US), and also to see whether other soils mapped in the area could be separated using computer classification.

Comparison of a ground observation map with the supervised classification map shows that the spectral patterns revealed in the computer-classified maps for salt-affected lowlands (Soil US) resembles the general pattern shown in the map prepared by aerial photointerpretation. The pattern for the other three soil classes does not match with those shown in the ground observation map because of the effect of vegetation, further because the units UL and UC are not separable from each other.

Spectral responses for class UC and UL are almost the same, which is evident from Figure 10. The four non-soil classes exhibit excellent spectral separability (Figure 11). The magnitude of spectral reflectance for class UL and UC is the same but is higher for class US (Figure 12). The ratio of V/IR reflectance for soil US is different but the same for soil UL and UC (Figure 13). However, the four non-soil classes have very different ratio values.

CONCLUSION

Computer-aided analysis of Landsat data showed that in a low contrast area, it is possible to identify and delineate salt-affected areas. However, all the soil patterns traditionally differentiated using aerial photographs cannot be differentiated if the spectral response is similar. For the Gangetic alluvial plain area, where a large portion is affected by a salt problem, Landsat data can be successfully used to delineate salt-affected from non-affected areas. Further categorization of salt-affected lands according to their physical chemical characteristics seemed possible, but requires further ground truth data.

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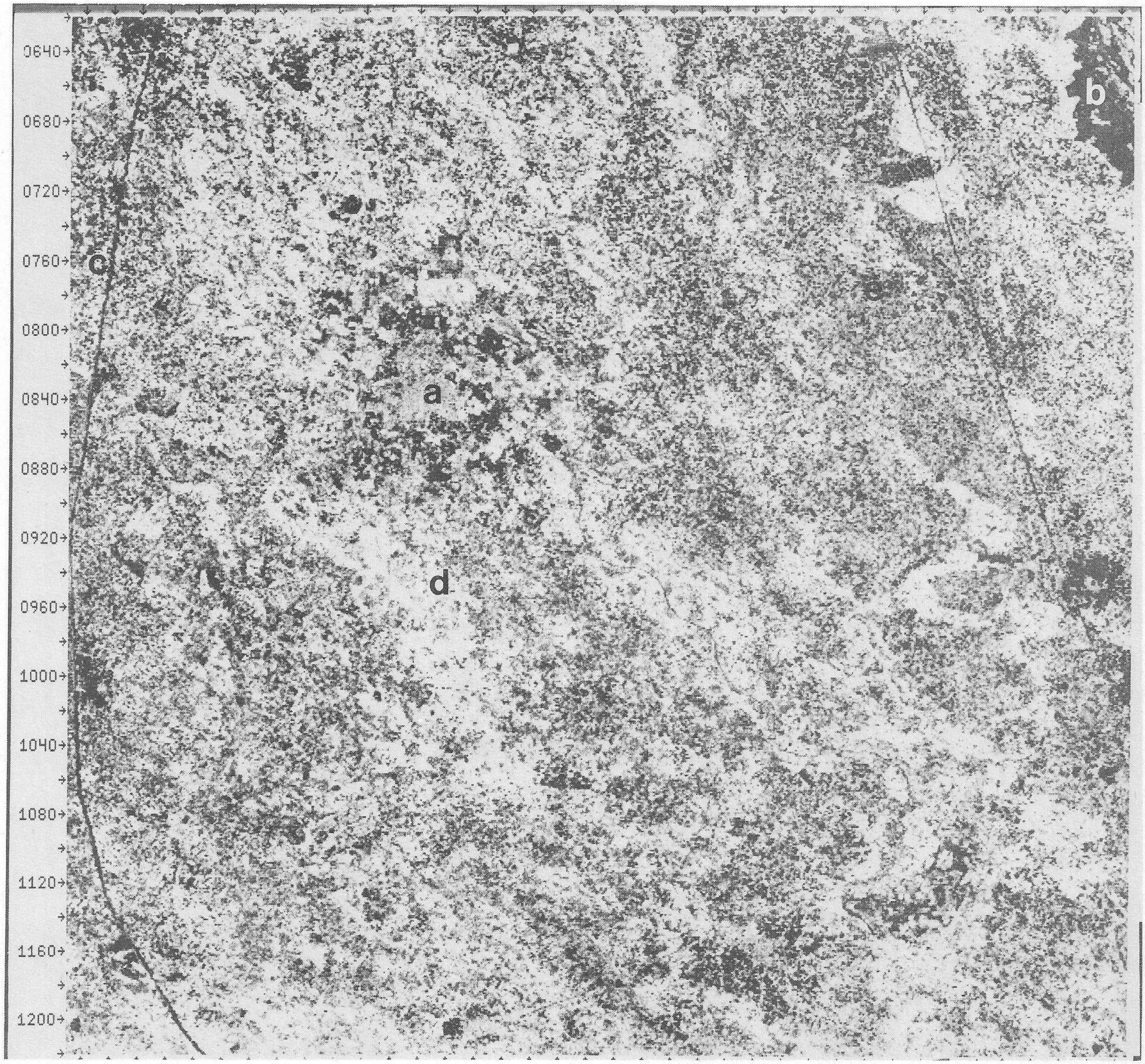


Figure 1. Unclassified image of the study area in Landsat MSS band 4 (0.5-0.6μm)

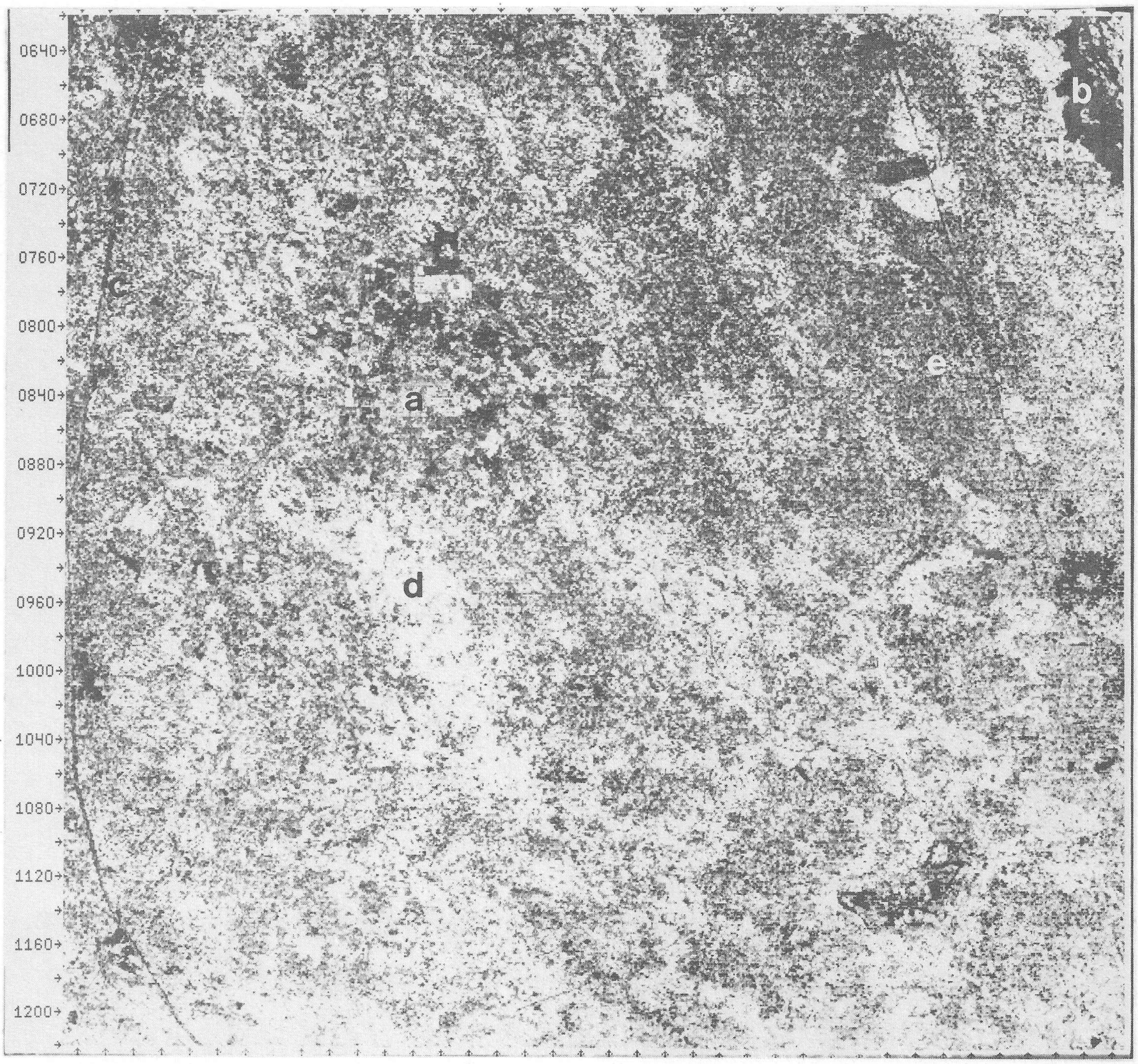


Figure 2. Unclassified image of the study area in Landsat MSS band 5 (0.6-0.7μm)

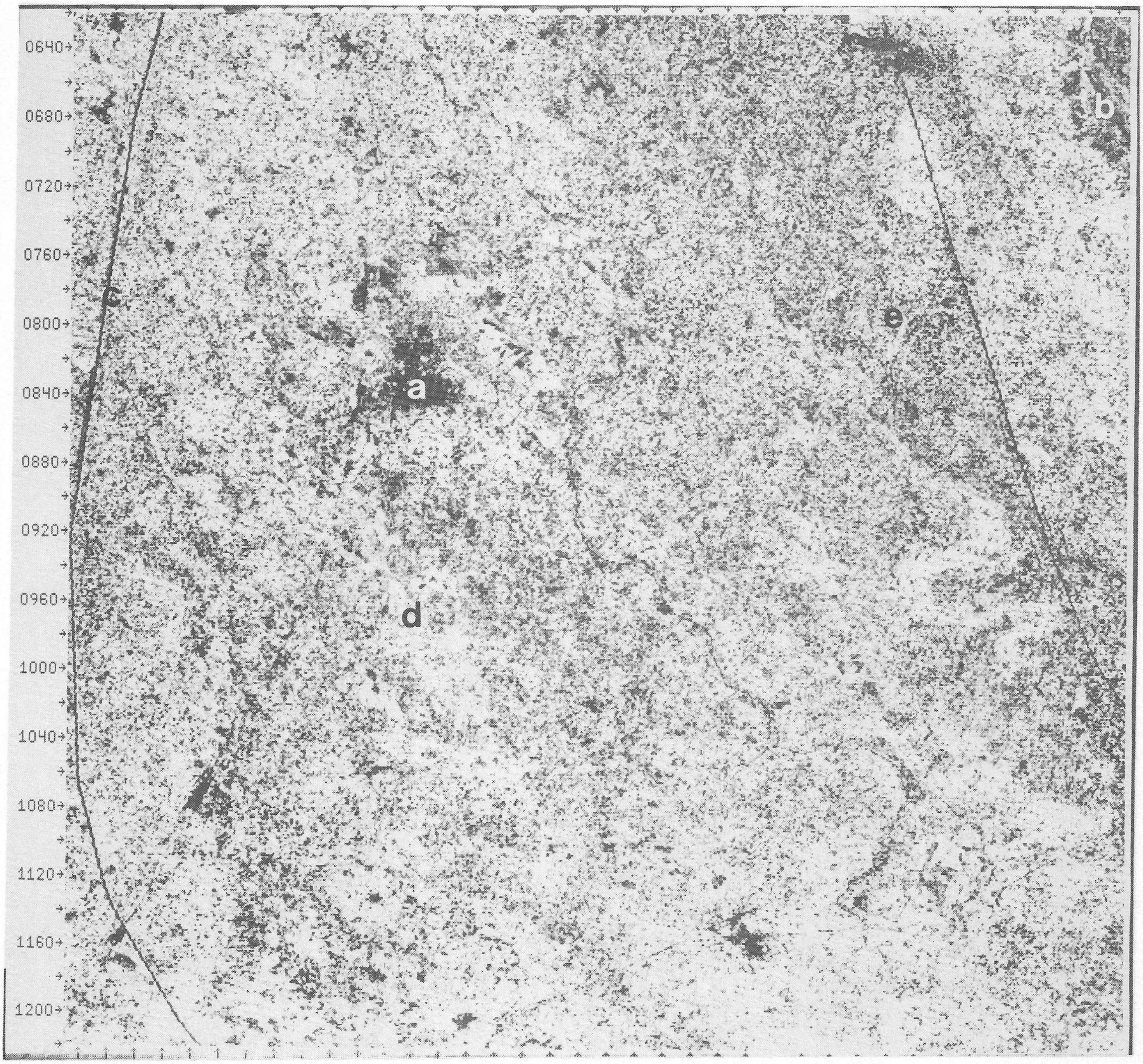
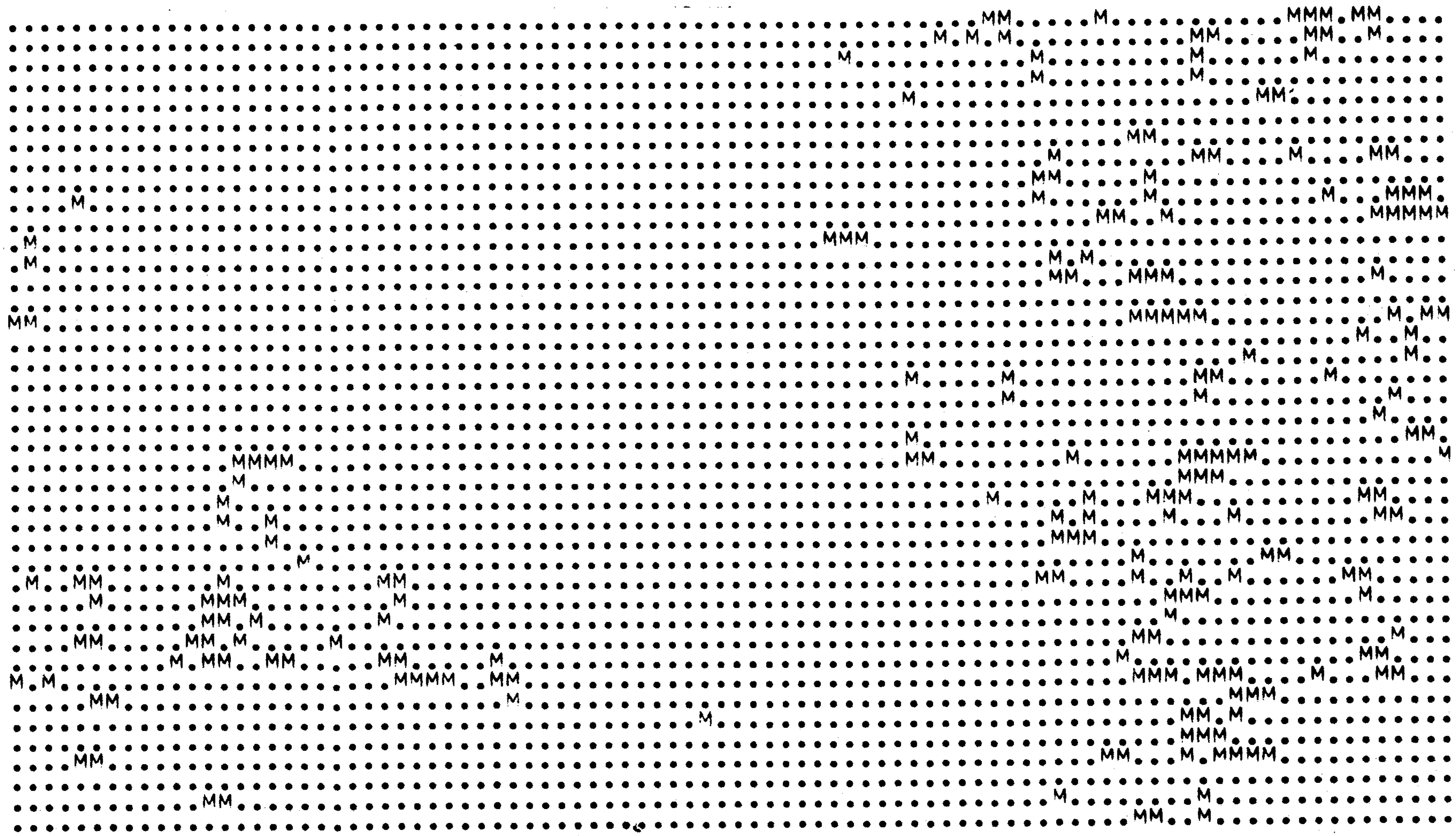
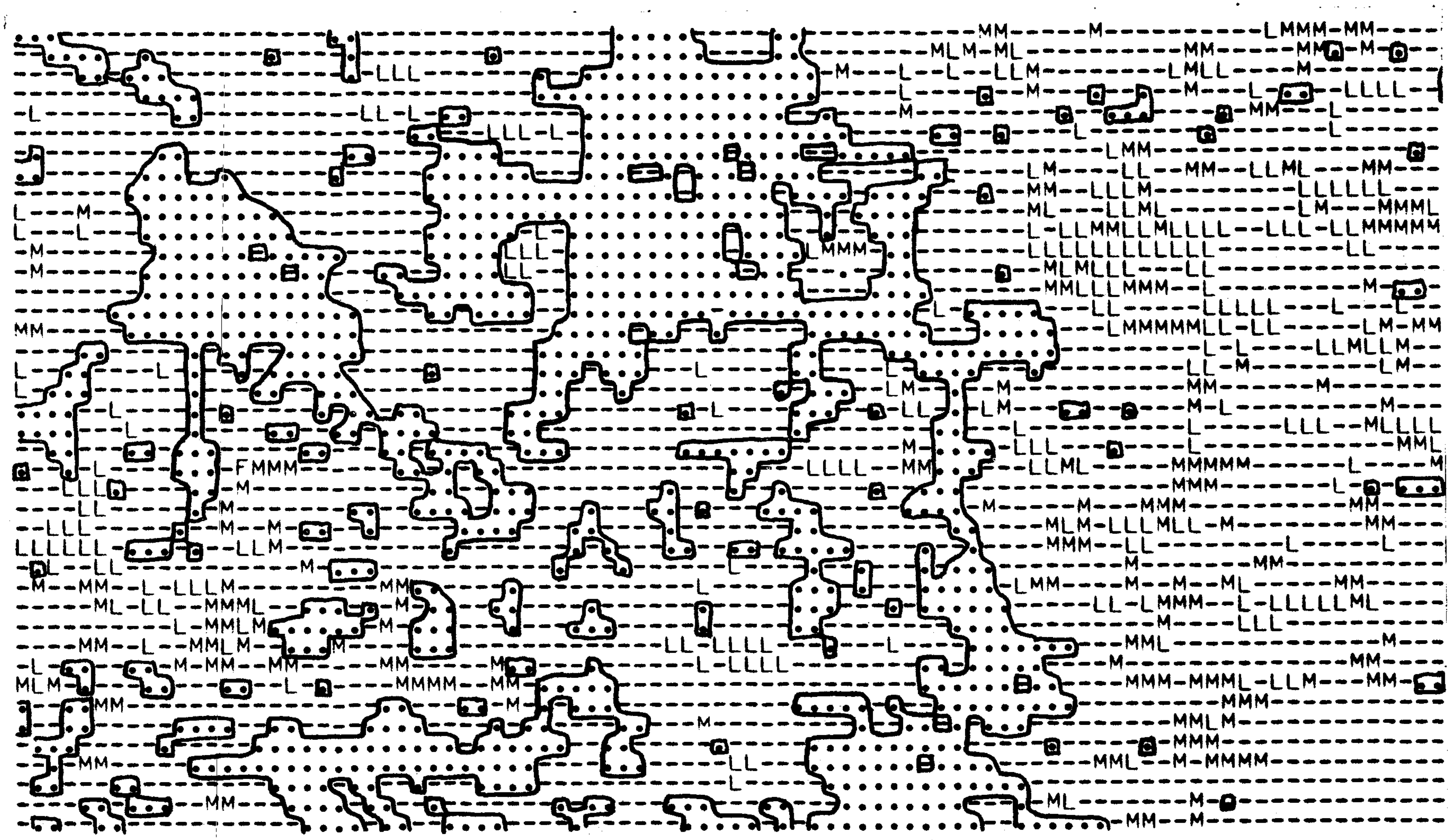


Figure 3. Unclassified image of the study area in Landsat MSS band 7 (0.8-1.1μm)



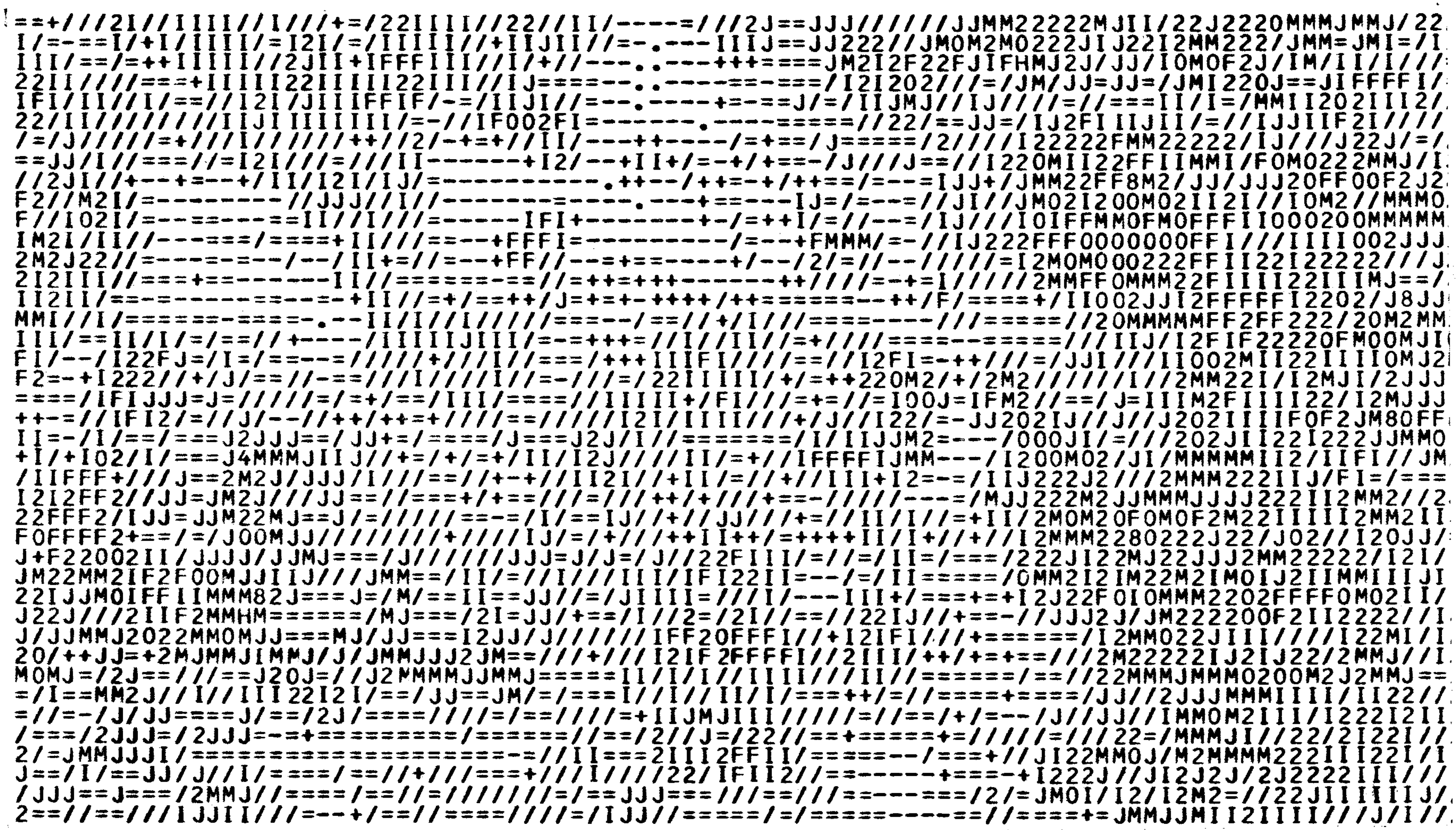
Legend: · Non-vegetated M Vegetated / Water

Figure 4. Unsupervised classification output of a small portion of study area showing 3 groups. (No water body in this area, so only two groups are seen.)



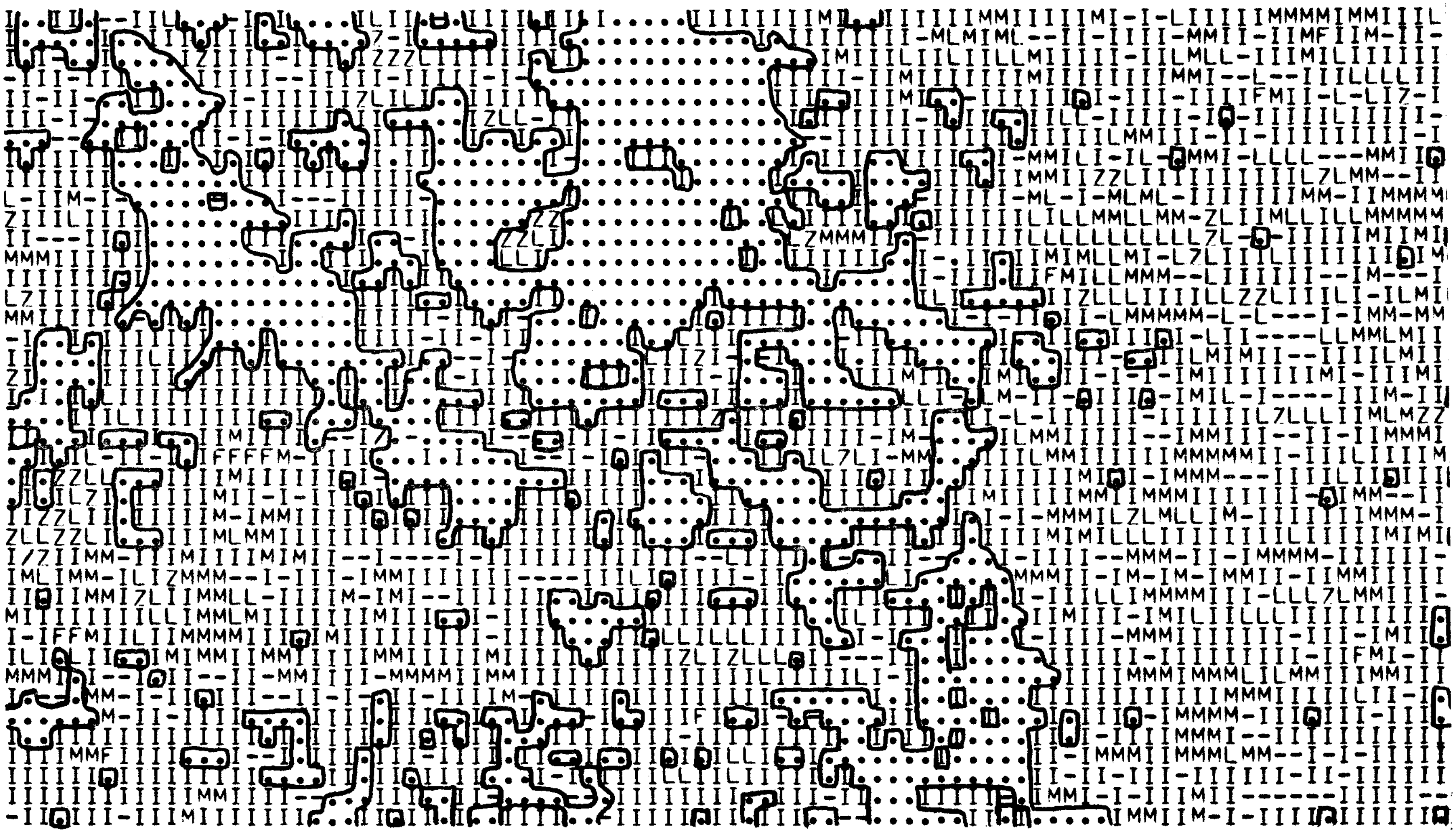
Legend: · Non-vegetated high magnitude
– Non-vegetated medium magnitude
L Non-vegetated low magnitude
F Vegetation A
M Vegetation B
W Water

Figure 5. Unsupervised classification output of a small portion of study area showing 6 groups.



Legend:				
	·,-,=,+	Non-vegetated high magnitude	4	Vegetation A
	/,I,J,Z	Non-vegetated medium magnitude	M	Vegetation B
	F,0,8,H	Non-vegetated low magnitude	W	Water

Figure 6. Unsupervised classification output of a small portion of study area showing 15 groups.



Legend:

·	Soil US	I	Soil UC	F	Vegetation A	/	Water
-	Soil UL	L	Soil UP	M	Vegetation B	Z	Township/Built-up area

Figure 7. Supervised classification output of a small portion of study area.

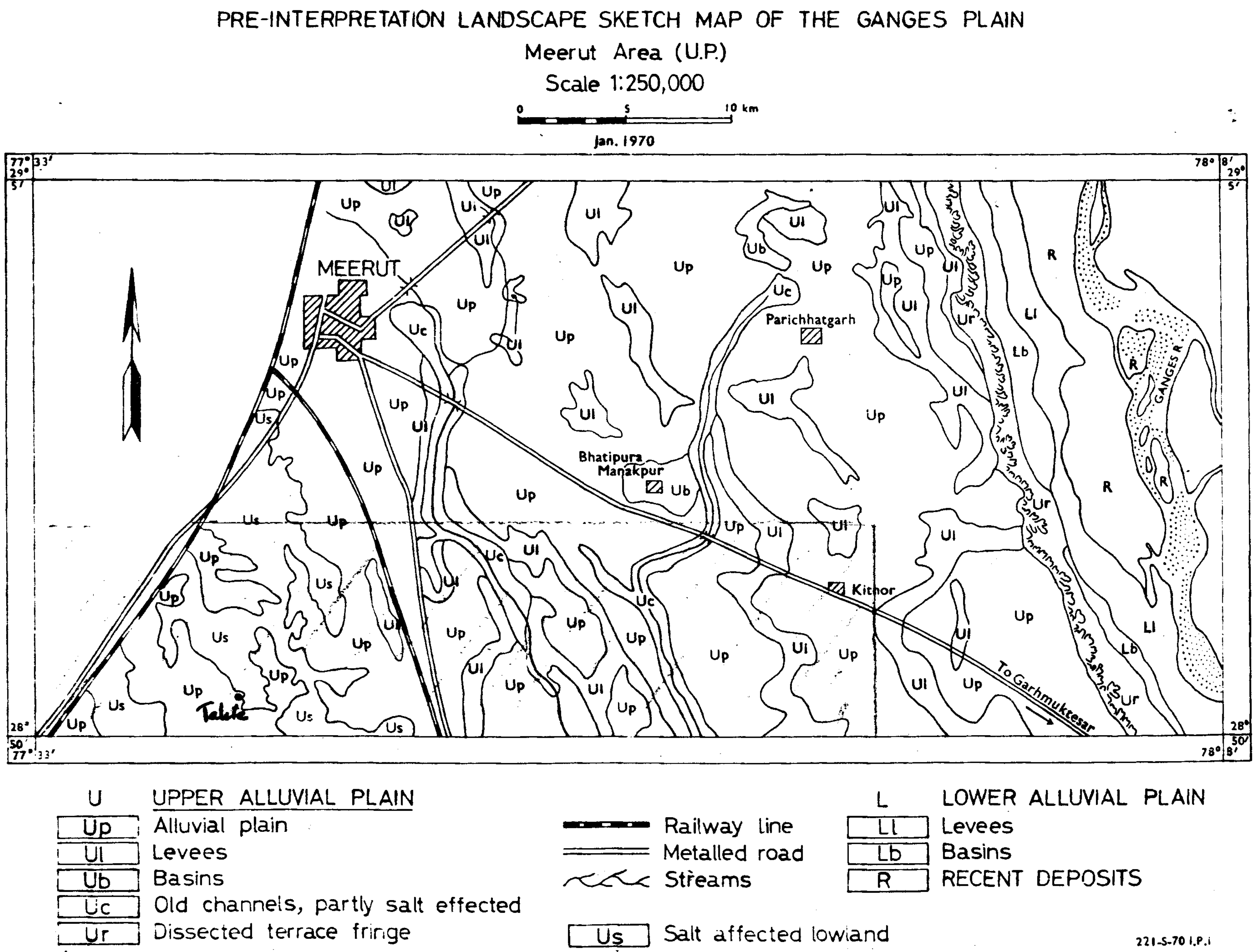


Figure 8. Ground truth map of a portion of study area.

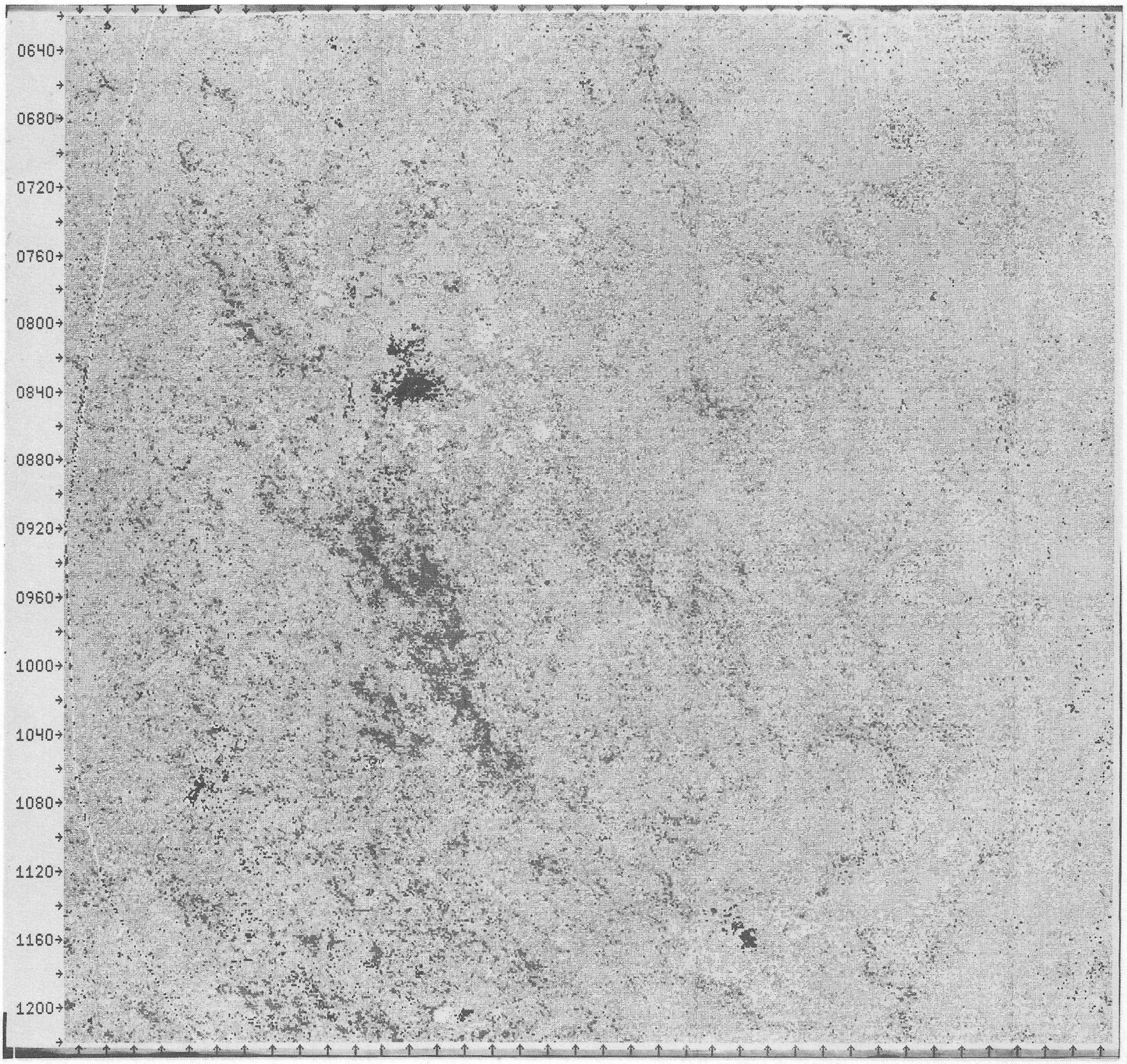
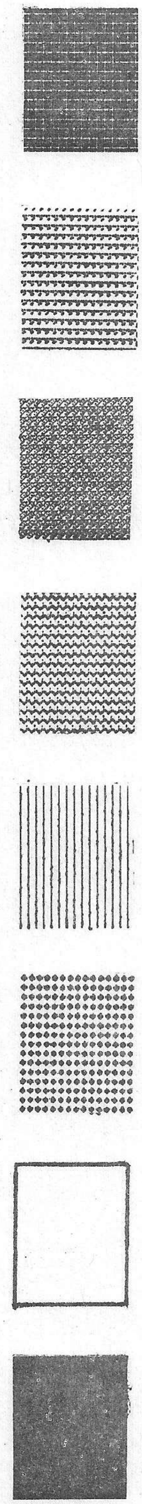


Figure 9. Supervised classification output of the study area.

LEGEND (Figure 9)

Classes



Soil US

Soil UL

Soil UC

Soil UP

Vegetation A

Vegetation B

Water

Township/Builtup area

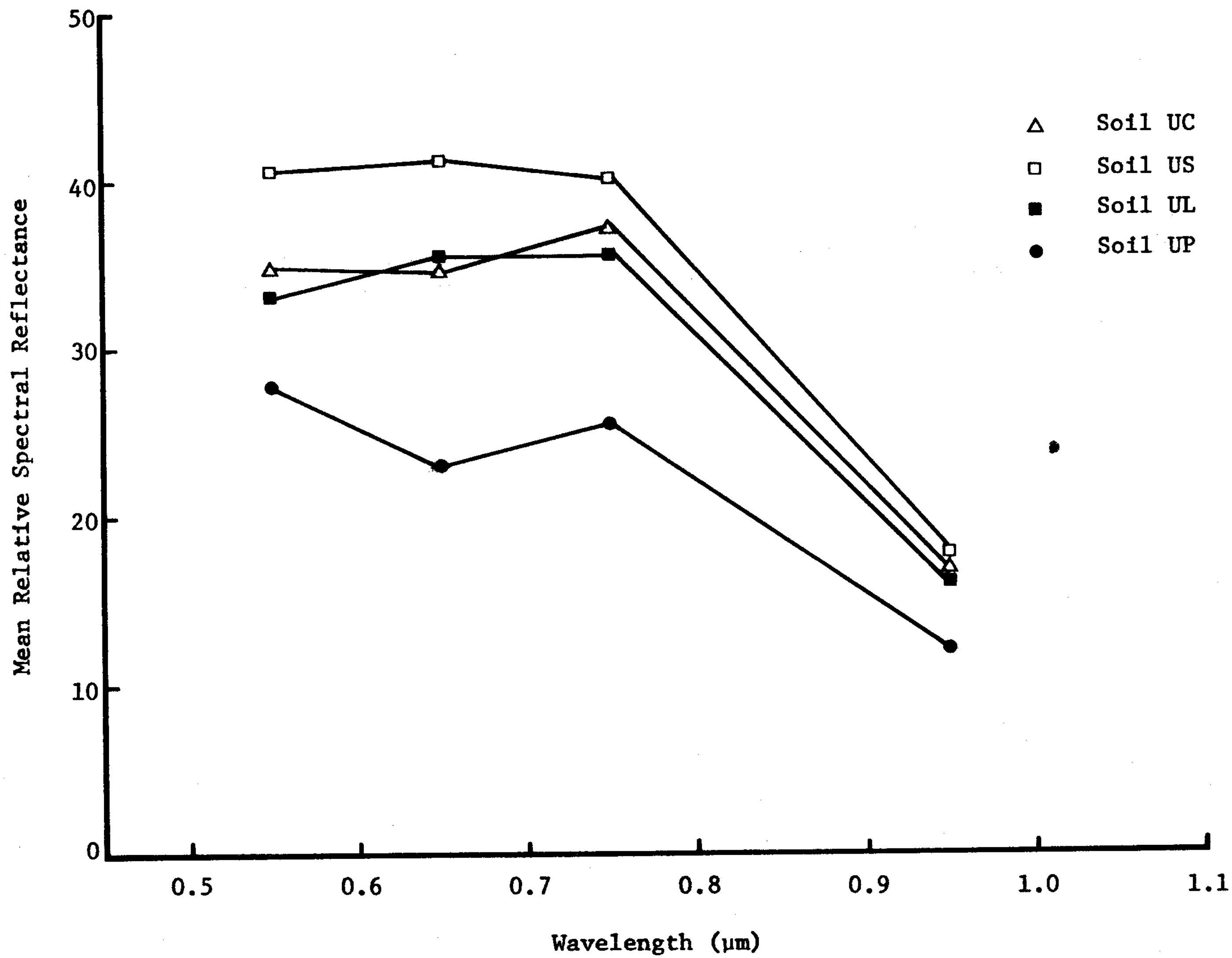


Figure 10. Landsat relative spectral reflectance values for four soil classes.

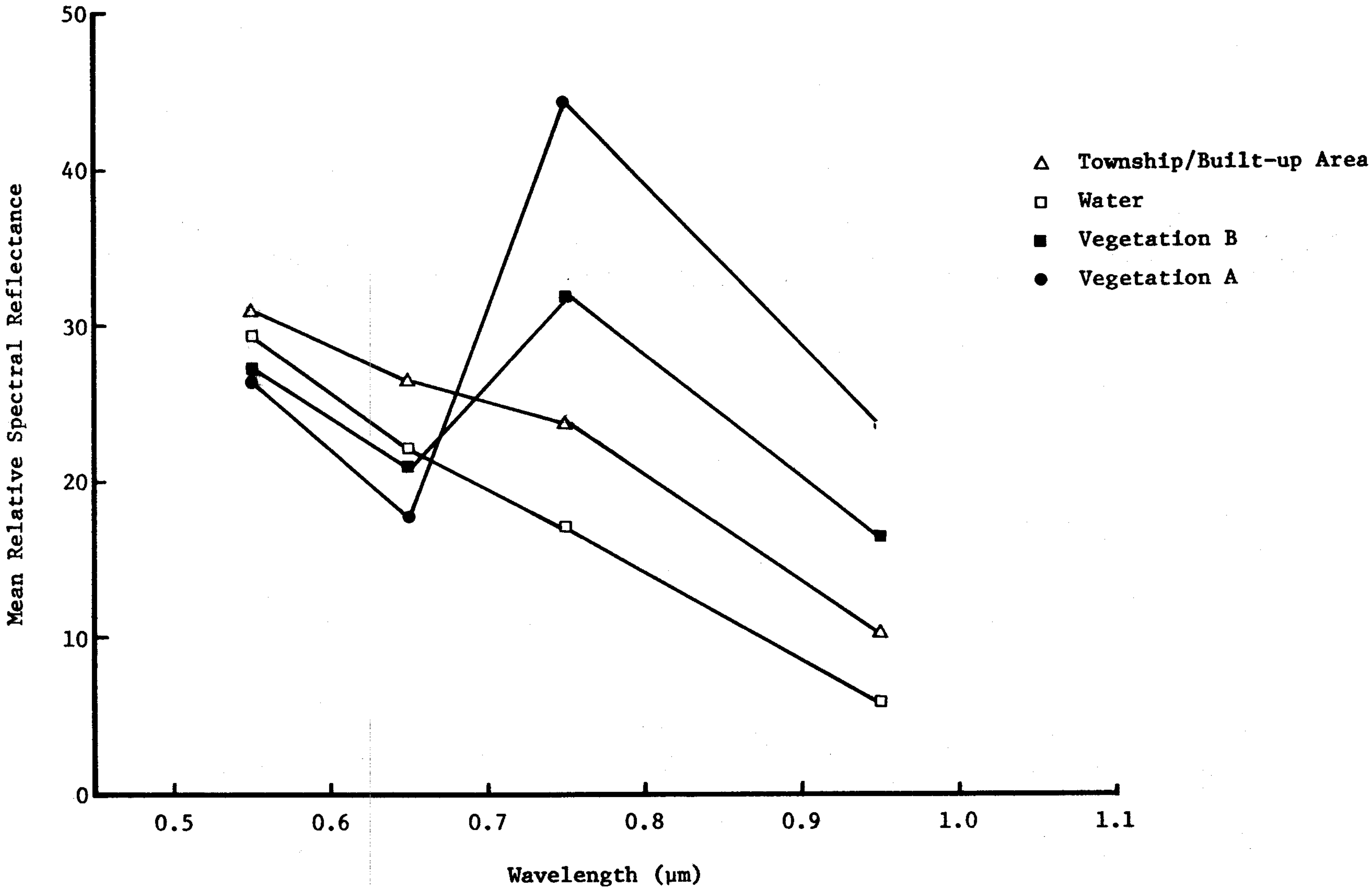


Figure 11. Landsat relative spectral reflectance values for four non-soil classes.

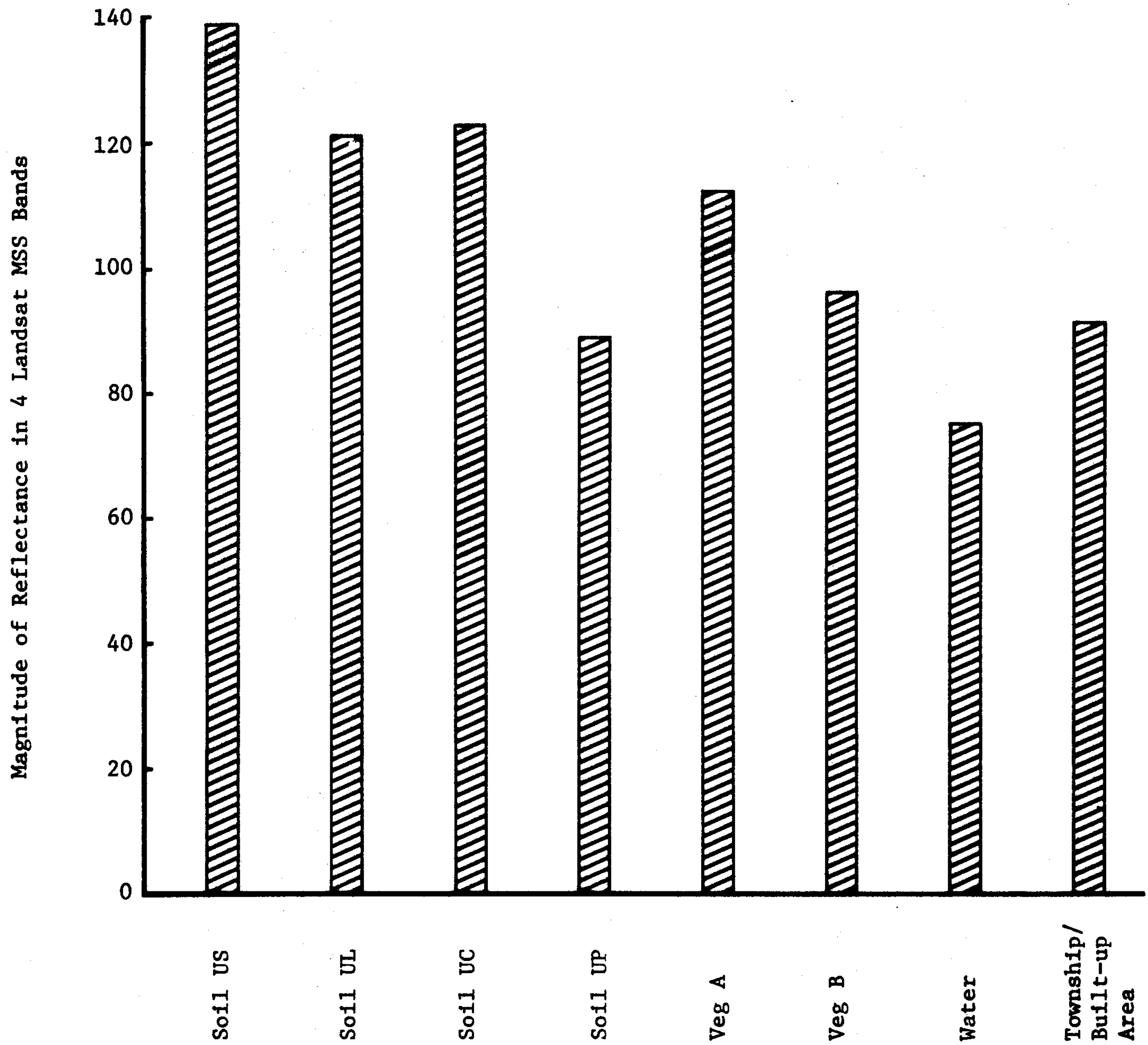


Figure 12. Magnitude of reflectance for four soil classes (US, UL, UC and UP) and four non-soil classes.

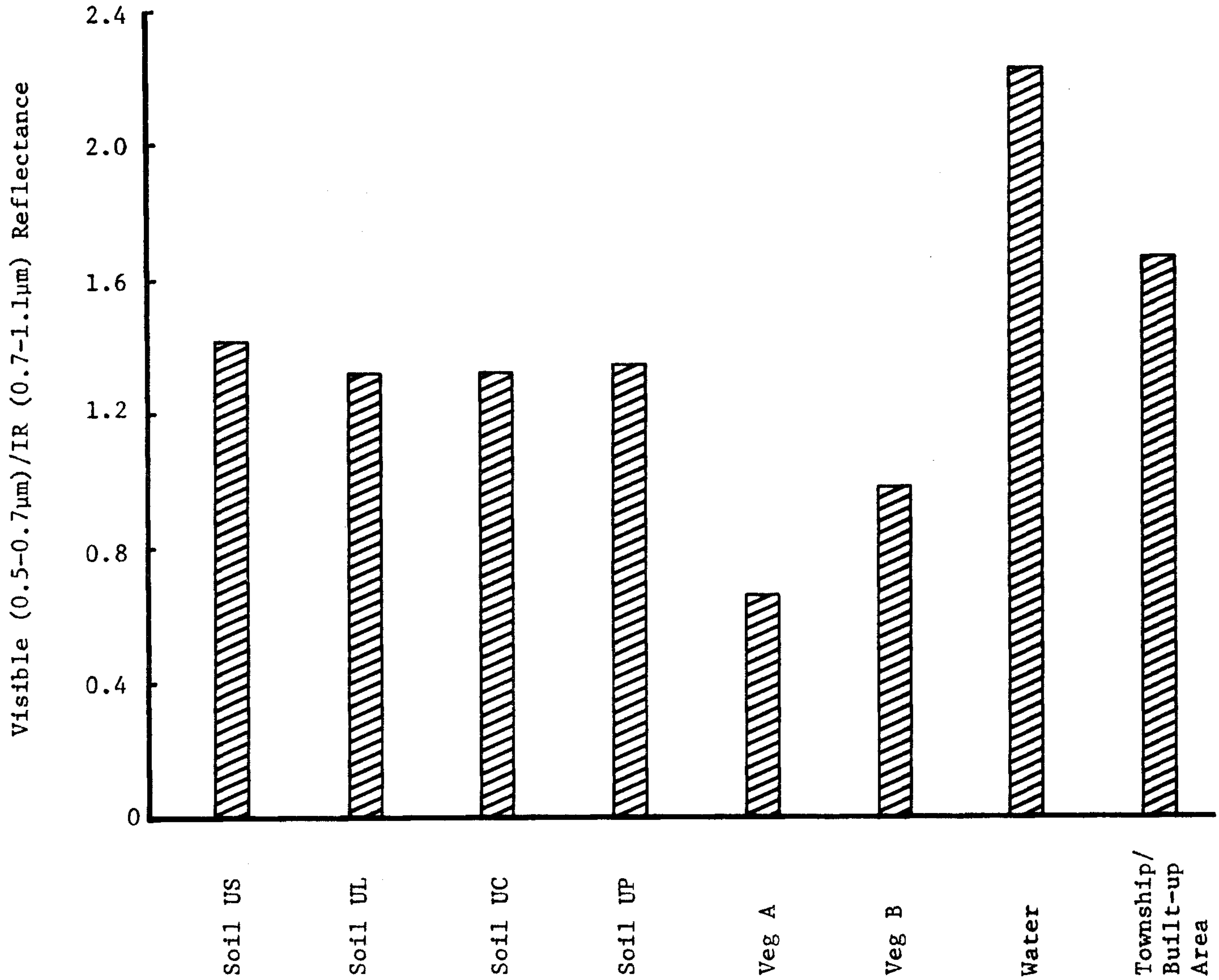


Figure 13. Visible/Infrared reflectance ratios for four soil classes (US, UL, UC and UP) and four non-soil classes.