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Land Use Classification of the Warsaw, Poland Area by Digital Analysis of Landsat Data

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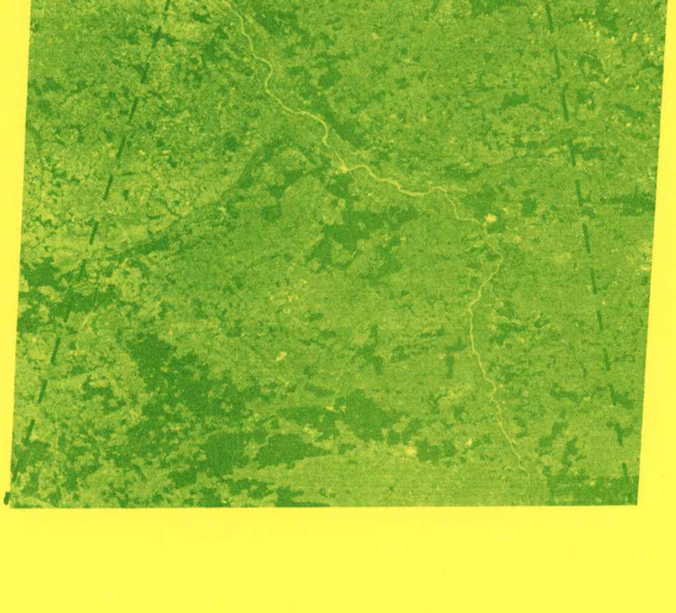
& Waldemar A. Madej



Laboratory for Applications
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West Lafayette, Indiana USA
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TABLE OF CONTENTS

LIST OF FIGURES

ABSTRACT

Satellite data, collected by Landsat on 26 June 1975, over the central part of Poland including the Warsaw area were analized by computer-implemented techniques to evaluate the usefulness of these data for land use classification. Several land use classes, such as forests, water, grassland, urban, and agricultural areas, were identified with reasonably good accuracy. Computer-aided analysis proved to be useful in discrimination of subclasses in forest, urban, water and grassland areas. Step-by-step procedures used in this study, as well as evaluation of results, are described.

INTRODUCTION

Computer-aided analysis of remotely acquired satellite data, developed in the Laboratory for Applications of Remote Sensing, has been applied with success in many disciplines for several years. The majority of research projects at LARS have utilized Landsat data for the United States and for the developing countries in Africa or South and Central America. The main purpose of this project was to demonstrate the possibilities of using satellite data for land use mapping in Europe, specifically in Poland, and to assess the usefulness of information obtained by means of digital image processing for land use studies.

The area, which was selected for detailed studies, is located in the central part of Poland, between $52^{\circ}05'$N - $52^{\circ}15'$N and $20^{\circ}45'$E - $21^{\circ}15'$E. It was chosen in the form of a square, 38 by 38 km. The area covered is about 1400 km^2. The largest city in Poland is Warsaw which is located in the central part of this square. To the south and west of the highly developed urban and industrial areas of Warsaw are agricultural and range lands. Forests, mainly coniferous, dominate in the eastern and northwestern part of the study area. There is no uniform type of agriculture in this region. The main crops are rye, barley, wheat, potatoes and sugar beets. There are many vegetable plots in this area. The dimensions of the fields are very diversified. They can vary from 10 to 1000 or more meters in width. Soils derived from sands dominate in this region.

It can be seen from this short description that the area is characterized by complicated land use patterns. The purpose of this project was to assess how accurately the particular ground cover types can be mapped using Landsat data and computer technology.

METHODOLOGY

The computer-compatible tape (CCT) for Landsat scene number 2155-08512 was obtained from EROS Data Center. This scene from the Landsat pass on 26 June 1975 covered the area of 185 by 185 km located in the central part of Poland. Figures 1 and 2 show this scene in MSS bands 4 and 6.

After displaying the entire scene on the digital image display, approximately one-fourth of the scene was chosen to be reformatted and geometrically corrected. Next, it was displayed in three modes using the IMAGEDISPLAY, PICTUREPRINT and GDATA functions of the LARSYS software system. The IMAGEDISPLAY processing function generates images of raw data on the screen of the digital display. Black and white hard copies or color slides of these images can be taken using Polaroid or 35 mm cameras.

The PICTUREPRINT processing function generates gray scale printouts of the desired area using the line printer with alphanumeric symbols representing various gray tones. Such a printout was obtained for the study area to be used in further steps of the analysis

The third mode of displaying was acquired through the GDATA processing function. This function produces gray scale printouts using an electrostatic printer/plotter in the form of quasi-photographic images. In our study two images from MSS bands 4 and 7 were obtained for the study area (Figures 3 and 4). The choice of candidate training areas for clustering was the next step of the analysis. Four areas, located in the most important places of the scene, were selected. Seventeen classes were assumed for clustering due to the diversity of terrain. Next, clustering was performed through the CLUSTER processing function and statistics for the training areas were obtained. Next, the entire area was classified using the CLASSIFYPOINTS processing function. The printout map containing 17 spectrally different classes was obtained as a result of this classification. This map was the initial product for the second stage of analysis.

At the second stage part of the classified area was chosen for further detailed elaboration. The selected region was described in the introduction to this note. Gray scale printouts of raw data using the electrostatic printer/plotter were obtained for this area (Figures 5 and 6). Next, the classification map with 17 classes printed for the study region was compared with ground observation data. The results obtained through the RATIO and STATISTICS function, characterizing spectral properties of distinguished classes, were studied in order to form new informational classes. Combining the spatial and spectral information about the study area resulted in nine spectrally discriminated classes.

Next, the samples were taken for each identified class, and the computer was "trained" to recognize them. In the following step the whole area of the vicinity of Warsaw was re-classified. As a result of this classification, a printout map containing 9 spectrally different classes was obtained. As some areas were not attached to any class, the samples were taken from these areas, and the classification was repeated. After this refinement of results, a land use classification map containing 10 classes was finally obtained. This classification was presented in several forms, namely as:

a) printout map from line printer using alphanumeric symbols.

b) printout map from the electrostatic printer/plotter using pictorial symbols.

c) color-coded map recorded on transparencies using digital image display, PHOTO program and 35 mm camera.

d) color-coded map using laser digital printer and Chromalin process.

The first two forms of presentation were shown in Figures 7 and 8.

RESULTS AND DISCUSSION

The discrimination of classes was based on the use of spectral and spatial information about the study area. Spectral information was obtained through the STATISTICS and RATIO processing functions, and spatial information was primarily achieved through the analysts' knowledge of this area. Using this information, the following main types of land use were identified:

1) Forest areas
2) Water areas
3) Urban areas
4) Agricultural areas
5) Grassland

Next, these general groups were separated into more detailed classes. Three classes were distinguished in the forest group according to the differences in spectral reflectance, namely:

a) deciduous forests characterized by medium magnitude and very high relative reflectance in infrared bands;
b) coniferous forests characterized by low/medium magnitude and medium/high relative reflectance in infrared bands;
c) forests, mainly deciduous, including open grassland areas and young forests, characterized by medium/high magnitude and very high relative reflectance in infrared bands.

In group c) the parks are also included.

Next, two kinds of spectrally different water areas were distinguished:

a) Vistula river characterized by low/medium magnitude and very low relative reflectance in infrared bands;
b) small lakes and ponds characterized by very low magnitude and very low relative reflectance in infrared bands.

Two classes were also distinguished in the urban areas:

a) densely built-up and residential areas characterized by medium magnitude and medium relative reflectance in the infrared bands;

b) open industrial and new built-up areas characterized by high magnitude and medium relative reflectance in the infrared bands.

Grassland areas could also be separated into two classes:

a) dense grass characterized by high magnitude and very high relative reflectance in the infrared bands;

b) sparse grass/pasture characterized by high magnitude and medium/high relative reflectance in infrared bands.

The agriculture class is characterized by medium magnitude and high relative reflectance in the infrared band. The comparison of magnitudes and visible/infrared ratios for all classes is shown in Figures 9 and 10. The graphs showing the differences in spectral response in four Landsat bands for all classes were also prepared (Figures 11 and 12).

A "rough" assessment of accuracy of the obtained classification was the final stage of this work. The term "rough" assessment was used because the authors did not possess the detailed thematic maps of the study region during their work on this project. More precise quantitative assessment can be done for the Warsaw area after comparison with specific maps and census data available in Poland. Nevertheless, some remarks can be made and conclusions can be drawn.

The forest areas were classified with high accuracy. Some confusion between forest subclasses can appear only in the case of mixed forests, but they cover small areas in this region. All the main city parks were mapped in this group. Water areas were classified quite well after the refinement of results.

Sandy and very shallow areas in the Vistula River were distinguished from water. There was only confusion between classes in the case of a channel located in the northern part of the study region. This narrow channel surrounded by wide concrete banks and parallel to the road nearby was classified into built-up land.

Urban areas were classified with reasonably good accuracy, especially in regard to the downtown area of Warsaw and the densely built-up areas. Roads and railroads, which are usually surrounded by built-up land in this region, were also included in this group. It is worthy to mention that more subclasses can be distinguished in this class if detailed information about the character of the urban area is available.

It is difficult to assess the accuracy of agriculture and grassland classifications. The information about the character of agricultural land use for this particular time of year, June 1975, in the form of test fields should be available in order to make a proper estimation. Nevertheless, there is no serious confusion between these classes and the remaining classes. As the latter ones were classified with reasonably good accuracy, it can be expected that the classification of agriculture and grassland is also done accurately enough. In this group many subclasses of non-forested vegetation can also be distinguished if detailed ground observation data are available.

CONCLUSIONS

This study revealed that computer-implemented analysis of satellite MSS data can be used for rapid and accurate mapping of complicated land use patterns. The main land use classes can be distinguished using routine, computer-aided analysis prepared in the Laboratory for Applications of Remote Sensing. Many subclasses can be discriminated also utilizing the possibilities of the LARSYS software system when detailed ground observation data are available. The great advantage of satellite and computer technology is the feasibility of monitoring land use changes through temporal, computer-aided analysis of Landsat data. Such analysis can be invaluable for urban studies, crop area estimation and regional planning. Its accuracy will still increase as new, more sophisticated systems of data acquisition are introduced and computer, user-oriented technology is improved. So, this technology can be a useful tool for land management at the regional and national level.

ACKNOWLEDGEMENTS

This work was supported by the Institute of Geodesy and Cartography, Warsaw, Poland, in agreement with the Laboratory for Applications of Remote Sensing, Purdue University. The authors would like to gratefully acknowledge the helpful assistance provided by Prof. M. F. Baumgardner, Dr. S. J. Kristof and the entire staff of LARS during the project.

REFERENCES

1. Swain, P. H. Pattern recognition: a basis for remote sensing data analysis. LARS Information Note 111572. 1972.

2. Landgrebe, D. A. Machine processing for remotely acquired data. LARS Information Note 031573. 1973.

3. Phillips, T. L. LARSYS User's Manual. Laboratory for Applications of Remote Sensing, Purdue University, West Lafayette, Indiana. 1974.

4. Kristof, S. J., M. F. Baumgardner and C. J. Johannsen. Spectral mapping of soil organic matter. LARS Information Note 030773. 1973.

5. Anderson, J. R., E. E. Hardy, and J. T. Roach. A land use classification system for use with remote-sensor data. Geological Survey Circular 671, Washington. 1972.

6. Cary, T. K., J. C. Lindenlaub. A case study using LARSYS for analysis of Landsat data. LARS Information Note 050575. 1975.

7. Baumgardner, M. F., E. H. Horvath, P. M. Adrien, A. M. Vasquez and C. L. Elizondo. Using satellites and computers to inventory the natural resources of the Tempisque Valley, Costa Rica. Report to the Inter-American Development Bank and Government of Costa Rica. 1976.

8. Odenyo, V. A. and D. E. Pettry. Land-use mapping by machine processing of Landsat-1 data. Photogrammetric Engineering 43:515-524. April 1977.

9. Davis, W. A. and F. G. Peet. A method of smoothing digital thematic maps. Remote Sensing of Environment. Vol. 6. No. 1. 1977.

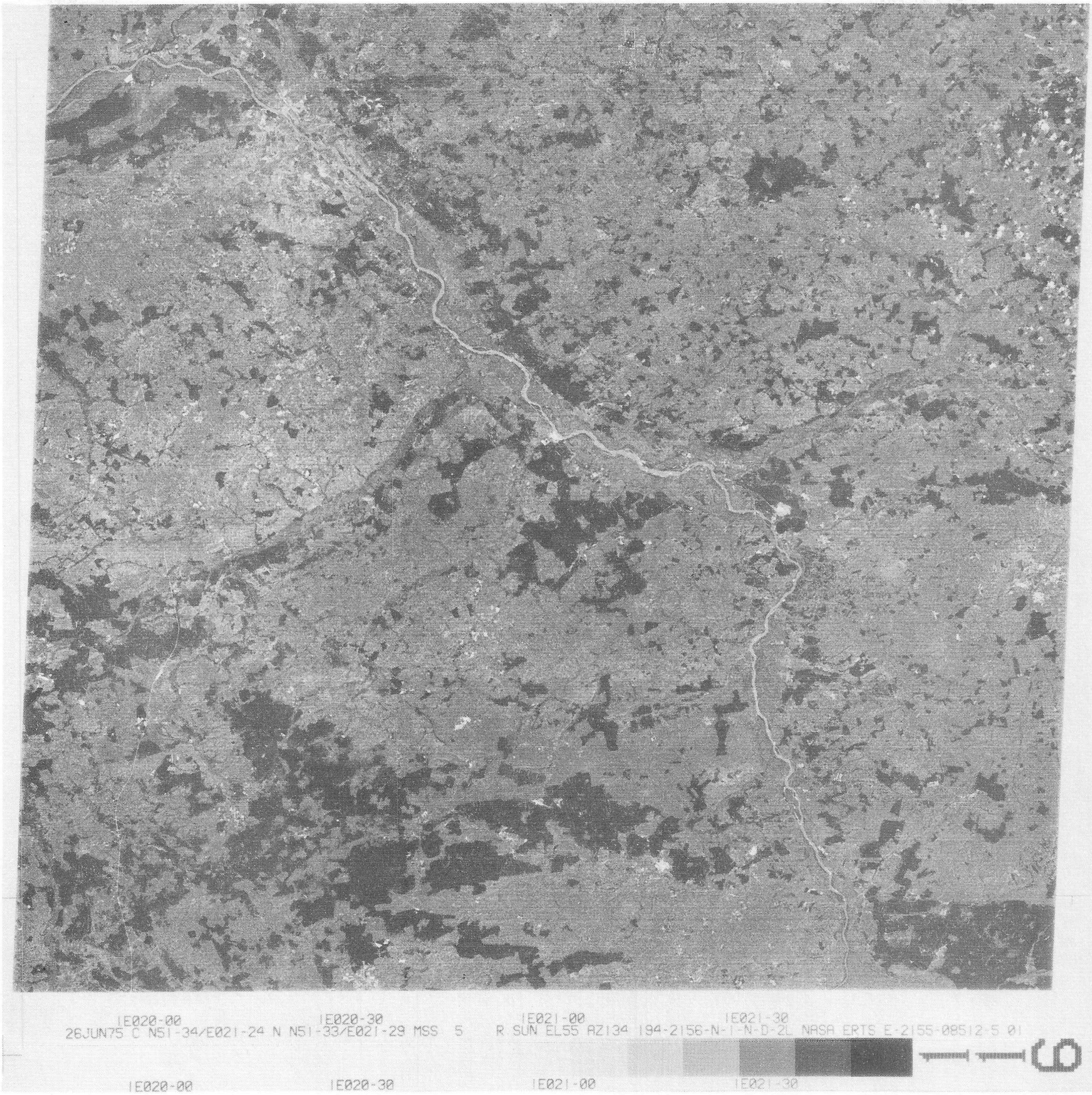


Figure 1. Image produced with data from MSS band 4 (0.5 - 0.6μm) obtained by Landsat on 26 June 1975 (Scene no. 2155-08512).

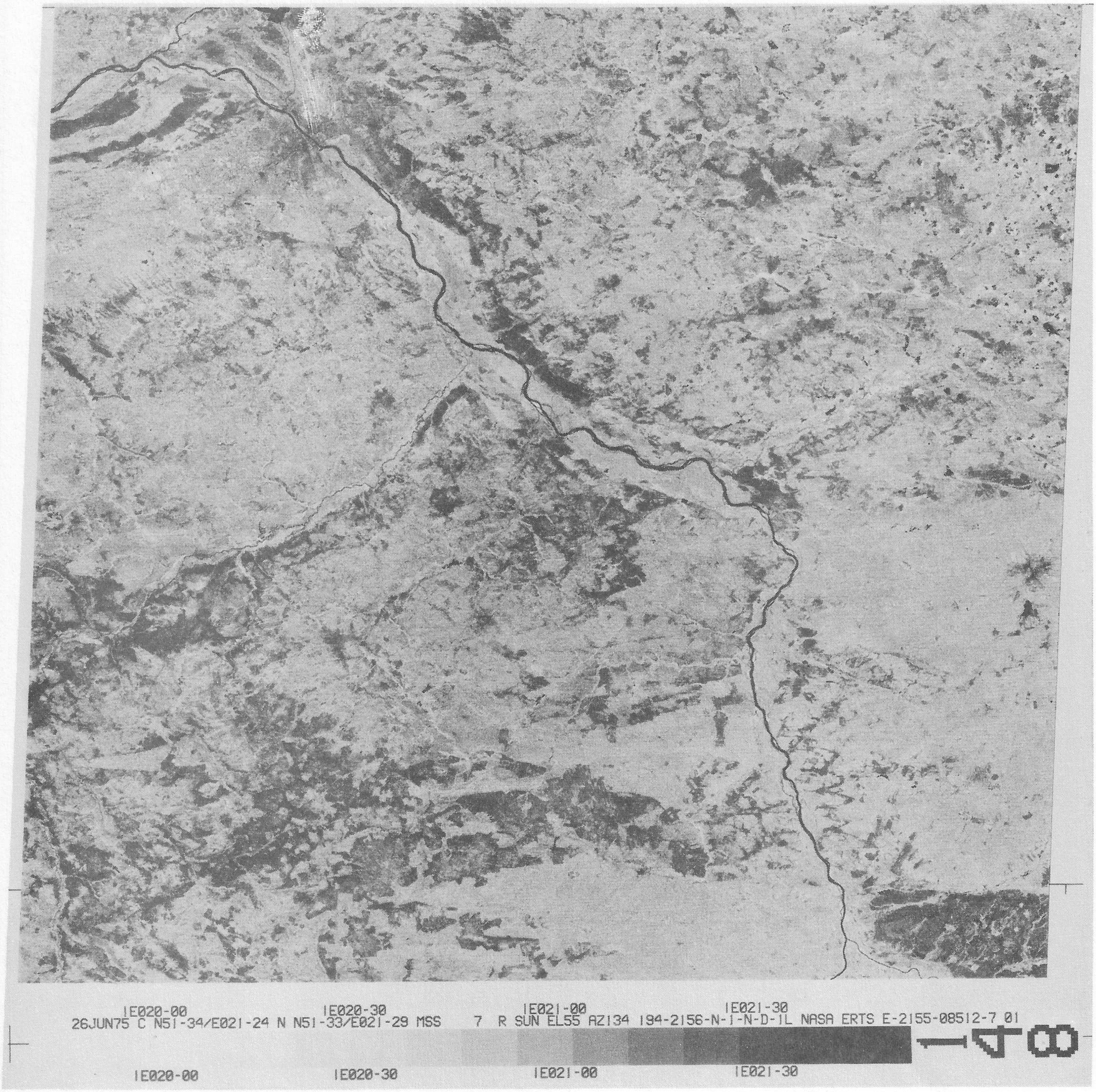


Figure 2. Image produced with data from MSS band 6 (0.7 - 0.8μm) obtained by Landsat on 26 June 1975 (Scene no. 2155-08512).

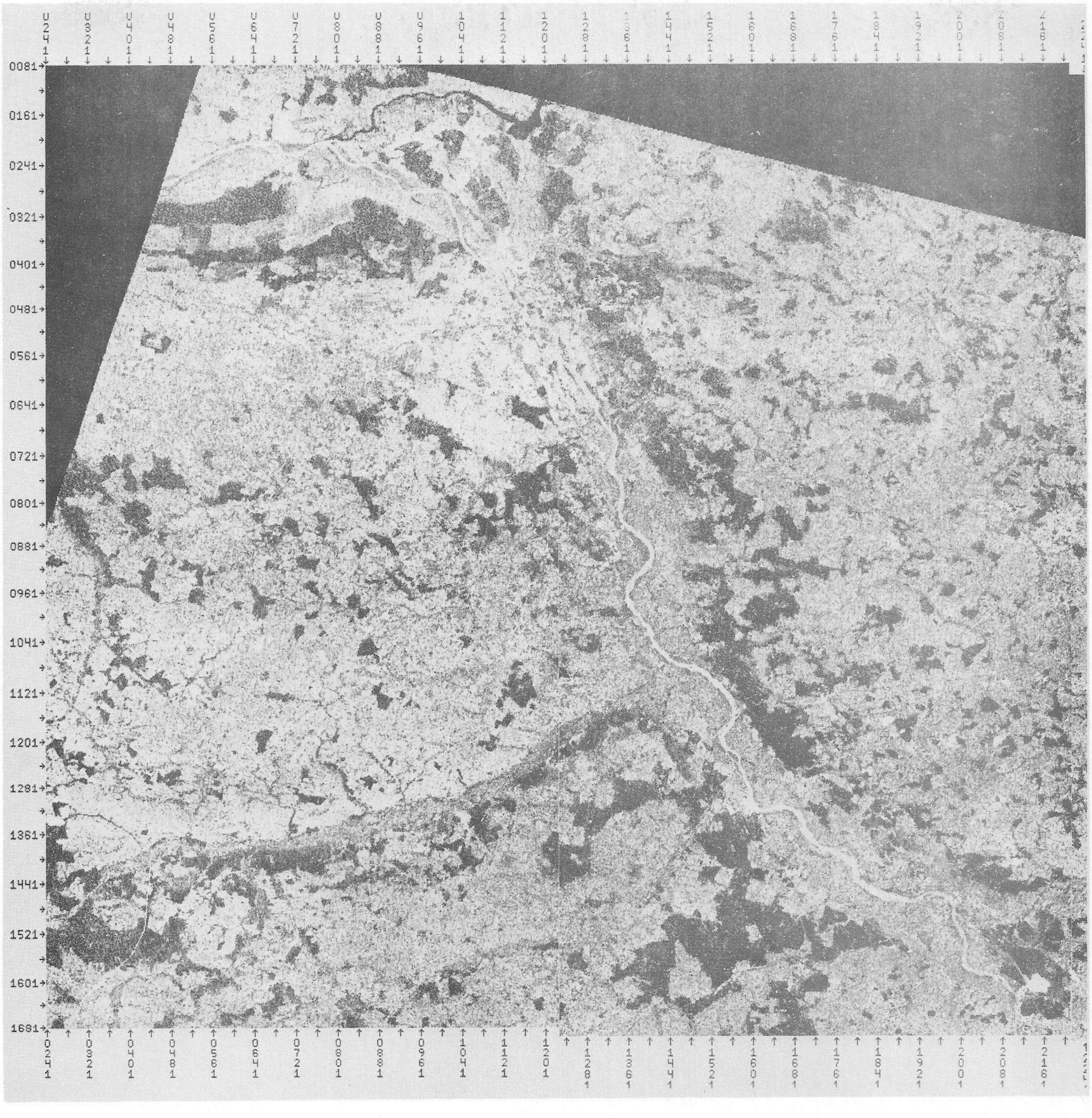


Figure 3. Geometrically corrected portion of Landsat scene no. 2155-08512 in MSS band 4 (0.5-0.6µm).

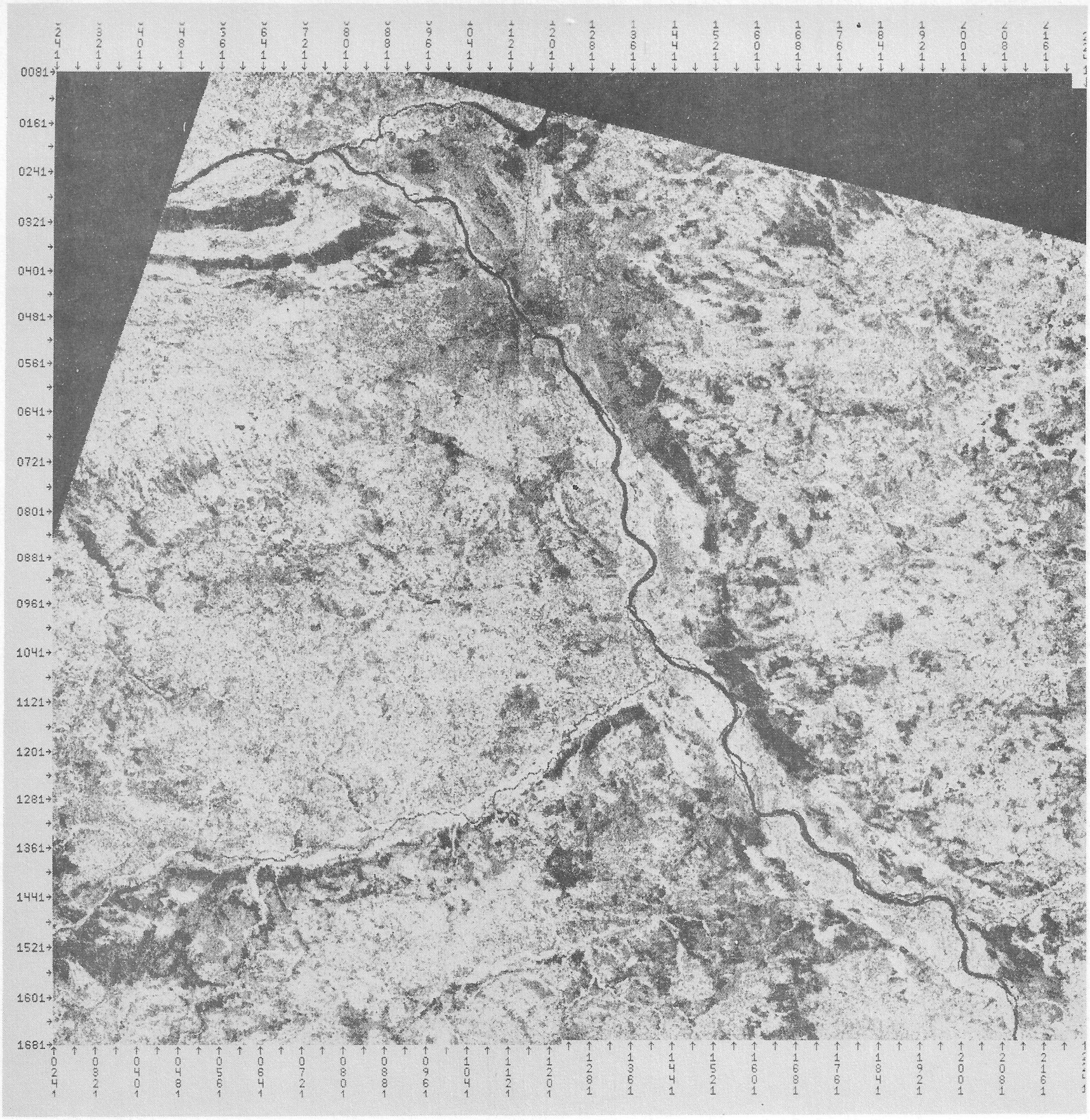


Figure 4. Geometrically corrected portion of Landsat scene no. 2155-08512 in MSS band 7 (0.8-1.1μm).

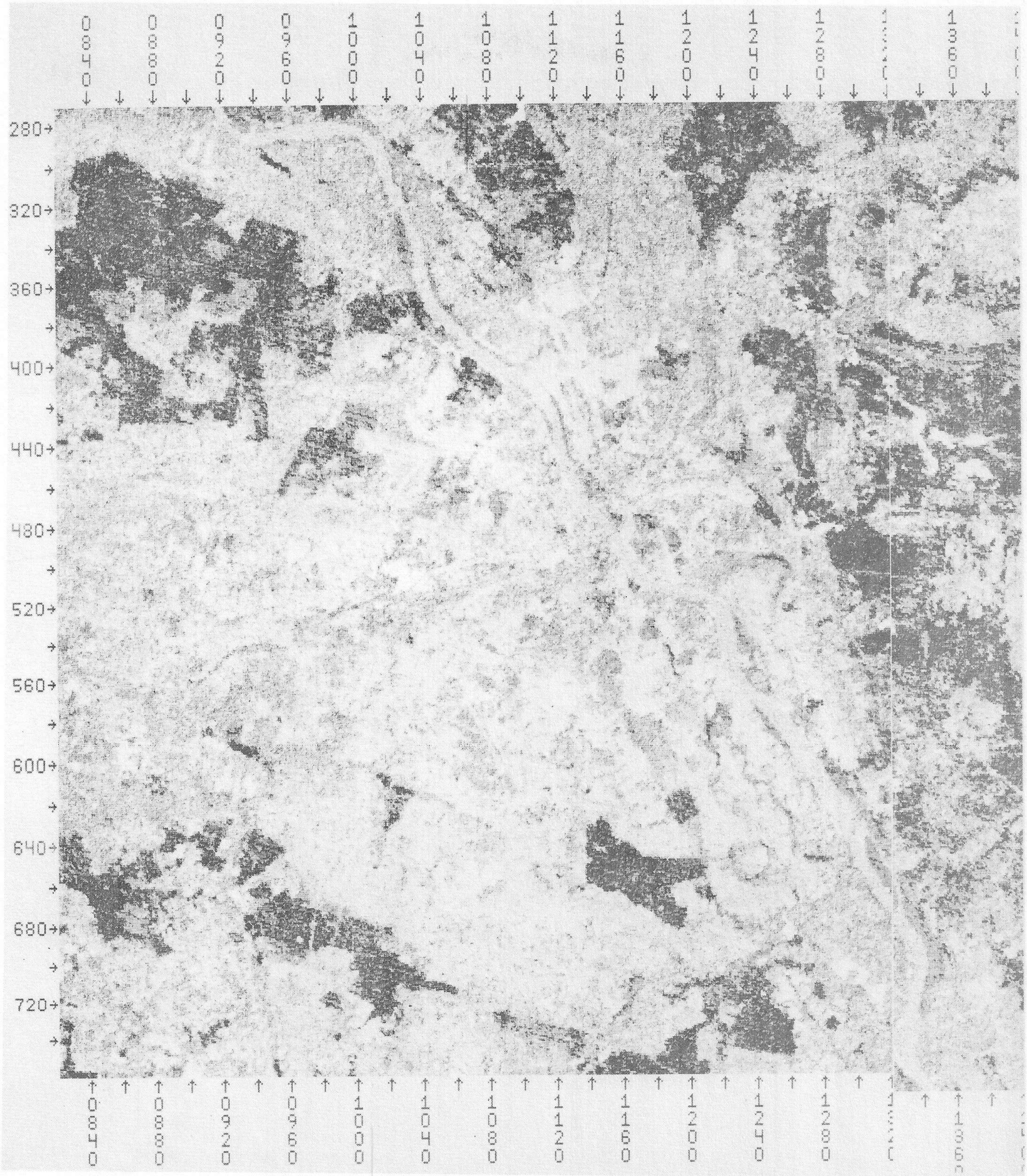


Figure 5. Unclassified image of Warsaw area in Landsat MSS band 4 (0.5-0.6μm).

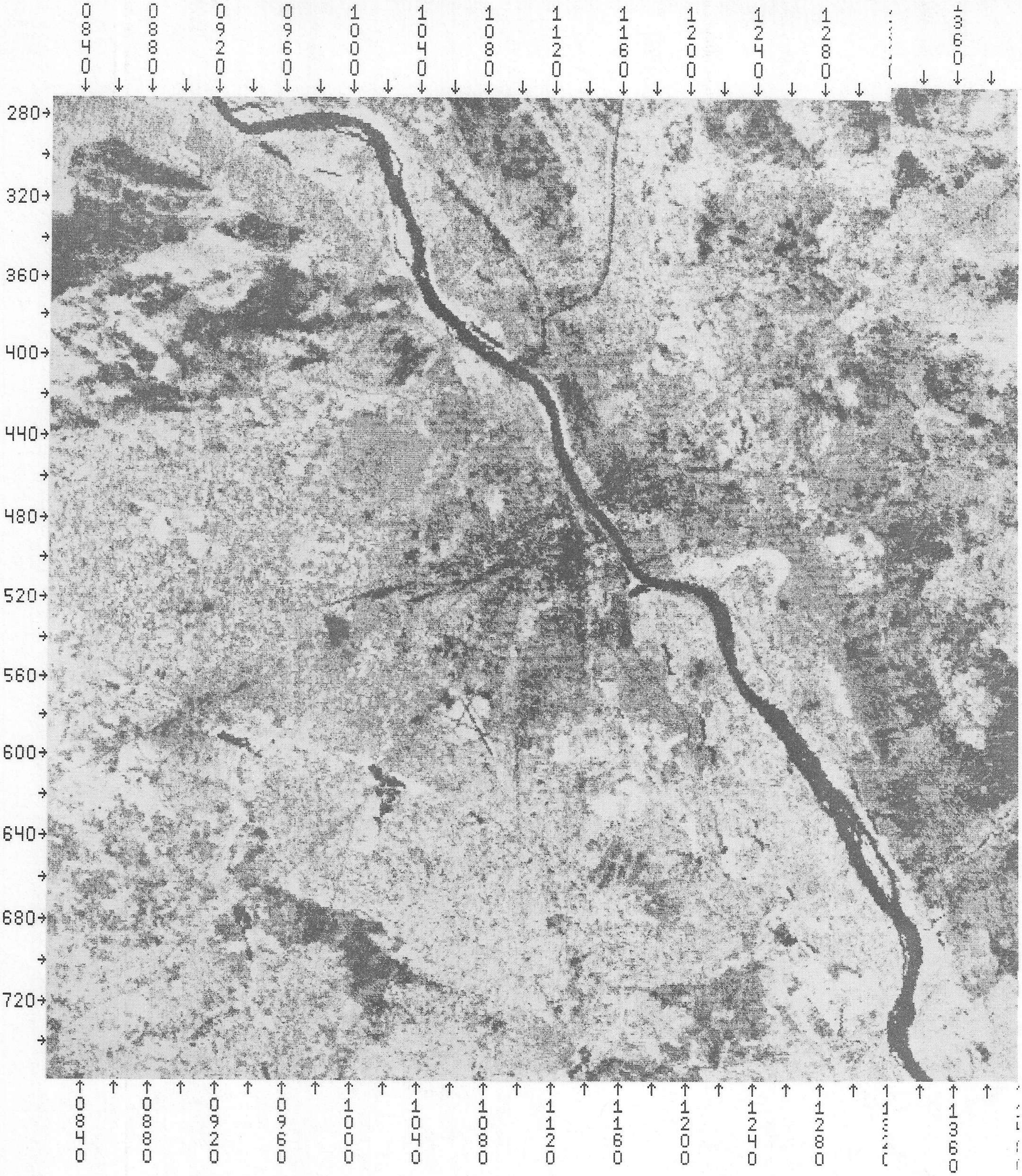
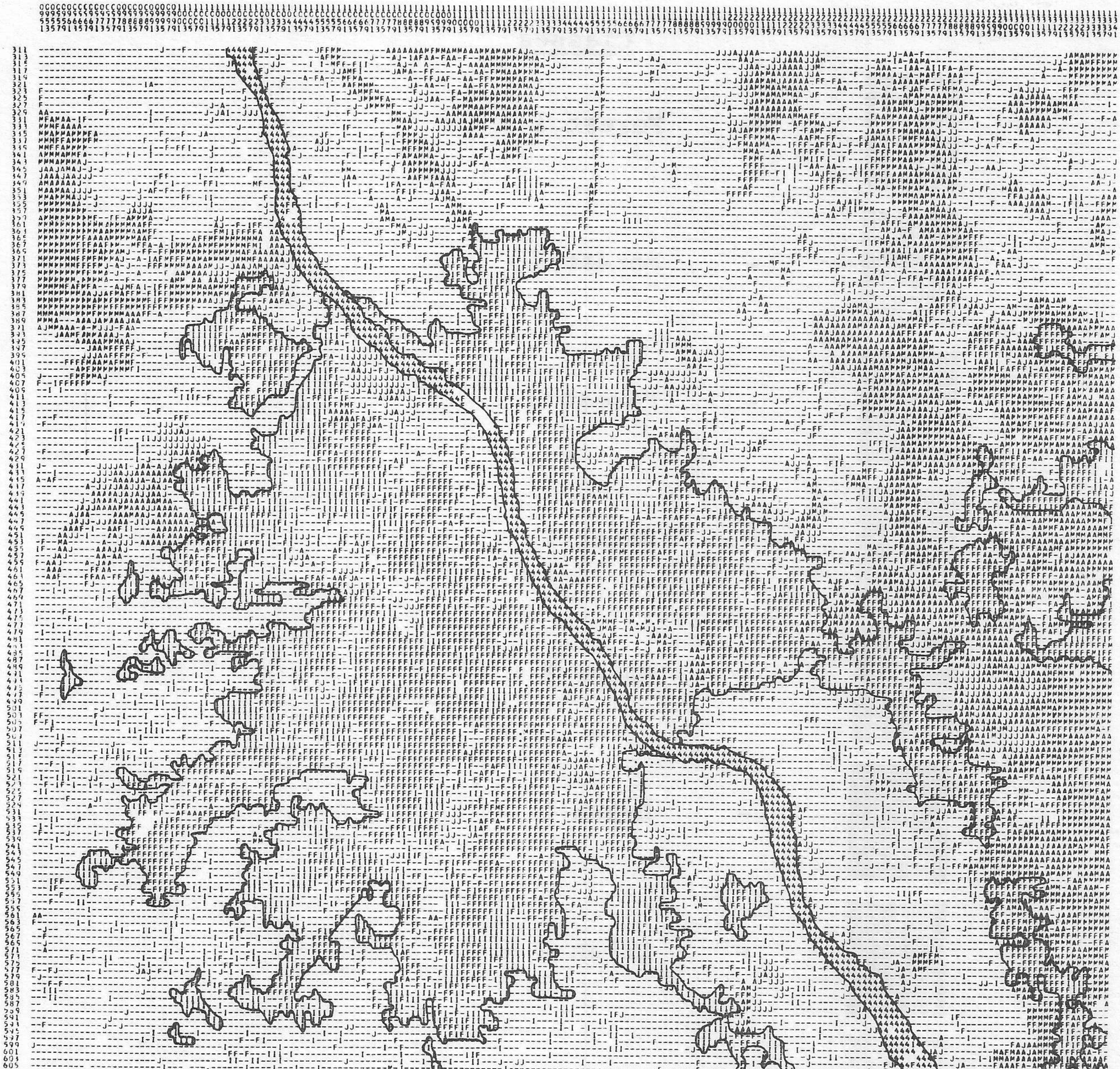


Figure 6. Unclassified image of Warsaw area in Landsat MSS band 7 (0.8-1.1μm).

CLASSES

SYMBOL	CLASS	THRES PCT	SYMBOL	CLASS	THRES PCT
A	FOREST1	0.50	F	URBAN1	0.50
M	FOREST2	0.50	I	URBAN2	0.50
J	Y.FOREST	0.50	-	AGRI	0.50
4	WATER 1	0.50	-	GRASS 1	0.50
.	WATER 2	0.50	-	GRASS 2	0.50



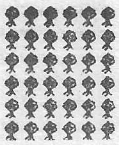
NUMBER OF POINTS DISPLAYED IS 17760

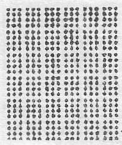
NUMBER OF POINTS DISPLAYED IS 13600

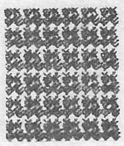
Figure 7. Printout classification map of Warsaw area using line printer.

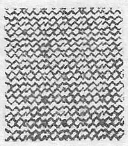
LEGEND (Figure 8)

<u>Classes</u>

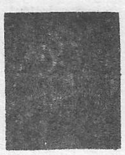
 - Forest 1

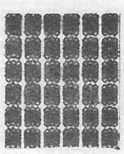
 - Forest 2

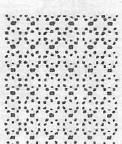
 - Forest 3

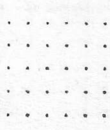
 - Water 1

 - Water 2

 - Urban 1

 - Urban 2

 - Agriculture

 - Grass 1

 - Grass 2

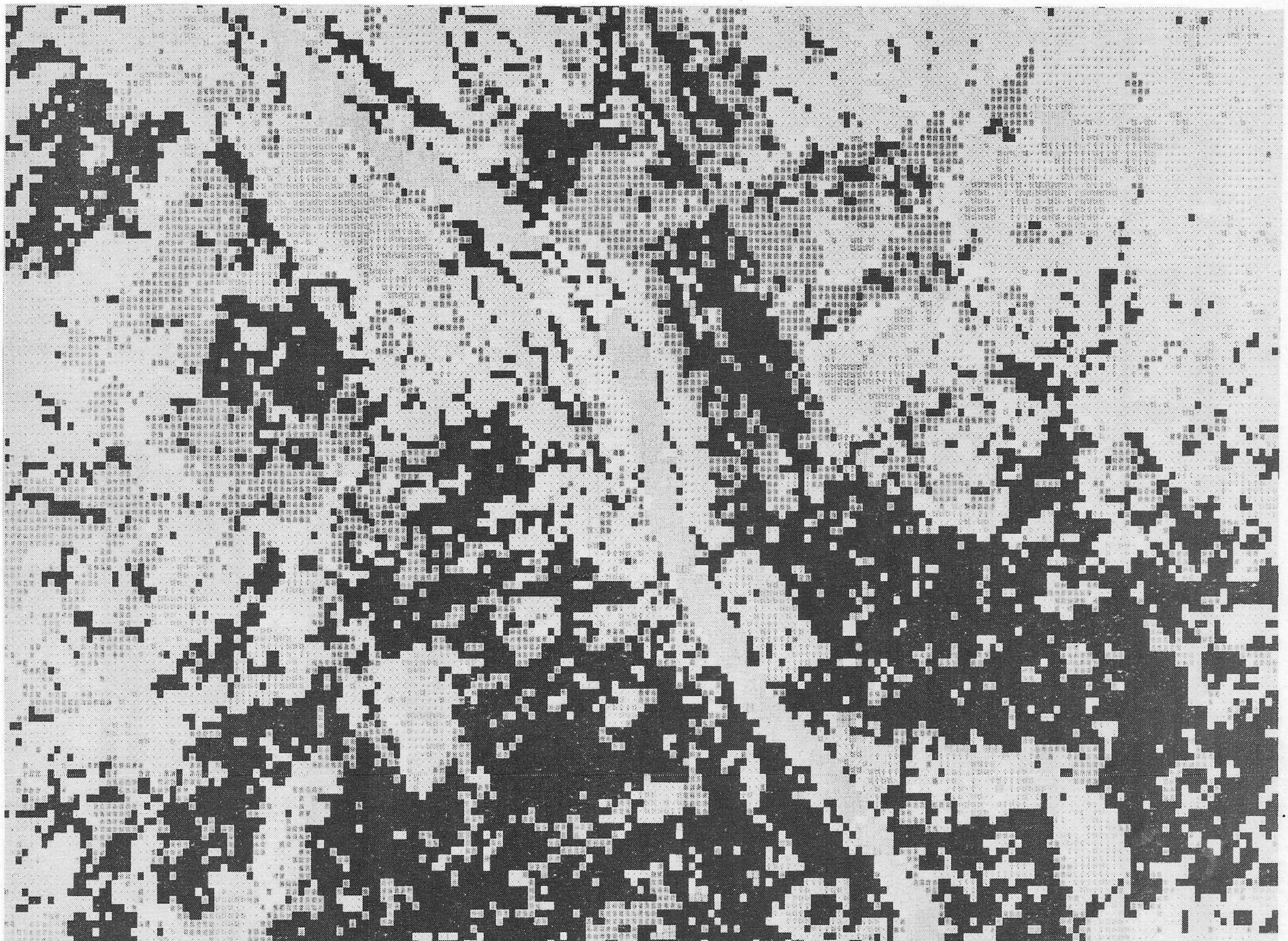


Figure 8. Printout classification map of Warsaw area using the electrostatic printer/plotter.

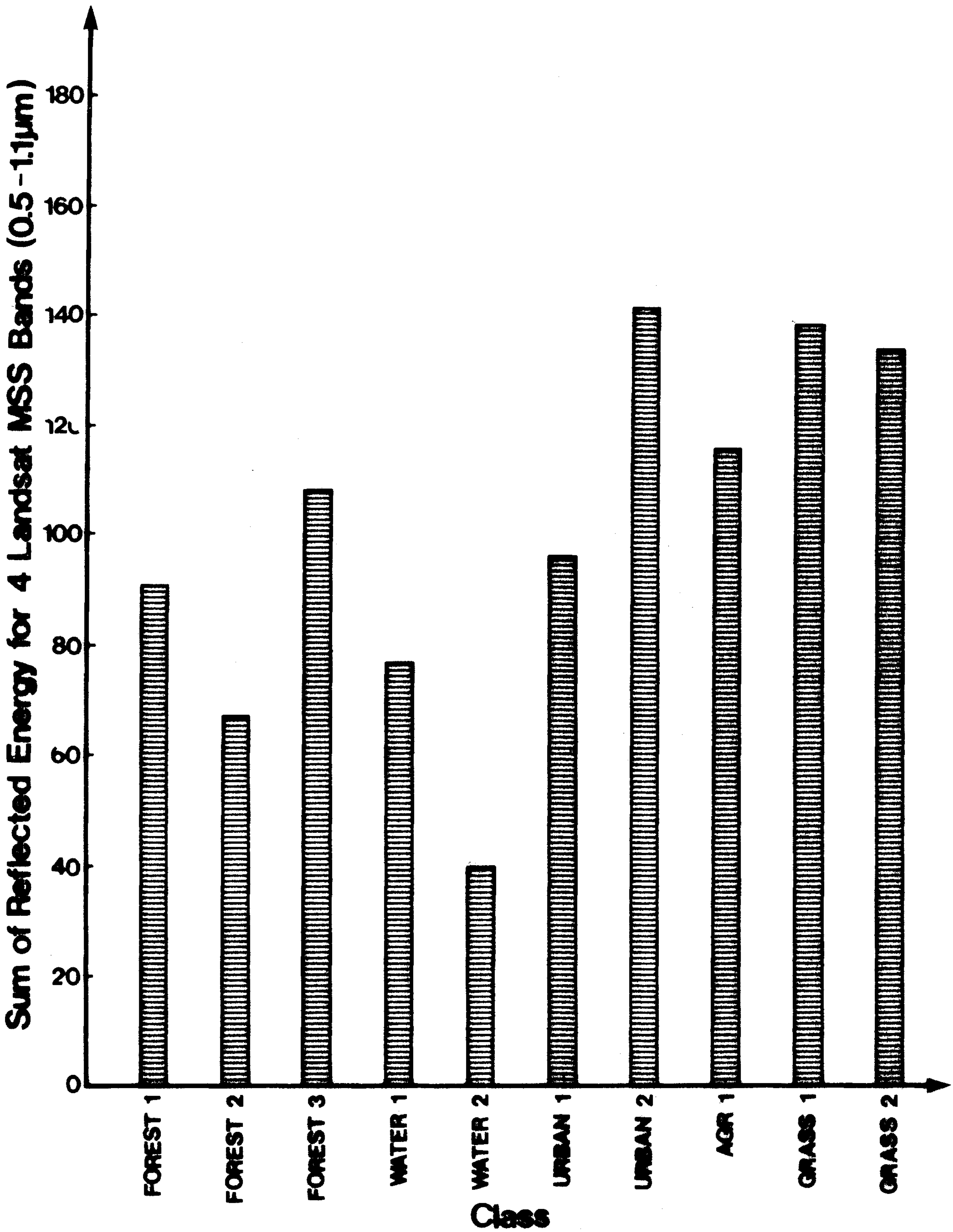


Figure 9. Comparison of magnitudes for 10 land use classes.

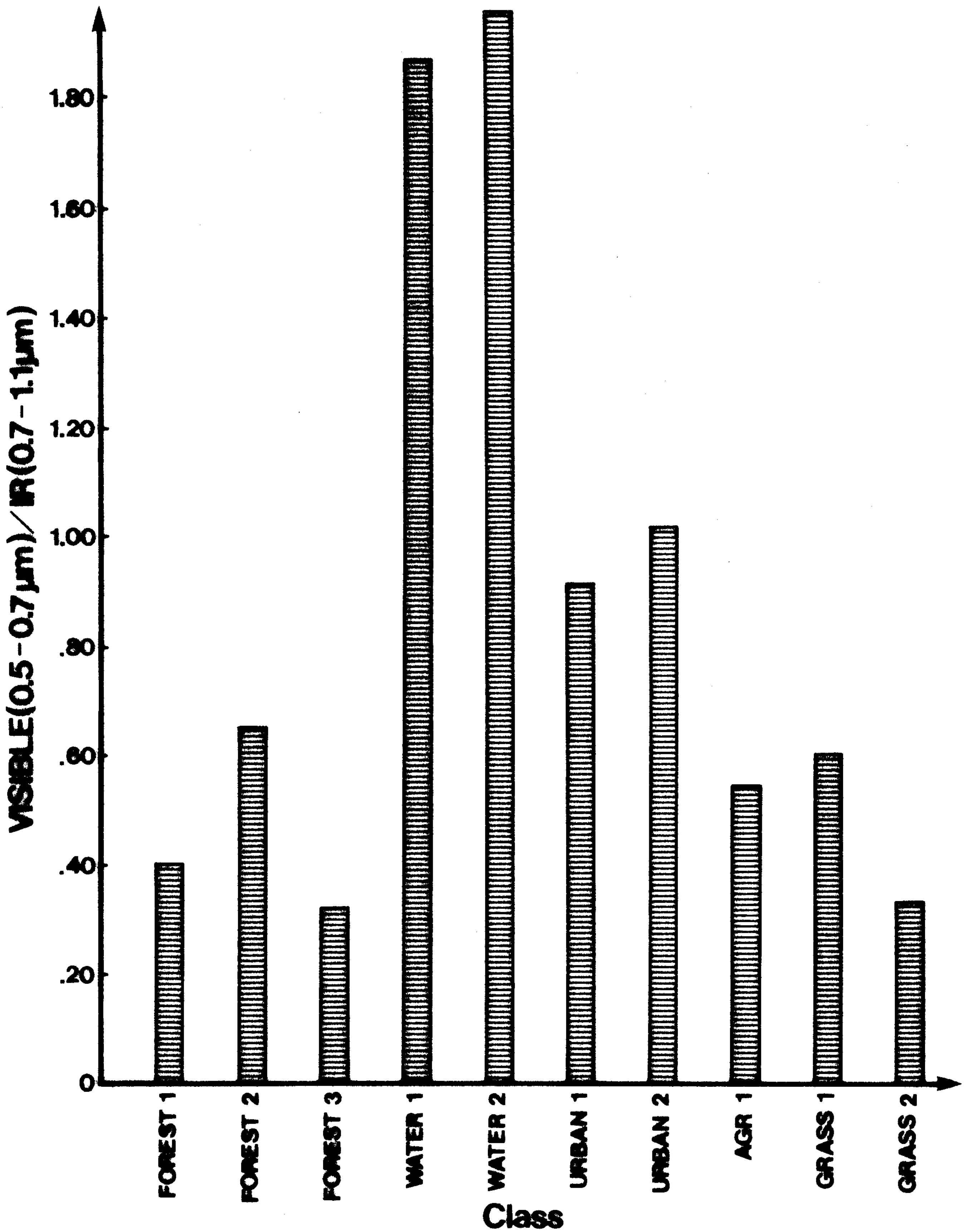


Figure 10. Comparison of visible/infrared ratios for 10 land use classes.

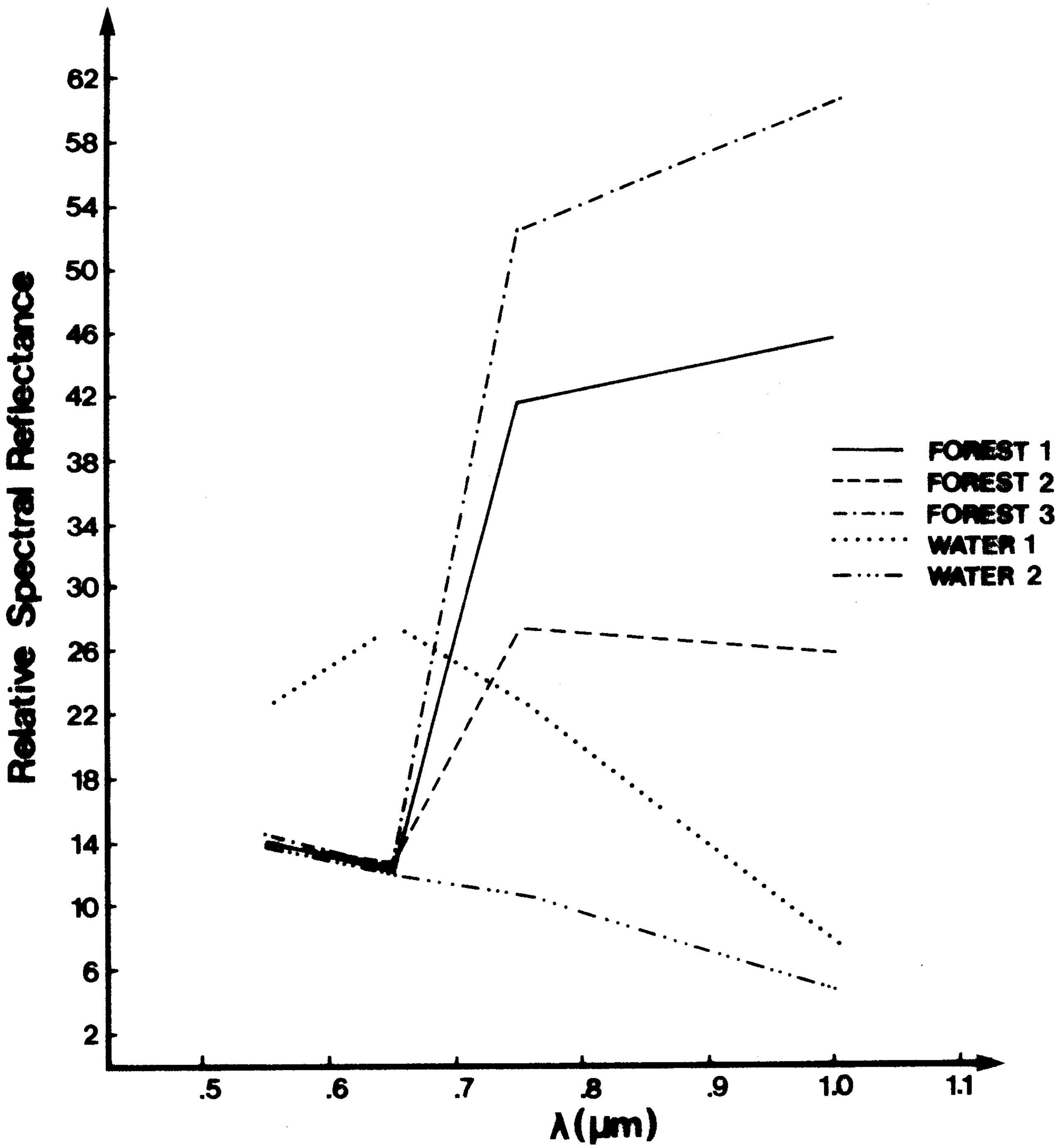


Figure 11. Comparison of relative spectral reflectance in 4 Landsat bands for 5 classes (1-5).

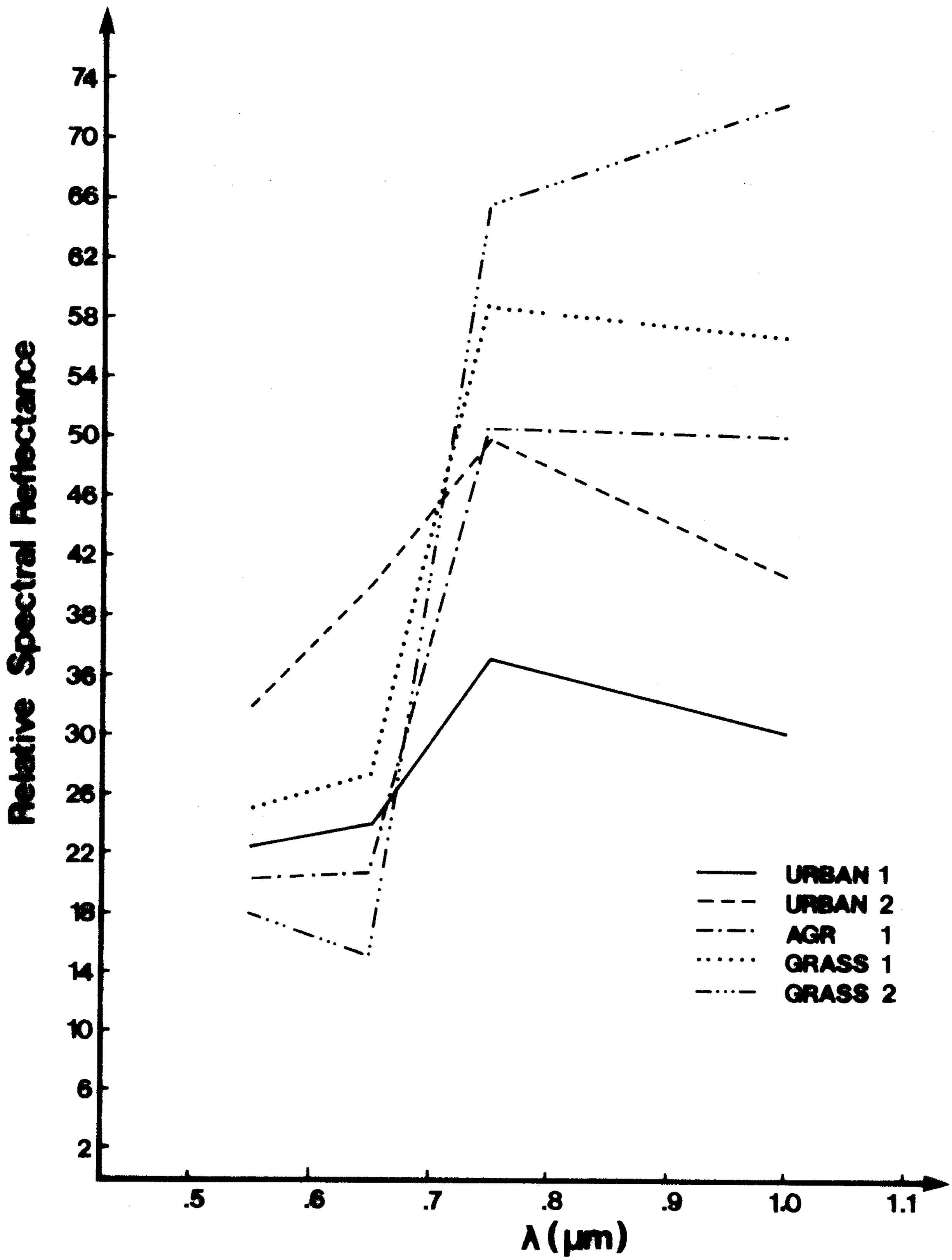


Figure 12. Comparison of relative spectral reflectance in 4 Landsat bands for 5 classes (6-10).