LARS Technical Report 112378

Land Cover Study for the Pulawy Region, Poland, by Digital Analysis of Landsat Data

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1978

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LAND COVER STUDY FOR THE PULAWY REGION, POLAND
BY DIGITAL ANALYSIS OF LANDSAT DATA

by

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November 1978

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Abstract.

Computer-aided technique was applied for the analysis of LANDSAT MSS data acquired over the central part of Poland in June, 1975.

The objective of this analysis was to determine the possibility of using satellite data for land cover study. Two methods of analysis, non-supervised technique and supervised technique, were performed.

As a result, 14 different land cover classes were distinguished: water, three classes of forests, industry, urban, open area and 7 agricultural classes.

Introduction.

Research on the applications of Remote Sensing for land cover study has been conducted since the late 1950's. Aerial black and white, color, color-infrared photos and aircraft scanner imagery have been utilized. (Bunnik N.J., 1978). Since 1972 satellite multispectral scanner (MSS) data has been used for obtaining imagery of the Earth's surface. Based on field and laboratory experiments, the spectral characteristics for different types of soil were stated (depending on the soil moisture, the organic material contents and the structure of soil). Similar characteristics were elaborated also for different land cover types, including vegetation in different growing seasons (Gates D.M., et al., 1965, Boer de, Th. A. et. al., 1974, Bauer M.E., 1975).

The research which has been carried out to the present, indicates that the accuracy of crop identification varies with the type of canopy and stage of the growing season. The highest accuracy is obtained for crops at the green stage of vegetation which completely covers underlying soil (Otterman J. et al., 1976). The recognition of the crops is based upon the values of the pattern of reflectance in the electromagnetic spectrum. These values depend highly on not only the type of crops, but also on the leaf angle distribution. Under some conditions the same reflectance values may be obtained for crops which do not completely cover the underlying soil as for crops completely covering the soil. This anomaly could be caused by the differences within the leaf angle distribution in the case of the full canopy cover of soil and by differences in soil moisture with crops not completely covering the underlying soil (Bunnik N.J., 1978). The reflectance value can also be influenced by the organic material content of soil. A significant decrease in reflectance of soil is noted for soils with 2% and higher content of organic materials (Baumgardner, M.F. et al., 1970). This relation was confirmed in practice by S. J. Kristof et al., 1973. The size of fields which can be identified on the satellite MSS imagery is also of great importance for crop inventory. The minimum size of a homogeneous field, recognizable on the satellite scanner imagery is approximately 4 ha; however, for fields of 30 ha and more, the accuracy of thematic mapping can be equal to 99% (Otterman J., et al., 1976). It must be considered that the accuracy of thematic mapping can vary with field conditions and cultivation methods.

Even though the above mentioned factors can influence and make some difficulties for land cover study with satellite data, this data is widely applied in a lot of countries for crop inventory. It makes possible repeatable monitoring of the Earth's surface at little cost, compared to other methods applied in Remote Sensing.

The presented digital land cover study based on Landsat data acquired over the chosen part of Poland is the second one carried out at the Laboratory for Applications of Remote Sensing, Purdue University. The first analysis was carried out in 1977 for urban areas within the vicinities of Warsaw, with a total area of approximately 1400 square kilometers (Bochenek Z.T., Madej W.A., 1977). It was a non-supervised classification study of land use.

The objective of the analysis presented in this report was to determine the possibilities of application of the Multispectral Landsat Data for the land cover study for Polish conditions. It was based on the extrapolation mode (Otterman J. et al., 1976). Before the analysis was started, the limited ground truth data was acquired, which represented the crops planted on the experimental fields in June, 1975. The experimental fields belonged to the Agricultural Academy in Lublin and to the Institute of Soil Science and Cultivation Plants in Pulawy. This data concerned only several crops which occur on the analyzed area. Some of the crops, for example: sugar beets, rape, rye, tobacco and also orchards and gardens were not represented on the experimental fields. The fields of other crops, for example: hemp, oat, cabbage, meadows and pastures were too small or too narrow and elongated to be seen on the satellite image. The fully useful ground truth data was available only for: corn, barley, wheat, clover, alfalfa, potatoes, as well as for forested areas, water and industrial areas.

The analysis was carried out based on one Landsat scene no. 2155-08512 obtained on June 26, 1975 over the central part of Poland.

Description of the analyzed area.

The southeastern part of the scene no. 2155-08512 (data acquired on June 26, 1975) was chosen to be analyzed using computer technique. The total acreage of this area was approximately 1890 square kilometers and its geographical coordinates were 51° 10' N - 51° 34' N and 21° 50' E - 22° 19' E.

From the geographical point of view, almost all of this area belongs to the Lublin Upland, composing its Northwestern part. The vast geomorphological forms of the Vistula River valley on the West and the Wieprz River valley on the North delimit the analyzed area. The entire area investigated is drained by the Vistula River and the Wieprz River, along with their tributaries.

The area under consideration was covered by the continental glaciers belonging to two glaciations during the Pleistocene period. It was covered completely by the South Poland Glaciation (Kansan); whereas, the Middle Poland Glaciation (Illinoian) occurred only on its North part. During the North Poland Glaciation (Wisconsin) the loess formations were deposited in the South part of the discussed area. In this way, the carbonate Cretaceous bed rocks were covered by the thick layer of the Pleistocene deposits. The present soils were created from these layers. Their types depend on the kind of the parent formation.

In the river valleys usually alluvial soils occur, seldom silty soils. On the boulder loam and on the loess formations, the pseudo-podzolic and leached brown soils and on the sands, the rusty podzolized and podzolic soils occur (Dobrzanski B. et al., 1974).

Depending on the soil family, wheat, sugar beets, barley, hemp, tobacco, alfalfa, clover and potatoes are mostly planted on the discussed area. Vegetables and orchards are also of frequent occurence but oats, rye and corn are very rare in this area, (Witek T. et al., 1975, Witek T. et al., 1977).

The soil map of the analyzed area is shown in Figure 1.

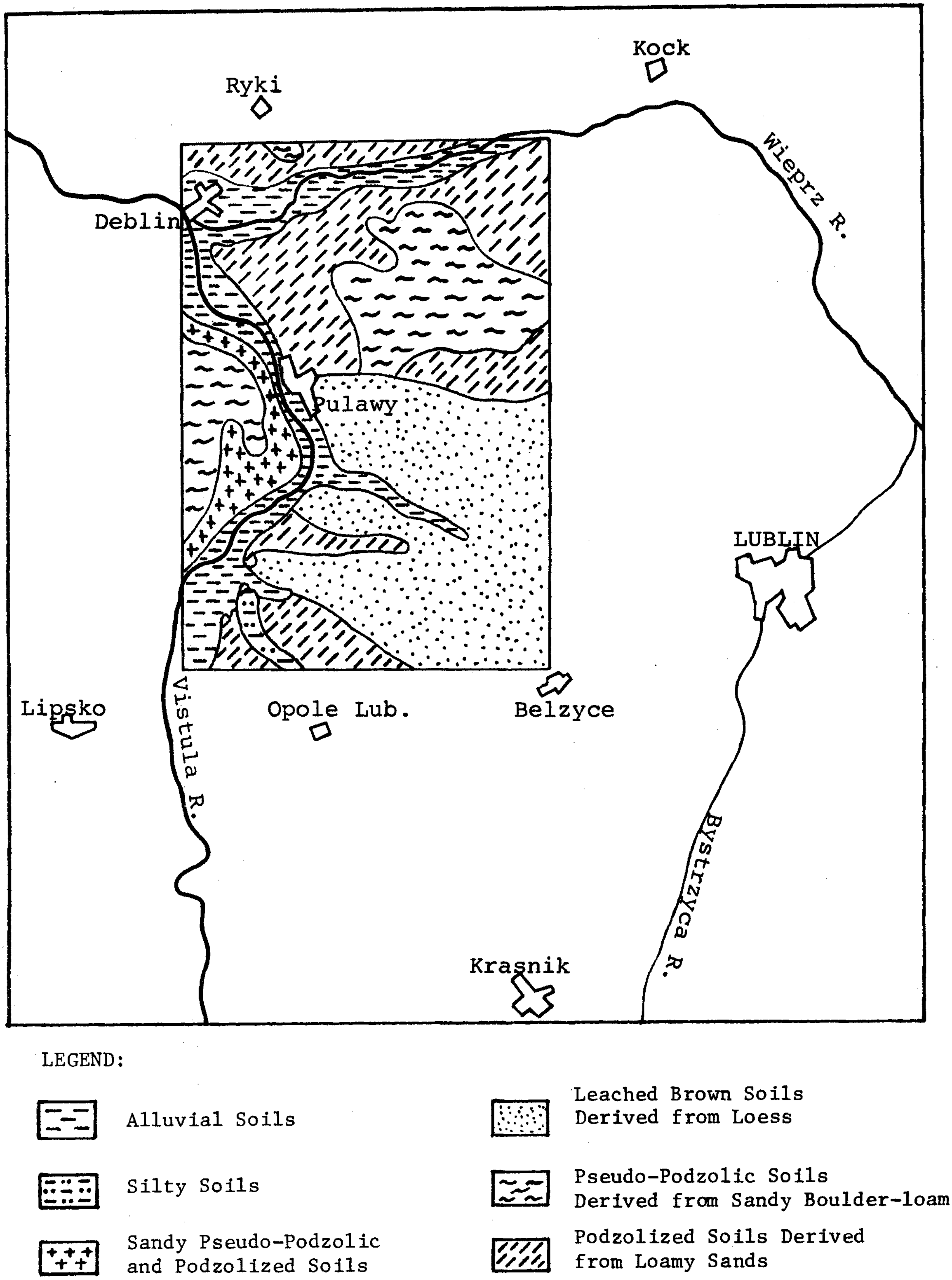


Figure 1. Soil Map of the Analized Area, Scale 1:500,000.

Methodology.

During the digital analysis of the Landsat data for the chosen part of Poland, a Computer Compatible Tape was used.

All computer programs applied during the analysis process were from the LARSYS System which is described in detail in the LARSYS User's Manual (Phillips T.L., 1973).

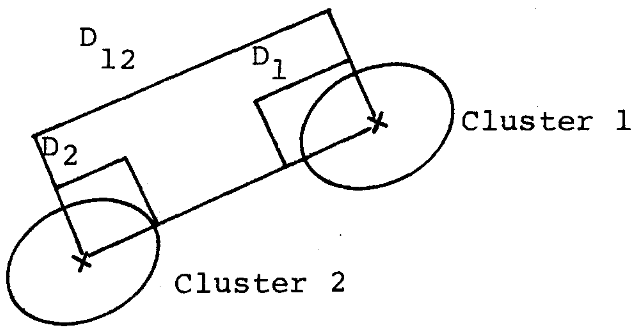
The southeast part of the scene, approximately one-fourth of the total was chosen as the preliminary area to be analyzed. The data from this part of the scene was reformatted to the LARSYS System and geometrically corrected. Then it was displayed on the screen of the Digital Display, using the Imagedisplay processor. This processor generates a black and white image from the particular, pre-defined scanner channels, on the screen. After displaying the data it is possible to take black and white or color photographs of the screen, using Polaroid or 35mm cameras.

When the image was displayed, the area to be analyzed, was selected. A Light Pen was used for this purpose which enables the investigator to input to the computer the coordinates of the four corners of the chosen area. The chosen area contained the images of the agricultural experimental fields, of which ground truth data was available. The satellite data from this area was then printed on the Line Printer in the scale of 1:25,000. The processor used for that step was Pictureprint. It uses the data registered on the Multispectral Image Storage Tape (Phillips T.L., 1973) and enables one to obtain an alphanumeric printout for each specified scanner channel. These printouts are used during the next step of the digital analysis process. Pictureprint provides a maximum of 16 alpha-numeric symbols with which to simulate gray levels pictures. These symbols are predefined by the system or can be specified arbitrarily by the user. In this case the printout for band 5 was obtained and then the non-supervised classification was initialized.

Non-supervised classification.

During the first stage of the non-supervised classification, three test areas were chosen and the processor called Cluster was run for these areas. The area was so small that the number of pixels was less than 10,000, this permitted the printout of every line and every column. The number of classes which were to be identified was assumed to be 17.

Cluster uses the algorithm of non-supervised classification which classifies single points into a predefined number of clusters. This classification is based on the distance measurements from each examined point to the center of the group of points (cluster). All points which lie within the smallest distance from the center of the cluster are classified as belonging to it. After the classifying new points into the given cluster, the new center coordinates are calculated for each cluster and the process is repeated from the beginning until the new center coordinates are computed or until the predefined accuracy is obtained. When the Cluster processor is completed, the information concerning the separability, basing on the statistics, is given to the user. The geometric interpretation of the separability function follows:



$$SF = \frac{D_{12}}{D_1 + D_2}$$

If SF>σ, the clusters are distinct.
σ - standard deviation.

The next processor used was Classifypoints. It was run for the chosen test areas. This processor uses the maximum likelihood algorithm, and classifies single points for particular classes. It utilizes the covariance matrices and spectral characteristics for particular classes and calculates the probability of the particular pixel belonging to a given class. Then, it classifies single points into the most probable classes. The results are registered on the results magnetic tape, the number of which is specified in the program. The user also specifies the number of the file on this particular tape. Besides the classification information, also the information concerning statistics (the description of the training fields, means and variances for particular classes, reduced statistics), the names of the classes and the number of channels are registered on the magnetic tape. The statistics data can be punched on cards using the Punchstatistics option.

Then the processor called Printresults was applied. This processor enables to obtain the printout of the classification results on the Line Printer.

After the comparison between the obtained printout and the road map of the area, it came out that there is almost no differentiation between water and forest areas. So the function Threshold (an option within the Cluster processor) was applied. It allows separation into several sub-classes within the class obtained earlier. This way two new subclasses in water and two in forest areas were obtained. The number of classes increased up to 21. For these 21 classes the new classification was made for the chosen parts of the examined. Several of 21 classes could be recognized basing on the road-touristic map of the area, made in scale of 1:500,000.

As a result of the non-supervised classification the following results were obtained:

1). The classification map of chosen training areas with 17 classes specified.
2). The classification map of chosen training areas with 21 classes specified.
3). The statistics data concerning 21 classes which were punched on cards. These cards were used during the next steps of analysis, the first of which was the initialization of the supervised classification.

Supervised classification.

The supervised classification was started with the Cluster processor which was run separately for three parts of the study area which were covered by the ground truth data. As a result, 20 classes were obtained (18 classes for terrain features and 2 classes of water, along with the statistics data for them.) For all these classes, a program called Ratio was run. This program computes the two following values for each class separately:

1). Magnitude, which is the sum of reflectance of the electromagnetic radiance in all channels of the scanner system.
2). Ratio, which is the ratio of the sum of the spectral reflectance in the visible part of spectrum over the sum of the spectral reflectance in the infra-red part of the spectrum.

On the basis of the above two values it is possible to determine the density of vegetation, the chlorophyll content, the soil moisture and to identify the non-vegetated areas and water areas. (Kristof, S.J. et al. 1977). As a result of the Ratio program the spectral characterisitics for pre-identified classes were obtained.

During the next step of analysis, the statistics data obtained after the supervised classification and those obtained after the non-supervised classification were merged. This merging is possible with the use of the Mergestatistics processor which belongs to the experimental version of the LARSYS System.

As a result of this program, the distribution of symbols for each class is obtained on the two-dimensional plane. In this case the axes of the coordinate system are:

- vertically - the average reflectance in the visible part of the spectrum
- horizontally - the average reflectance in the infrared part of the spectrum.

Since, in our case, there were 41 classes (20 classes from the supervised classification and 21 classes from the non-supervised classification), and some of them had very similar spectral characteristics, symbols corresponding with those classes deviated very little from one another. So, the separability information concerning all classes was necessary. The processor called Separability was run for this purpose. This processor gives the information about the pixels distribution for each class, and it calculates transformed divergence value for each pair of classes. This value characterizes the possibility of obtaining the proper classification results based upon the statistics. It is assumed that 100% accuracy of classification can be obtained when the transformed divergence value is equal to 2000. In practice it is enough to obtain the classification results with accuracy of 90 to 95%, so the transformed divergence value can be smaller and equal to 1750, for example. The Separability processor lists all pairs of classes for which the transformed divergence value is less than the predefined value. On the basis of these calculations one can find the classes which should be combined or deleted.

As a result of the Separability processor, the information was obtained that some of the 41 classes are impossible to be separated. Some of them had to be deleted and some of them had to be combined with other classes. The options called Delete and Pool were applied. This process was repeated several times, but the results were not fully satisfactory, even when the number of classes was reduced to 18. Some of the agricultural classes were impossible to be separated. The reasons for that will be discussed later.

The Classifypoints processor was run for 18 classes. As a result, the classification map of the whole study area was obtained. The following classes were determined: residential A and B, industry, man-made, corn, potato A and B, barley, wheat, crops A and B, grass A and B, tree/grass, forest A, B, and C and water.

During the last step of the digital analysis some of the classes obtained after the supervised classification were combined, since they had almost the same spectral characteristics (for example barley and wheat were combined into class "cereal"). As a result of this operation 14 classes were obtained. They were as follows: urban areas, industry, open area, tree/grass, grasses, cereal, two classes of root crops, legumineous/gramineous plants, mixed crops, three classes of forested areas and water. The classification map of the entire study area with 14 classes was obtained. It was the last step of the digital analysis of the Landsat data for the chosen part of Poland.

After that the colors for the color copy which was to be obtained on the Laser Digital Recorder were specified, data was reformatted to the required scale. Two parts of the area were chosen to be color copied: Pulawy region (in scale of 1:25,000 and entire study area (in scale 1:100,000).

Results and discussion.

Spectral characteristics (the values of spectral reflectance in particular bands, magnitudes and ratios) and the ground truth data were the basis for separating 5 main land cover types. They were as follows:

1) Water
2) Built-up areas
3) Forested areas
4) Areas covered by mixed woody, shrubby and grassy vegetation
5) Agricultural land.

These main groups were then separated into more detailed classes.

Water. Since water areas were not of particular interest, they all were classified into one class characterized by low/medium magnitude and the highest ratio.

Built-up areas. Two classes were separated within this group:
- industrial areas, characterized by the highest magnitude and medium ratio,
- urban areas, characterized by the high/medium magnitude and medium ratio.

Forested areas. Three classes were distinguished within the forested areas:

- deciduous forest, characterized by medium magnitude and low ratio,
- mixed forest, characterized by slightly lower magnitude and higher ratio than the values obtained for deciduous forest,
- coniferous forest, characterized by medium magnitude and medium/low ratio.

Areas covered by mixed woody, shrubby and grassy vegetation. Two classes were separated within this group:
- open area, characterized by medium magnitude and medium ratio,
- tree/grass, characterized by medium magnitude and medium/low ratio.

Agricultural land. The following classes were distinguished:
- grasses, characterized by high magnitude and low ratio,
- cereal, characterized by medium/high magnitude and low ratio,
- gramineous/legumineous plants, characterized by medium/high magnitude and medium/low ratio,
- mixed crops, characterized by slightly lower magnitude and higher ratio than in the case of gramineous/legumineous plants,
- root crops A, characterized by high magnitude and medium ratio,
- root crops B, characterized by medium/high magnitude and medium/low ratio.

The comparison of magnitudes and ratios for all classes is shown in Figure 2. The values of spectral response in four Landsat channels for all distinguished classes are shown in Figures 3,4,5,6.

The presented classification is not over-detailed. It was influenced by the following factors:

- the ground truth data concerned only certain crops and in just one portion of the growing season, this directly influenced the canopy size,
- the satellite data was not multitemporal,
- the satellite data was acquired in June. In this time of year in Poland it is possible to distinguish cereals very easily. The root crops, hemp and corn, are in the preliminary growing season, so very strong reflectivity of the underlying soil is visible on the datellite imagery,
- agricultural farms on the classified area are mostly smaller than 10 hectares,
- agricultural farms are not compact; they consist of several smaller fields, mostly narrow and elongated, with several different crops planted on each of them,
- different sowing dates significantly influence the differences in the growing stages.

In this particular spectral analysis the real land cover was not represented, due to the difficulties mentioned above. The highest accuracy was obtained for water, which can be visible on the satellite image even for very small areas, approximately 1 hectare (Otterman J. et al., 1976). High accuracy was also obtained for forested areas which are very easy to distinguish from surrounding fields. After the comparison of the classification results with the available cartographic materials, it turned out that the urban areas are classified with relatively low accuracy, because of large green areas (trees, shrubs and grasses) existing in towns. As for the industrial areas class, this included the factory areas and very strongly reflecting bare soils and river deposits, consisting of clear, washed out, yellow quartz sands.

The areas with sparse vegetative cover, with bare soils and concrete were classified into the "Open area" class. For example: railroads, the periferal vicinities of factories, towns, young forest and clearings in forests were included into this class.

Class "Tree/grass" included areas covered by mixed arborescent-grassy vegetation. Orchards, large green areas in towns, areas surrounding big forest complexes were classified into this class. In Poland it is very difficult to determine the border between forest and surrounding areas. Even if it is possible, the border is very complicated geometrically. Because of that, on the satellite image, mixed spectral response from trees, shrubs, grasses and agricultural fields is obtained.

Several classes included in the group "Agriculture" were very easy to be distinguished. They were: cereal, gramineous/legumineous plants and mixed crops. Cereal and gramineous/legumineous plants are very easy to be distinguished in June, since they are green

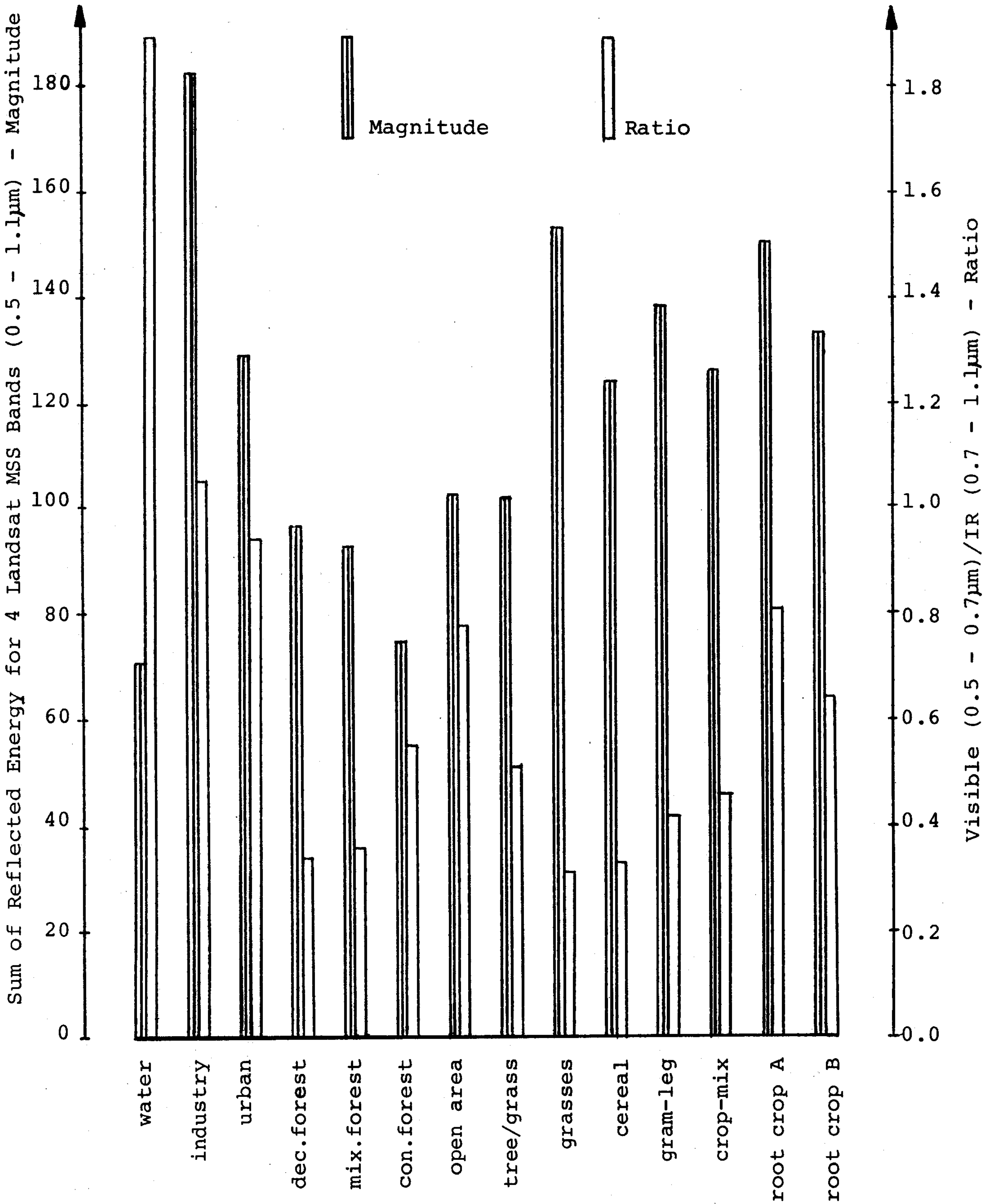


Fig. 2 .: Comparison of magnitudes and ratios for 14 land cover classes.

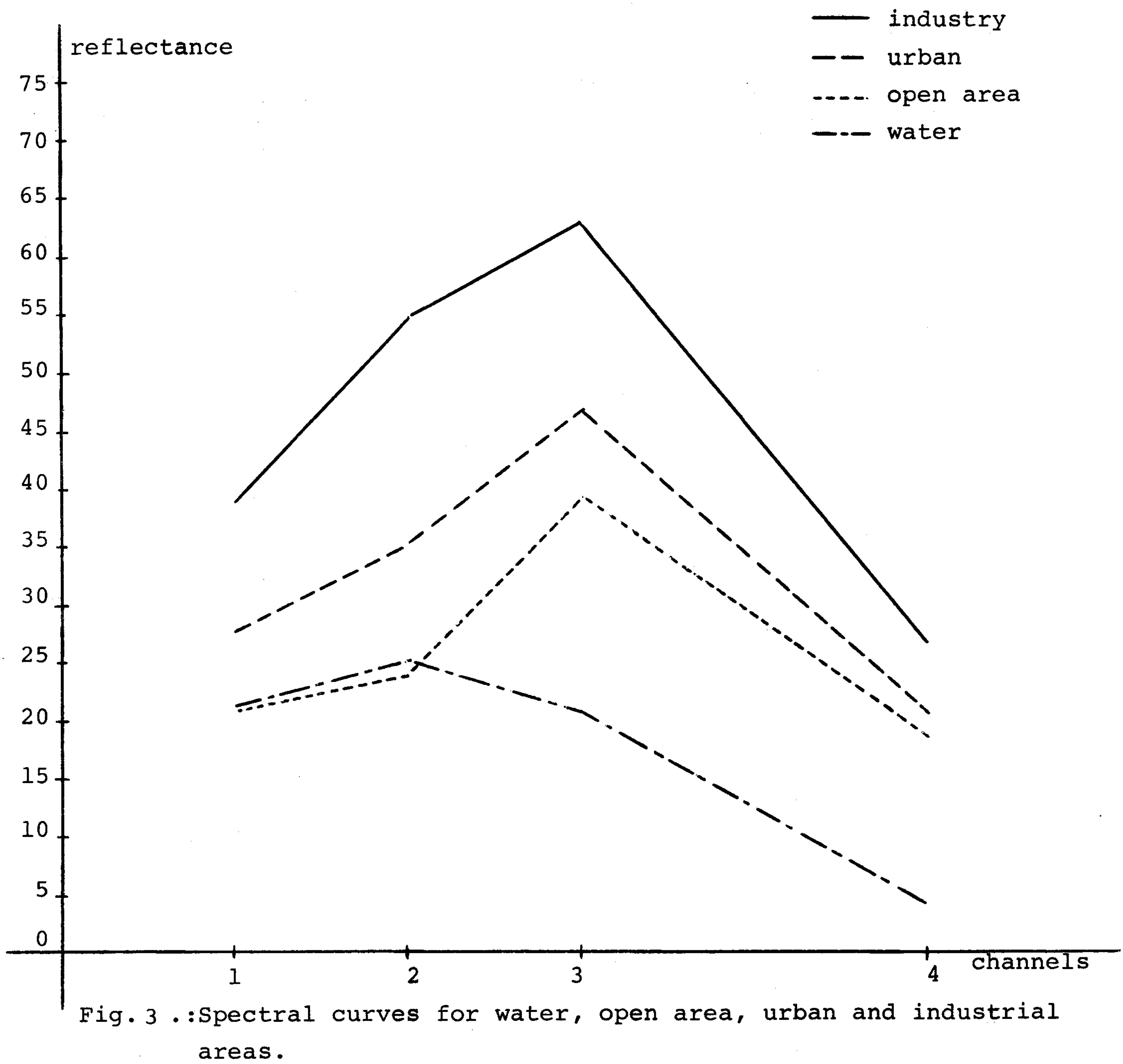


Fig. 3 .:Spectral curves for water, open area, urban and industrial areas.

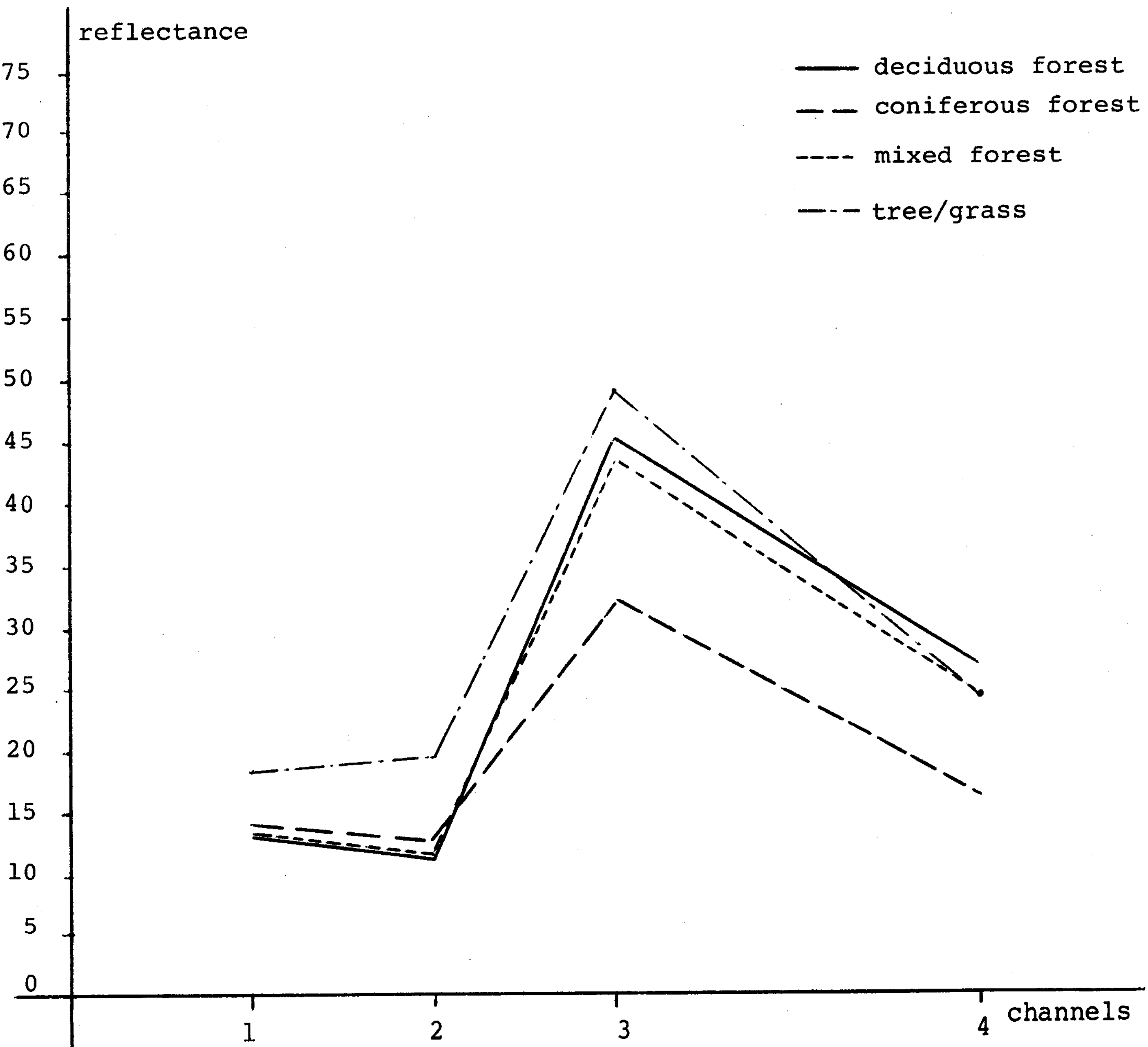


Fig. 4 .:Spectral curves for forested areas and tree/grass.

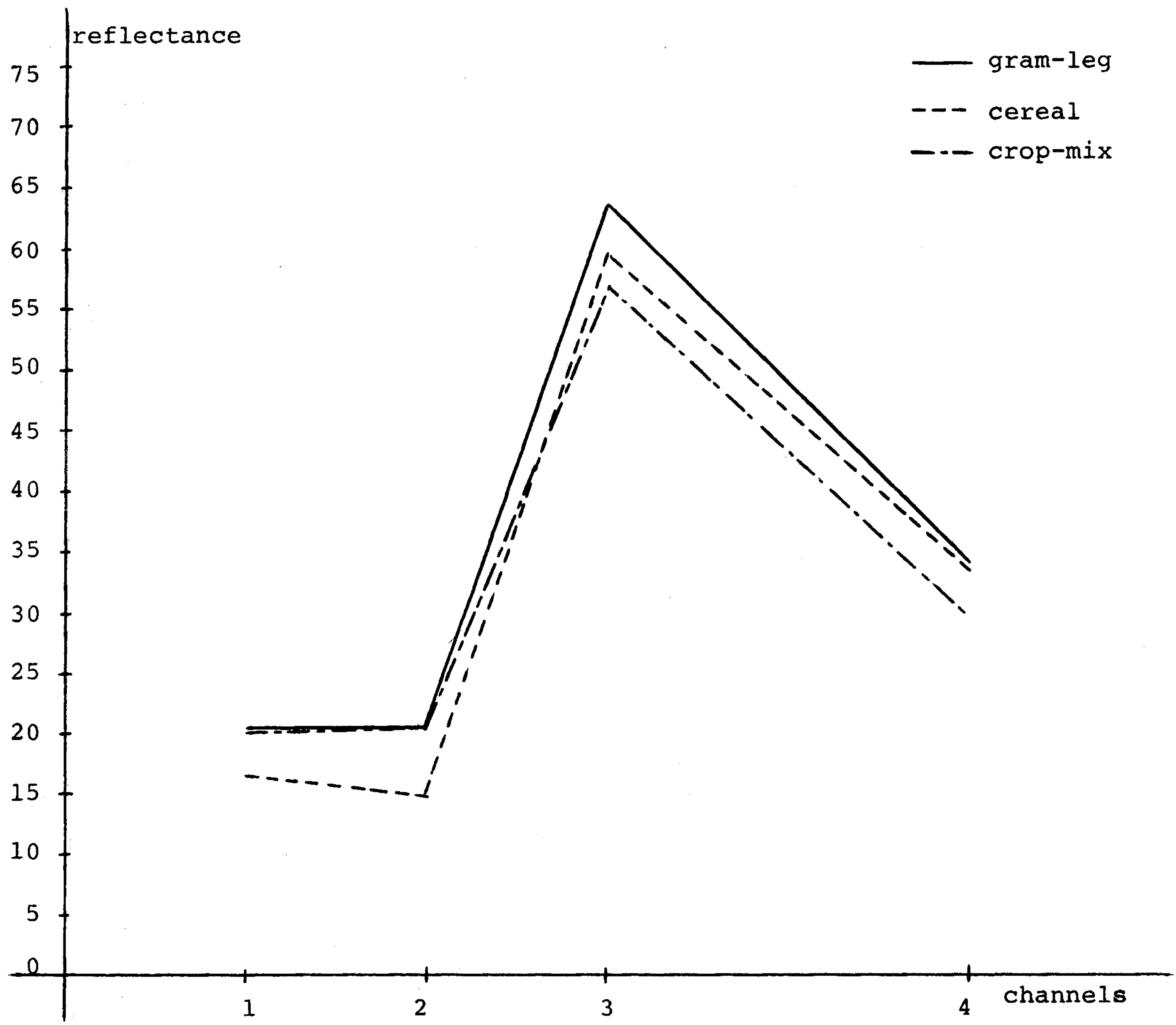


Fig.5.:Spectral curves for cereal, gram-leg and crop-mix.

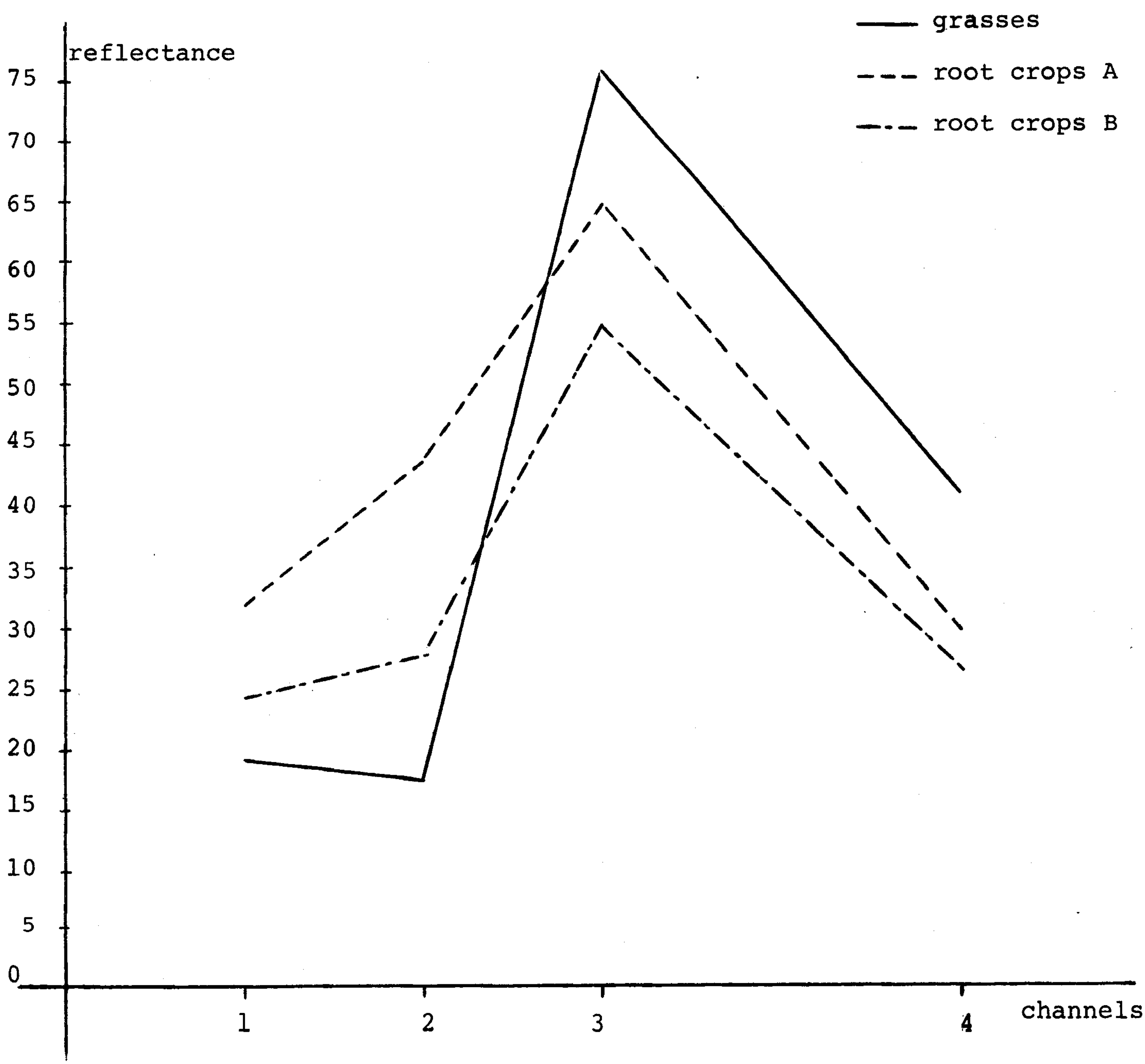


Fig. 6 : Spectral curves for grasses , root crops A and root crops B.

and completely cover underlying soil in this time of year. Class "Mixed crops" produces mixed reflectance for different crops. It is in agreement with reality, since this class includes approximately 1/3 of the whole analyzed image.

Different types of grasses and clover were classified into the class "Grasses". It must be considered that the date of the acquisition of the satellite data coincides with the blooming season for clover. Because of that some fields which should be classified into the class "Grasses" are probably classified into completely different classes. Potatoes, corn and hemp (which are included in the ground truth data) were classified into classes "Root crops A" and "Root crops B". Probably, sugar beets, cabbage and tobacco were also classified into these classes. Unfortunately, ground truth data was not available for these plants. It is difficult to say, which of the mentioned crops were classified into classes "A" and "B". It is probable that all of them can belong to both classes. The assignment to a particular class is determined by the size and density of plants and type and moisture of soil, since for both classes very strong reflections from soil are noticeable.

For the presented classification, 14 distinguished classes seems to be the optimum number. The classification of agricultural areas could be more detailed if multitemporal satellite data and accurate ground truth data were available.

Conclusions.

1. For Polish conditions, in June it is very easy to distinguish cereals, but it is very difficult to distinguish root crops, corn and hemp.

2. The type and moisture of soil are factors which significantly influence classification results.

3. Urban areas are not very distinguishable on the satellite image.

4. The "Ratio" and "Magnitude" functions are very helpful for the distinguishing of the particular classes.

5. In specific Polish conditions, where acreages of agricultural fields are mostly small, the accuracy of crops identification is relatively low. One-third part of the analyzed area was classified as mixed crops, (it is approximately 42% of the agriculturally cultivated area).

6. For the accurate distinguishing of classes, optimum quantity and quality of ground truth data is necessary. It should concern all crops during the whole growing season.

7. For the maximum accuracy of classification results with use of satellite data for agricultural purposes, multitemporal satellite data is necessary.

8. For the present satellite systems it is easy to separate fields of the acreage 4 hectares and more, but the smaller fields can be impossible to be distinguished.

9. More accurate results of crop inventory could be obtained with use of satellite MSS systems with much higher resolution capabilities.

WNIOSKI

1. Na obrazach satelitarnych uzyskanych w trzeciej dekadzie czerwca z ternu Polski stosunkowo latwo mozna wyroznic uprawy zbozowe, natomiast identyfikacja roslin okopowych, kukurydzy i chmielu jest powacnie utrudnoiona.

2. Glownym czynnikiem wplywajacym na wynik klasfikacji upraw okopowych, kukurdzy i chmielu w analizowanym okresie jest gleba, a szczdgolnie jej rodzaj i wilgotnosc.

3. Obszary miejskie w obrebie analizowanego terenu nie uwidaczniaja sie dobrze na obrazie satelitarnym.

4. Funkcje "Ratio" i "Magnitude" sa bardzo pomocne przy wydzielaniu poszczegolnych klas pokrycia terenu.

5. W specyficznych, polskich warunkach, gdzie gospodarstwa rolne sa w przewazajacej wiekszosci niewielkie i rozdrobnione, dokladnosc identyfikacji upraw jest stosunkowo niska. Na analizowanym terenie 1/3 jego ogolnej powierachni zostala sklasyfikowana jako uprawy mieszane, co stanowi okolo 42% obszaru kultywowanego rolniczo.

6. Dla uzyskania dokladnych wynikow klasyfikacji wymagana jest duza ilosc danych terenowych i archiwalnych, zawierajacych maksimum informacji o analizowanym terenie.

7. Dla uzyskania klasyfikacji o duzej dokladnosci konieczne jest analizowanie danych satelitarnych zebranych w roznych okresach wegetacji.

8. Obecnie stosowane skanerowe systemy satelitarne rozrozniaja w obrazie refleks pochodzacy z homogenicznego pola w postaci przynajmniej jednego pixela tylko wtedy, kiedy to pole ma powierzchnie 4 ha lub wieksza. Pola mniejsza sa praktycznie nierozroznialne.

9. Zastosowanie skanerowych systemow satelitarnych o zwiekszonej rozdzielczosci umozliwi osiagniecie wiekszej dokladnosci identyfikacji upraw.

Acknowledgements.

The presented 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 express their appreciation to Dr. S. J. Kristof, Prof M. F. Baumgardner, Dr. L. A. Bartolucci-Castedo and the entire staff of LARS for the assistance provided during the project.

The authors would also like to gratefully acknowledge the helpful assistance provided by the staff of the Agricultural Academy in Lublin and the Institute of Soil Science and Cultivation of Plants in Pulawy for their assistance in obtaining ground truth data.

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296    &7EQNNXEK&7SK37R&EEKQQQES====)--7S77333&3XS3I&&&&&3&KK3KK3EEKKQ
297    K3NNNNNN&&)II=SS  E3SEEE3I==S=S)I33=77&)&EES=)I)K3SKK3E3KKK3ENNN
298    NMNNNNNNN77I=   ==X==&)))))IESXNSS33337&&33S=&&))3&3EK3SE3&&3KNNN
299    MMQMMQNNX  =           =)))&NXXSXN3NK&33)&&77&&77773&3EKEE3&3&&&3&)
300    MMMMMMMMN              =)-)&NNQQNKNK&3I7&&773KK737333XEEXS3&&&)&&)&
301    MMMMMMMMX              S7=XXNK&&NNKK&733I7=EE37=33773XNEE33&3&33E33
302    MMGQMMMNM            XXXXXSS--IKNK)))33III=II337373EEESX333E33&3E&
303    KEKKK37ENX     X     X X      I--XXEE&)3)&))&I&K3K))K3&&&33K3K)&K3I37
304    MMMK&KQQNNNNXXXXX          &IXXXXXX3&3))))3))&3EK&I33&3EEKK&33&3KQK)
305    MMMMMMMMQMMMXX             )-IXXXXE)IE)))&3)&33&3333))7EE&&3&&KK&)3
306    MMMMMMMQMMQQN              =IMMXXXE773I733&333E&3S33I))I7&K&&&K3E3KE
307    MMMMMMMQRRQMQX              XXN)33E77I7=73SE33EK&E3333&&&&7&&K&)IKK
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309    KN&&&RRQQQQQRS      XXI==SXS7--RKE7SI77I33I)37S7I37)I733)I)-)77&7
310    33&KKRQRQNXXR3     XXXS==    XX33EQRXXE==777II73IIIII))I&3II&I7EEEX
311    EE&RKQMQNNNNRRSS7====I          XNQR)&EE=7IIII77III77=-3I)II3373EEX
312    EKKNNMMQNMMNKREE&77--I==         XNKK&3KXX3E37III7SII-I73IIIII)3ES3
313    NNNENQMMMMMQNNE33E3)-I--         SENK3EEEKKNNII33N3===S7&-II)))))77
314    N3)&&EMMMMMMMQKEE&3I---=        777EIS=XKKNNKNSXXXNNXXX&KQ&SII---)I
315    K)&)&3EKNNNMN33E&&KI---=       S&33&7SIXENXXKKNNESXEXXXENNXS3737))-
316    K33&)KKKQNNNNN3E37XS--=        SKN7E73ISS7E)NN3&)X=IISEI3EENEENSI3=
317    33KKK&&KKEK33EEXS7S3SS3SX       S777))I3S333I77III==7=)I)IISEK&3XSS
318    E3&3QK&R&&3EEEE337SE3SXI7XXX3II3&)I3I)77I737I7==I=I&I-II-III737
319    E&)NN&&)&&&KE7EE=I737XE773ESXI3333 7)7S77I333I777S=77IIIII-IIIII
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322    NK))N3KK&&&)3E37S7)37EKK&33&SEKESS7777=I)3377EES=I&&&I7&&I)I===
323    NN3)3)&3)&337E3377)&KK3K37IISXSS7SEES7=73337)IEI=I&)7I)&&)))&&7
324    E)&&&&EE3KNEI7)7ES)K333&3))33SSSXSSEEKSS=3S&&7&7=I3&EI)&73))&33
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337    QMMMMMMMMMRNE73E7=EQQKNMMM&KKKKKKEENEEE3EIEE3ENNNSNNXXNE7I-IIS7
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347    MQMQQQMMMMQNNE&KNQMQKKEEEEEEEKK3&E3EEEE3&E3)&&3E&3SEEKK&K3)-)I&7
348    MQQQQQQMMMK&ENK&&NQKKK&&KENSEEE&33EEK7&3&)3I))&EEEEEE&I&&3&)&3K7
349    QQRQQMMQQRKNEE&&3KQQ&K))KKESEEKKEKKEK&&)&I&7&&KKKE3KE)&&)E&&&))
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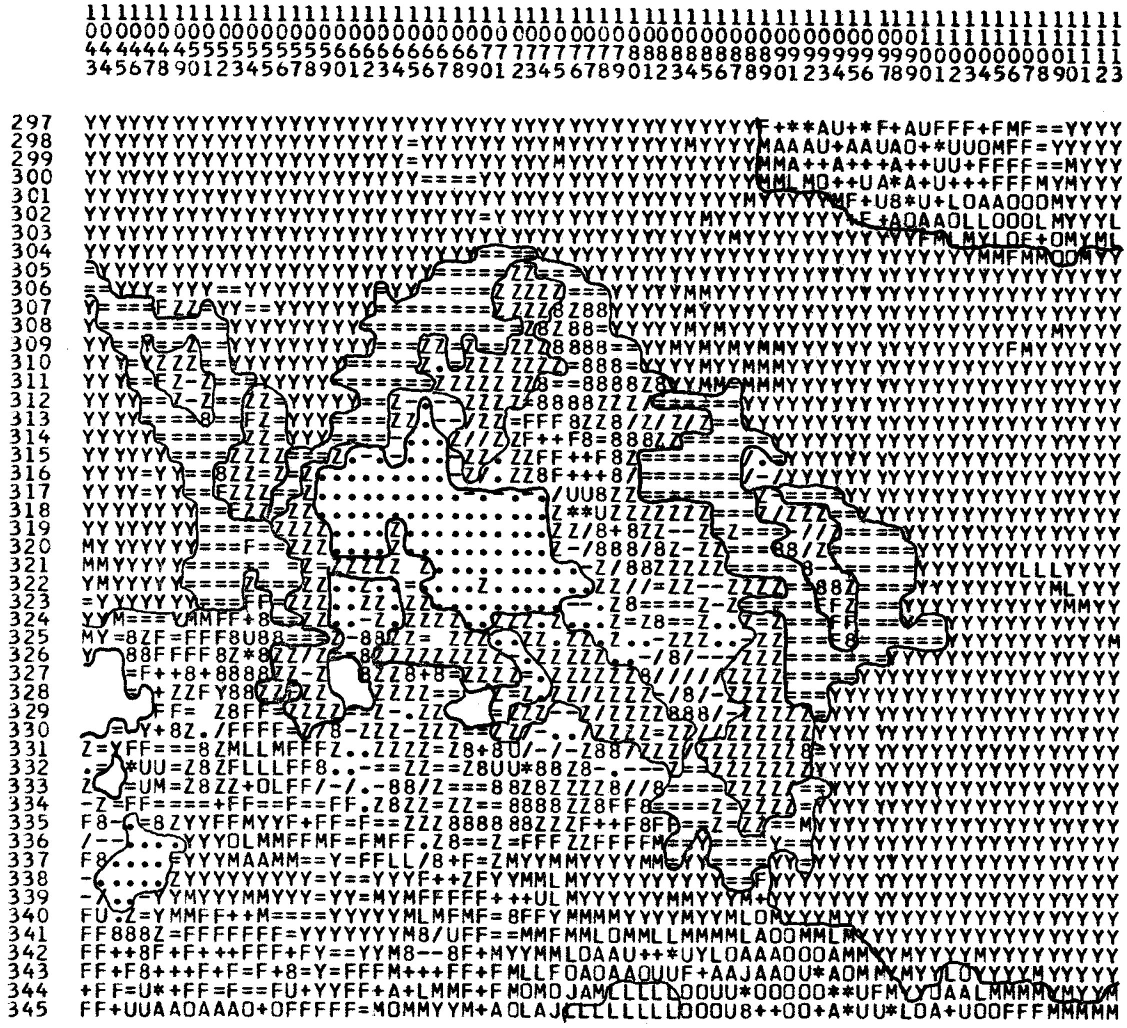
```

Figure 7. Cluster map for Osiny training area.

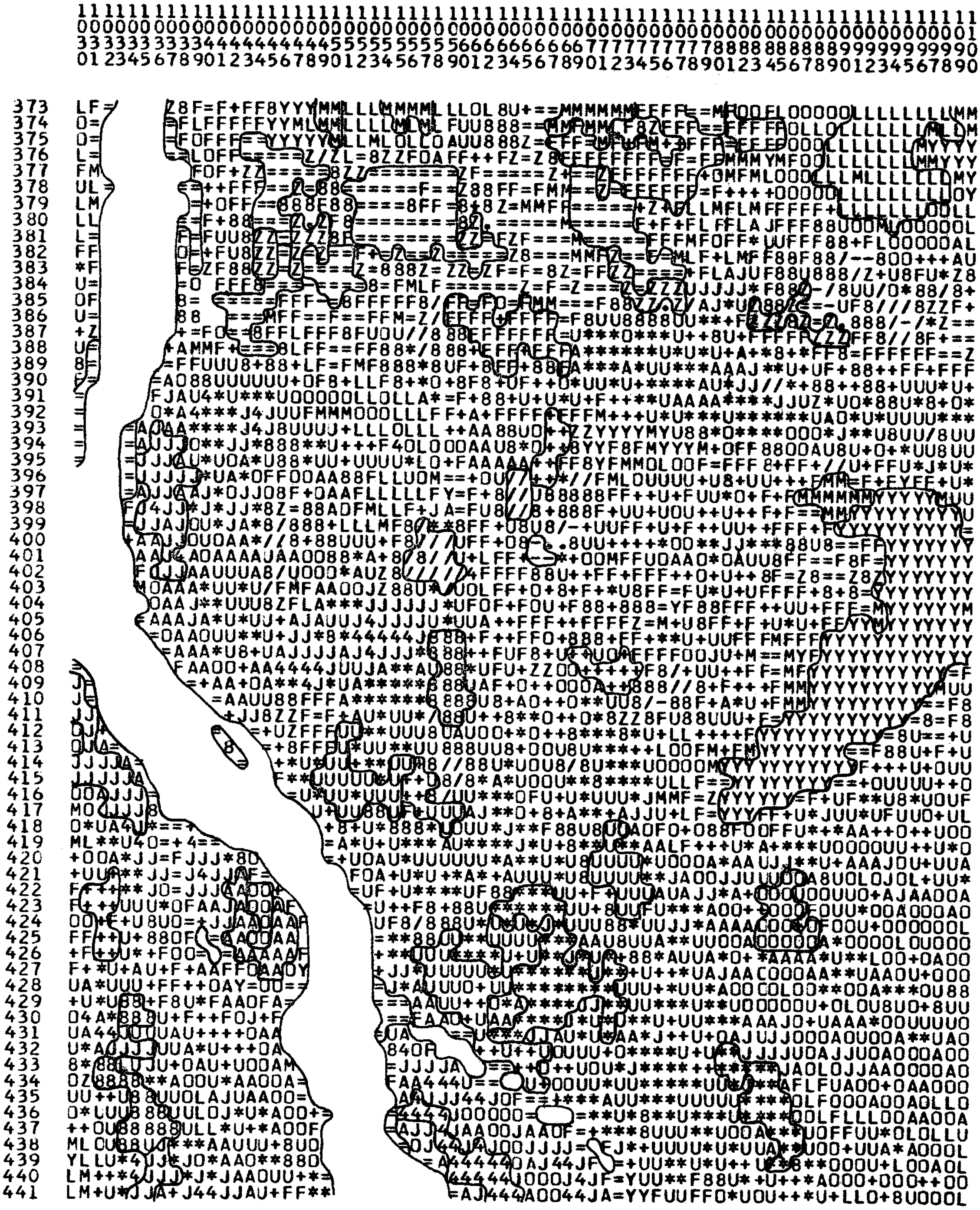


NUMBER OF POINTS DISPLAYED IS 3479

Figure 8. Sample of the classification map for Azoty area.

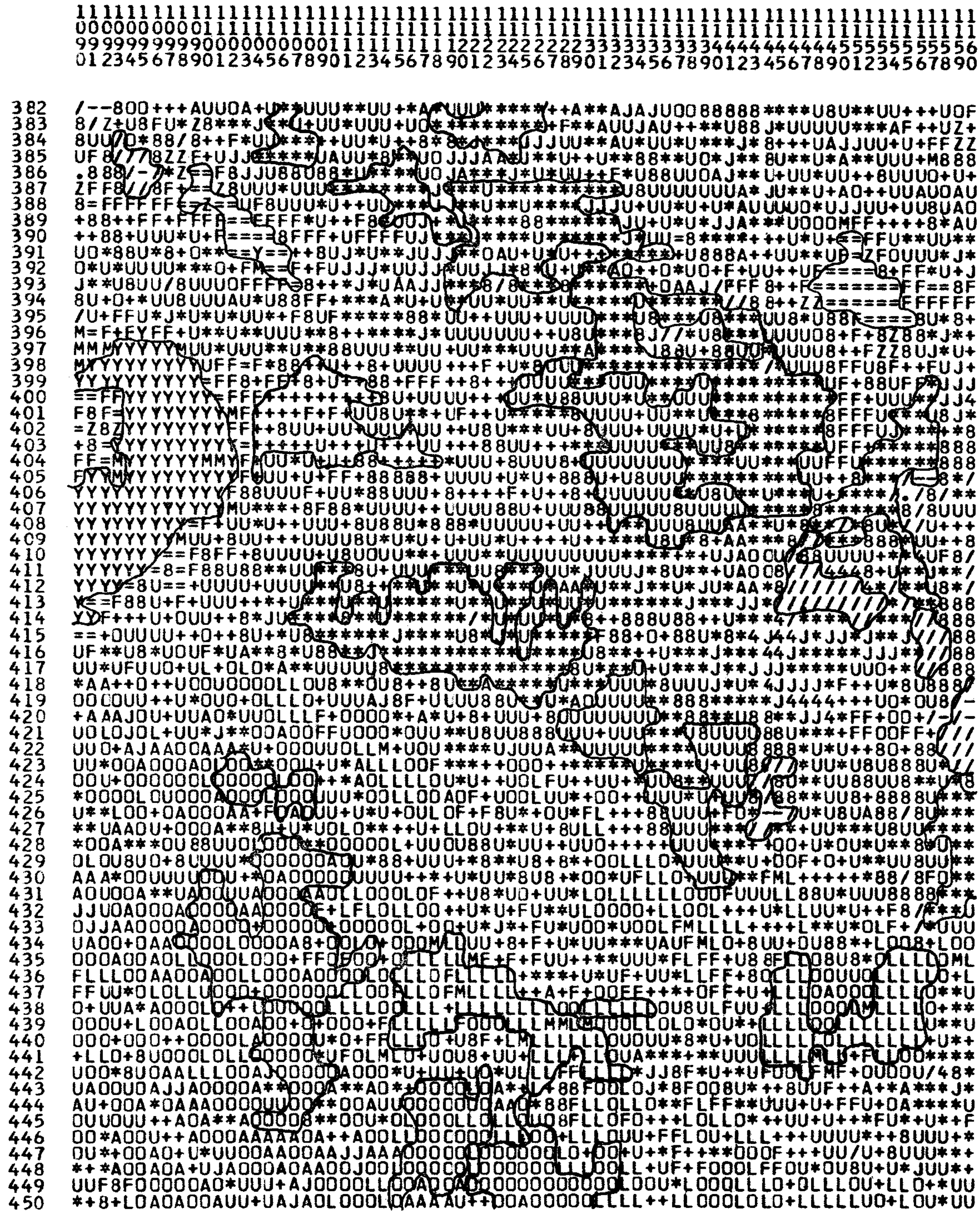
- - water	F - tree/grass
. - industry	4,J - grasses
Z - urban	O,A - cereal
L - deciduous forest	* - gramineous-legumineous
M - mixed forest	+,U - crop mix
Y - coniferous forest	-,/ - root crops A
= - open area	8 - root crops B

This legend is for Figures 8, 9, and 10.



NUMBER OF POINTS DISPLAYED IS 4899

Figure 9. Sample of the classification map for Pulawy area.



NUMBER OF POINTS DISPLAYED IS 4899

Figure 10. Sample of the classification map for agricultural land.