NASA Technical Paper 1371

Eulusmap; an International Land Resources Map Utilizing Satellite Imagery

T. Paludan and E. Csati

DECEMBER 1978

NASA

NASA Technical Paper 1371

Eulusmap; an International Land Resources Map Utilizing Satellite Imagery

T. Paludan
George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama
and
E. Csati
Institute of Surveying and Mapping
Budapest, Hungary

NASA
National Aeronautics
and Space Administration
Scientific and Technical
Information Office
1978

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF TABLES

NASA TECHNICAL PAPER

EULUSMAP; AN INTERNATIONAL LAND RESOURCES MAP UTILIZING SATELLITE IMAGERY

HISTORICAL BACKGROUND

Many of the Earth's resources considered vital to man's existence and comfort are directly related to man's use of land – land use – or, more precisely, land resources. In recognition of this, studies of land resources have been under way for hundreds of years. However, as frontiers were developed or closed to further exploitation, the optimization of land resources became more vital. Unless the space colonization proposals originated by G. O'Neill materialize, the rationalization will become more acute.

The period of the 1930's and 1940's saw the beginnings of comprehensive national land-use surveys, many inspired by the leadership of Sir L. Dudley Stamp of the United Kingdom. In 1949 the International Geographical Union (IGU) established a Commission on World Land Use Survey (WLUS). The WLUS Commission established a standard classification system and a goal of world survey and mapping at a scale of 1:1 million (Geographical Journal, 1950). ". . . . but this idea faded with the abandonment of the map." (Clark, 1976). The progress of the WLUS was documented by UNESCO, The Shell Company and by Monographs and Occassional Papers published by Geographical Publications, Ltd. The most recent publication of the WLUS Commission was a report to the IGU General Assembly in Moscow (World Land Use Survey Commission, 1976).

With WLUS Commission encouragement, a number of land-use maps were produced – usually of relatively small areas and by utilization of ground surveys. The decision during the early 1970's by the National Office of Lands and Mapping in Hungary to sponsor a land-use map of Europe represented one of the most ambitious projects of this nature ever proposed. The World Map (WM) at a scale of 1:2 500 000 was chosen as a base map. In 1972, the WLUS Commission, under the Chairmanship of Prof. H. Boesch of Zurich, meeting in Montreal, selected this project, known as Eulusmap, as one of five major projects sponsored during the 1972-1976 period. The organization for international participation was accomplished in 1973-1976. Acknowledgement of the extensive contributions of many scientists and national institutions is too lengthy to give here, but is documented in an earlier report (Csáti, 1976, pp. 59-61).

INFORMATION RECEIVED

Contributions ranged from complete national map-manuscripts, to various source materials, to nothing. Twelve countries (Austria, Belgium, Bulgaria, Czechoslovakia, Denmark, Federal Republic of Germany, German Democratic Republic, Hungary, Ireland, Poland, Spain, and United Kingdom) prepared maps especially for this purpose, using common nomenclature. For various reasons, no liaison was established with Greece, Turkey or Albania; therefore, information on them was derived solely from Landsat imagery. European parts of the Soviet Union were deliberately omitted for two reasons: (1) matching WM sheets presenting areas around and north of 60 deg latitude to southern territories may not be performed without total transformation of the northern parts, and (2) WM sheets covering parts of the Soviet Union toward the Ural and Caucasus Mountains (Europe/Asia boundary) were not ready when the work was carried out in 1973-1974.

By mid-1974, it was obvious that gaps in the map would exist unless additional data were found. Landsat-1, launched in July 1972, had, by that time, acquired cloud-free imagery of most of the missing areas. Of equal importance, a number of researchers had devised techniques for theme extraction from Landsat data. The authors of this paper were able to adapt these in a satisfactory manner (Csáti and Paludan, 1976). Figure 1 shows the approximate (usually referred to as "nominal") centers of Landsat scenes of Europe. Since individual images are romboidal, approximately 185 km on each side, there is considerable overlap between adjacent paths, especially at the northern latitudes. The numbering system shown in Figure 1 has become a recognized standard – the "nominal scene number" – when the path number is listed first, followed by a dash and the row number. Thus, for example, Dubrovnik is located in the southwest portion of Nominal Scene 201-030 and the southeast portion of Nominal Scene 202-030. Figures 2 and 3 illustrate examples of these two scenes. Figure 2 shows the "infrared" band, and Figure 3 shows one of the "red" bands. These are from Landsat's four-band multispectral scanner.

ANALYSIS

The larger percentage of Eulusmap was composed by adaptation of map manuscripts furnished by cooperating individuals and national institutions. This was accomplished at the Geocartographic Research Department, Institute of Surveying and Mapping, Budapest. This report concentrates on the lesser percentage – that composed from analysis of satellite data.

Under sponsorship of the International Geographical Union and with the cooperation of the employing agencies of the two authors (the U.S. National Aeronautics and Space Administration/George C. Marshall Space Flight Center and the Hungarian Institute for Surveying and Mapping), the Landsat analysis was accomplished in Huntsville and Budapest during the period 1974-1976.

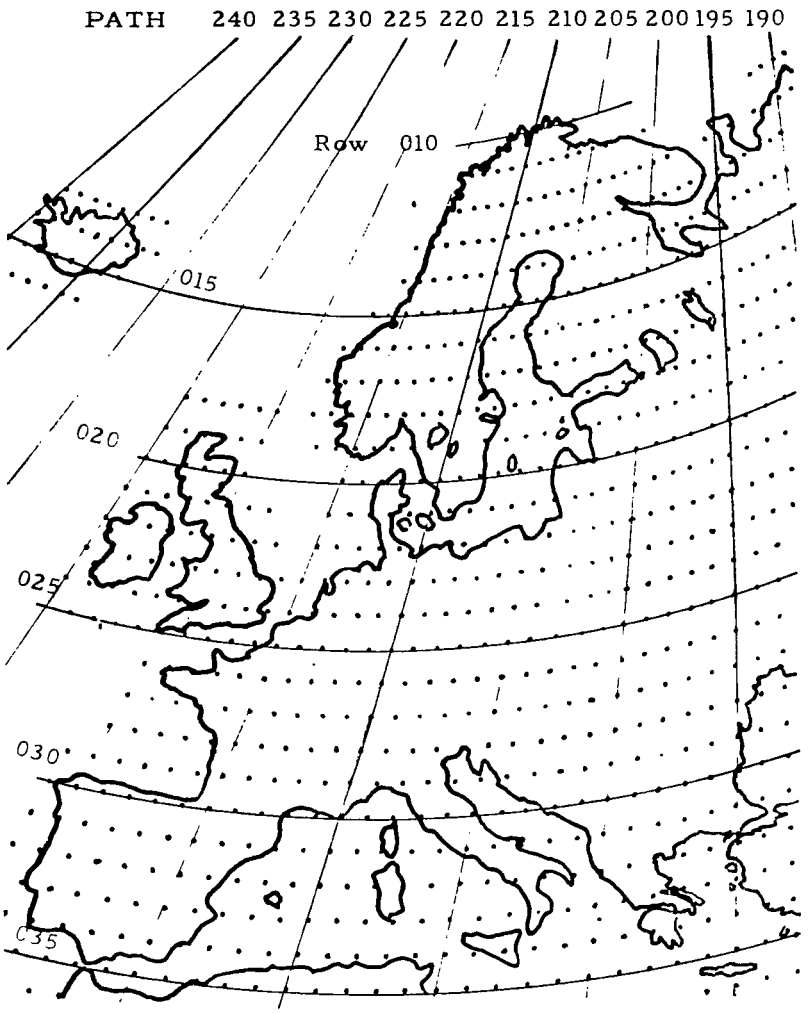

Figure 1. Nominal Landsat scene centers.

Although the authors were aware of the several automated Landsat data analysis techniques, resources available at the time precluded their application. The analysis was purely photogrammetric. In Huntsville, a color additive optical projector was available which permitted the creation of false color images from two or three of the spectral bands. In Budapest, a technique of combining several bands by means of overlaying Diazo colored films was devised; the latter technique was described in detail at a recent Congress of the International Cartographic Association (Csáti, 1978). A similar technique has also been described by researchers at the University of Missouri (Whitebay and Mount, 1978). The theme extraction analysis was then performed using enlarged or magnified false color images. The final product was a map of Europe printed in color on four sheets in May 1978. A black and white detail of the map is shown in Figure 4. It

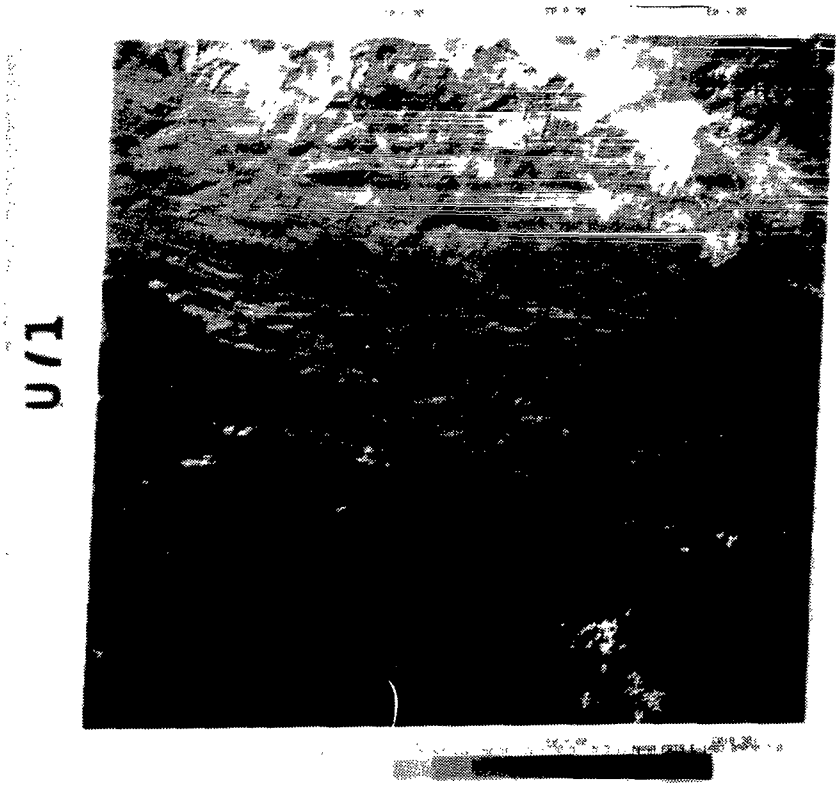

Figure 2. Scene 202-030 in infrared.

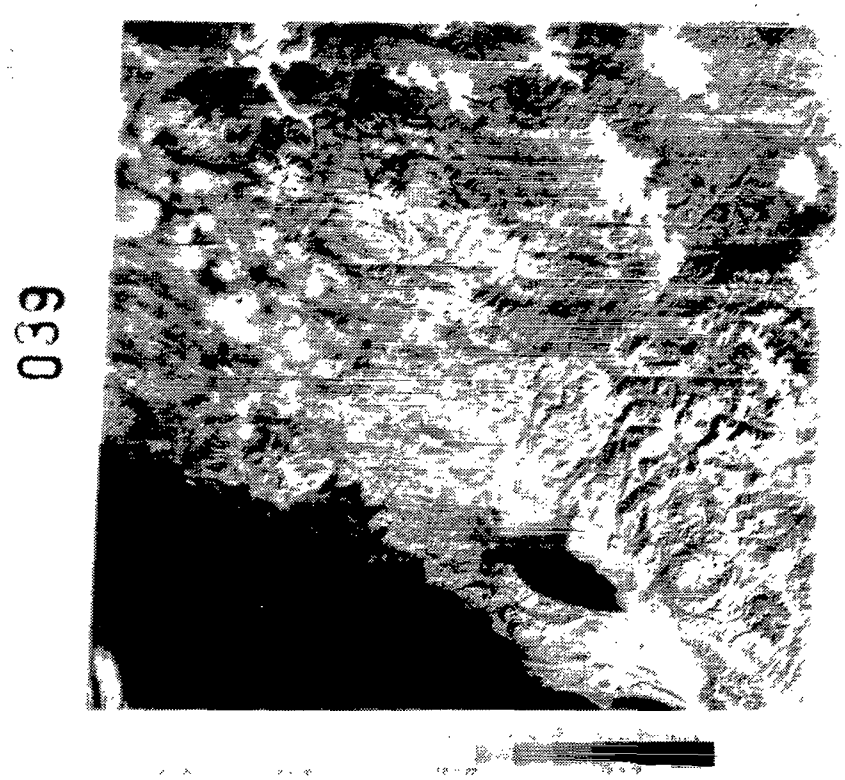

Figure 3. Scene 201-030 in red.

must be noted that recognition of the land-use codes is not possible on this illustration due to the lack of color. The four sheets, each approximately 67 X 97 cm can be trimmed and mosaicked into a single map approximately 1.32 X 1.90 m. It reaches from Iceland to Crete and part of Turkey, from Spain to Norway and Finland. All legends are given in four languages: Hungarian, English, French, and Spanish.

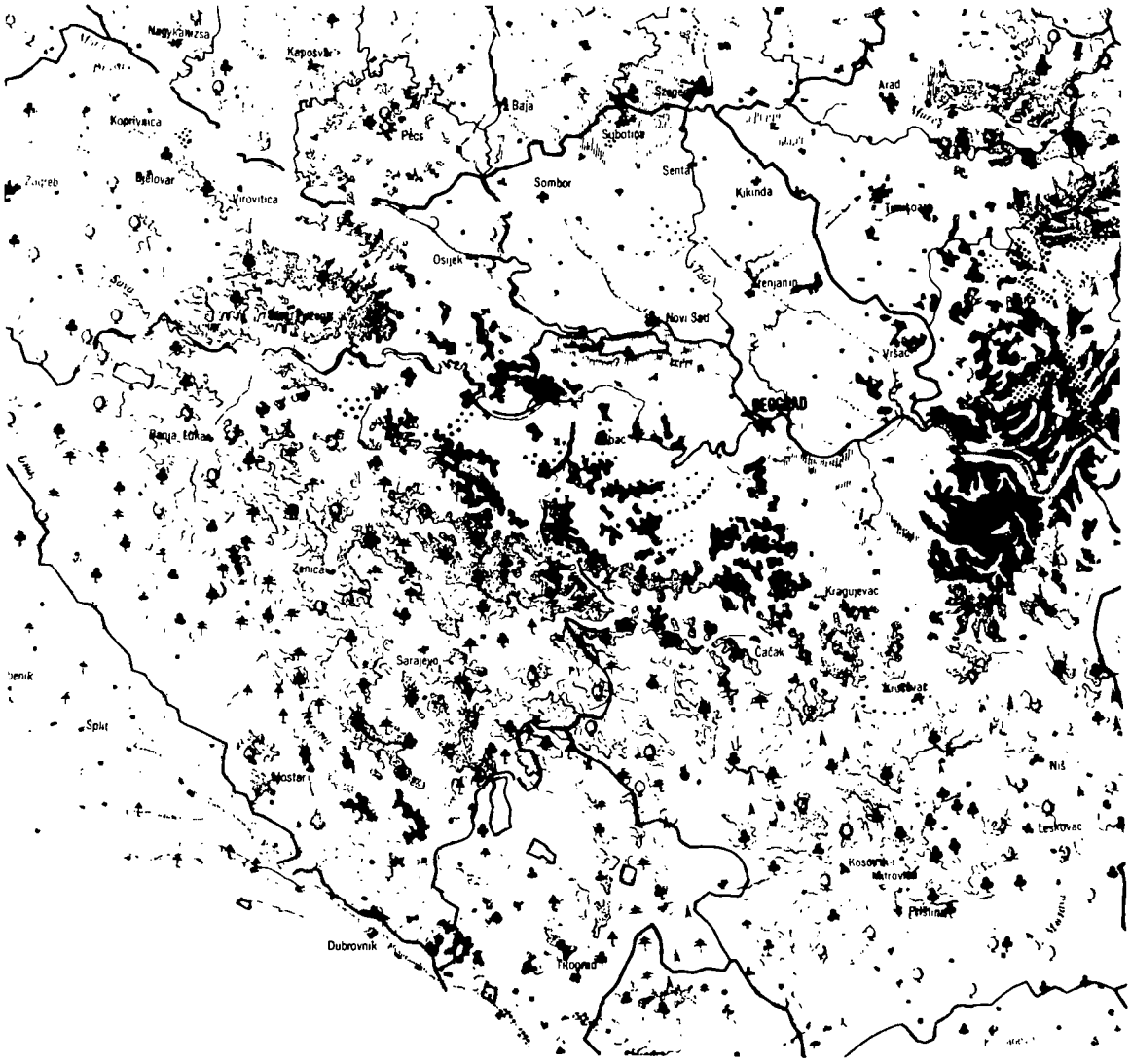

Figure 4. Detail of Eulusmap.

LAND-USE CLASSIFICATION SYSTEM

The WLUS Commission established a classification system in 1949 which contained nine categories (Geographical Journal, 1950). This was later referred to as a "master key" (IGU, 1952, p. 8), with the idea that it would be a uniform system throughout the world, including the color code. This intention was restated by WLUS Commission Chairman L. D. Stamp (1965): "The aim . . . was and is to encourage all countries of the world to make their results comparable. A cardinal rule is that countries shall not combine any of the major world categories but may make as many subdivisions as local circumstances may require or render desirable." The original classification system is outlined in Table 1 (Geographical Journal, 1950).

TABLE 1. LAND-USE CLASSIFICATIONS, WLUS, 1949.

Number	Land-Use	Color
1	Settlements and associated non-agricultural lands	Dark and light red
2	Horticulture	Deep purple
3	Tree and other perennial crops	Light purple
4	Cropland	
	(a) Continual and rotation cropping	Dark brown
	(b) Land rotation	Light brown
5	Improved permanent pasture (managed or enclosed)	Light green
6	Unimproved grazing land	
	(a) Used	Orange
	(b) Not used	Yellow
7	Woodlands	
	(a) Dense	Dark green
	(b) Open	Medium green
	(c) Scrub	Olive green
	(d) Swamp forests	Blue green
	(e) Cut-over or burnt-over forest areas	Green stripple
	(f) Forest with subsidiary cultivation	Green with brown dots
8	Swamps and marshes (non-forested)	Blue
9	Unproductive land	Grey

Table 2 gives the classifications on Eulusmap. It can be seen that Stamp's "cardinal rule" has not been broken and that his suggestion of subdivisions has been utilized to have the map convey much additional information.

TABLE 2. LAND-USE CLASSIFICATIONS, EULUSMAP.

FAO Symbol	Land-Use	Color
Ah Ap	Permanent crops	
	Concentration of plantations and/or of small plots	
	Vineyards	Vertical red stipple
	Orchards	
	Soft fruits (apples, pears, etc.)	Red dots
	Stone fruits (apricots, cherries, etc.)	Red
	Citrus fruits (lemons, oranges, etc.)	Yellow dots on orange
	Nuts (chestnuts, almonds, etc.)	Purple
	Berries (raspberries, strawberries, etc.)	Red hatch
	Mixed	Pink
	Olives	Purple dots
Fa	Mainly productive forests and woodlands (lumbering)	
	Conifers	Light green
	Deciduous	Dark green
	Mixed	Blue
Fa	Other forests and woodlands	
	Conifers	Light green with stipple
	Deciduous	Dark green with stipple
	Mixed	Blue with stipple
	Temporary crops (arable lands of constant use, including grain crops)	Light brown
	Build up areas	Black
	Inland waters	
	River	Light blue
	Canal	Light blue
	Natural lake	Light blue
	Reservoir	Dark blue
Ag	Improved grasslands	
	Wet (annual precipitation over 500 mm)	Dark green
	Dry (annual precipitation under 500 mm)	Medium green
Ar	Unimproved grasslands	
	Wet (annual precipitation over 500 mm)	Light green
	Dry (annual precipitation under 500 mm)	Yellow green
	Alpine meadows	Bluish light green

TABLE 2. (Concluded).

FAO Symbol	Land-Use	Color
O	Waste lands or zones of extra low productivity	
	Rocks, glaciers, sand dunes, tidal flats, swamps-marshes	Gray
	Scattered grass, reindeer moss, rocks, low shrubs, permanent snow	Gray
	Mediterranean scrubs, rocks, scattered grass, low temporary grazing	Gray green
	Heavy dominance of peat and/or bog	Blue dashes
	Other symbols	
	Concentration of glasshouses (only in Iceland and the Netherlands)	Blue [x]
	Regions of flower production	Red *
	Boundary of significant protection areas	Red
	Boundaries of nations, states, and administrative divisions	Black
	Longitude and latitude	Black
	Letter symbols for land-use categories of the FAO	Black

It should be noted that analysis of remotely-sensed data, even if calibrated with samples of ground truth data, has a basic limitation of detection of land cover rather than land use. This is especially troublesome when trees are involved. Groves of trees of sufficient area are readily detected, but are they a productive forest, a protective park, an orchard, or a well-shaded urban region?

Satellite images of multispectral character may directly be used for evaluation, even with very little technical background, for producing land cover/land use information from them. Only a light table and some transparent material are needed for manual visual theme extraction. Multispectral data used for the Eulusmap were usually on 1:1 million scale black and white images of various bands, mostly 5 (red) and 7 (infrared), and rarely blown up to 1:500 000. Original third generation 1:3.6 million images cannot be used directly by manual-visual information extraction techniques. This scale is too small to work with, even if the pattern of certain information (Fig. 5) is simple.

Black and white MSS images on two of the previously mentioned bigger scales may be subdivided into two main types. The first is when the desired information has a simplified pattern with great tonal differences from other land cover information. Extremely good examples are found in Northern Europe, especially the geographical territorial distribution of arable land. For example, for Eulusmap the total bottom bay

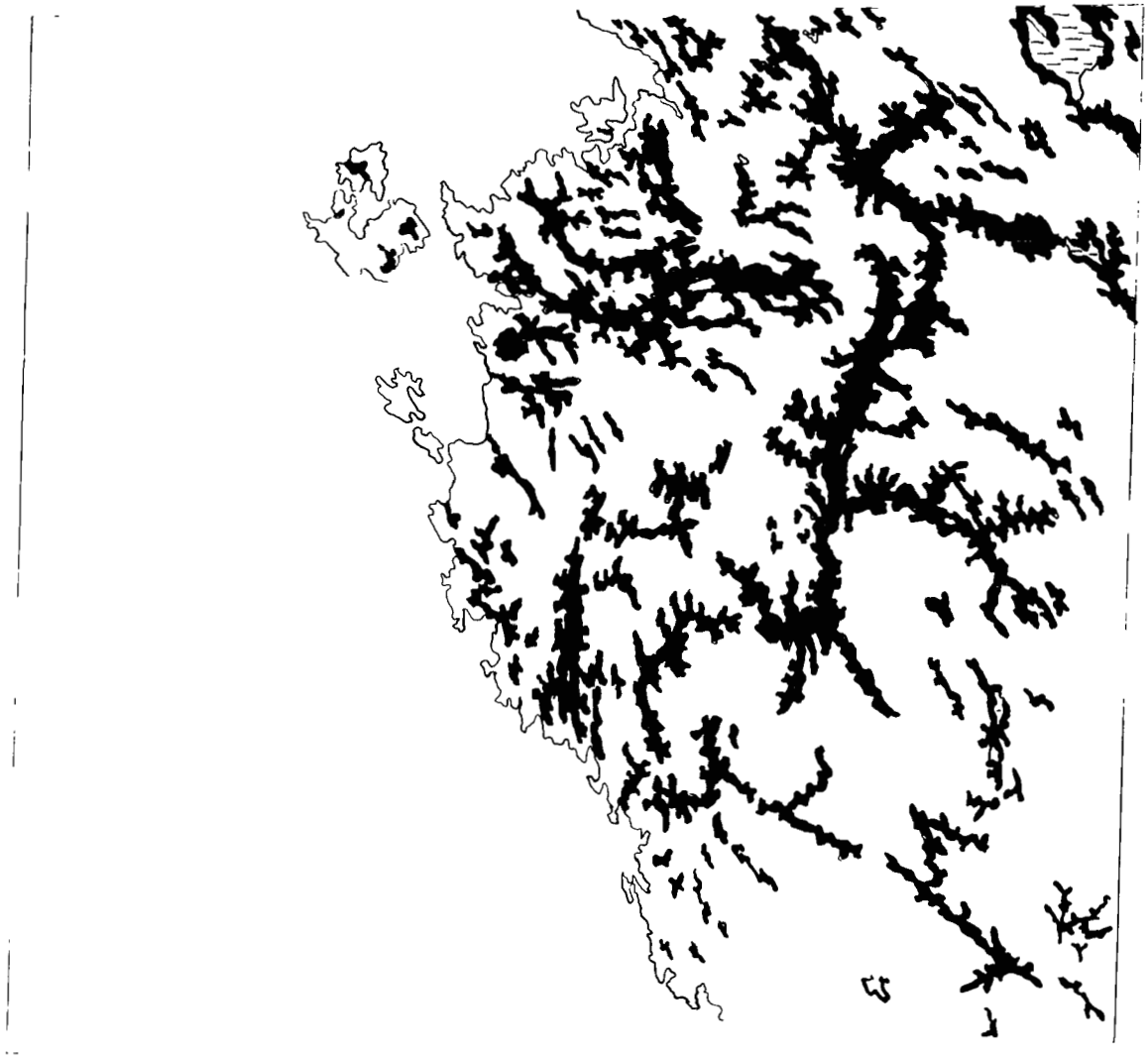

Figure 5. Arable land extracted from Landsat band 5.

coasts of Finland's arable lands were extracted manually from multispectral scanner 1:1 million images, mostly from band 5.

The second type – small mosaic like pattern, hairthin lines – is shown on Figure 6. In this case Landsat images may not be used directly.

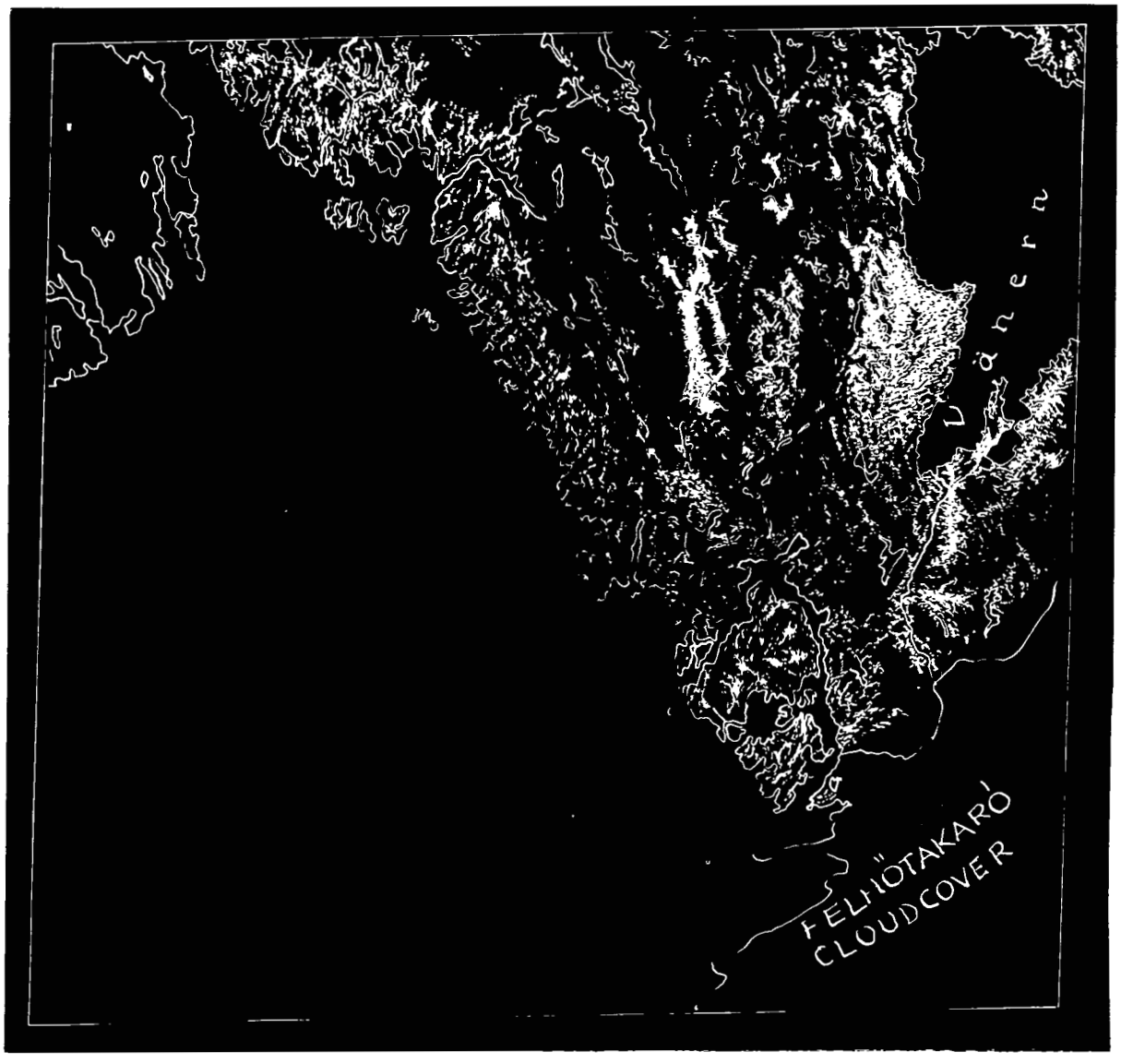

Figure 6. Hairthin lines depicting arable land southwest from Lake Vanern, Sweden; extracted from Landsat band 7.

From practical experiences of the authors, it may be concluded that for Central Europe and Central Eastern Europe, where arable lands dominate the area of the countries between 50-60 percent (e.g., Poland, Hungary, Rumania, main part of Bulgaria, Northern Yugoslavia), for manual extraction the best information from Landsat are the densely covered woodlands. The biggest part of the forms of woodlands shown on the Eulusmap for this area was extracted, or at least corrected, by using Landsat images on

1:1 million scale, mostly in black and white from band 5 in negative. For manual-visual extraction of woods the best is band 5 negative film, on which the densely covered areas of woodlands are nearly white or very light gray. Thus their forms can be easily recognized and depicted.

It is also concluded by the authors that for mapping in small scale the land use/land resource information, the best information carriers are the Landsat Multispectral Scanner images, because they are the only source which show the great geographical units or great distributional patterns at one time and for big areas (36 000 km^2).

Future users of Landsat images applying only manual-visual extraction techniques are advised that one can work with one black and white half-tone image continually no more than half an hour, because the human eye tends to decrease the limit of perception power after this time.

A study of land-use classification systems was made by the Commission on Geographic Applications of Remote Sensing of the Association of American Geographers during a 3-year period prior to the Landsat-1 launch. The results were published in April 1971 (Anderson, 1971). In June of that year, a "Conference on Land Use Information and Classification" was held in Washington, D.C., under the joint sponsorship of NASA and the U.S. Department of the Interior. An Inter-Agency Steering Committee of a number of U.S. agencies was established under the chairmanship of A. Gerlach until his untimely death in May 1972, and subsequently under J. R. Anderson. This has led to a tentative, but non-official, national standard for the U.S.; it is based on use of remotely-sensed data with recognition of limitations of the type mentioned in the preceding paragraph. It recognized the WLUS system of Table 1, but Stamp's "cardinal rule" is broken in two cases: pasture and crop-land are combined, and horticulture is combined with tree and other perennial crops. The proposed system, shown in Table 3, has been published twice to encourage professional discussion (Anderson and others, 1976). Most current Landsat land cover experiments in the U.S. utilize this system or modifications of it. The system of Eulusmap (Table 2) differs from it very little.

EULUSMAP

A color draft or part of the Eulusmap was displayed by Csáti at Simferopol, Ukranian S. S. R., and Moscow in July-August 1976 at the Symposium on World Land Use Survey and the 23rd International Geographical Congress. It was published in complete form in May 1978. Inquiries on availability should be addressed to:

Földmérési Intézet
H-1373 Budapest
Guszev u. 19.
Pf. 546
Hungary

TABLE 3. LAND COVER CLASSIFICATIONS, USGS, 1976.

Level I	Level II
1 Urban or built-up land	11 Residential 12 Commercial and services 13 Industrial 14 Transportation, communications and utilities 15 Industrial and commercial complexes 16 Mixed urban or built-up land 17 Other urban or built-up land
2 Agricultural land	21 Cropland and pasture 22 Orchards, groves, vineyards, nurseries, and ornamental horticultural areas 23 Confined feeding operations 24 Other agricultural land
3 Rangeland	31 Herbaceous rangeland 32 Shrub and brush rangeland 33 Mixed rangeland
4 Forest land	41 Deciduous forest land 42 Evergreen forest land 43 Mixed forest land
5 Water	51 Streams and canals 52 Lakes 53 Reservoirs 54 Bays and estuaries
6 Wetland	61 Forested wetland 62 Nonforested wetland
7 Barren land	71 Dry salt flats 72 Beaches 73 Sandy areas other than beaches 74 Bare exposed rock 75 Strip mines, quarries, and gravel pits 76 Transitional areas 77 Mixed barren land
8 Tundra	81 Shrub and brush tundra 82 Herbaceous tundra 83 Bare ground tundra 84 Wet tundra 85 Mixed tundra
9 Perrennial snow or ice	91 Perrennial snowfields 92 Glaciers

LANDSAT IMAGES

World wide imagery data were acquired by Landsat-1 from 23 July 1972 until 6 January 1978. Landsat-2, launched 22 January 1975, and Landsat-3, launched 5 March 1978, continue to acquire data. These data are available at moderate cost from data centers in the U.S., Canada, Brazil, and Italy. The addresses of these data centers are:

EROS DATA CENTER
U. S. Geological Survey
Sioux Falls, South Dakota 57198
U.S.A.

NATIONAL AIR PHOTO LIBRARY
615 Booth Street
Ottawa, Ontario K1A OE4
Canada

Instituto de Pesquisas Espaciais
São José dos Campos
Estado de S. Paulo
Brazil

Telespazio Corso Space de'Italia
00198 Rome, Italy

FUTURE DIRECTIONS

The goal set by the WLUS Commission in 1949 to produce maps of the world's land-use at a scale of 1:1 million has never been achieved. However, in one sense it has. The thousands of Landsat images at the 1:1 million scale do themselves constitute land-use maps, if one accepts the task of reading the raw data. Classification systems, at least for land cover, are becoming standardized; therefore, another goal of the WLUS Commission has been essentially met.

The research of the International Geographical Union in this field is the responsibility of two commissions: The Commission on Rural Development, especially its Sub-Commission on Land Resource Mapping; and the Commission on Geographical Data Sensing and Processing.

There has been a shift away from the concept of present land use, with new emphasis on the total resources of land. An alpine lake represents not only water, but also food (fish), transportation and, due to its altitude, potential energy. The concept of

"land resources" has been discussed extensively by Vink (1975). The authors of this paper believe that applications of modern technology – satellites, computers, photogrammetric instruments, etc., – will lead toward rationalization of use of land resources, primarily because accurate information will be available in a timely fashion.

REFERENCES

Anderson, J. R. (1971): Land Use Classification Schemes. Photogrammetric Engineering, XXXVII, pp. 379-387.

Anderson, J. R., E. E. Hardy, J. T. Roach, and R. E. Witmer (1976): A Land Use and Land Cover Classification System for Use with Remote Sensor Data. Geological Survey Professional Paper 964. U. S. Government Printing Office, Washington, D. C. 20402, Stock No. 024-001-02809-3.

Clark, A. (1976): The World Land Use Survey. In World Land Use Survey Commission (1976), pp. 27-28.

Csáti, E. (1976): The Land Use Map of Europe. In Hungarian Cartographic Studies 1976. National Office of Lands and Mapping, Budapest (1976), pp. 55-61.

Csáti, E., and C. T. N. Paludan (1976): Satellite Image Theme Extraction for Small Scale Land Use Mapping. In Hungarian Cartographic Studies 1976. National Office of Lands and Mapping, Budapest (1976), pp. 63-64.

Geographical Journal (1950): A World Land Use Survey, Geographical Journal, CXV. pp. 223-226.

International Geographical Union (1952): Report of the Commission on World Land Use Survey for the Period 1949-1952. Clark University Press, Worcester, Massachusetts.

Stamp, L. D. (1965): Land Use Statistics of the Countries of Europe. In The World Land Use Survey Occassional Papers No. 3. Geographical Publications Limited, Berkhamsted, Herts., England.

Vink, A. P. A. (1975): Land Use in Advancing Agriculture. Springer-Verlag, Berlin Heidelberg New York.

Whitebay, L. E. and S. Mount (1978): Techniques for Using Diazo Materials in Remote Sensor Data Analysis. NASA Contractor Report 2953. 20 pp. (January 1978). Available from National Technical Information Service, Springfield, Virginia 22161.

World Land Use Survey Commission (1976): World Land Use Survey; Report of the Commission to the General Assembly of the IGU. Geographica Helvetica, 31, pp. 1-28.

TECHNICAL REPORT STANDARD TITLE PAGE

1. REPORT NO.	2. GOVERNMENT ACCESSION NO.	3. RECIPIENT'S CATALOG NO.
NASA TP-1371		

4. TITLE AND SUBTITLE

Eulusmap; an International Land Resources Map Utilizing Satellite Imagery

5. REPORT DATE
December 1978

6. PERFORMING ORGANIZATION CODE

7. AUTHOR(S)

T. Paludan and E. Csáti*

8. PERFORMING ORGANIZATION REPORT #

9. PERFORMING ORGANIZATION NAME AND ADDRESS

George C. Marshall Space Flight Center
Marshall Space Flight Center, Alabama 35812

10. WORK UNIT NO.
M-271

11. CONTRACT OR GRANT NO.

13. TYPE OF REPORT & PERIOD COVERED

Technical Paper

12. SPONSORING AGENCY NAME AND ADDRESS

National Aeronautics and Space Administration
Washington, D.C. 20546

14. SPONSORING AGENCY CODE

15. SUPPLEMENTARY NOTES

Prepared by Earth Resources Office, Science and Engineering

* Geocartographic Research Department, Institute of Surveying and Mapping, Budapest, Hungary

16. ABSTRACT

In 1972, the International Geographical Union's Commission on World Land Use Survey adopted a project for a land-use map of Europe. Such a map, under the name "Eulusmap," had been started earlier under sponsorship of several government offices in Hungary. Although there was great response from a number of contributors in many countries, it became evident by mid-1974 that the map would contain gaps and some inaccuracies unless additional data sources were utilized. By then, the satellite Landsat-1 had obtained imagery of most of Europe. Using theme extraction techniques, the map was completed in draft form and portions of it displayed at the 23rd International Geographical Congress in Moscow during July 1976. Printing of the completed map was accomplished in May 1978.

A comprehensive standard land-use classification system was established in 1949. A goal of world mapping at a scale of 1:1 million was also set, but remains far from realization. The advent of satellite data makes achievement possible, but only if some compromises are made in the classification system. It is now realistic to map land resources of large areas and regions undergoing rapid change. This is especially important in developing areas of the world.

17. KEY WORDS

Remote Sensing
Satellite Mapping
Land-Use
Multispectral Imagery
Landsat
International Cooperation
Space Applications

18. DISTRIBUTION STATEMENT

STAR Category 43

19. SECURITY CLASSIF. (of this report)	20. SECURITY CLASSIF. (of this page)	21. NO. OF PAGES	22. PRICE
Unclassified	Unclassified	19	$4.00

MSFC - Form 3292 (Rev December 1972)

*For sale by the National Technical Information Service, Springfield, Virginia 22161

NASA-Langley, 1978

5 1 1U,E, 112778 S00903DS
DEPT OF THE AIR FORCE
AF WEAPONS LABORATORY
ATTN: TECHNICAL LIBRARY (SUL)
KIRTLAND AFB NM 87117