E7.3 10725
CR-130692

SR. 051
F 433

A. R. N. I. C. A.

MANAGEMENT OF NATURAL RESOURCES THROUGH AUTOMATIC CARTOGRAPHIC INVENTORY

(E73-10725) MANAGEMENT OF NATURAL RESOURCES THROUGH AUTOMATIC CARTOGRAPHIC INVENTORY Progress Report, Aug. 1972 - Jan. 1973 (Service de la Carte de la Vegetation CNRS) 80 p HC $6.00 CSCL 08B G3/13 N73-27234 Unclas 00725

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TYPE II PROGRESS REPORT
for Period August 1972 - January 1973
N° 1

May 1973

Sponsoring Agency
CENTRE NATIONAL D'ETUDES SPATIALES
129 rue de l'Université 75007 PARIS

051 ARNICA II - 1

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1. SR 051	2. TYPE II Report	3.
4. A.R.N.I.C.A. MANAGEMENT OF NATURAL RESOURCES THROUGH AUTOMATIC CARTOGRAPHIC INVENTORY		5. Report Date : May 1973 6. Period covered : Aug. 72 - Jan. 73
7. Principal investigator : Paul-Augustin REY		8. N° of Pages :
9. Name and Address of Principal investigator Organization Service de la Carte de la Végétation CNRS 29 rue Jeanne Marvig TOULOUSE France BP. 4009 31055 TOULOUSE CEDEX		10. Principal investigator Report : N° 2 11. GSFC Technical Monitor George ENSOR
12. Sponsoring Agency Name and Address CENTRE NATIONAL d'ETUDES SPATIALES 129 rue de l'Université 75007 PARIS France		13. Key Words : - Natural Resources - Botany - Geology - Management - Inventory

14. Supplementary Notes :

Report presented with cooperation of Y. GOURINARD, F. CAMBOU, C. GUYADER, H. PICCA, G. FLOUZAT, P. GOUAUX, M. MONCHANT.

15. Abstract :

Significant results of the ARNICA program (August 1972 - January 1973)

- Establishment of image to object correspondence codes for all types of soil use and forestry in northern Spain.
- Establishment of a transfer procedure between qualitative (remote identification and remote interpretation) and quantitative (numerization, storage, automatic statistical cartography) use of images.
- Organization of microdensitometric data processing and automatic cartography software.
- Development of a system for measuring reflectance simultaneous with imagery.

CONTENTS

PART I

PREFACE

- OBJECTIVES
- SCOPE OF ACTIVITY
- SIGNIFICANT RESULTS
- CONCLUSIONS

OBJECTIVES

ERTS A MSS Imagery will be correlated with exixting vegetation and geological maps of southern FRANCE and northern SPAIN, to develop correspondence codes between maps units and satellite data.

These codes will then be used in numerical form for eventual automatic charting of natural resources.

Microclimate data from certain experimental ground stations, spectral measurements from a few meters to 2 km. using ERTS - type filters and spectrometers, and leaf reflectance measurements will be obtained to assist in correlation studies.

SCOPE OF ACTIVITY

A major part of the test-site selected for the ARNICA program was clouded over in 1972. The documents received for the August to December period therefore concern essentially only marginal parts of the site or parts outside.

Furthermore, except for the eastern section (Rhone delta), no repetitive cover could be assured.

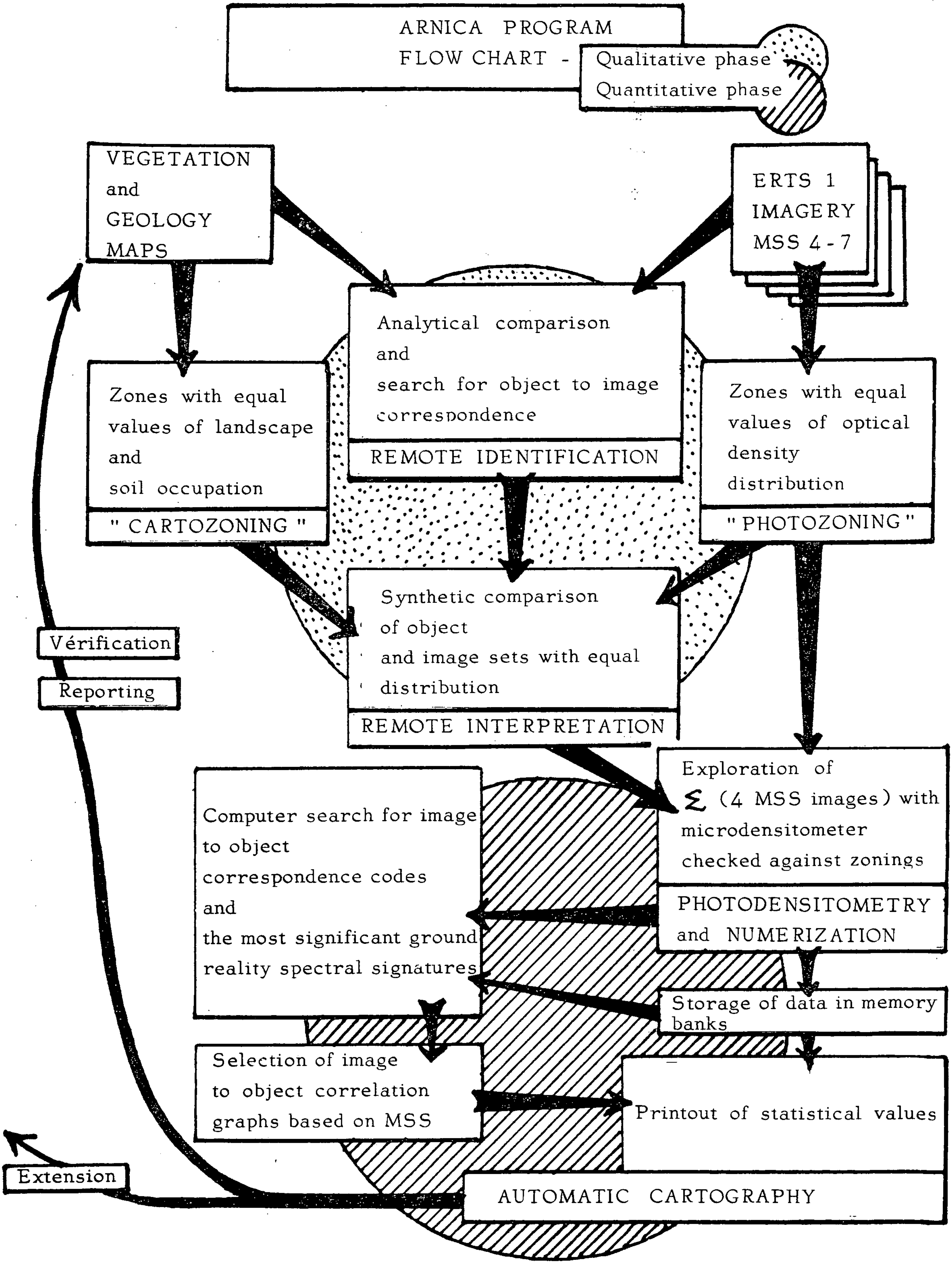
The activity of the ARNICA studies group has therefore been limited to specific themes, but under geographical conditions different from those initially defined. Certain ground activities, performed in November and December, could not be used as planned for correlations simultaneous with ERTS imagery, because this imagery has not yet been received.

With these organizational problems, data were not processed from September 1972 to Juanuary 1973 in the directions explained in the TYPE I PROGRESS REPORT (Nov. 1972), in accordance with the attached FLOW CHART.

See Attachment A

The present report illustrates the results acquired at four levels of investigation :

- Qualitative studies
- Qualitative and Quantitative Studies
- Quantitative studies
- Experiments


ARNICA PROGRAM
FLOW CHART -
Qualitative phase
Quantitative phase
VEGETATION and GEOLOGY MAPS
ERTS 1 IMAGERY MSS 4 - 7
Analytical comparison and search for object to image correspondence
REMOTE IDENTIFICATION
Zones with equal values of landscape and soil occupation
" CARTOZONING "
Zones with equal values of optical density distribution
" PHOTOZONING "
Synthetic comparison of object and image sets with equal distribution
REMOTE INTERPRETATION
Vérification
Reporting
Exploration of Σ (4 MSS images) with microdensitometer checked against zonings
PHOTODENSITOMETRY and NUMERIZATION
Computer search for image to object correspondence codes and the most significant ground reality spectral signatures
Storage of data in memory banks
Selection of image to object correlation graphs based on MSS
Printout of statistical values
Extension
AUTOMATIC CARTOGRAPHY

SIGNIFICANT RESULTS

A. QUALITATIVE STUDIES

see Part II, Chapter 1

Data : 1027-10141 MSS 4, 5, 6, 7

The excellent cover acquired by ERTS over northeastern Spain permitted a detailed study of the search for correspondences between ground use types and 4-band multispectral scanner imagery.

The available Cartographic Information
- Forest Map of Spain, scale 1/400.000
- Soil Map of the Lusitano-Iberian Peninsula, scale 1/500.000

provided the basis for equal cartographical zoning which could be compared with photographic zonings established for each image.

Correspondence codes were defined as follows :

1. Major landscape and soil types
   Crops, Irrigated crops
   Forests, Arid brushlands
   Calcareous soils

2. Most frequently found forestry types
   Quercus lusitanica
   Pinus halepensis
   Pinus silvestris

In this way the value of making basic comparisons between multispectral scanner bands 5 and 7 in order to establish correspondence codes, for phytogeographical and geological studies, has been confirmed ; multispectral scanner band 6 and to a lesser extent multispectral scanner band 4 add useful supplementary details for finer identifications.

SIGNIFICANT RESULTS (continued)

B. QUALITATIVE and QUANTITATIVE STUDIES

see Part II, Chapter 2

Data : 1027-10135 MSS 4, 5, 6, 7

The principal effort of the remote sensing department has developed at the "interface" level between qualitative reading operations, identification and interpretation of data, and quantitative automatic information processing operations.

The work was carried out over a part of the Spanish Pyrenees (Aran Valley) where both very accurate vegetation mapping and excellent multispectral scanner band 4, 5, 6 and 7 images were available.

The results obtained involve the following processes :

- Preprocessing of the vegetation map : Use of "Cartozoning" by remote identification of forestry known on the map and charting of "Zones with equal values of forestry".
- Preprocessing of ERTS 1 Imagery : Use of "Photozoning" by remote interpretation of "Zones with equal values of densitometric distribution".
- Search for densitometric correspondence codes between ground-reality and ERTS imagery , checked against the above equal value zones.
- Establishment of graphs of the most significant correspondences.
- Application to automatic statistical cartography Inventory of FIR FORESTS.

SIGNIFICANT RESULTS (continued)

C. QUANTITATIVE STUDIES

see Part II, Chapter 3

Data : 1027-10135 MSS 4, 5, 6, 7

In the first phase, the Centre d'Etudes Spatiales des Rayonnements (C.E.S.R.) is primarily involved in defining conditions of information transfer between qualitative visualization of the image to object correspondence codes and automatic cartographic output.

The group has advanced through the following stages :

- Calibration of the densitometry apparatus
- Development of available software

The examples of automatic output in visual simulation provide some interesting preliminary results, which can be refined as soon as two problems have been solved :

- data compression
- improved accuracy of geographical referencing of parts of images to be numerized.

Also, all of the operations will obviously be much easier as soon as the original digital bands become available.

SIGNIFICANT RESULTS (end)

D. EXPERIMENTS

Two groups of experiments had been planned in association with the ERTS/1-ARNICA program :

- aircraft experiments
- ground experiments

reflectance and ecological measurements made simultaneous with the imagery.

In view of the recent recording problems in the satellite, from now on the studies will be conducted in such a way as to make experimentation possible in the framework of the next ERTS B program in the event that it cannot be redone for ERTS A.

The present report discusses the technological advances made in the air-based part of the experiment (development of an aircraft-borne system) The ground-based measurement system will be discussed in a future report.

CONCLUSIONS

The work presented in this report illustrates the fundamental phases of the ARNICA program.

The method developed for the most significant imagery of the test-site, available December 31, 1972, will be extended to other as a function of the date which can actually be used, especially in regions where repetitive cover can be made.

REQUIREMENTS

In order to extract the best part of the acquired information, the following documents are necessary :

a) color composite images of the data
   1027-10135
   1027-10141
   1028-10193
   1028-10250
   1064-10190
   1066-10294

b) original digital bands of the data

1027-10135	1028-10193
1027-10141	1064-10190

PART II

RESULTS

Chapter 1. QUALITATIVE STUDIES

- STUDY OF LAND USE PATTERN IN NORTHERN SPAIN

  1. Qualitative processing : Interpretation of ERTS 1 Imagery

by Mme P. GOUAUX, Department of Teledetection, Université Paul Sabatier

Chapter 2. QUALITATIVE and QUANTITATIVE STUDIES

- REMOTE SENSING OF FORESTRY (USING ERTS 1 DATA)

  1. Identification

by G. FLOUZAT, Department of Teledetection, Université Paul Sabatier

Chapter 3. QUANTITATIVE STUDIES

- DIGITAL PROCEDURES ON REMOTE SENSING IMAGERY FOR THE ARNICA ERTS 1 PROGRAM

by M. MONCHANT, Centre d'Etudes Spatiales des Rayonnements

Chapter 4. EXPERIMENTS

- STUDY OF A RADIOMETER FOR VISIBLE WAVELENGTHS

by Laboratoire de Physique de l'Atmosphère, under the direction of Professor PICCA, Université Paul Sabatier

Chapter 1.

STUDY OF LAND USE PATTERNS IN NORTHERN SPAIN

1 - Qualitative processing : Interpretation of ERTS 1 Imagery

P. G O U A U X
Université Paul-Sabatier
TOULOUSE

This study is included in ARNICA Project.

The ERTS 1 data available at first, in November-December 1972, were obtained from countries that could be defined in reference with the presence of absence of the Vegetation Map.

The processed ERTS 1 data in this study are issued from countries no covered by the Vegetation Map. The absence of the Vegetation Map misses the analysis of the preliminary work performed for this map. So, it is not possible to find directly the determination keys of soil units. Their determination will be based on documents and cards available in the studied country.

This study concerns Multispectral Scanner 1027-10141 data which covers the Ebro basin from Zaragoza to the mediterranean.

I. REFERENCE MAPPING

- Forest Map of Spain-Scale 1 : 400,000
- Soil Map of the Lusitano-Iberian Peninsula-Scale 1 : 1,500,000

1. The Forest Map of Spain published by the Spanish Department of Agriculture in 1966, shows three principal features :

- Crops.
- Lightly covered soils, e.g., steppes, moorlands, grasslands, natural pasture, wasteland.
- Forests with tree species indicated.

2. Soil Map of the Lusitano-Iberian Peninsula by H. Del Villar (1938), (Scale 1 : 500,000). Different soils are indicated in the test site :

- Alluvial soils : along the wide valleys, about 10 km. wide along the Ebro and wider along the Segre.

- Area of frequency of saline patches inland from the Ebro.

- Saline soils : the Ebro basin is unique in that its saline soils are of tertiary origin creating special land formations, e.g., desert steppes ; some of this soil has been developed through irrigation.

- Dry and intermediate calcareous soils : covering a large part of the Ebro basin, becoming skeleton-like, especially in mountain areas.

- General occurence of xerosiallitic soils, found only in the mountanous zones.

In addition to maps, various notes have been used (see Bibliography).

II. QUALITATIVE ANALYSIS

A. Method

The same principles used for small scale data apply to large-scale data. The data records the various textural areas in varying shades of gray in the different spectral bands. These textural areas represent soil occupation units which are identified by cartographic correlation.

B. Analysis

1) Amplitude of optical density

The four Multispectral scanner data are characterized by the amplitude of optical density, thus indirectly indicating the fluctuations caused by photographic printing conditions.

2) Texture

Textural areas are delimited by analysis of the optical density characterizing each particular area.

Each of these textural areas groups several components ; these one being soil occupation states.

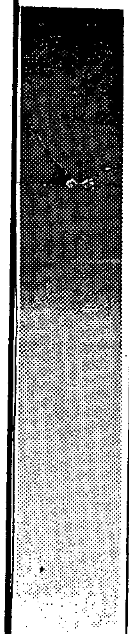
GRAY SCALE	MSS 4		MSS 5		MSS 6		MSS 7	
	A	Homogeneous Texture Areas	A	Homogeneous Texture Areas	A	Homogeneous Texture Areas	A	Homogeneous Texture Areas
	↕	Crops irrigated from main rivers bed Crops irrigated from alluvial terraces Crops at the mouth of the Ebro Forests of [Quercus lusitanica, Pinus halepensis, Pinus silvestris] Mainly forest landscape Crops irrigated from saline soils Lightly covered soils and non irrigated crops	↕	Forests of Pinus silvestris Crops at the mouth of the Ebro Crops irrigated from main rivers bed Crops irrigated from alluvial terraces Forests of [Pinus halepensis, Quercus lusitanica] Crops irrigated from saline soils Mainly forest landscape Lightly covered soils and non irrigated crops	↕	Forests of [Pinus halepensis, Pinus silvestris] Mainly forest landscape Forests of Quercus lusitanica Lightly covered soils and non-irrigated crops Crops irrigated from saline soils Crops irrigated from alluvial terraces Crops irrigated from main rivers bed Crops at the mouth of the Ebro	↕	Forests of Pinus halepensis Forests of Pinus silvestris Mainly forest landscape Lightly covered soils and non-irrigated crops Forests of Quercus lusitanica Crops irrigated from saline soils Crops irrigated from alluvial terraces Crops irrigated from main rivers bed Crops at the mouth of the Ebro

Table I - Homogeneous texture areas and their components the boundaries of an optical level change according to the spectral bands. In effect the responses recorded for various formations (e.g., plant, pedological, geological, hydrographical) correspond to the reflectance in each spectral band. By checking against other data, all of the soil occupation states are known and isolated : they are thus characterized by the combination of their four spectral responses.

Table I shows the optical amplitude (A) and homogeneous texture areas for each spectral band, interpreted and placed in the gray scale. Spectral band analysis separates soil occupation states by "natural selection", since this method follows from investigation of the various textural areas.

Thus, in the example below (cf. Table II) the knowledge of the soil occupation state F_1, isolated in the Multispectral scanner 5 data, implies those of F_2 (MSS 6 data) and Z_1 (MSS 6 data), even if the last two states are not isolated in any band.

Spectral band	Texture	Textural group	
		Number of components	Components
4	Medium gray	7	B_1-B_2-B_3 F_1-F_2-F_3 Z_1
5	Dark gray	1	F_1
6	Medium gray	2	F_1-F_2
7	Light gray-Medium gray	3	F_1-F_2 Z_1

TABLE II

3) Structure

The textural character is not sufficent to determine all the feature groups. The structural character improves the data analysis. It defines the textural character by indicating the arrangement of forms which make up the textural area. It is most useful in band 5. For example, differences in structure allow one to separate 2 forms of soil occupation C_1 and C_2 in a homogeneous texture area C_1 C_2 (cf. Table III).

Spectral band	Texture		Structure	Distinction
4	Medium gray	C_1C_2	Same homogeneity	Impossible
5	Dark gray-Medium gray	C_1C_2	Average homogeneity	C_1
			Very homogeneous within the lightest grid	C_2
6 7	Light gray	C_1C_2	Same homogeneity	Impossible

TABLE III

III. INTERPRETATION

By means of interpretation of the different textural and structural groups using maps (I), data analysis (II. 1 and 2) is possible.

The figure, "Document ERTS 1 Interpretation", shows an interpretation of MSS 5 data. 10 feature groups are distinguished.

The phytogeographic profile, between A and A' in next figure, was made from the Forest and Soil maps.

The purpose of the profile is to locate all the formations in space and thus establish a direct parallel between the vegetal group and the ecological parameters such as climate and soil. There is more botanical data from forest maps than from interpretation of multispectral scanner data : thus lightly covered soils and non-irrigated crops are not distinguishable by interpretation of ERTS 1 data, whereas the arborescent formations and the irrigated crops are very clear. The pedological date, from the Soil Map, completes the profile and clarifies soil-plant relations.

A) <u>Crops</u>

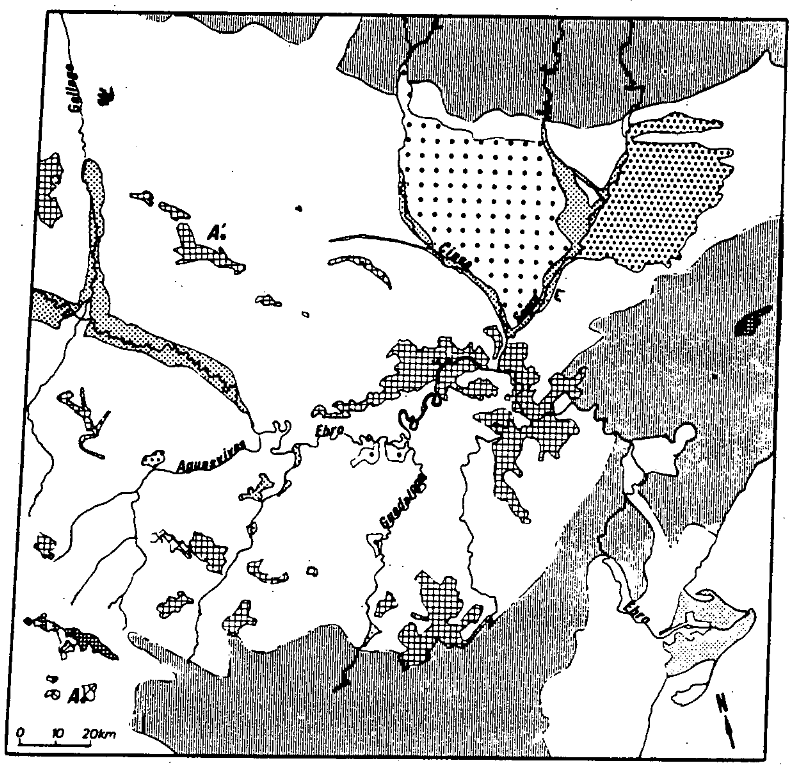
The place occupied by these feature groups corresponds to the crop zone on the forest map. The soil map indicates alluvial soils and soils altered by irrigation, saline soils, and irrigated soils. The last two soil types are planned for cultivation. Different crops can be distinguished.

1. Irrigated crops in alluvial soils

   1a. Crops irrigated from main river beds
   1b. Crops irrigated from alluvial terraces

2. Crops irrigated from saline soils

Salt serves as a limiting factor in conditioning a particular landscape characterized by uncultivated soils. With irrigation, a part of these soils are transformed and can be cultivated, particularly in the district of the Segre and Cinca rivers.

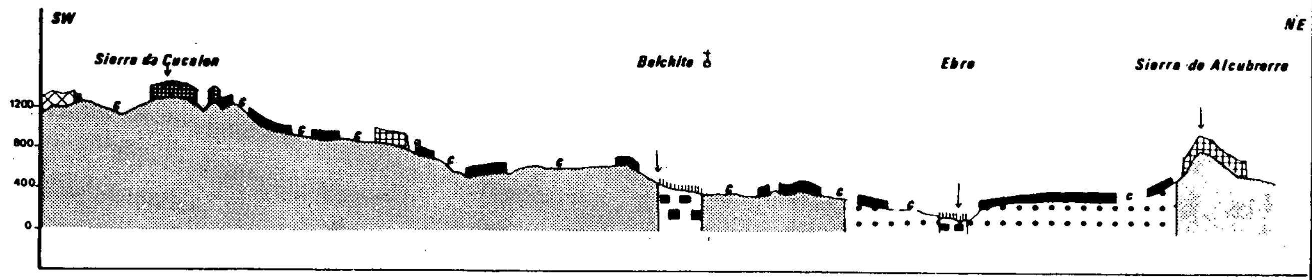


DOCUMENT ERTS-1 INTERPRETATION
MSS 5 - 1027 . 10141

from Forest Map of Spain - 1/400 000
and Soil Map of the Lusitano-Iberian Peninsula
1/1. 500 000

- Crops irrigated from main rivers bed
- Crops irrigated from alluvial terraces
- Crops irrigated from saline soils
- Crops at the mouth of the Ebro
- Lightly covered soils and non-irrigated crops
- Forests of Quercus lusitanica
- Forests of Pinus halepensis
- Forests of Pinus silvestris
- Sparse forest of Pinus silvestris
- Mainly forest landscape

A-A' : Direction of the profile



PHYTOGEOGRAPHIC PROFILE

realised from Forest Map of Spain

VEGETATION

- Irrigated crops
- Crops
- Lightly covered soils

Forest of:
- Quercus lusitanica
- Pinus halepensis
- Pinus silvestris

SOIL

- Alluvial soils and soils altered by irrigation
- Area of frequency of saline patches
- Dry and intermediate calcareous soils

SCALE

height: 0,8 km; 0,4; 0

lenght: 4; 8 km

3. Crops at the mouth of the Ebro

Plans for land use include cultivation of saline soils. The district at the mouth of the Ebro is comparable to the Camargue in France, a district located at the mouth of the Rhone River.

Table IV (parts 1 and 2) shows the crops and their characteristic combinations of textural and structural characteristics in the four spectral bands.

Spectral band		Crops	
		1 a	1 b
4	(Textural (level	Medium gray	Medium gray
	(Structure	Homogeneous	Average homogeneity
5	(Textural (level	Dark gray	Medium gray/ Dark gray
	(Structure	Average homogeneity	Average homogeneity
6	(Textural (level	Light gray	Light gray
	(Structure	Homogeneous	Homogeneous
7	(Textural (level	Light gray/ White	Light gray/ White
	(Structure	Homogeneous	Homogeneous

TABLE IV (part 1)

Spectral band		Crops	
		2	3
4	(Textural (level	Medium gray/ Light gray	Medium gray
	(Structure	Heterogeneous	Homogeneous
5	(Textural (level	Medium gray	Dark gray
	(Structure	Heterogeneous	Homogeneous
6	(Textural (level	Light gray	Light gray
	(Structure	Average homogeneity	Homogeneous
7	(Textural (level	Light gray	Light gray/ White
	(Structure	Average homogeneity	Homogeneous

TABLE IV (part 2)

B) <u>Forest</u>

Three forest types are identified :

1. Forests of Quercus lusitanica : Quercus lusitanica is a sclerophyll hardwood. In the near IR spectral band, sclerophyll hardwoods have the same spectral response as conifers under imagery recording conditions at low altitude (3000 to 8000 meters) ; they absorb near IR radiation whereas the deciduous trees reflect it. Quercus lusitanica has a spectral response in between responses of deciduous hardwoods and those of conifers. Quercus lusitanica may exhibit an identical response at higher altitudes.

2. Forests of Pinus halepensis : Pinus halepensis is an indeciduous lowland conifer. It is very common in this test site, covering all moderate elevations (Sierra de Alcubierre, 871 m), which are favorable to its growth.

3. Forests of Pinus silvestris : Pinus silvestris is also an indeciduous conifer. But ecological conditions favorable to its growth are found at altitudes above those favoring the growth of Pinus halepensis. It is present in only two points of the test site. It covers two mountain chains (Sierra de Cucalon - alt. 1491 m., the other 1201 m.)

Table V shows that identification of this tree species is possible from textural characteristics. The Multispectral scanner 5 data permits isolation of the two conifers (dark gray for Pinus silvestris and medium gray for Pinus halepensis). With the MSS 6-7 data it is possible to distinguish sclerophyll hardwoods (light gray) from conifers (medium gray).

Spectral band	Upper stratum		
	Quercus lusitanica	Pinus halepensis	Pinus silvestris
4	Medium gray	Medium gray	Medium gray
5	Medium gray	Medium gray	Dark gray
6	Light gray	Medium gray	Medium gray
7	Light gray	Medium gray	Medium gray

TABLE V

C) <u>Total identification zones</u>

Certain zones are not easily recognized. The difficulty is due to low contrast which does not allow one to plot the boundary between two formations.

Two features groups can however be roughly determined using the forest map :

- lightly covered soils and non-irrigated crops which cover the lowlands.

- Mainly forest landscape covering the highest districts. This set of features covers the Pyrenees in the North the chains parallel to the Mediterranean coast which then bend inland at the level of Tortosa near the mouth of the Ebro, in the east and south.

IV. ISSUE

The data analysis makes possible to identify quickly ten soil occupation units by means of structural and textural features of multispectral scanner imagery. These features can be held only as hypothetic interpretation basis, whenever the quantitative analysis does not involve a ground-truth phase.
Only after this phase, it will be possible to use the hypothetic basis as standards. The ground-truth phase could be made in cooperation with the Ecology and Botanic Laboratories in the University of Barcelone (Spain).

After unit identification, the second ERTS 1 data processing phase, the quantitative analysis, could be made from results obtained during the first qualitative phase. So, these results will be significant quickly for the areas which have been identified as interesting zones.
This processing phase will be included in the next report.

The ERTS 1 processed date census, will improve the knowledge of the different units located in the North-East of Spain, from a physionomic and specific point of view as well as in an economic aspect.
However, a great interest can be found in the ERTS 1 data, because they are up-to date, repeated.
So, they present intervention possibilities, which they are significant from an economic point of view.
So, it will be possible to map forest and agricultural inventory ; and next, this one will permit to know any change hapenned in the morphology of the different vegetal soil-occupation units, whether is foreseeable (different phenologic state of plant) or sudden (fire). Finally, this change will bring to realise the different necessary actions.

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Chapter 2.

REMOTE SENSING OF FORESTRY
(USING ERTS 1 DATA)

G. F L O U Z A T
Department of Teledetection

PART I - IDENTIFICATION

I. ABSTRACT

This paper discusses the use of ERTS 1 data in forestry remote sensing by correlation with the vegetation map (a known ground truth). It describes the first part of an experiment on the application of acquired results ; further descriptions will appear in two following papers. Identification of forest trees is made using part of a determination key, such as phenological cycles of remote sensing. With ERTS 1 data from one pass, fir forests (Abies pectinata) are easily detected, as are forests in which fir trees are mixed with beech (Fagus silvatica) or other pines (Pinus silvestris, Pinus uncinata). Forests of pine only are also located.

II. INTRODUCTION

The remote sensing of forestry is a fundamental aspect of the ARNICA/ERTS 1 program carried out by the Remote Sensing Group of Toulouse (France). The first stage of this study consists of applying point correspondences research to this type of ground object. In keeping with the ARNICA project and the data analysis plan, the operational definition of a correspondence code between satellite imagery and the vegetation map involves searching for ground object identification keys. These phenological cycles of remote sensing are made from point calibrations established in well known spectral bands during significant phenological periods. The ground truth reference is given by the Vegetation Map of France (scale 1/200.000). Thus, calibration of vegetal phenomena is possible everywhere in the test site, depending only on the availability of ERTS 1 data.

This experiment uses data acquired by ERTS 1 during Summer 1972. It will define the meaning of an image in several wavelength bands for a given date, in relation to the characteristic phenological cycle of remote sensing.

III. REMOTE SENSING CONDITIONS

a) Recording Conditions :

The following experiment used ERTS 1 imagery taken on August 19, 1972. It was the first data to be used in the ARNICA program. Due to late arrival in Toulouse, however, this data was not available until the end of November 1972.

The characteristics of these images are given in the following table :

002 19AUG72 C N42-49/E000-37 N 42-49/E000-39 MSS 4
R SUN EL52 AZI134 192-0372-G-I-N-D-IL NASA ERTS E
1027-10135-4 01

014 19AUG72 C N42-49/E000-37 N 42-49/E000-39 MSS 5
R SUN EL52 AZI134 192-0372-G-I-N-D-IL NASA ERTS E
1027-10135-5 01

026 19AUG72 C N42-49/E000-37 N 42-49/E000-39 MSS 6
R SUN EL52 AZI134 192-0372-G-I-N-D-IL NASA ERTS E
1027-10135-6 01

038 19AUG72 C N42-49/E000-37 N 42-49/E000-39 MSS 7
R SUN EL52 AZI134 192-0372-G-I-N-D-IL NASA ERTS E
1027-10135-7 01

At the time these images were recorded, the French side of the Pyrenees was under clouds. The Spanish watershed and high mountains were clear.
The National Weather Report for these data shows clear weather for the south side.

The data acquired over mountainous areas is apparently more reliable than that acquired over level country where the air layer traversed by the reflected flux was thicker. These conditions limit the optimum region for efficient sensing to the Aran Valley. However, it is necessary to known the limits of the angular variation of the images over the region studied. The luminous flux levels recorded are a function of :

(4)

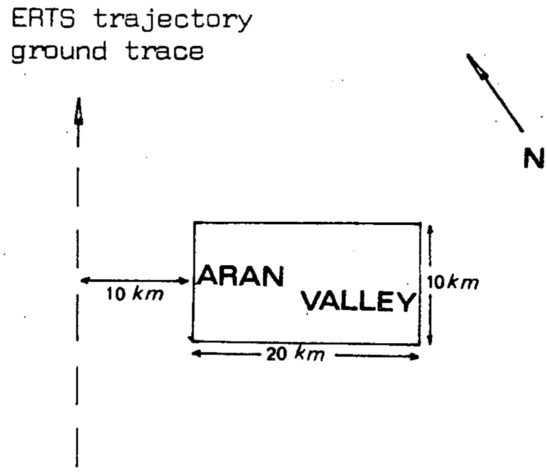


FIGURE a

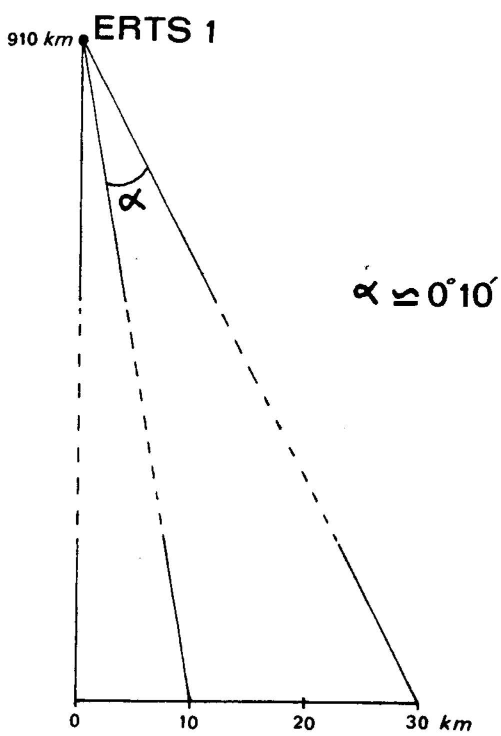


FIGURE b

- changes in the instantaneous scanning direction
- changes in the slope and orientation of the detected objects

The site analysed is a 20 km. x 10 km. rectangle ; the longer sides are parallel to the ground scan direction, and the distance from the smaller western side to the ERTS trajectory ground projection is 10 km. (Figure a). The maximum scanning angle variation for the Aran Valley is about 0° 10' (Figure b).

The maximum slope variation for the objects studied is approximately 15°. All the samples were taken from an approximately NNW direction, all within 10° of one another. The distorsion of the responses due to topography is thus negligible for this experiment, in view of the methodology used.

b) Phytogeographic features of the site :

The experimental region contains three types of soil occupation units :

- agricultural areas
- woodlands
- brushwoods and high moorlands

The distribution of these units in altitude is from 1200 to 2500 m. Agricultural areas occupy the valleys (mostly grazing lands), while forests are situated on watersheds down to 1900 m.
The trees present consist of several vegetation series :

- Beech series (Fagus silvatica)
- Fir series (Abies pectinata)
- Pine series (Pinus silvestris and Pinus uncinata)

In general, the afforestation density decreases as the alpine moorlands are approached. For example, at their upper altitude limit, the pine series (Pinus uncinata) display small isolated patches of wooded area. Pine forests are frequently unmixed, whereas fir forests are practically non-existent. Above wooded areas, moorlands cover limited areas. Alpine grass and grassy vegetation are generally found in the highest parts of this region.

IV. PREPROCESSING OF ERTS 1 DATA AND VEGETATION MAP

1. Preprocessing of the Vegetation Map

The definition of identification keys is based on quantitative correlation of information obtained from the satellite and the map. In order to make use of compatible data, codification processes for zones and samples were applied to the whole test site (Doc.-SCV 102572) during the preparatory period of the program (Jan.-July 1972).

Cartographic zones are defined by five physionomic criteria and two specific criteria which define the constant characteristics in numerical terms using the code (Conditions for the use of the CNRS Vegetation Map in the ARNICA Program, G. Flouzat, Doc. SCV 050472, in French). Thus each zone has its own criteria ; those for the Aran Valley are given in the "Zone characteristics" columns of Table I.

Point samples are likewise located and defined numerically for these regions. A few of the samples treated are shown in Table II in the "Sample characteristics" columns.These numerical data make it possible, during an experiment, to modify correlations between ERTS 1 data results and digitized ground truth data.

Figure 1 shows the Vegetation Map of the Aran Valley with boundaries and locations of some of the homogeneous areas (See V,2).

2. Preprocessing of ERTS 1 Imagery

The data consist of 70 mm. positive transparencies in which the usable data occupy 55 mm. These data are obtained by the multispectral scanner ; the four wavelength bands (4,5,6,7) are processed identically. Photogrammetric referencing is done by punching the centers of the four crosses on each document. These holes are made on the film under a photogrammetric microscope and have a 50 micron diameter ; when numerized, they have the maximum transmittance. The corresponding optical densities, located on the magnetic tape, are used for rotation and translation, to superpose the 4 channels point by point.

The numerization is done with a Joyce and Loebl microdensitometer (SCANDIG 25) with a 50 micron step, which provides ground deviation measurements approximately 160 m. apart. The digital record of the measured optical densities thus constitutes a sub-sampling of ERTS 1 data. These data are sufficient to test the validity of the data analysis plan, established through the use of simulations. (Data Analysis Plan for ERTS 1 - ARNICA program, G. Flouzat, Doc. SCV 102572, in French).

The region studied is shown in Figure II. This document is taken from a photographic enlargement (scale 1/200.000) of an interesting portion of the processed negative (MSS band 5). The zones from the vegetation map are superimposed over the numerical analysis areas.

V. METHOD OF LOCATION OF CORRESPONDING OBJECTS

The method used for the location of corresponding objects between satellite imagery and the vegetation map is based on the principle of phenological cycles in remote sensing.

The determination procedure defines the relations between the nature of ground objects and their detected responses. It is possible to apply it just after preprocessing. The processed samples are then accepted as valid and significant according to ground truth.

The establishment of such an experimental procedure extends the possibilities of the method in several ways :

- by the use of a greater number of samples without subjective and limitative determination of the pureness criterion
- by a quick choice of samples with relatively rough indications
- by the possibilities for generalizing the method.

1. Scientific Justification

The determination keys sought for the identification of ground objects are based on the idea of phenological cycles of remote sensing. These recognition models are obtained by a combination of correspondences established between :

- the composition of a type of ground object
- the characteristics detected in samples of that type of object.

In the case of remote sensing by the ERTS 1 multispectral scanner, determination is a function of the relationship between the nature of samples of the same type of ground object and the form of the multiband relations for these samples.

This relationship is significant for only a limited time.
Thus, an identification key must be used on several significant relations of the same type on different dates.

The sum of these relations defines the phenological cycle of remote sensing.
In our experiment on the remote sensing of forestry with ERTS 1, the present study comprises one part of the development of determination keys. Ground reference is given by the Vegetation Map (See IV, I ; VI, Table I, Table II), and numerical analyses are made from the ERTS 1 magnetic tape data (See IV, 2).

2. Experimental approach

The experimental approach consists of selecting homogeneous areas on the Vegetation Map.
It allowes one the location of pure samples of studied objects. The zones containing the soil occupation types are indexed and the area of analysis is narrowed down to forests. Some of these area white spots in figures I and II in which 29 of the 37 forest regions in the Aran Valley are analyzed.

Using these results the homogeneous sites are selected withe the statistics distributions characteristics which correspond at the digilized analysis of samples responses. The homogeneity threshold is defined with previously analysis of know samples used as references. An confidence interval (90 %) defines the distribution domain of homogeneous sites (fig. III). The pure samples are, after placed in these homogeneous areas. Using this procedure the appropriate calibrations for determining correspondences can be chosen.

3. Determination procedure

First this second stage determines the correspondence between the nature of the objects and their multispectral response. Their response is studied in each channel and characterized by the statistical distribution of optical densities.

VEGETATION MAP OF ARAN VALLEY

(Zoning and samples, Scale 1/200 000)

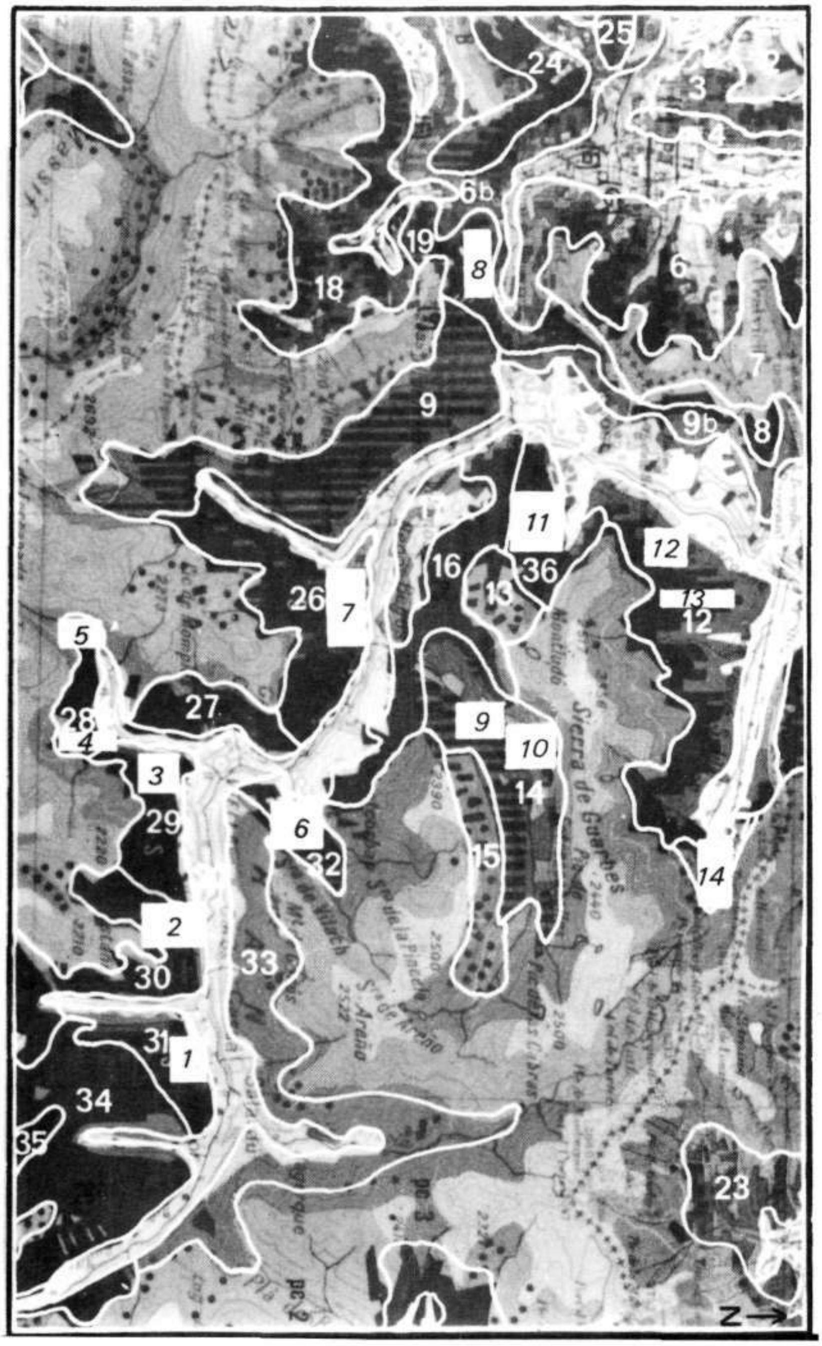


Figure I

ERTS 1 DATA ON ARAN VALLEY
(Enlargement from MSS 5 negative, Scale 1/200 000)
Zoning and samples from Vegetation Map

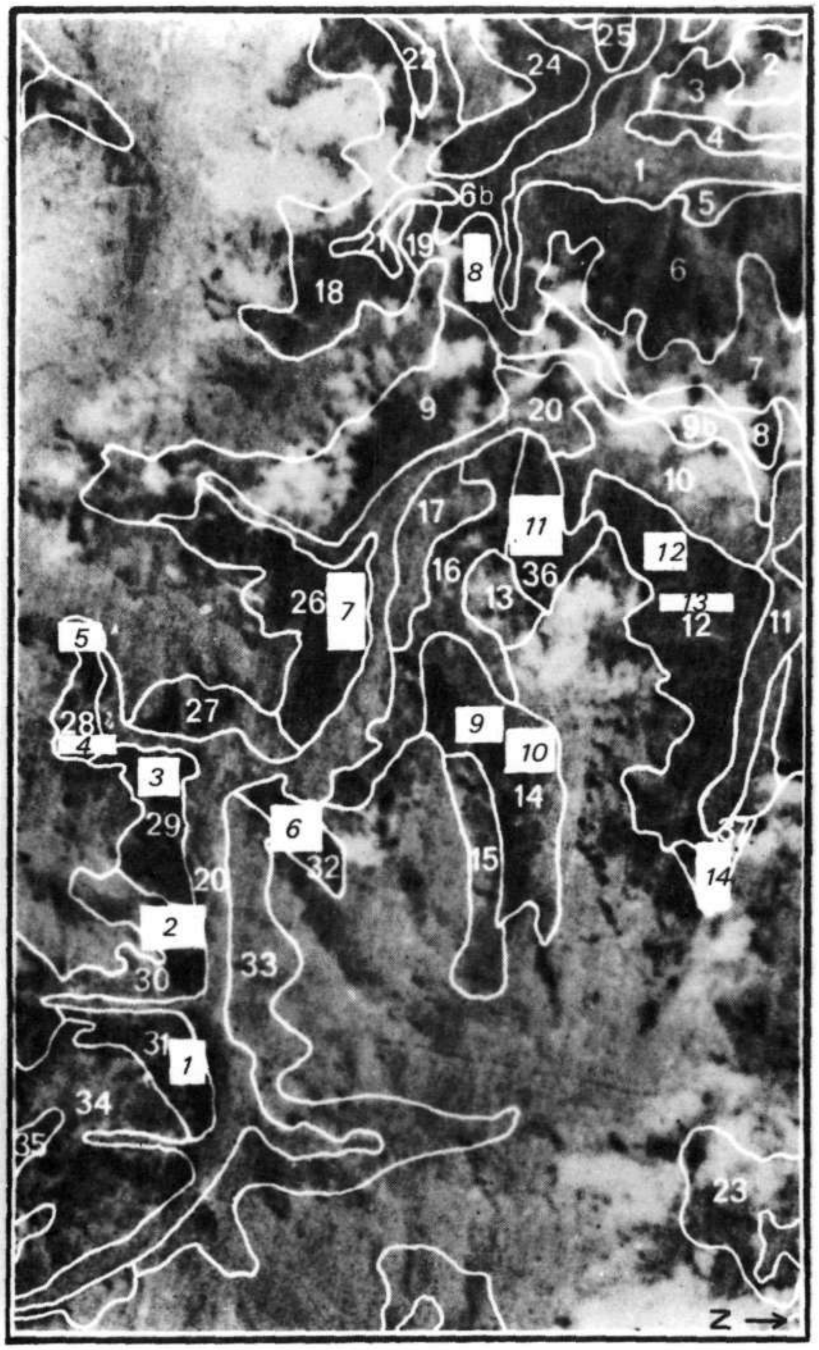
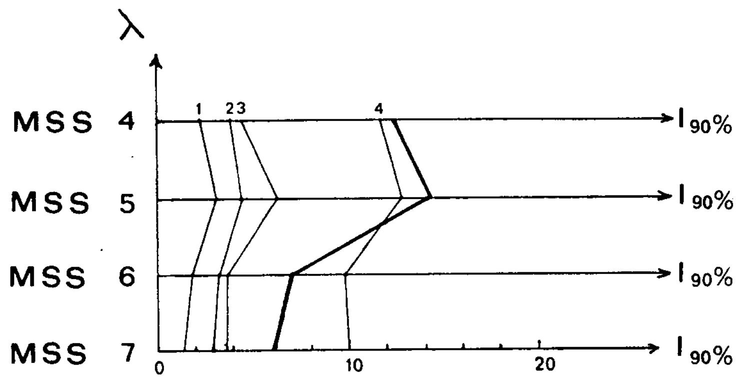


Figure II



Multiband relation examples for 4 sites according to their I 90 %

Homogeneity threshold for I 90 % in this experiment

FIGURE III : Diagram of multiband relation for I 90 %

The averages acquired in the four-dimensional system define clusters of responses corresponding to different types of ground objects. These clusters form a part of the phenological cycles of remote sensing of the objects studied.

Utilization and application of this determination works with the same procedure. Multispectral analysis permits the identification of the response of an unknown object in the space of calibrated clusters. Its location must have two forms :

- in a cluster area : the determination is directly acquired

- between several clusters. A method of barycentric classification defines the nature of the object.

4. Modification of the method

The first part of the experiment in remote sensing of forestry did not follow exactly this procedure :

- The pre-processing and approach were followed normally as described.

- The determination procedure was modified in this study. This change affects the order of regrouping operations. Clusters of responses are established : in each spectral band.

The combination of these clusters determines the characteristics area of an object an a four dimensional system.

After this simulation, several of these pre-analyses show possible areas for improvement of the technique :

1. The availability of a numerization with a 25μ step.
2. Improvements in lining up the points in the different spectral bands.
3. The automatic inclusion of geographical coordinates.
4. Use of the ERTS 1 magnetic tape.

VI. RESULTS-INTERPRETATION

This study is being conducted for the purpose of forestry identification. Nevertheless, sites and samples of zones without forests have also been treated. The cartographic pre-processing shows 29 wooded zones and 8 low-vegetation zones.

1. Experimental approach

This analysis has been carried out using the method described in V, 2, applied to the characteritic sites in 37 zones. The code determines the areas to be treated as a function of the dominant elements in the zone. The average area of the sites studied is about 150 ha. In order to show the successive phases of this procedure, examples are given on one type of object : Fir forests (Abies pectinata). Figure IV shows the sites selected in multispectral band 5 after the establishment of a homogeneity threshold. The confidence interval I 90 % permits the elimination of non-significant distributions coming from heterogeneous areas with :

$I\ 90\ \% \leqslant 14$ classes of optical density

Selection by cartographic coding in figure IV shows the homogeneous fir forest sites. Table I gives the corresponding characteristics of this analysis. (The areas presented here in white in figures I and II). This operation is carried out for all the sites treated in the four available spectral bands. The definitive selection of homogeneous sites is made with the four thresholds according to the principle in figure III. In this study of the Aran Valley this procedure reveals 70 homogeneous sites in which samples can be chosen. The cartographic pre-processing designates 50 forest sites (in the 29 corresponding zones).

From the first calibration results several things can be noted concerning the control phase of this experiment. The four spectral bands reveal two types of homogeneous fir sites. Figure IV, alone, suggests this distinction between analyses 11-16 and 17-114.

SYMBOLS USED IN TABLES AND FIGURES

n° F	Sheet identification of Vegetation Map
n° O	Zone identification in the sheet
n° A	Numerical analysis identification
n° E	Sample identification in the zone
C. UTM	Square location in UTM System
X	Location in UTM System :
Y	X=meridian location Y=parallel location
Ar	Artificialization
Sbt	Total woodland surface
B/V	Woodlands/Natural vegetation ratio
R/S	Reforestation/Woodland parcels surface
T	Topography
U.S.	Soil Utilization
NM	Number of measures
NMo	Number of modes
Vm	Maximum value obtained
Var	Variance
Moy	Statistical distribution average
T	Standard deviation
D.O.	Optical densities
Serie 9	Pine vegetation series (Pinus silvestris)
Serie 10	Pine vegetation series (Pinus uncinata)
Serie 11	Beech-tree vegetation series (Fagus silvatica)
Serie 12	Fir-tree vegetation series (Abies pectinata)
Phy : 3	Physionomy : forest
Nat	Nature of the vegetation series
Mel	Mixing : 01 = 2nd species 10 % ; 10 = 2nd species 10 %
E	Exposition : 8 = NNW, 1 = N
P	Slope percent : 5 to 7 = 40 to 60 %

(16)

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TABLE I

LOCATION						ZONE FEATURES							DISTRIBUTION CHARACTERISTICS				
n°F	n°O	n°A	C UTM	X	Y	Ar	Sbt	B/V	R/S	T	SERIES	US	NM	Vm	Moy	Var.	σ
77	31	11	CH	0324	4728	50	5	5	15	5	12 00 10	00	60	5	144,03	37,70	6,14
77	30	12	CH	0322	4727	50	5	5	25	5	12 10 00	00	88	7	145,95	57,33	7,57
77	29	13	CH	0321	4729	50	5	5	05	5	12 00 09	00	70	6	148,83	54,43	7,38
77	28	14	CH	0318	4727	50	4	4	05	5	12 00 00	00	56	8	147,96	76,57	8,75
77	28	15	CH	0318	4727	50	4	4	05	5	12 00 00	00	28	4	148,12	34,33	5,86
77	32	16	CH	0321	4732	51	4	4	05	5	12 09 00	00	30	3	145,60	31,24	5,59
77	26	17	CH	0315	4732	50	5	5	05	5	12 00 11	00	154	13	149,71	12,04	3,47
77	19	18	CH	0308	4738	50	5	5	15	5	12 00 11	00	105	14	148,52	18,45	4,30
77	14	19	CH	0319	4738	50	5	4	05	5	11 12 00	00	42	5	148,54	28,19	5,31
77	14	110	CH	0319	4738	50	5	4	05	5	11 12 00	00	42	4	148,08	26,93	5,19
77	36	111	CH	0313	4739	50	5	5	05	5	12 00 09	00	63	6	148,93	12,53	3,54
77	12	112	CH	0316	4742	51	5	5	05	5	12 11 00	00	35	4	147,27	16,03	4,00
77	12	113	CH	0316	4742	51	5	5	05	5	12 11 00	00	26	4	147,92	5,42	2,33
77	37	114	CH	0321	4743	50	1	1	01	5	11 00 00	00	42	5	147,41	22,68	4,76

ARNICA II-1

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ARNICA II-1

TABLE II

LOCATION				SAMPLE FEATURES						DISTRIBUTION CHARACTERISTICS					
N°F	N°O	N°E	N°A	Phy	Nat	Mel	E	P	Alt	NMo	NM	Vm	Moy.	Var.	σ
77	31	1	31	3	12	00	8	7	1500	1	30	3	141,50	9,98	3,16
77	30	1	42	3	12	01	8	7	1550	1	28	5	144,00	9,30	3,05
77	29	1	23	3	12	00	1	7	1400	1	40	4	148,12	17,97	4,24
77	28	1	54	3	12	00	8	5	1500	1	22	6	147,85	36,60	6,05
77	28	2	45	3	12	00	8	7	1500	1	18	3	147,49	19,71	4,44
77	32	1	46	3	12	01	8	7	1450	1	36	7	144,65	16,64	4,08
77	26	1	57	3	12	00	1	5	1200	1	64	6	147,65	18,57	4,31
77	19	1	48	3	12	00	1	7	1400	1	45	7	148,22	14,44	3,80
77	14	1	59	3	12	10	8	7	1300	1	16	2	146,83	16,24	4,03
77	14	2	410	3	12	10	8	7	1500	1	28	3	145,94	26,21	5,12
77	36	1	411	3	12	00	8	7	1400	1	36	5	148,24	33,40	5,78
77	12	1	412	3	12	00	8	7	1350	1	32	4	146,04	21,52	4,64
77	12	2	213	3	12	00	8	7	1550	1	24	10	148,82	15,44	3,93
77	37	1	214	3	12	00	2	7	1400	1	36	5	146,32	12,04	3,47

The largest heterogeneity in the first group is due to the geometric shape of the site locations : the vegetation map shows that the points of non-wooded areas overlap into the forest areas. With the homogeneity of the second group (No. A : 17-114) sites 19 and 110 cannot be distinguished as on the vegetation map : they contain an equal mixture of beech and fir.

2. Determination procedure

a) analysis of samples :

The samples used in this second analysis are taken in homogeneous sites. They therefore have a slightly smaller area (average about 100 ha).
The numerical analysis for the determination procedure (V, 3) is applied to these samples in the four spectral bands (MSS 4, 5, 6, 7). The pureness of these reference objects is defined by a variance analysis. It is clear that the statistical distribution of measured points occupies a smaller number of density levels. Figure V shows the average and standard deviations of 14 samples taken in the sites presented in figure IV. Here, the distribution of points where fir trees are present is found in a region $\pm$ 5.5 standard deviations about the mean. The characteristics for these samples are given in Table II. These make it possible to define the optical region in which the presence of fir forests has a high probability. The grouping of the analyses for this band is thus found at :

145 $\pm$ 5.5 classes of D.O. (optical density)

Identical regroupings are made in other bands for soil occupation units (or sets of units). The following groups have been found :

- Firs and Pines ; Beech and brushwoods ; Pasture and moorlands (MSS 4)
- Firs ; Pines and Beech ; Pasture and moorlands (MSS 5)

- Conifers, Deciduous, Pasture and moorlands (MSS 6)

- Conifers, Deciduous, Pasture and moorlands (MSS 7).

Their position on the optical analysis scale is given in figure VI for various multispectral scanner bands.

b) Interpretation of clusters :

The determination is based on the combination of clusters in different spectral bands. However, one cannot distinguish between 2 objects unless their response groups are separated by one channel. Figure VII illustrates the multiband relation : the relative positions of the clusters revealed by a combination of two bands are shown (MSS 5 × MSS 7).

Identifications are possible for the following :

1. Fir woodlands
2. Pine woodlands
3. Beech and brushwoods
4. Pasture and moorlands

The use of the 4 channels makes it possible to eliminate ambiguities between groups of ground objects. This does not improve the specific identification in groups 2, 3, or 4, since there is no spectral band in between. Other imagery dates are therefore needed in order to improve these determination keys. The regions defined in the 4 dimensional system of this multispectral correlation make up a part of the phenological cycles of remote sensing of the four sets of soil occupation units.

The identifications obtained are the results of three different factors :

- Physiognomy of vegetation growth.

The distinction between fir and pine can be made because the fir forests are dense and the pine forests are sparse.

APPROACH PROCEDURE
SELECTED HOMOGENEOUS SITES
(fir woods example)

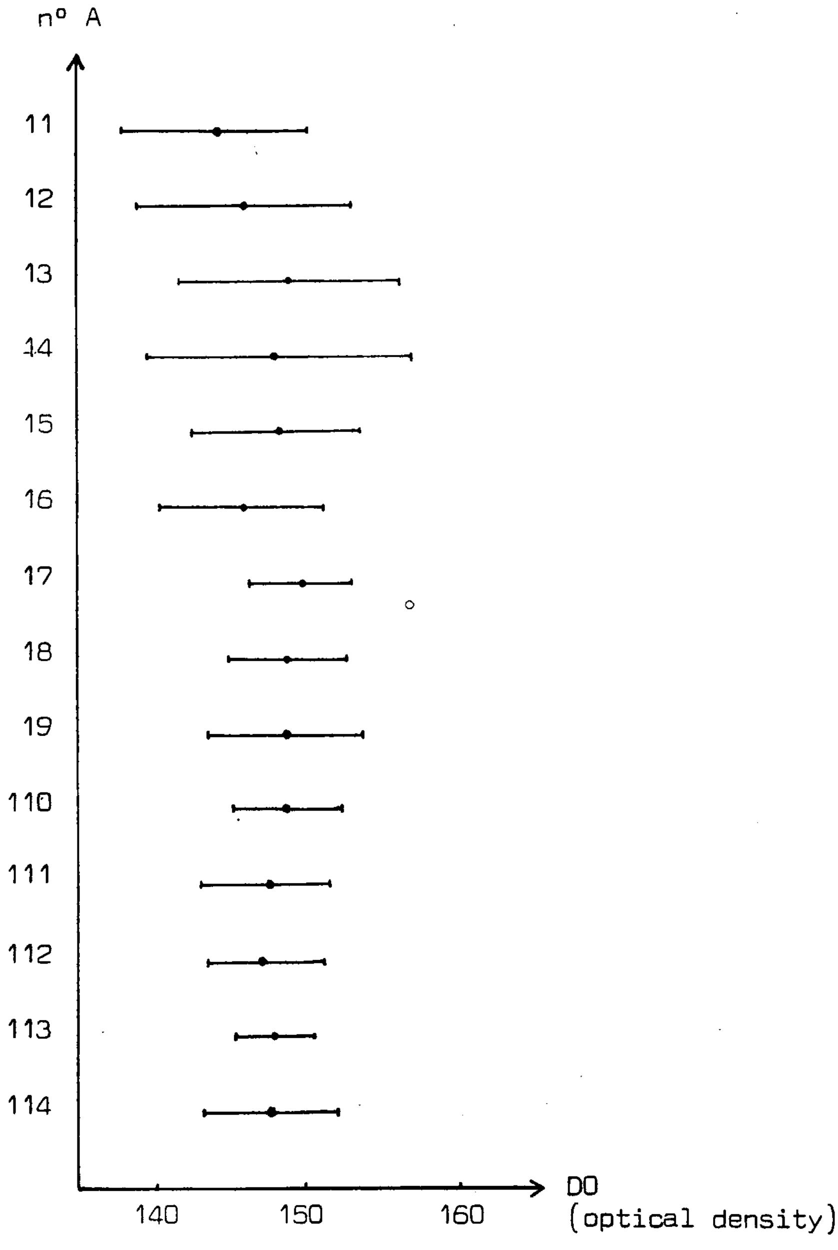

FIGURE IV

Average responses on spectral band (MSS 5). These characteristics show approximately the homogeneity threshold by the confidence interval for this band.

DETERMINATION PROCEDURE
Example of significant sample responses for fir woods

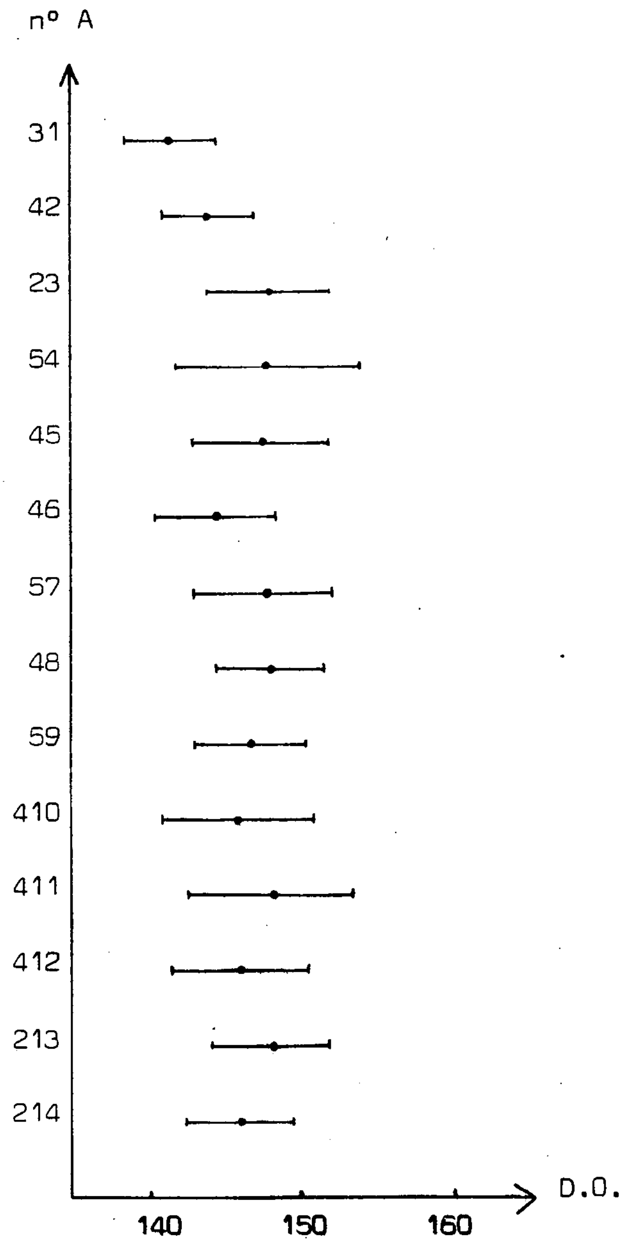

FIGURE V

This figure shows the increase in pureness of the samples taken in homogeneous sites

EXAMPLE OF PRINCIPAL GROUPS OBTAINED
(set of point correspondences)

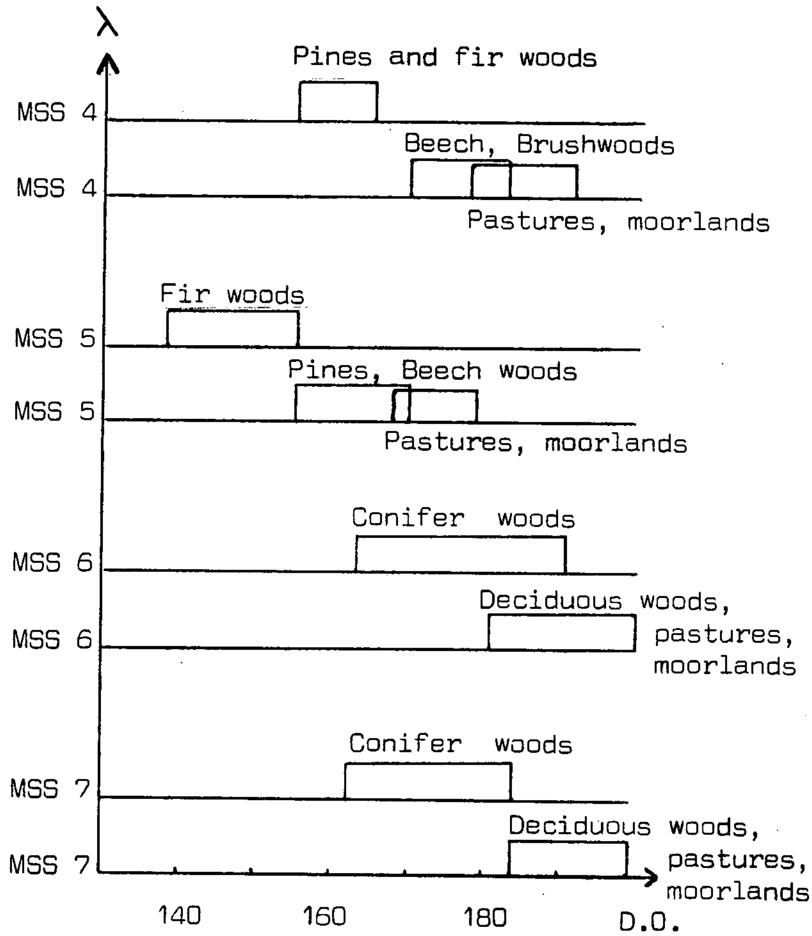

FIGURE VI

Groups are made, in each spectral band, with the cartographic sample code and characteristics of the responses analyzed on the same samples (modified process of the determination procedure).

ILLUSTRATION OF BISPECTRAL DIAGRAM

(example of simple correlation)

Principal determination areas

The use of the four channels avoids overlapping and ambiguity. Thus, the confidence of the identification is good.

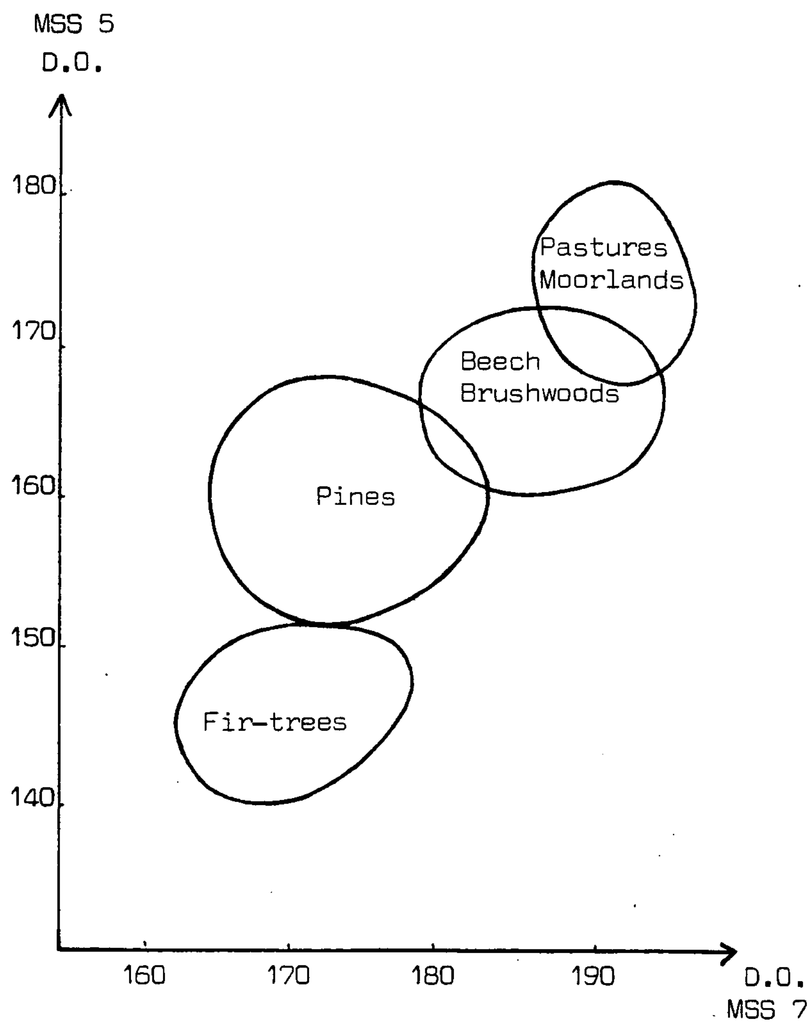

FIGURE VII

- Specific plant response : a clearer specific identification can be made between conifers and deciduous trees than between conifers and low vegetation.

- Regional phytogeographical conditions : Beech is identifiable because it is the only deciduous forest tree which can grow in this region.

Thus it seems that the essential criterion for identification is the distribution of plant masses on the ground. These various results are in agreement with previous experiments using satellite data. (E.g. : NIMBUS data over the Landes forest (France, SW) ; analyses and interpretations of ERTS 1 data over Spain (NE) (P. Gouaux 02-73)).

VII. APPLICATIONS : ANALYTICAL PLOTTING AND INVENTORY

Using part of a determination key, the efficiency of the preliminary study can be tested.

1. Analytical cartography

The example of the fir forest will be used again. The multispectral correlation defines a cluster whose cartographic representation can be made selectively. For this, the geographical distribution of optical densities contained in the clusters in each band are combined for a given ground object. A cartographical simulation of this combination is given in figure VIII (scale 1/200.000). Only the black symbol is significant ; it represents fir forests. The other symbols used merely indicate vegetation masses on the ground.

2. Inventory

Surface calculations can be made using the automatic production of this simulation.
For the characteristics of the numerization, one digitized point corresponds to a 160 m. square, or an area of 2.65 ha.

The planimetric simulation at 1/200.000 in figure VIII requires a contraction of the output processing. This diagram uses one character for 15 points of the basic numerical analysis. Thus the black marking for fir forests equals 40 ha. The direct count thus provides us with an estimate of the area occupied by this natural formation.
The measurements thus obtained can only have meaning for an entire region in which the number of points counted provides good confidence.
Thus in the study of the Aran Valley it is the measurement of the total fir forest area that is indicative. This region contains 123 sifnificant "fir" cluster characters, or 123 x 40 $\simeq$ 5000 ha. measurable fir forest. However, the forests in Zone No. 9 are masked by cloud cover (see figure II). One must therefore compensate with an estimate. This adjustment applies to 1000 ha. The fir forest area detected in this region is thus a minimum of : 6000 hectares.

A parallel measurement is made on the vegetation map over the fir forests plotted in the area studied with the following result :

7 400 hectares

Therefore, between the inventory made by means of remote sensing and the cartographic analysis, there is a deviation of 1400 hectares, which represents about 18 %. Part of this inconsistency ($\sim$7,8 %) is due to deforestation made after the cartographic analysis date. (The sheet for FOIX was edited in 1964). Another part ($\sim$10 %) is due to the data processing method. This difference can be reduced in two ways :

- improvements in pre-processing : using a 25 μ numerization (sampling x 4), processing the original magnetic tape.

- repetition of the calibration experiment : definition of new correspondences on characteristic phenological dates in order to improve the determination key ; grouping according to the unmodified determination procedure.

SIMULATION OF AN ANALYTIC CARTOGRAPHY
OF FIR WOODS

a █ covers 40 ha of fir woods

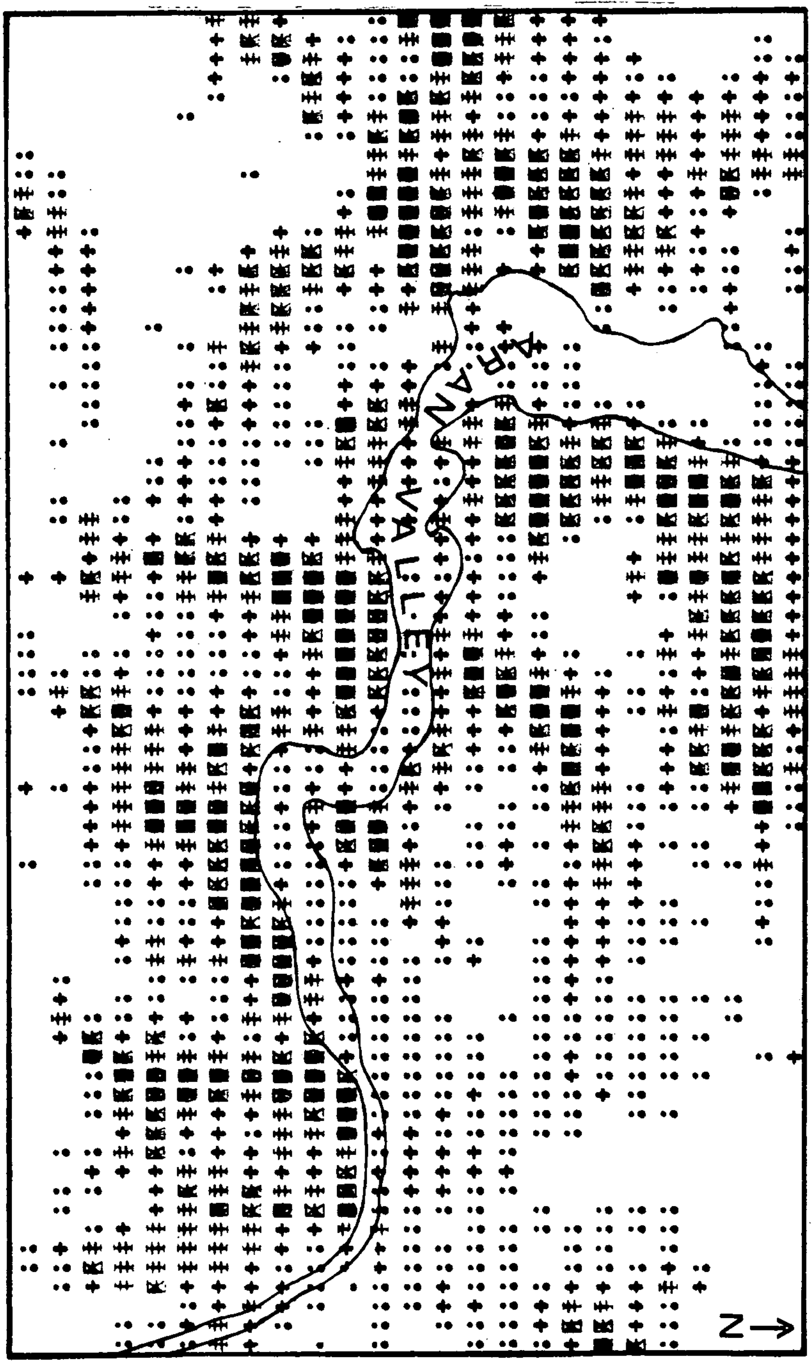

FIGURE VIII

The expected accuracy of this improved inventory is about 5-6 %. This seems sufficient and satisfactory for regional studies carried out with remote sensing data obtained by satellite.

VIII. CONCLUSIONS

This first phase of the experiment in the remote sensing of forestry thus provides us with two types of results :

- The four main sets of soil occupation units in mountain areas can be identified from correspondences determined by ERTS 1 imagery.

- The selection of points belonging to significant groups makes it possible to measure the areas occupied by these units.

The application of this method of finding correspondences will provide a means of checking the plotting of natural ressources in the zones chosen. The ensemble of experimentation has the following structure :

- First part :

  Identification and plotting of soil occupation units.

- Second part :

  Application to the actual construction of the Vegetation Map on the Spanish watershed (sheet for FOIX).

- Third part :

  Applying the acquired determinations to the vegetation map (sheet for LUZ, now in preparation).

These methodological results and their possible application have a twofold importance : first, for technical reasons, the working application of determination keys for ground objects is a major objective of the ARNICA B on ERTS B proposal ; second, for economic reasons, it serves as a check on and helps the planning of the vegetation mapping using ERTS 1 data.

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Chapter 3.

DIGITAL PROCEDURES
ON REMOTE SENSING IMAGERY
FOR THE ARNICA/ERTS 1 PROGRAM

M. MONCHANT

CENTRE D'ETUDES SPATIALES
DES RAYONNEMENTS

This paper summarizes the microdensitometer calibration and defines the great lines of available software. Schema of actual work is presented and figures show some examples.

I. Calibration of the Apparatus

We have calibrated the densitometry apparatus using two types of grids :

- one graduated in optical density in the nominal density range of 0.05 - 3.05 (I)
- the other a 25 resolution grid

The numerical data were then displayed on C II 10070 by means of a 3-step program :

- translation of the numerical tape into 10070 characters
- calculation of histograms
- printout of these histograms

The results take into account imperfections due to the slightly non-uniform rotation of the drum and to the positioning of the image, and have enabled us to get a quantitative idea of the limits of the apparatus and the necessary corrections.

II. Procedure

First Stage

- In order to use microdensitometer data on the CDC 6600, special data treatment, translation of information, and the development of exploitation software (COMPASS) have been necessary.

- In figure I, showing the display of the nominal density range grid, one observes a jitter in the numerization of the zones of constant intensity which can be estimated at $\pm$ 4 divisions. In order to remedy this we have investigated :

  - the dark current of the photomultiplier
  - the statistical fluctuations in the recording

A correction program for dark current and for smoothing of a line photo by a spline method has been developed.

Second Stage

- Development of a sorting program permitting the selectioning of any portion of a photograph. The user defines a working zone in lines and columns which is extracted, smoothed or not according to need, and stored, according to size and eventual use, on disc or central memory.

- On the zone chosen, an integration is performed on an elementary surface defined by the user, as a function of the zone to be analyzed and the dimension of the printer outputs.

- A study is performed of the distorsion of the image due to the printer and corrections.

- With a 6 line per inch carriage tape a character is inscribed in a rectangle of 1/10 inch - 1/6 inch ; if a symmetrical image exists, there must be a corresponding symmetry between the elementary surface image and the printer display. This is performed at the discretion of the user.

- Tracing of frequency histograms at the selected area, absolute and relative, after smoothing, with or without integration.

- Determination of the statistical characteristics of the distribution : the average, the variance, errors. (II)

- Visual simulation on the printer. For this display the user defines
  - the factor of intensity groupings
  - the coding scale. This has been done in such a way as to create to the eye a visual printout close to that given by a photo with a density of 14 levels. (III)

In order to increase flexibility, the user defines his coding as he desires it using any number of these 14 levels. This provides us with three possibilities for display :

- numerical (internal)
- numerically external
- simulated by grey tones. (IV)

III. Work in Progress

First Stage, partially completed

- Localization of the same zone on the 4 channels of an ERTS photo. For this each photo is perforated with holes to define a coordinate system.
Next an axial rotation O_i is made for each channel on each photo (i.e., [1, ... 4]), where O_i is the angle between the axial system of the photo and the axial system of the numerization and consequently of memory.

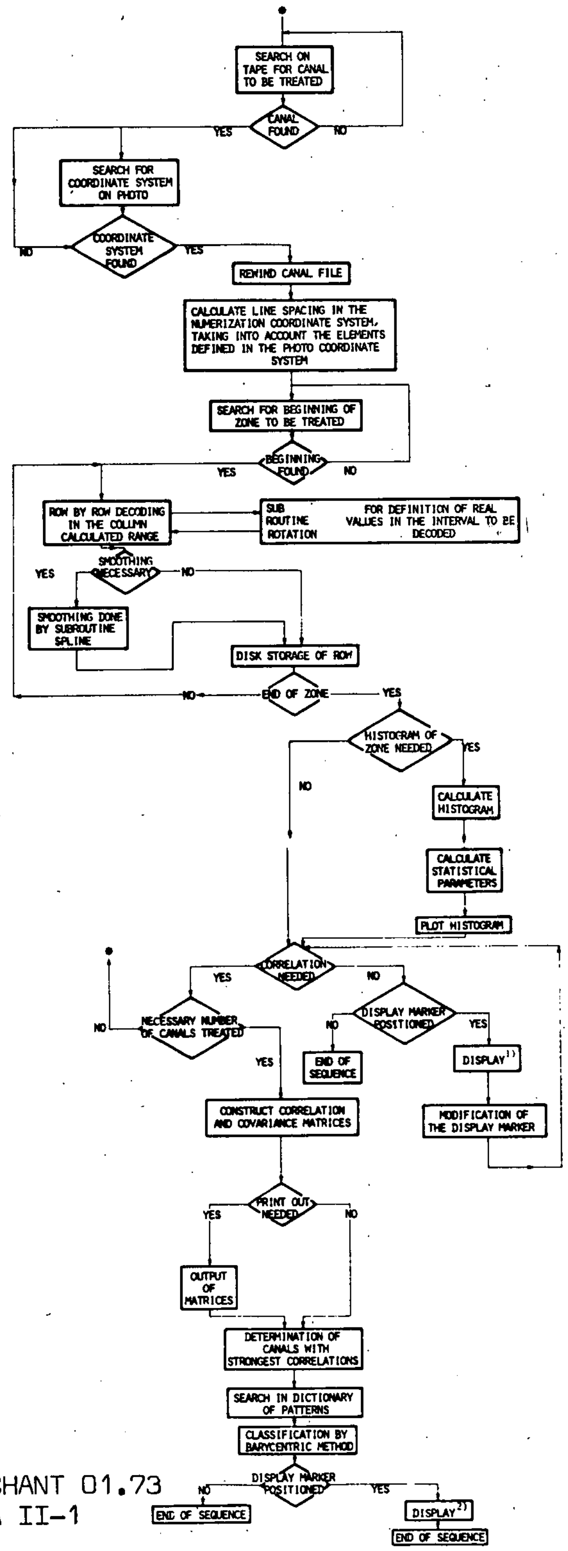
- Study of the correlations between the E_i classes of Ω_j ($d \in [1, \dots n]$) land forms taking ω_K ($K \in [1, \dots m]$) samples ; the covariance and correlation matrices are defined enabling the user to choose the most interesting channels.

- Classification of responses by the barycentric method, or by the elliptic method on the most clearly correlated responses.

- Extension of these methods to the differences between the 4 D1, D2, D3, D4 channels which define C_4^2 = Six differences in optical density.

Second Stage

- Extension of the preceding methods to four dimensions.
- Classification of the responses on known samples for the construction of probability laws with 2, 3, and 4 variables.
- Application of the Fourier transform to the study of the spatial frequencies of the image.


SEARCH ON TAPE FOR CANAL TO BE TREATED
CANAL FOUND
YES
NO
SEARCH FOR COORDINATE SYSTEM ON PHOTO
COORDINATE SYSTEM FOUND
REWIND CANAL FILE
CALCULATE LINE SPACING IN THE NUMERIZATION COORDINATE SYSTEM, TAKING INTO ACCOUNT THE ELEMENTS DEFINED IN THE PHOTO COORDINATE SYSTEM
SEARCH FOR BEGINNING OF ZONE TO BE TREATED
BEGINNING FOUND
ROW BY ROW DECODING IN THE COLUMN CALCULATED RANGE
SUB ROUTINE ROTATION
FOR DEFINITION OF REAL VALUES IN THE INTERVAL TO BE DECODED
SMOOTHING NECESSARY
SMOOTHING DONE BY SUBROUTINE SPLINE
DISK STORAGE OF ROW
END OF ZONE
HISTOGRAM OF ZONE NEEDED
CALCULATE HISTOGRAM
CALCULATE STATISTICAL PARAMETERS
PLOT HISTOGRAM
CORRELATION NEEDED
NECESSARY NUMBER OF CANALS TREATED
DISPLAY MARKER POSITIONED
END OF SEQUENCE
DISPLAY 1)
MODIFICATION OF THE DISPLAY MARKER
CONSTRUCT CORRELATION AND COVARIANCE MATRICES
PRINT OUT NEEDED
OUTPUT OF MATRICES
DETERMINATION OF CANALS WITH STRONGEST CORRELATIONS
SEARCH IN DICTIONARY OF PATTERNS
CLASSIFICATION BY BARYCENTRIC METHOD
DISPLAY MARKER POSITIONED
END OF SEQUENCE
DISPLAY 2)
END OF SEQUENCE

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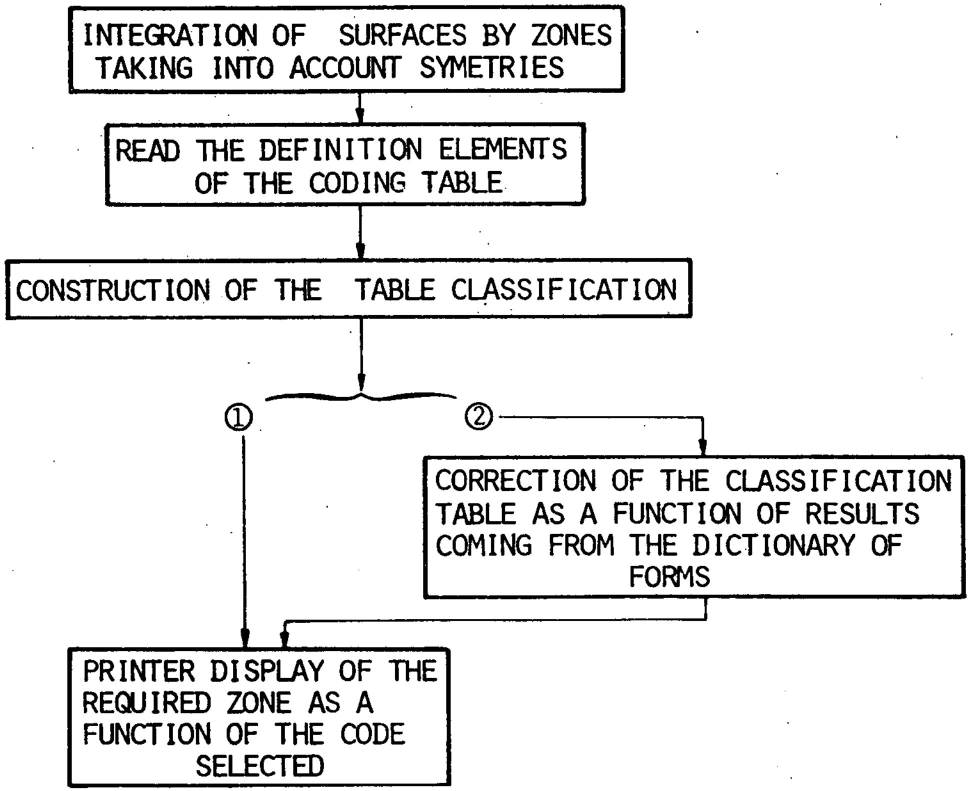

ARNICA II-1

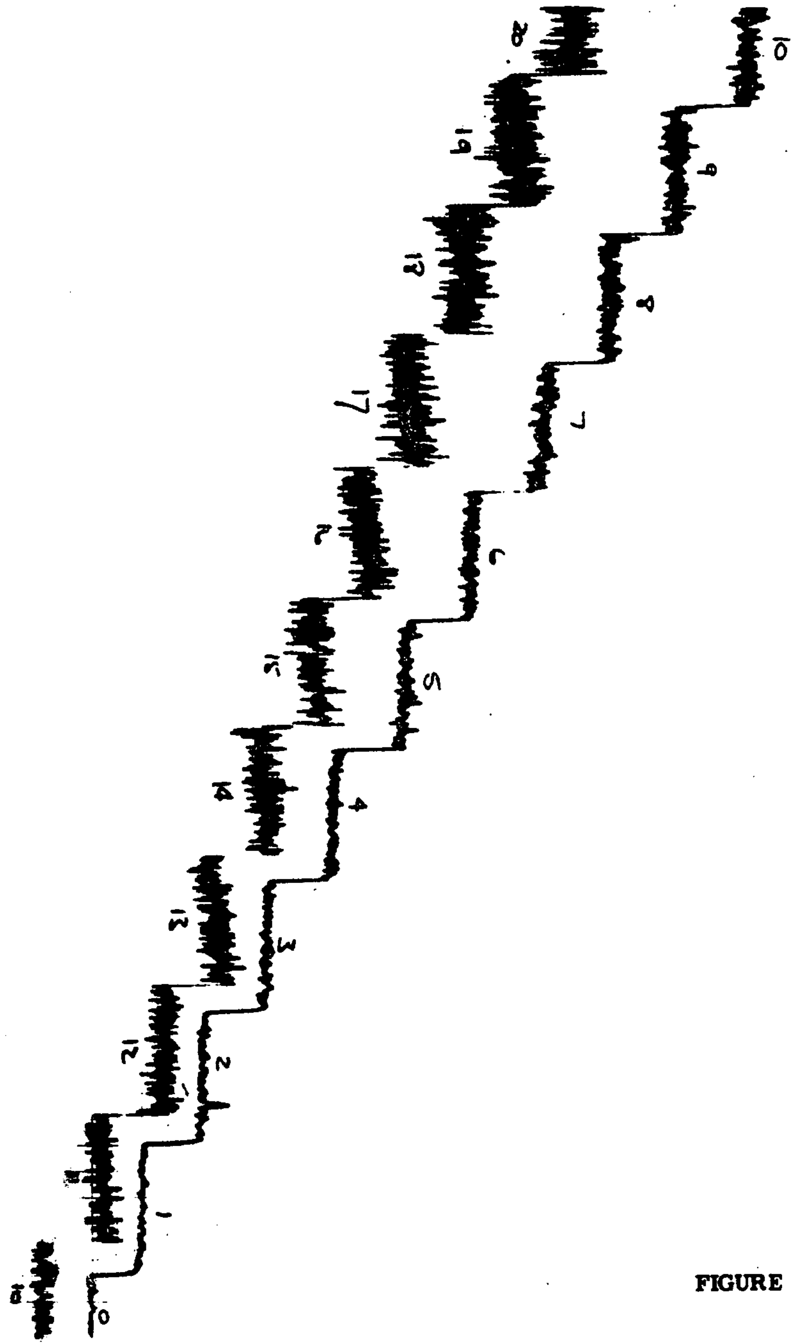

FIGURE I

20 8. 0·15b/cm. Kodak Stop Watch.

24/

ARNICA II-1

```
VAL D ARAN  2  8     TRACE DE L HISTOGRAMME DES DENSITES OPTIQUES

LIDEB  597  LIFIN  602  CODEB  498  COFIN  510

VALEUR MAXIMUM      10  NOMBRE DE VALEURS ACQUISES      78   UN B REPRESENTE   1 VALEURS

            0    10    20    30    40    50    60    70    80    90   100   110

149    0   I
150    1   IB
151    3   IBBB
152    4   IBBBB
153    6   IBBBBBB
154    6   IBBBBBB
155    6   IBBBBBB
156    6   IBBBBBB
157    5   IBBBBB
158   10   IBBBBBBBBBB
159    9   IBBBBBBBBB
160    4   IBBBB
161    3   IBBB
162    4   IBBBB
163    4   IBBBB
164    2   IBB
165    1   IB
166    1   IB
167    1   IB
168    1   IB
169    0   I
170    0   I
171    1   IB
172    0   I
***CARACTERISTIQUES DE LA DISTRIBUTION***

NOMBRE D'ECHANTILLONS    78    MOYENNE    157.73    VARIANCE    18.56    ECART TYPE    4.31
```

FIGURE II

(8)

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EXAMPLE OF A 10-LEVELS GRAY SCALE

(for visual simulation ouput)

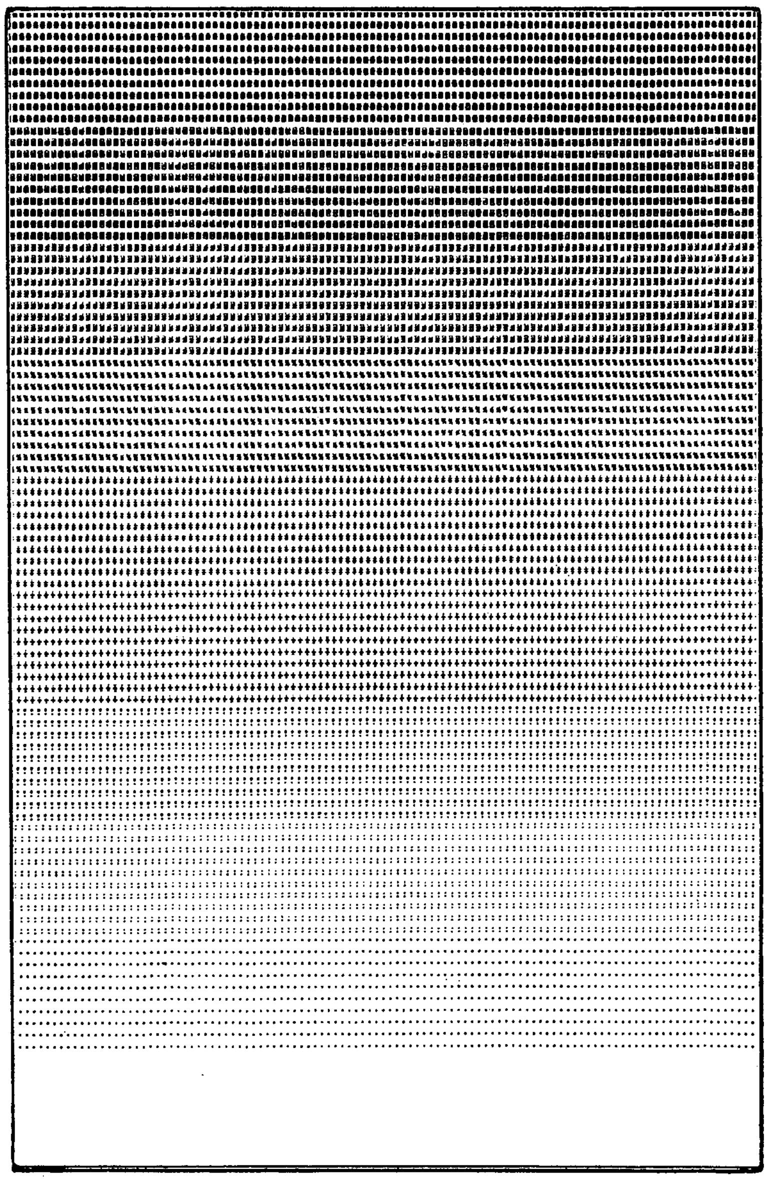

FIGURE III

```
*******************************************************************
     VAL D ARAN   CODAGE DE LOCALISATION 2   MSS 5
*******************************************************************
```

CADRAGE ET MISE EN FORME DE L*IMAGE

```
                350              520
                 +                +
                 +                +
                 +      171       +
                 +       +        +
     530---------I----------------I
                 I****************I
                 I****************I
     131---------I****************I
                 I****************I
                 I****************I
     660---------I----------------I
```

ELEMENT DE SURFACE

```
        1
        18
```

TABLE DE CODAGE

139 - 139	█	≡	X	V	O	14
140 - 140	█	≡	X	V	O	14
141 - 141	█	≡	X	V	O	14
142 - 142	█	≡	X	V	O	14
143 - 143	█	≡	X	V	O	14
144 - 144	█	≡	X	V	O	14
145 - 145	B	≡	X	F		10
146 - 146	B	≡	X	F		10
147 - 147	B	≡	X	F		10
148 - 148	B	≡	X	F		10
149 - 149	B	≡	X	F		10
150 - 150	B	≡	X	F		10
151 - 151	‡	=	I			8
152 - 152	‡	=	I			8
153 - 153	‡	=	I			8
154 - 154	‡	=	I			8
155 - 155	‡	=	I			8
156 - 156	‡	=	I			8
157 - 157	+	:	-			6
158 - 158	+	:	-			6
159 - 159	+	:	-			6
160 - 160	+	:	-			6
161 - 161	+	:	-			6
162 - 162	+	:	-			6
163 - 163	:	:	.			4
164 - 164	:	:	.			4
165 - 165	:	:	.			4
166 - 166	:	:	.			4
167 - 167	:	:	.			4
168 - 168	:	:	.			4
169 - 169	.	.				2
170 - 170	.	.				2
171 - 171	.	.				2
172 - 172	.	.				2
173 - 173	.	.				2

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ARNICA II-1

FIGURE IV

FIGURE IV ARNICA II-1

VISUAL SIMULATION
(with recorded gray scale)

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Chapter 4.

STUDY OF A RADIOMETER FOR VISIBLE WAVELENGTHS

Laboratoire de PHYSIQUE de l'ATMOSPHERE
Service du Professeur PICCA

UNIVERSITE PAUL-SABATIER
T O U L O U S E

I. ANALYSIS OF THE EXPERIMENT

A) PURPOSE

To measure the energy flux received from the ground at various wavelengths in the visible range.

B) USES

1. Study of the effect of lower atmosphere transparency by recording the energy flux received from the ground at various altitudes.

2. Study of the influence of atmospheric transparency between plane and satellite levels.

3. Study of radiation received from the ground in conjunction with weather conditions ; study of land and vegetation characteristics observed from the air ; all of these in three bands of the visible spectrum.

4. Evolution of radiation received from the ground during the year.

NOTE : The measurements are affected by ground illumination (solar radiation), re-emission from the ground (land and vegetation characteristics) and transmission of radiation through the lower atmosphere. These three effects can interfere with each other. In carrying out these experimental flights the relative influence of each of these factors will have to be determined as accurately as possible.

C) THEORETICAL STUDY

Illumination E produced on a screen with area S' illuminated at normal incidence by a source with area S at distance r and luminous energy L is :

$$E = L \frac{S}{r^2} \quad (1)$$

If S' is the image of source S in a lens with a focal length f whose aperture is limited by a circular diaphragm with diameter D (see figure 1) and if the source is far enough away, formula (1) becomes :

$$E = \frac{L\pi}{4} \left(\frac{D}{f}\right)^2$$

$\frac{D}{f}$ = relative aperture of the lens.

II. EXPERIMENTAL APPROACH

A) ORDER OF MAGNITUDE OF THE MEASUREMENTS

The total solar radiation received by the ground, in the visible range (between 0.4 μ and 0.7 μ) is an average of 400 Watts/m^2 in a clear sky. In the following calculation the energy flux is considered to be uniformly distributed in this spectral band.

The terrestrial albedo is highly variable (from a few % to 70 or 80 % for snow). It is generally estimated to be 10 %. The filters used have a bandwidth of approximately o.1 μ and their absorption in this range is 30 %.

The luminous flux transmitted through each filter is then of the order of 9 Watts/m^2.

The area of the source is 10^4 m^2 and the altitude of the sensor is $r = 10^3$ m.

Without a lens, equation (1) gives :

$$E = 90 \text{ mW/m}^2$$

With a lens having a relative aperture of $\frac{D}{f} = \frac{1}{3,5}$ and neglecting its own absorption :

$$E = 500 \text{ mW/m}^2$$

B) CHOICE OF EQUIPMENT

Our choice was influenced by two conditions :

1. To limit the angular field of view so that measurements are made on a ground area of 1 hectare, which corresponds to the recording resolution of the satellite.

2. The detector must be able to record low illumination. In order to sight the same area at different altitudes, we have chosen SOLIGOR lenses whose focal length varies between 55 and 135 mm ; with the addition of a focal length extender a 1 hectare area on the ground can be sighted from altitudes of 550-2700 meters.

The detectors must be capable of measuring illumination much lower than 100 mW/m^2, since this experiment is being performed to a large extent for the comparative study of the reflectivity of various land areas. Also experimental conditions require light materials ; therefore, we have eliminated photomultipliers, whose power sources and associated electronics are too bulky. We have chosen a photo diode coupled to an I.C. amplifier a UDT 500 from United Detector Technology, Inc. Figure 2 lists its principal features.

The filters, made by Metallisation et Traitements optiques, were chosen to have bandwidth which differ as little as possible from those of the filters aboard the satellite. They are two filters in the SPECIVEX series ; the DA 531C and the DA 620C' whose transparency maxima are 0.531μ and 0.620μ , respectively ; they work under normal incidence and are obtained by combining absorbent materials and thin layers multi-dielectric or not. The third filter A 680b' is a Fabry-Derot interference filter its maximum is 0.680μ .

In order to relate recorded signals to the nature of the ground sighted, the Service des Activités Aeriennes of the Institut Géographique National has put at our disposal a type T 232 MK 7 35 mm camera equipped with a 50 mm lens. Measurements and photographs are coordinated by means of an intervallometer adapted to the camera.

All of the results are stored in a Multicorder Watanabe 4 channel chart recorder, series MC 611 H ; three channels are used for recording signals transmitted through the photo diodes ; the fourth is used for peaks coming from the intervallometer on the camera. The sensitivity is 1 mV to 100 volts full scale ; the chart speeds of the 25 cm-wide paper are 300, 600 and 1200 mm per minute or hour ; each pen uses the entire width of the paper. This apparatus works on 220 v. AC ; the measuring system is completed by a SDO 501 SODILEC DC to AC converter which converts the 27 volts DC available in the plane into 220 volts AC.

Photo 3 shows the detector ; figure 4 shows the experimental system.

In conclusion; this first report consists of a preliminary study of the experiment. The entire system has been operational since January 15, 1973. The technical description and the various calibrations will be presented in the next report.

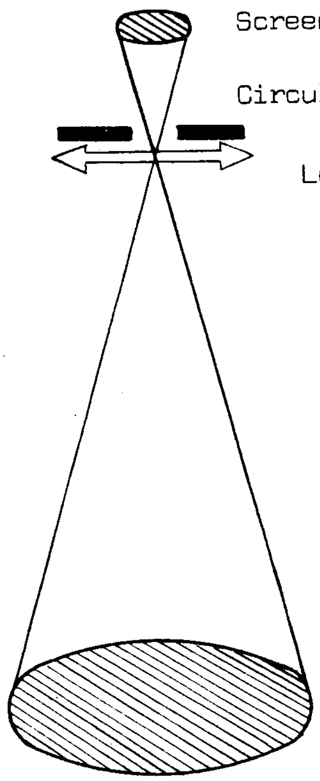
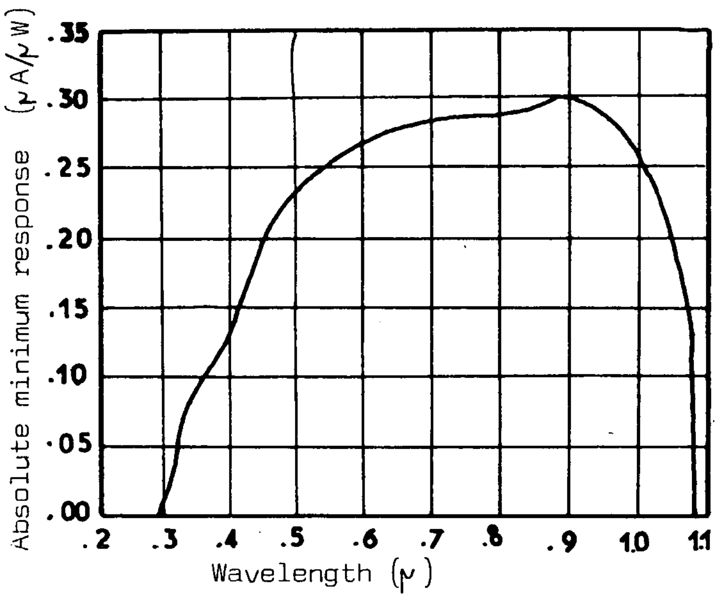
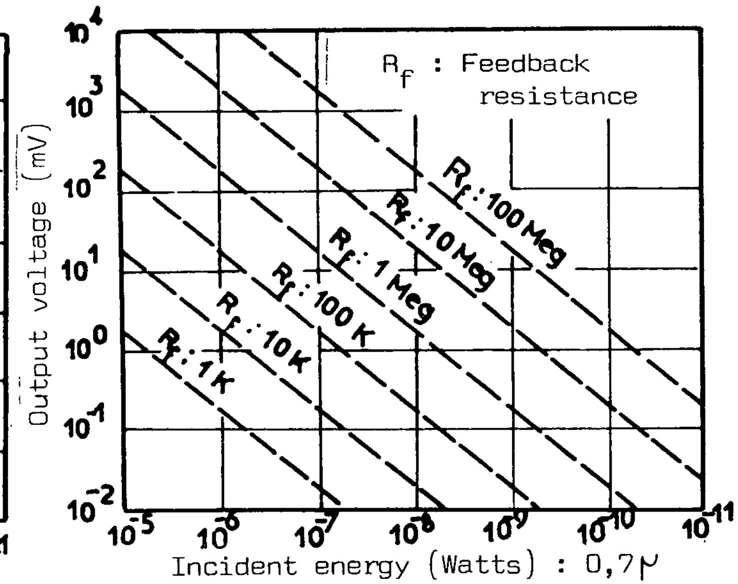

Screen with area S'
Circular diaphragm with diameter D
Lens with focal length f
Distant source with area S

Figure 1





Range	10 à 10^{-8} W/m^2
Background	10^{-8} W/m^2
Response time	1 Volt/μ sec
Active area	1 cm^2
Amplifier bandwidth	0 à 10^5 Hz
Temperature drift	± 5μ Volts/°C

Figure 2 : Photo-diode U D T 500

(Characteristics provided by the manufacturer).

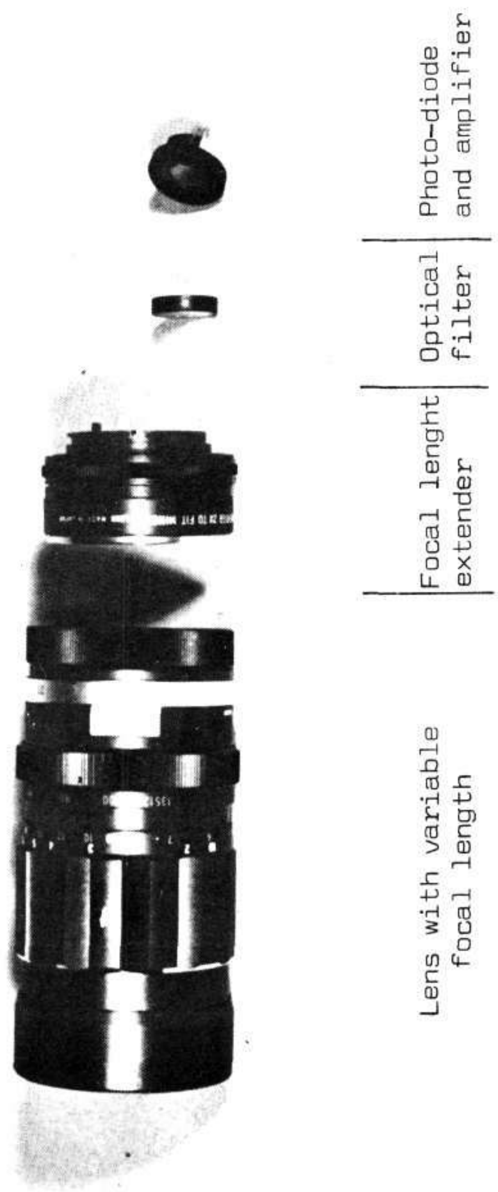


Figure 3 : Detector components

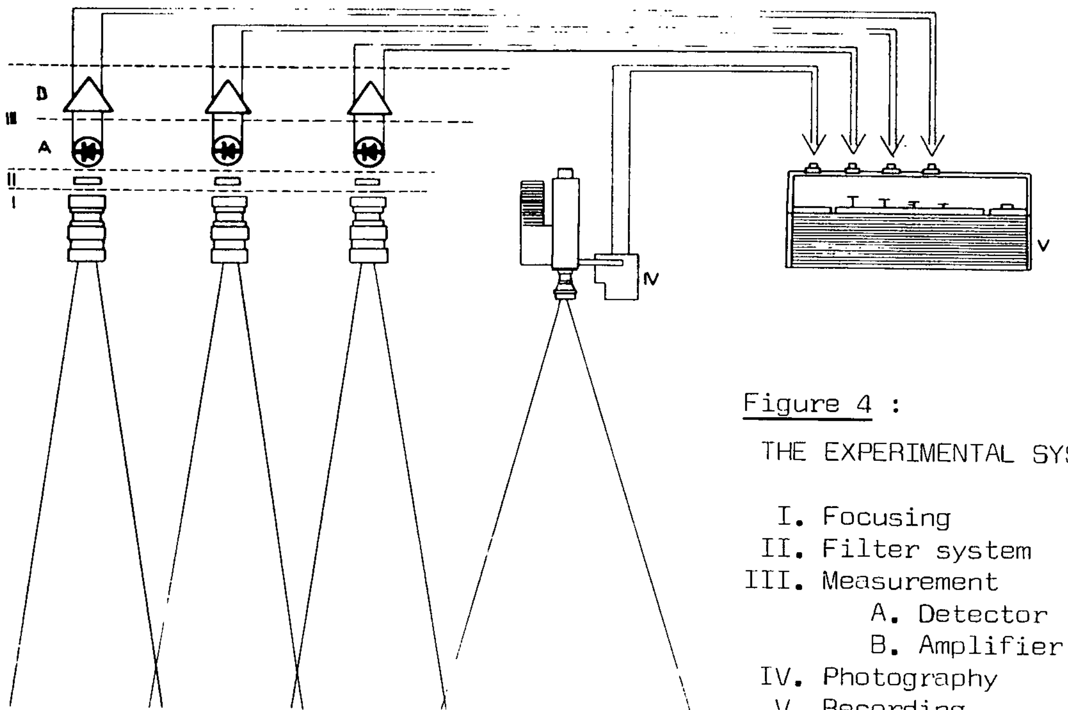


Figure 4 :

THE EXPERIMENTAL SYSTEM

I. Focusing
II. Filter system
III. Measurement
A. Detector
B. Amplifier
IV. Photography
V. Recording

LIST OF ILLUSTRATIONS