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MANAGEMENT OF NATURAL RESOURCES
THROUGH

AUTOMATIC CARTOGRAPHIC INVENTORY

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15. Abstract :

Significant results of the ARNICA program (February - December 1973)

a) The qualitative processing of ERTS data was developed along 2 lines :

- the study of geological structures and lineaments of spanish Catalonia

- the phytogeographical study of the forest region of the Landes of Gascony (France)

In both cases it is shown that the ERTS imagery can be used in establishing zonings of equal quantitative interpretation value.

b) In keeping with the operational transfer program proposed in previous reports between exploration of the imagery and charting of the object, a precise data processing method was developed, concerning more particularly the selection of digital equidensity samples computer display and rigorous referencing.

/

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PART I

PREFACE

- OBJECTIVES

- SCOPE OF ACTIVITY

- SIGNIFICANT RESULTS

- CONCLUSIONS

OBJECTIVES

In keeping with the research plan proposed in the previous reports, the processing of ERTS imagery has been carried out along 2 basic lines :

. Two-fold qualitative studies

- to evaluate the level of correlation between knowledge acquired from ground truth (vegetation or geology) and satellite imagery.

- to derive laws of correspondence for use on ERTS imagery in conjunction knowledge about natural resources on poorly known or unknown sites.

. Quantitative studies for coordinating the qualitative processing of the imagery with the automatic restitution of date on inventory and evolution of major types of natural resources.

Thus this report is concerned with methodology.

SCOPE OF ACTIVITY

● The qualitative studies concentrate on basic themes :

- geological, using as test-site the northeastern region of spanish Catalonia, where stratigraphy and tectonics are presently well known, notably from the work of B. DONVILLE.

- phytogeographical, selecting the Landes of Gascony area for its particularly favorable conditions for studying methodology rela-ting to models of forestry and agriculture.

● The quantitative studies, completing the re-sults already obtained, involve the following problems :

- computer display techniques after microdensitometer treatment of the imagery

- development of high precision methods for referencing imagery information

- coordination of successive sampling opera-tions required for feasible automatic data processing.

SIGNIFICANT RESULTS

A. QUALITATIVE STUDIES
see Part II, Chapters 1 and 2

1. Data 1115-10033   MSS 4, 5, 6, 7 (Geology)

ERTS imagery was compared with known geological structures in Catalonia, which prove to be particularly complex : the "brittle tectonics" of the region shows up perfectly on the satellite imagery and the 3 main lineament directions (NE-SW ; NW-SE ; NS) are confirmed.

This example clearly shows that a preliminary interpretation of ERTS imagery would have greatly facilitated the very complex ground studies that have been carried out in this region for many years.

2. Data 1064-10190   MSS 4, 5, 6, 7 (Phytogeography)

The great forest area of the Landes of Gascony lends itself particularly well to a "photozoning" interpretation of the ERTS imagery as well as to a comparizon with the "cartozoning" derived from the vegetation maps.

The forestry landscapes are closely tied to the geomorphology of the land and to drainage conditions assured by the hydrographical network on essentially sandy soil. There is therefore a very useful correlation between "densitometric ensembles" revealed by the imagery and phytogeogra - phical ensembles actually present on the ground.

SIGNIFICANTS RESULTS (continued)

Furthermore the mixture of deciduous-conifer which characterizes the forestry distribution is perfectly shown by comparizons of MSS 5 and 7 data, as are the major zones of intensive irrigated corn cultivation.

This break down of the imagery into zones of equal value has been studied quantitatively and the results confirm its limits and its interest.

SIGNIFICANT RESULTS (continued)

B. QUANTITATIVE STUDIES

see Part II, Chapters 3 à 5

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

1. (Chapter 3)

The first series of operations to be carried out after microdensitometric treatment of the imagery (cf. Type II Progress Report n° 1, chapter 3) consists of obtaining a good visual restitution of the image using a printer.

This display can be obtained by means of either graphical symbole giving a visual impression like the original, or numerical values which give the optical density of each point.

Such restitution, applied to the entire image, or to partial zones preselected for their qualitative value, involves the following stages :

1 - Calculation and transformation of data
- decoding of information
- calculation of integral optical density in the test zone under consideration
- calculation of density frequency histograms
- calculation of statistical distribution characteristics

2 - Automatic data restitution
- numerical output
- printout

Testing and development were conducted jointly on ERTS documents, on a very small scale, and on imagery taken from stratospheric balloons on a larger scale. This assurer a good relay of information between known land features and remote sensing data.

SIGNIFICANT RESULTS (continued)

2. (Chapter 4)

One absolutely indispensable condition for accurate treatment lies in the absolute rigorous referencing of the samples on ERTS imagery. The precision detection by microdensitometer ($25\,\mu$ steps) is only usable if the mechanical selection of test-zones can be insured with an equal degree of accuracy.

The method developed is based on :

1° the automatic referencing of 4 reference crosses at the 4 corners of the original ERTS document (referencing is facilitated by microdensitometric analysis of the microscopic pinholes punched manually in the center of each cross directly on the film).

2° transposition of the reference system : a sample defined in the reference system formed by the crosses on the ERTS image can thus be referenced very accurately with respect to the microdensitometer digitalization axes by translating and rotating the axes.

SIGNIFICANT RESULTS (end)

3. (Chapter 5)

The third stage of the chain of transfer operations consists of selecting successive of digital equidensity levels on the test-site, which indicate ground truth to be analyzed.

The following stages of work are involved :

- "Qualitative" selection of the test-site by means of "cartozoning - photozoning" comparison and identification on the ERTS image.

- Processing the sample by means of a FORTRAN program and the establishment of density histograms.

- "Filtering" of the information and break down of the general histogram into the most significant major density levels.

- Display of the entire test-site after coded information compression according to the levels retained.

- "Qualitative" preselection of new more homogeneous samples of different soil occupation types, in parts of the image where the correlation between spectral response and ground truth seems most satisfactory.

- Statistical treatment of the homogeneous samples in the 4 ERTS bands and numerical and graphical detection of the best decoding combinations for each ground truth.

Results show the primary interest of comparing MSS 5 and MSS 7, which proves to be the best for class discrimination. Recourse to MSS 4 and MSS 6 information is necessary only in subsequent operations to avoid possible ambiguities.

CONCLUSIONS

The studies presented in this report show feasi-
bility of the main stages in the chain of transfer
operations from ERTS imagery to automatic car-
tography.

The general feasibility of one example of trans-
fer has been shown in the last report. Here it is
necessary to specify in detail certain stages of
the program :

- selection of qualitative data

- sampling problems

- rigorousness of experimentation

The methods proposed here should be useful in
other fields as will be shown in the next defini-
tive report on the ARNICA program.

PART II

RESULTS

Chapter 1. QUALITATIVE STUDIES : Geology

- ERTS 1 SATELLITE DOCUMENTS AND
GEOLOGICAL STRUCTURES OF NORTH-
EAST OF CATALONIA

  by B. DONVILLE, Department of Geology
  and Geomorphology, Université Paul Sabatier

Chapter 2. QUALITATIVE STUDIES : Phytogeo-
graphy
- IDENTIFICATION OF LANDSCAPE TYPES
FROM ERTS 1 IMAGERY (Landes de Gasco-
gne - France)

  by Mme P. GOUAUX, Department of
  Teledetection, Université Paul Sabatier
  and D. LOUBET, Centre d'Etudes
  Spatiales des Rayonnements

Chapter 3. QUANTITATIVE STUDIES

- DISPLAY PROBLEMS
  by Mme T.LE TOAN and M. MONCHANT,
  Centre d'Etudes Spatiales des Rayonnements

Chapter 4. QUANTITATIVE STUDIES

- METHOD FOR LOCATING SAMPLES ON
ERTS IMAGERY

  by Mme T. LE TOAN, J.C. GUYADER,
  Centre d'Etudes Spatiales des Rayonnements
  and Mme P. GOUAUX, Université P. Sabatier

Chapter 5. QUANTITATIVE STUDIES

- RESPONSES OF DIFFERENT TYPES OF
SOIL OCCUPATION DEFINED FROM
HOMOGENEOUS SAMPLES

  by Mme T. LE TOAN, J.C. GUYADER,
  M. MONCHANT, Centre d'Etudes Spatiales
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Chapter 1.

ERTS SATELLITE DOCUMENTS
(1115-10033 MSS 4, 5, 6, 7.)
AND GEOLOGICAL STRUCTURES
OF NORTHEAST OF CATALONIA
(Spain)

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ERTS 1 SATELLITE DOCUMENTS 1115,

1033 MSS 4, 5, 6, 7 and

GEOLOGICAL STRUCTURES OF NORTHEAST CATALONIA

- B. DONVILLE -

We shall briefly review the geological
composition of the northeastern part of
Catalonia. We shall consider only the region
limited on the north by the French border, on
the west by the eastern end of the Ebre basin,
on the south by the southern boundary of the
Montseny mountain range and on the east by the
Mediterranean. In this zone mainly the
following units are found (figures 1 and 2) :

- The eastern part of the axial zone of the
Pyrenees, composed mainly of palaeozoic and
cristallophylian materials (1, 2, 3).

- The eastern part of the sub-Pyrenean zone,
characterized by eocene formations with rather
intense crumpling (4).

- The Transversal Catalan system, composed
of eocene formations in particular the block of
Cabreres, the graben of Olot and the horst of
the Garrotxa.

- The Ampurdan depression, in which
primarily continental formations of the Neogene
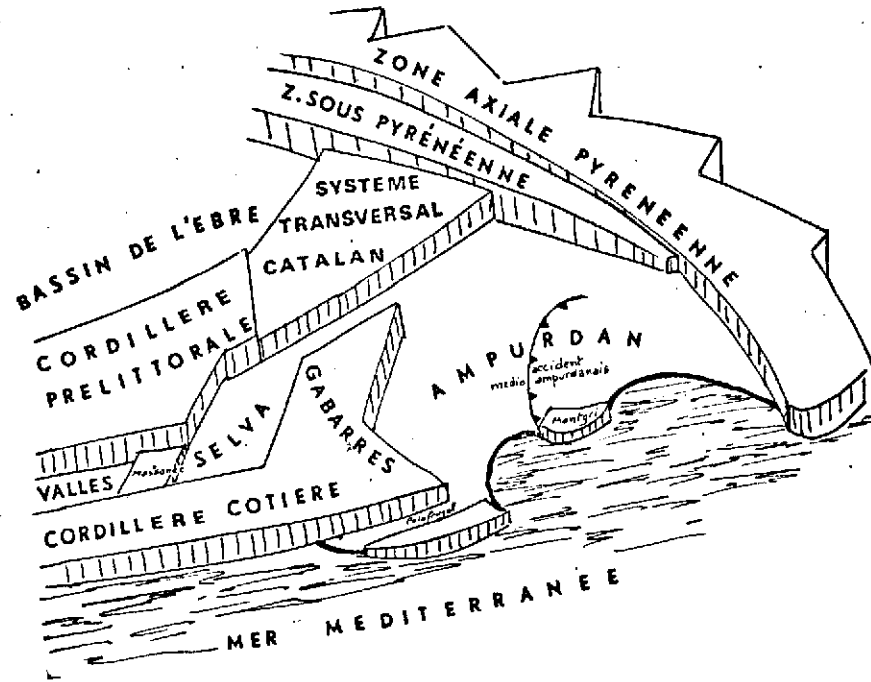and Quaternary overlap the intensely folded and
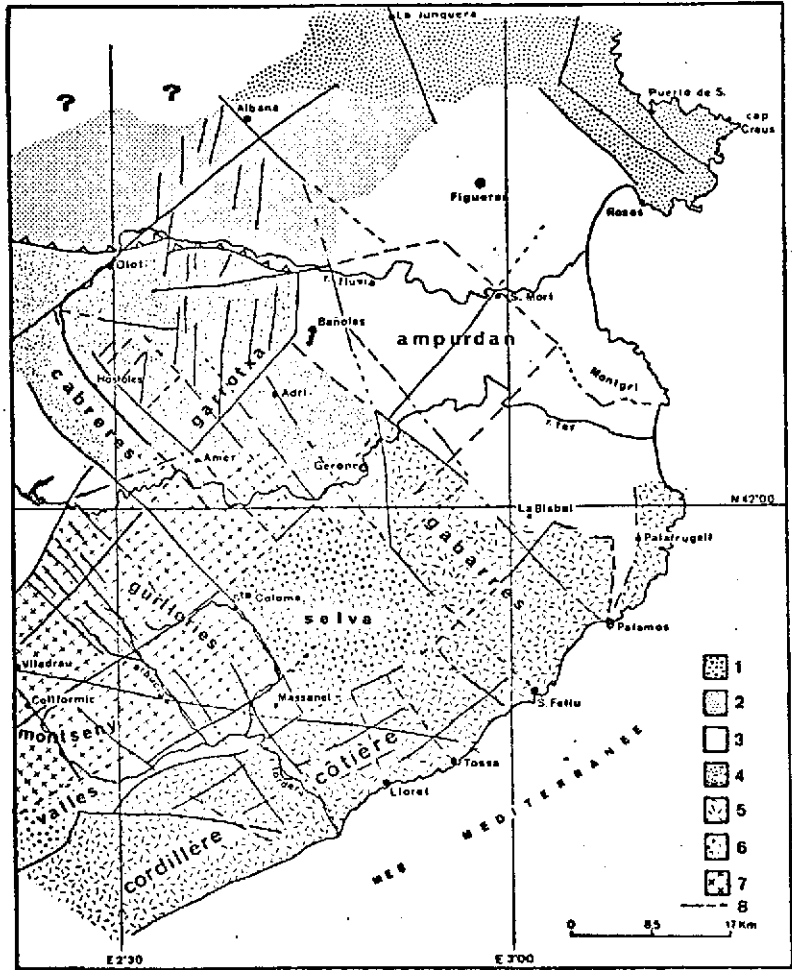faulted Eocene (5).

Figure 1

SCHEMA STRUCTURAL DU NE DE LA CATALOGNE.

1-Zone axiale pyrénéenne.2-Zone sous-pyrénéenne.3-Ampurdan
4-Système Transversal Catalan.5-Cordillière cotière catalane.
6-Dépression prélittorale.7-Cordillière prélittorale.
8-Principaux "linéaments" carsants.

Figure   2

— The western part of the Catalanides,
composed of the coastal cordillera including the
Gabarres mountain range formed by palaeozoic and
granitic areas, prelittoral depression (Valles,
Selva) filled by continental ponto-plio-quaternary
sediments and the prelittoral cordillera formed
essentially by palaeozoic and granitic areas (6).

The structural data above can be found in and
supplemented by documents 1115 10033 MSS 4,5,6,7,
because of the brittle character of the substratum
of this region accentuated by many lineaments (7).
Figure 3 reproduces the MSS 6 document on a larger
scale and emphasizes these lineaments.

If only those lineaments which seem to corres-
pond to fractures are considered, certain general
observations can be made (8) :

— With rare exceptions there are only 3 main
directions : NE-SW ; NW-SE ; N-S.

— Possible N-S aligned fractures do not seem
to be found systematically outside the Garrotxa
and the sub-Pyrenean zone.

— The NE-SW Catalan direction, whose impor-
tance has already been pointed out on the French
side of the axial zone, seems to play an important
role, even outside of the Catalanides.

When possible, we shall analyse the
observational results of these images for each of
the previously defined structural units.

1. Pyrenean axial zone (Zone axiale pyrénéenne)

As we see in figure 2 all observations have
been obscured by cloud formations, in the N and
NW. Nevertheless, in the Alberes region one can
notice that the preferential direction of the
major lineaments is NW-SE. From E to W the
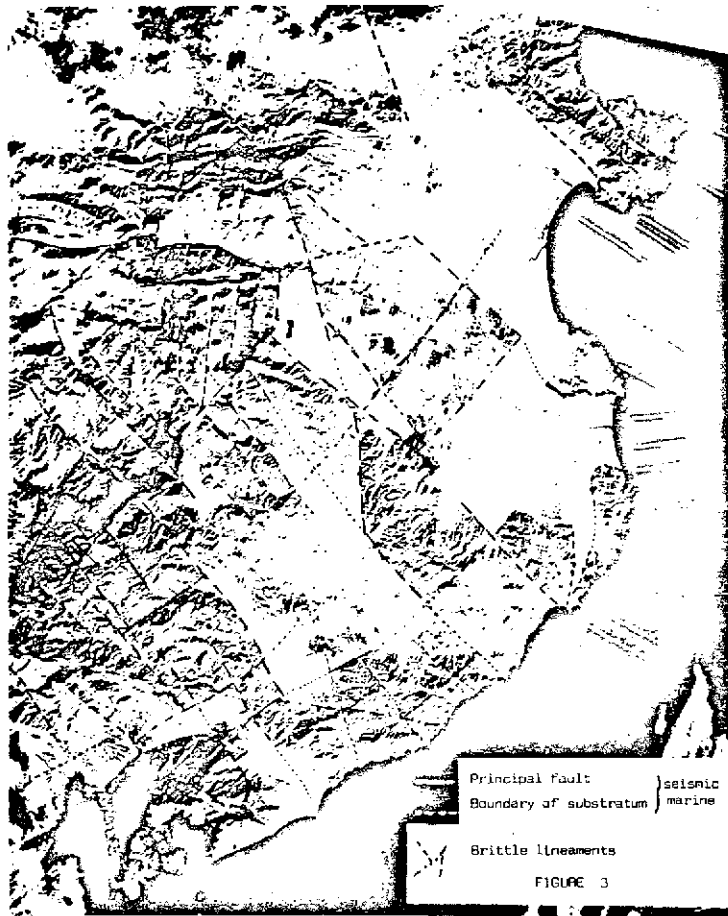following are identifiable :

Figure   3

- the Puerto de la Selva fault (NW-SE) ;

- the bordering fault of the Ampurdan passing by Rosas (NW-SE) ;

- the great Junquera fault (NNW-SSE).

2. Sub-Pyrenean zone (Zone sous-pyrénéenne)

This zone is also usually covered with clouds. However one can recognize the great Albaña fault (NW-SE) which starts in the axial zone. It seems to reappear in the Ampurdan after curving inward (NNW-SSE) and further south follows the western edge of the Gabarres mountain range. Further west a set of N-S lineaments is situated north of the overlapping line separating this zone from the Garrotxa, a line which is barely visible on the image because it is parallel to the principal alignments of the eocene structures. In addition, let us point out the penetration of the great Olot fault into this zone, described in the following section.

3. Transversal Catalan System (Système transversal Catalan)

There is a great fault from NE-SW passing through Olot and penetrating deep into the sub-Pyrenean, even cutting into the Albaña fault. The existence of this fault has already been stressed by CHEVALLIER and can be found in the works of MARCET RIBA (4 ; p. 94).
But on the latest maps, particularly the Figueras geologic map (scale 1 : 200,000) (1) it is not shown at all.

To the east of this fault the southern limit of the Garrotxa seems to correspond, in the southwest to the Hostoles fault (NW-SE) and, in the east, to a fault NE-SW, less apparent, which apparently goes through lake Bañolas. These two fractures seem to be southern limits for many of the N-S accidents observable in the horst of the Garrtoxa.

These accidents cut back the directions of the EW
lineaments corresponding to the main eocene
structures of this zone (not shown on Figure 1).

It must be pointed out that in this same zone
is a slightly E-W lineament which could correspond
to a fracture whose extention may be found in the
Ampurdan.

The eastern border of the horst of the
Garrotxa may then correspond to a fracture belon-
ging to the N-S system which passes west of lake
Bañolas.

4. The Ampurdan (L'Ampurdan)

Buried beneath neogene and quaternary, often
argillaceous formations, the brittle structures
of the Ampurdan are usually difficult to see.
However certain lineaments with directions mainly
NW-SE and NE-SW can be seen. Thus such a line
(NW-SE) beginning at Montgri and passing near San
Mori must correspond to the deep accident locally
indicated by evidence of Cretacian overlying
Eocene.
In addition, a long lineament directed NE-SW
seems to be found in the entire Ampurdan. It may
not correspond to any known structure or fault.
It nevertheless seems important since, its
extension is found along to the north of Gerone
in the Catalanides mountain range ; it crosses
the Montseny range and reappears north of
Barcelona (8). It would seem to indicate the
presence of another deep accident noticeable
perpendicular to the first (NW-SE) and very wide.
To the NE of the depression, the Gerone-San Mori
alignment is seen to pass through Puerto de Selva.
It is not inconceivable to admit its existence in
the axial Pyrenean zone where it could have played
a certain role in cutting out the great Cap Creus-
Rosas peninsula.

In the western part of the depression, outside
the fault bordering the Garrotxa (N-S), one can
recognize the southern extension of the great
Albaña fault. To the east of lake Bañolas it seems
to branch off : there it gives rise to a NW-SE
lineament which passes near La Bisbal (although
showing of course no evidence on the ground) and
also it extends southward.

5. The coastal cordillera (Cordillère côtière)

The Palafrugell corridor, which may constitute
evidence of the shoreline depression, is limited
by N-S faults. Everywhere else the main lineament
direction of this cordillera is NE-SW which is
also the direction of the coast.

It must be pointed out that, contrary to
previously expressed ideas, the Gabarres mountain
range seems to form a particular structure and
the fact that it belong to the Catalanides is not
apparent from these images. In fact, it seems that
the NW-SE fault serves as a contact with the
Ampurdan, to the west of La Bisbal, extends, to
the southeast, toward Palamos, and thus specifies
to the Northeast of the range, a part wedged
between the graben of Palafrugell and the exten-
sion of the great southern bordering fault of the
prelittoral depression. The western limit of the
Gabarres, as we have already shown, seems to
correspond to the extension of the great Albaña
fault towards the south. This limit represents the
southernmost manifestation of the N-S direction of
fracture systems in the region. The Albaña fault
runs into a NW-SE fault passing perceptibly to
Canet d'Adri and crossing the coastal cordillera
toward the southeast to San Feliu de Guixols.
Furthermore the Gabarres mountain range seems
fractioned by the extension of the great southern
Valles fault (NE-SW) which limits the coastal
cordillera towards the NW.

The preferential direction (NE-SW) can further be seen in a certain number of alignments within the range, and is like that of many veins of porphyric rocks found there.

This structure lying NE-SW is cut off perpendicularly by several NW-SE fractures, mainly that of the Rio Tordera, the Lloret de Mar and the Tossa de Mar.

In addition, towards the southern part of the zone under study, one notices the presence of two E-W, very wide lineaments. The first, crossing the threshold of Massanet, penetrates deep into the prelittoral cordillera, where it forms the western limit of the Montseny block, passing near Viladrau. The second and smaller lineament creates a transverse fault from the great southern bordering fault of the prelittoral depression.

6. The prelittoral depression (Dépression
                                        prélittorale)

The remarks made about the Ampurdan apply here as well, namely that buried under recent clay sediment, different lineaments corresponding to fractures in the support are scarcely visible. There is only evidence of the bordering faults of the depressions and these are described in the paragraphs about other units.

7. The prelittoral cordillera (Cordillère
                                       prélittorale)

It is in this structure that the most brittle lineaments are to be found. They belong typically to two systems of fractures oriented NE-SW and NW-SE.

Besides the extension of certain fractures of the Transversal Catalan System, the main NW-SE fault observable in the western part of the Cordillera, is the Santa Coloma de Farnes fault.

Following this same direction (NW-SE), a very
large number of fractures of varying sizes,
outline stepping blocks in this Cordillera,
mainly the previously mentioned Santa Coloma,
the Arbucias river, and the Collformic.
This same orientation of fractures is found well
developed in many lineaments in contact with the
inner depression to the NW of the Guilleries
block. The NE-SW preferential direction is
accentuated by very long but fewer fractures.
The main one of these appears to be composed of
the extension, towards the SW, the accident,
which we have named San Mori-Gerona, and what
can be found to the north of Barcelona. It thus
seems to divide the prelittoral cordillera
longitudinally and serves as a NW limit to the
La Selva depression. To the SE of this median
accident, the outline of the bordering fault of
the prelittoral depression is more jagged and
eventually disappears where it meets the ridge
of Massanet and La Selva. Conversely, towards
the NW, the extension of the great accident
passing near lake Bañolas, previously mentioned
in connection with the Garrotxa, penetrates deep
into this prelittoral cordillera.

The E-W Collformic accident which as we have
seen penetrates deep into the coastal cordillera
toward Tossa de Mar must be added to the two
abovementioned quite perpendicular directions.

Conclusions

Outside the Pyrenean zones (the axiale zone,
the sub-Pyrenean zone) the different structural
groups in the NE part of Catalonia are defined
by a tectonic of blocks. These are the result
of a considerable fracturation but go in few
directions.

Belts lying NE-SW have been created by the
following great faults :

- the Olot fault

- the Bañolas fault

- the San Mori-Gerone fault

- the western fault of the Valles depression

- the western fault of the coastal cordillera.

Overlying this structure a large number of fractures, with an general NW-SE orientation, have formed different blocks which are vertically separated.

The following main fractures have such an orientation :

- the western fault of the Gabarres

- the Adri fault

- the Hostoles fault

- the Santa Coloma de Farnes fault

- the Arbucias fault

- the Collformic fault.

Thus three depressions surrounded by steps of varying heights can be identified.

- The Ampurdan, situated between the Pyrenean zone, the Garrotxa and the Gabarres mountains.

- The Selva, located between the Gabarres mountains in the NE, the Guilleries mountain ranges to the NW and SW, and for the moment including the Massanet ridge, and the coastal cordillera to the SE.

- The northeastern end of the Valles situated between the coastal and prelittoral cordilleras and locked in to the NW by the Massanet ridge.

To complete this simplified structural sketch one
must add the presence of a set of N-S fractures,
which seem to effect only the northern part of
the zone under investigation, evidenced mainly
by the extension of the Albaña fault in the south.

Finally some great E-W accidents (the Viladrau
fault, for example) complete this picture apparen-
tly without influencing the previously discussed
structural diagram.

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Chapter 2.

IDENTIFICATION OF LANDSCAPE
TYPES FROM ERTS-1 IMAGERY
(Landes de Gascogne, France)

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The study of the major landscape types was
carried out on multispectral scanner imagery from
September 25, 1972. The annotation block for this
document includes the following : 1064-10190 - 01.

This image covers southwestern France. The
usable part is reduced to an area well known by
biogeographers : the "Landes de Gascogne" (Moors
of Gascony).

I. FEATURES OF THE REGION

Situated on the maritime front of the
Aquitaine, the moors of Gascony, a triangle-shaped
area largely open to the ocean, forms a remarkable
natural unit. The coast is planked by dunes behind
which are lines of ponds ; of these only the
Arcachon Basin connects with the ocean. The back
country is a vast plateau of sand, 158 m high in
the east, sloping down imperceptibly toward the
west and the north.

In this region the landscape features can be
very specifically isolated and identified. These
features are included in the following areas :

- pedology : large differences in drainage ;

- geomorphology : alternating plateaux and
        deep narrow valleys ;

- land features : very marked development
        of soil occupation : much clearing
        and reforesting within clear-cut
        geometric areas ;

- ecology : combination of pedological and
        climatic factors resulting in a
        particular vegetation pattern
        (forest arcades, reforested moors,
        cleared moors, wooded dunes, bare
        dunes, etc ...) ;

- history : development of the moors by
        means of reforesting (creation of the
        Landes Forest in the 19 th century) ;
        fires.

II. LANDSCAPE ANALYSIS

II.1. Qualitative analysis

The images show a mosaic of textures
representing the various landscapes in the region.

The analysis consists of drawing a "photozo-
ning" so that identical textures are grouped
together. This operation is performed on images
in MSS bands 5 and 7 which seem to be the most
significant. Zones of equal texture are decoded
using the zoning previously drawn up on the
Vegetation Map for comparison : Bordeaux and
Mont-de-Marsan sections.

Thus, after the MSS band 5 and 7 images have
been studied, two photozoning are made.
The photozoning for MSS 7 is the most complete.

Zone 1 : Pine forest

A homogeneous stand of pine forest (Pinus
pinaster Sol.) on very old dunes, i.e., on
intensively drained soil, divided up by a large
system of fire-breaks. The land features and
pedologic conditions of the soil are apparent,
so that this zone can be very clearly distin-
guished in the two spectral bands 5 and 7.

Zone 2 :

Spectral band 7 best defines this zone by
distinguishing 2 very clear sub-sets, 2 a and
2 b, not visible in spectral band 5.

2a : Forest agricultural complex

This outlines a very clear scallop around the ponds ; the points of the scallops correspond to streamside vegetation growing up to the ponds.

2b : Forestry complex

Consists of pine forestry (Pinus pinaster Sol.) in soil with average drainage. The texture of this area is different from that of zone 1 (pine in soil with intensive drainage). Within the wooded areas a light gray line shows the courses of streams. The response recorded at this level and in spectral band 7 is therefore not water but trees (Deciduous : Quercus pedonculata Ehrh.) bordering the stream and organized so that they cover and hide the course of the river in a aerial view, like the pattern of tropical "forest arcades". This feature appears often and is peculiar to the moors of Gascony.

Zone 3 :

As for zone 2, spectral band 7 best reveals, this zone. Spectral band 5 shows a coarse textured zone grouping various land features, the most frequent being the moors ; cultivated land appears on the edges of villages and along lines of communication.

Two sub-sets, 3 a and 3 b, can be distinguished in spectral band 7 :

3a : Forestry complex (Pinus pinaster Sol.) on well drained moorland, scattered along the course of the Great Leyre and the Little Leyre which drain a major part of the moors of Gascony. The course of the river and its affluents are emphasized by the "forest arcades" of deciduous trees (Quercus pedonculata Ehrh.).

3b : Heterogeneous complex of open forest, brushwood, reforesting, and cultivated land.

Zone 4 : Forestry and pasture complex

A rather poorly defined zone, in spectral bands 5 and 7, with very heterogeneous textures.

It corresponds mainly to very badly drained moorland with patches of pine woods (Pinus pinaster Sol.) which have grown back naturally after the serious fires of 1940 and 1947.

Zone 5 : Forest agricultural complex of Bazadais

This landscape does not belong the Landes plateau. It consists of small extents of woods (Quercus pedonculata Sol. and Pinus pinaster Ehrh.) with wide areas of cultivated land in between (primarily vineyards).

The MSS 5 image faithfully reproduces this landscape, showing the forests (dark gray) in the middle of the cultivated areas (light gray). The MSS 7 image clearly isolates this zone from the first 4 of the Landes plateau, although the difference in signature between forests and cultivated land is less clear than on the MSS 5 image.

Zone 6 : Agricultural complex on the left bank of the Garonne River.

Major vineyard zone, on stony soil, very clearly detached from the Landes plateau in spectral band 5.

Zone 7 : The Mas d'Agenais Forest

Included in zone 6, this dark gray area with very clear boundaries is clearly distinguished on spectral band 5.

It is a large forest area formed by trees with
falling leaves (Quercus pedunculata dominating).
In spectral band 7 this zone can hardly be
located.
This difference between the two spectral bands
brings up two points.
Two very different features are mixed in spectral
band 7 :

    − high formation : extensive forestry with
clear outlines ;

    − low formation : cultivated land.

In this case, the land features are not predomi-
nant. However, the phenological state of the
formations plays an important role, so that on a
spring recording (March 23, 1973), the forest was
clearly distinguishable from its surroundings in
the same spectral band (band 7).

Zone 8 : Swampy grassland

    Swampy grassland near Bordeaux, northward,
are easily located in both spectral bands 5 and 7.

Zone 9 : Urban

    The city of Bordeaux clearly visible in
spectral bands 5 and 7. Cities with average
population density are only visible in band 7
(Langon, La Reole, Marmande, Tonneins, ...).

Zone 10 : Water

    10a : Ocean water-ponds ;

    10b : Waters in the tidal zone, clouded by
suspensions of silt due to the continual motion
of the water in both directions in the Gironde,
Garonne, and Dordogne.

LANDSCAPE ZONING

MSS 7-IMAGE - 1064-10190
1972, 25 SEPTEMBRE

☐ 1   ☐ 5
▦ 2a   ☐ 6
▦ 2b   ☐ 7
▤ 3a   ▤ 8
☐ 3b   ☐ 9
☐ 4   ▤ 10
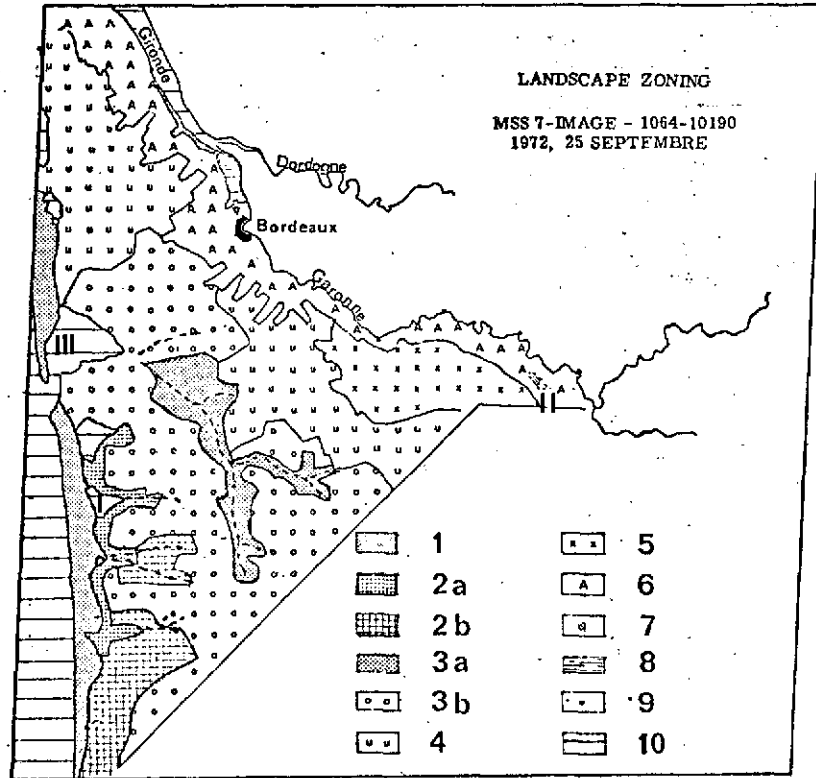
Figure 1

1 — Pine forest ; 2a — forest agricultural
complex ; 2b — forestry complex on soil with
average drainage ; 3a — forestry complex on
soil with well drainage ; 3b — heterogeneous
complex ; 4 — forestry and pasture complex
5 — forest agricultural complex of Bazadais ;
6 — agricultural complex ; 7 — deciduous
forest site (hardly located in spectral band 7)
8 — swampy grassland ; 9 — urban ; 10 — water
(ocean-ponds) ;---- arcade forest.

I   The Born region
II   The Mas d'Agenais region
III The Arcachon Basin

Figure 1 represents the MSS 7 photozoning.
The qualitative study allowes to identify and to
characterize landscapes part of landscape descri-
bed by examination of 2 spectral bands.

In a spectral band, the analyzed structure is
defined owing to its gray level which is the
result of different teledetection factors.

The structure is, then, determined by its four
spectral responses. Figure 2 indicates the
responses distribution in a two-dimensional
graph (MSS 5 and MSS 7).

Figure   12
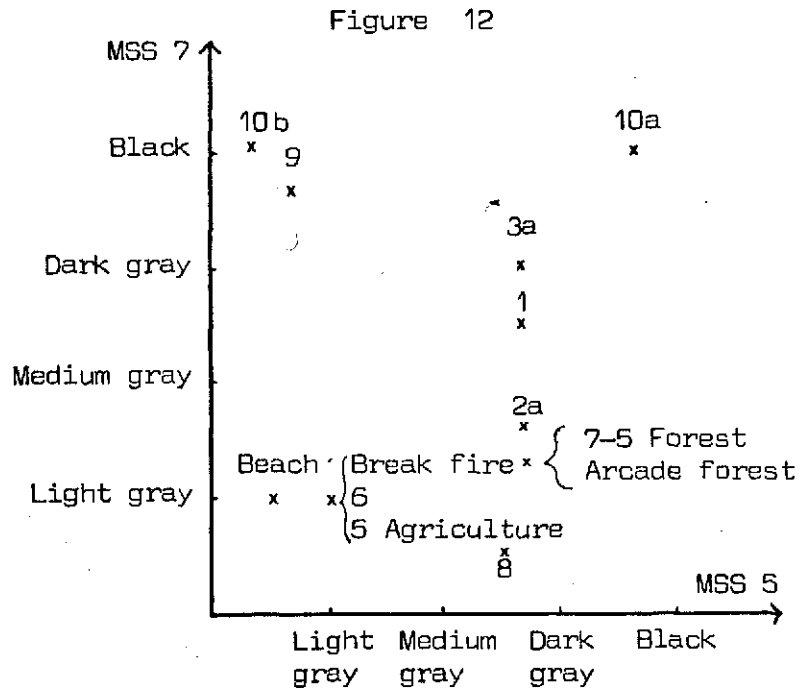
1, 2a, 3a, 5 Agriculture, 5 Forest, 6, 7, 8, 9,
10a, 10b : landscapes.
Arcade forest, break fire, beach : part of
landscape.
2b, 3b, 4 : very heterogeneous landscape not
indicate.

II.2. Quantitative analysis

The zones obtained by means of qualitative
analysis are used as basic data for the quanti-
tative phase of this study. The most significant
sites on the image are selected and treated
quantitatively. The following test sites were
chosen :

- The Born region
- The Cocumontais region
- The Arcachon Basin.

1 - The Born region

The landscapes found in the Born region are
described above with determining of zones 1, 2a,
10a, (figure 3).
The data restitution corresponds to a 7 levels
displays of the image, taken in spectral band 7,
in which this landscape are clearly pointed out.
The coding table indicates the correspondance
between levels of density and landscapes.

CODING TABLE : MSS 7

60	-	69	■	≡	X	V	O	14
70	-	79	■	≡	X	V	O	14
80	-	89	▩	≡	Z	N		11
90	-	99	▩	≡	Z	N		11
100	-	109	▦	≡	X	F		10
110	-	119	▦	≡	X	F		10
120	-	129	▦	≡	X	F		10
130	-	139	‡	I	=			8
140	-	149	‡	I	=			8
150	-	159	‡	I	=			8
160	-	169	✦	;	-			6
170	-	179	;	;	.			5
180	-	189	;	.				2
190	-	199	;	.				2

Water (60-129)

Pine forest (160-179)

Beach (180-189)

Arcade forest
Forest agri-
cultural
complex (190-199)
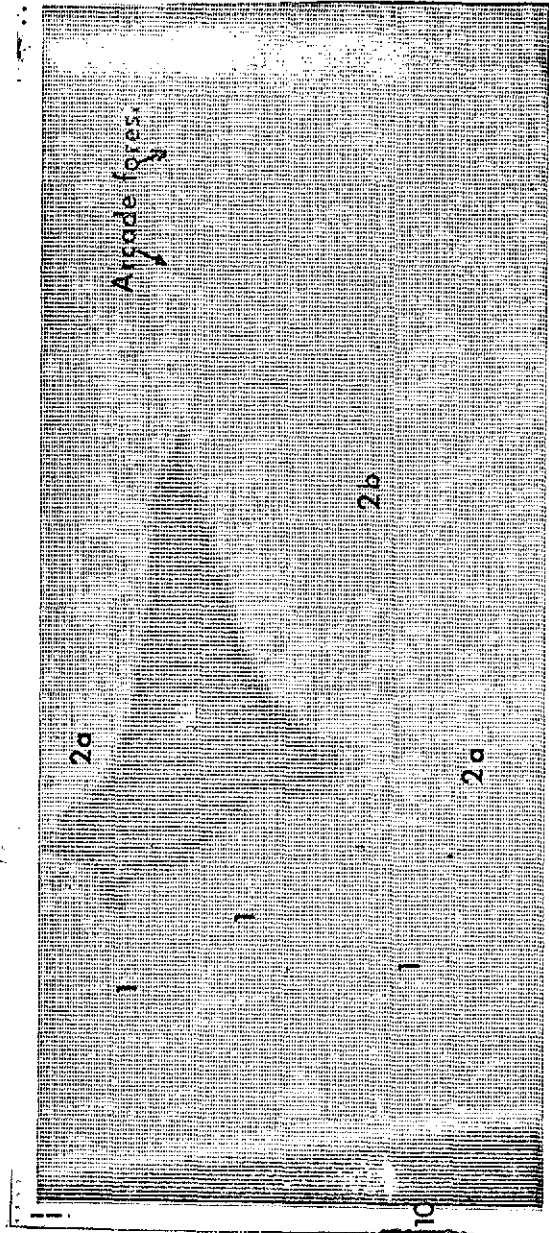
Figure 3 : Printout of the Born region MSS 7

    1 : Pine forest
   2a : Forest agricultural complex
   2b : Forestry complex
   10 : Water = Ponds-Ocean
       Arcade forest

The symbol 8 does not correspond to any
particular landscape. It marks on the printout,
boundaries of very contrasted zones.

2 - The Cocumontais region

The Mas d'Agenais forest (zone n° 7) surrounded
by agriculture (zone n° 6), mainly makes up of
deciduous trees is easily located on the display
of MSS 5 image (figure 4).
Three gray levels can be brought out on the
display of the forest. Now if the floristic
composition of the forest is well known, it is
not the case of the repartition of principal
species which needs and actual notions of ground
truth.
The three gray levels are defined by physionomic
criteria, and no floristic criterium is used.
These levels correspond to : clearing (symbols
n° 9 and 6) and arborescent state (symbol n° 14).

CODING TABLE : MSS 5

125	-	129	▓	≡	⋏	V	()	14
130	-	134	▓	≡	X	V	()	14
135	-	139	▓	≡	X	√	()	¬14
140	-	144	▓	≡	X	V	()	14
145	-	149	▓	≡	⋏	V	()	14
150	-	154	▓	X	⊢			9
155	-	159	✦	⋮	—			6
160	-	164	▮	•	✦			3
165	-	169	▮	•				2

14	⎫ Shadows of
14	⎬ clouds
¬14	⎭
14	⎫
14	⎬ Arborescent
9	⎫ state
6	⎬ Clearing
3	⎫
2	⎬ Agriculture
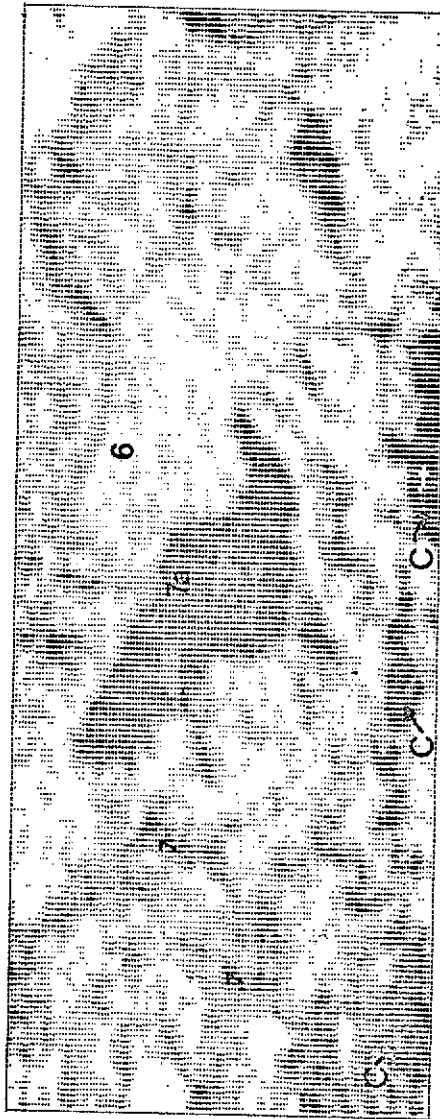
Forest

Figure 4 : Printout of the Cocumentais region
          MSS 5

    6 : Agriculture complex
    7 : Deciduous forest
   7a : The Mas d'Agenais forest
    C : Shadow of clouds.

3 - The Arcachon Basin

The information from the multispectral scanner
images of September 25, 1972 is collected about
1 hour before the equinoctial low tide (coeffi-
cient 110). Most of the area uncovered by the
Basin is dry. The water appears only in isolated
channels of the Basin and lays bare sand and mud
banks from 60 cm and 2 m above sea level.
The oyster beds and fisheries of Audenge-Lanton,
situated to the east of the Basin can be
distinguished. The southern part of the Basin is
somewhat hidden by the shadow of a cloud.
The repartition of features of the Basin :
channels, sand-banks, island, is well materiali-
zed in the display of data obtained from MSS 7
image (figure 5). Furthermore the display gives
information on the sand-bank morphology.
The sand-bank which are the first emerged, are
represented by the symbol n° 6 (A-figure 5),
other sand-banks by symbol n° 8 (B-figure 5) and
island by symbol n° 5 (C-figure 5).

CODING TABLE : MSS 7

60	-	69	▨	≡	X	V	O	14	⎤
70	-	79	▮	≡	X	V	O	14	
80	-	89	▩	≡	Z	N		11	
90	-	99	▨	≡	Z	N		11	Ocean and channels
100	-	109	▦	≡	X	F		10	
110	-	119	▦	≡	X	F		10	
120	-	129	▦	≡	X	F		10	⎦
130	-	139	‡	I	=			8	⎤ Others
140	-	149	‡	I	=			8	sand-banks
150	-	159	‡	I	=			8	⎦
160	-	169	✦	;	-			6	Sand-banks
170	-	179	⁑	;	•			5	the first
180	-	189	⁑	•				2	emerged
190	-	199	⁑	•				2	Island

A finer slicing of the optical density range
between 130 and 179 should permit a trace level
contours. It is particularly interesting in the
case of Arcachon Basin, where sand strips are
unstable, especially those sans trips at the
mouth of the Arcachon basin.
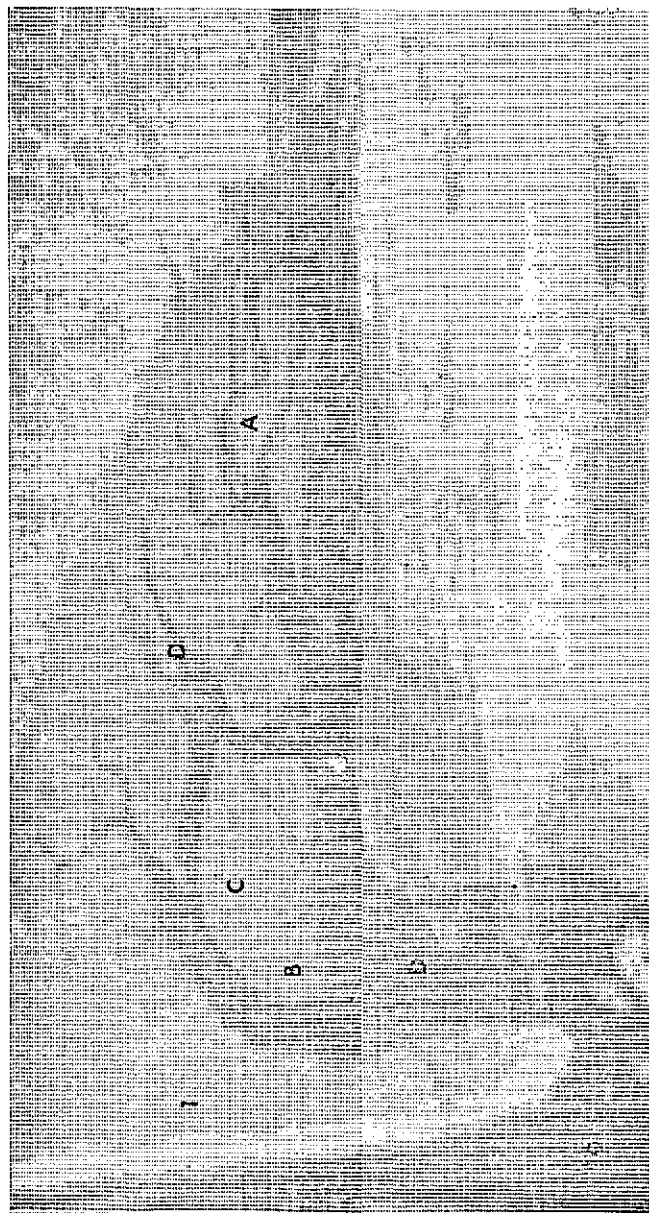
Figure 5 : Printout of Arcachon Basin MSS 7

    1 : Pine forest
  10 : Water
   A : Sand-banks the first emerged
   B : Others sand-banks
   C : Island
   D : Channels

III. ISSUE

     This present study correspond to the first
work of the ERTS-1 data processing operations.
This work permits to describe ERTS-1 image and
to select characteristic zones which are
according to the studied images, either lands-
capes (Landes of Gascony) or homogeneous
clusterings of vegetal species (cf. Val d'Aran).
In the second part, quantitative analysis of
selected sites represents only a little part of
the informatical processing. Indeed, only
displays of selected sites are carried out,
describing selected landscapes on MSS imagery.

Chapter 3.

DISPLAY PROBLEMS

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In order to compare results with ground
truth or biological truth, a restitution of the
image is required.

This restitution can be made in several ways
using a printer :

- in graphic symbols giving the same visual
pattern as that produced by the original,

- in numerical values corresponding to the
optical densities of each point.

The restitution can be applied to the image
as a whole or to preselected zones. Various
programs written in FORTRAN and machine language
are necessary for the extraction and transforma-
tion of microdensitometer information stored on
magnetic tape.

I. DATA CALCULATION AND TRANSFORMATION

I.1. Information decoding :

A program written in machine language takes
the information stored in the buffer which is
transmitted in FORTRAN and decodes the CP words
in bytes : 15 bytes per 2 CP words. The optical
density of all points in one row of the zone
treated is thus stored in a table.

The decoding starts at the beginning of the
file corresponding to the image or at a word
defined in advance by its position, i.e., the
row and column, centered on the axes of the
digitized image.

The beginning decoding word is defined by :

$$MOTD = \frac{(first\ column-1)}{15} \times 2$$

Likewise, the number of words to be decoded
is :

$$MOTF = \frac{(last\ column-1)}{15} \times 2 + 1$$

I.2. <u>Calculating the optical density integra-
ted on an elementary surface</u> :

The numerized image can be reconstructed point by
point or by elementary surfaces, in which case,
the numerical output value is the optical density
averaged over all the points of the elementary
surface.

```
┌─────────────────────────────┐
│                             │
│   ELEMENT DE SURFACE        │
│   ---------------------     │
│           4                 │
│         ₽₽8₽                │
│         ₽888                │
│         ₽888                │
│        4₽888                │
│                             │
└─────────────────────────────┘
```
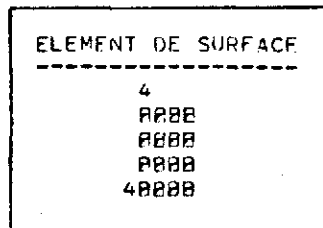
K_C and K_L are the
contraction coefficients
of column and row, and
dij is the optical
density of point Pij,
the optical density of
the elementary surface
is :

Figure 1 : An example
   of an elementary
      surface.

$K_C = 4$ $K_L = 4$

$$D = \frac{1}{K_C \times K_L} \sum_{i=1}^{K_L} \sum_{j=1}^{K_C} dij$$

The information is stored in a table and
recorded on a disk.

I.3. <u>Histogram calculation for optical density
frequencies</u> :

A histogram is presented in the form of a
trace in which the different levels representing
optical densities are placed on the abscissa, and
the number of points having the same optical
density is placed on the ordinate.

A FORTRAN program accumulates all points
from the zone under study which have the same
optical density and arranges them in a table which
will then be translated into a x - y graph.
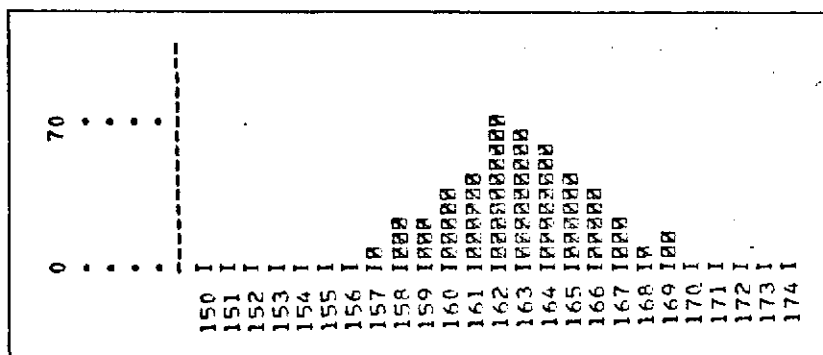
Figure 2 : Example of a histogram.

I.4. Calculation of statistical features

A statistical study is made for each surface
corresponding to N measurement points. The
statistical features of this population of N
points provide useful information for identifying
classes or for verifying the homogeneity of a
class.

- Distribution average : given a population
of N points whose optical density, x_i, is measu-
red, and each value x_i coming out n_i times, the
arithmetical average of the values measured is
written :

$$\bar{x} = \frac{\sum n_i x_i}{N} = \sum \frac{n_i}{N} x_i = \sum f_i x_i$$

where f_i is the relative frequency of x_i.

The arithmetical average is most often replaced
by the variance or standard deviation.

- Distribution variance :

$$\sigma^2 = \frac{1}{N} \cdot \sum_{i=1}^{K} f_i \left(x_i - \overline{x} \right)^2 \qquad \text{where K is the}$$

where K is the
number of
classes

- Estimate of the variance :

$$\sigma^2 = \frac{1}{N-1} \sum_{i=1}^{K} f_i \left(x_i - \overline{x} \right)^2$$

- Standard deviation : σ

II. DATA RESTITUTION

II.1. Numerical output :

Stored numerical values can be printed out
either systematically by aligning the values of
each row in the zone on the output listing, or
geographically by lining up points.

Figure 3 shows an example of the numerical
output of a zone of 13 rows and 8 columns.
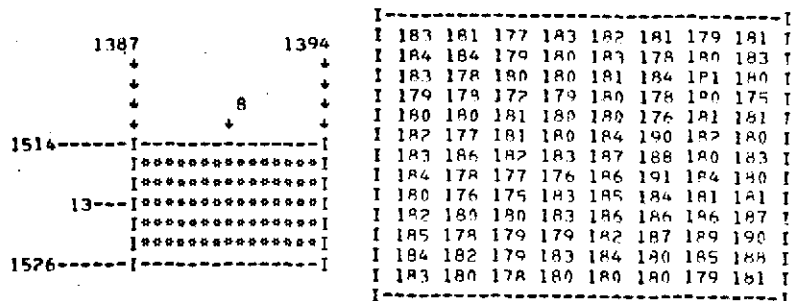
Figure 3

II.2. Display

The printout consists of a restitution of the image using the graphic symbols available on a printer.

To insure an accurate image a correction of the distortion on the output image must be made. A character is inscribed within a 1/10 × 1/6 − inch rectangle, thus straigntening out the image by means of a row and column contraction equal to : $K_C/K_L = 6/10$.

Each optical density level is represented by a graphic symbol. With adequate grouping, the total number of optical density levels (256) redu- ced, according to the number of populations to be identified on the photographic sample under study. 14 combinations of symbols are used.

Figure 4 : Table of the graphic symbols used : the symbols are represented by numbers 1 to 14 (1 = white) and are the results of overprinting 1, 2, 3, or 4 characters.

    The coding scale can be chosen arbitrarily,
but generally the choice is made so that the
shading is as close as possible to the original
image.

Figure 5 a   Figure 5 b

Example of a coding table (figure 5 a) showing
3 classes of points which are then printed out.

    In addition, with a selective printout one
class of points can be made to stand out from
all the other classes (figure 6).
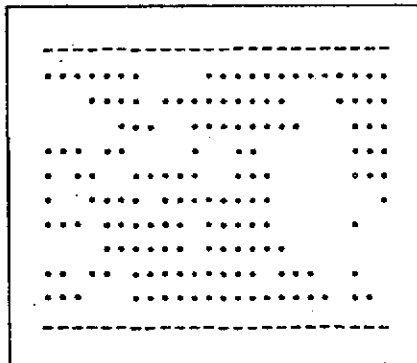
Figure 6 : Example
of a selective
printout.

III. EXAMPLES OF RESULTS

III.1. Treatment of a photograph taken from a sounding balloon.

The image treated was taken during the flight of a sounding balloon at an altitude of about 40 km, during a CNES mission in March, 1971, and shows the Toulouse area, specifically the Bouconne forest surrounded by cultivated land (figure 7).

Treatment by the color equidensity method developed by the Service de la Carte de la Vegetation shows the three types of vegetation in the forest.

Zone 1 : area reforested in maritime pine.

Zone 2 : deciduous trees, oaks and hornbeams.

Zone 3 : zone of oaks recently cut.

The digitization of the image followed by an integral printout shows these three classes of vegetation (figure 8), while the selective display shows only one class (figures 9, 10, and 11).

Figure 7

Image of Bougogne Forest,
taken by a sounding balloon

Figure 9

Printout of a digitized
image of Bouconne Forest.
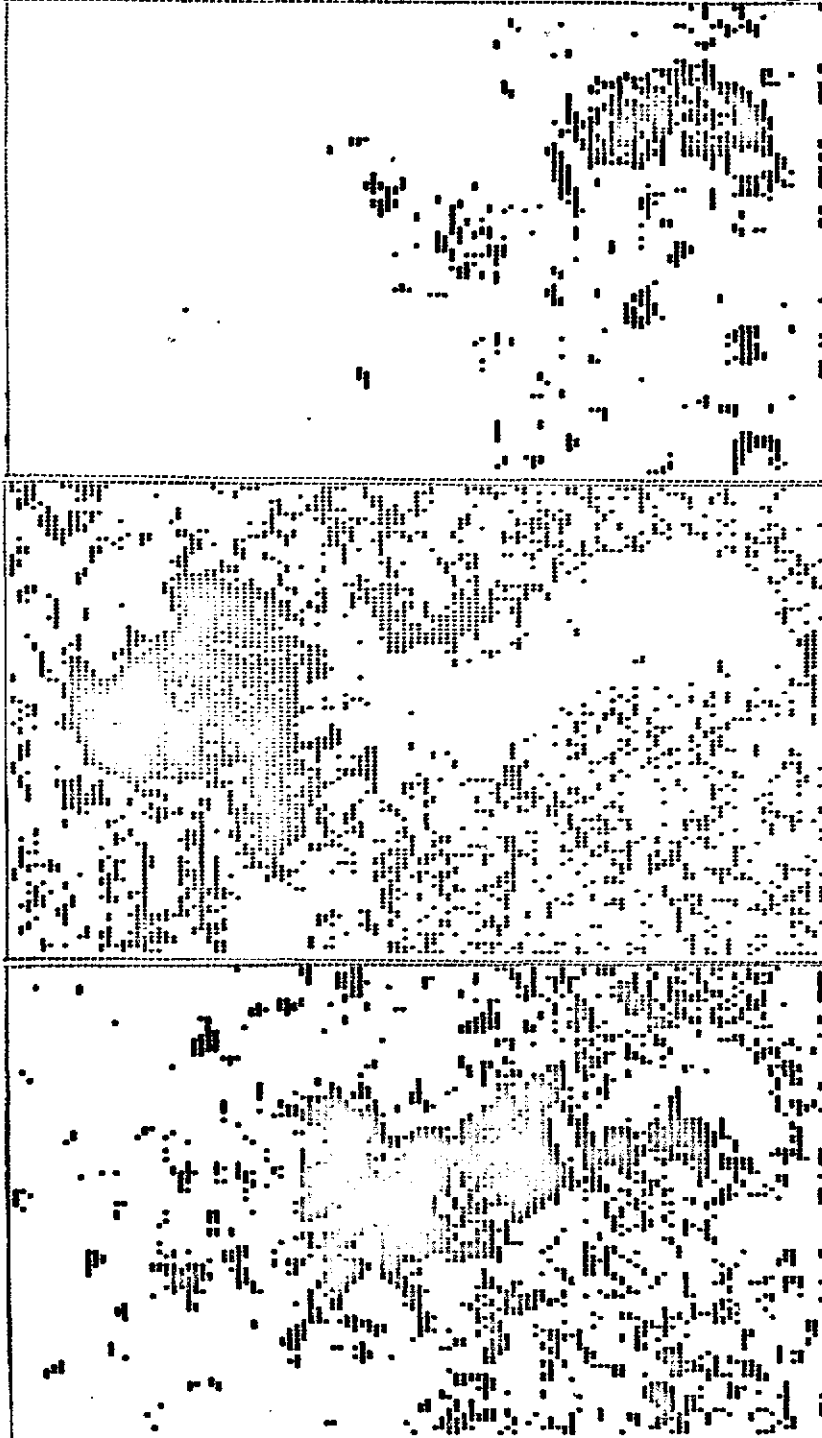
Figures 9, 10, 11 : Selective display isolating
Zones 1, 2, 3.

III.2. <u>Treatment of a photograph taken from the ERTS A satellite</u> :

This example of applying the methods developed is part of the ARNICA program. The photographs treated are furnished by the ERTS A satellite, which flies above the earth at an altitude of approximately 900 km.

The test zone was chosen in a geographical setting in which the distribution of natural resources is already known.

· Figure 12 shows the photograph taken by ERTS in the area of the Aran Valley in a visible spectral band $(0,6-0,7\mu)$. The forests, particularly fir, are shown as on the Vegetation Map (figure 13).

The digitized image, treated using the study of homogeneous samples of soil occupation types, especially for the 3 predominant classes of vegetation in the zone, i.e., firs, pines, and moors, exhibits agreement with ground truth (figure 14). On the reconstituted image, the firs are shown in dark gray, pines in medium gray, and moors in light gray.
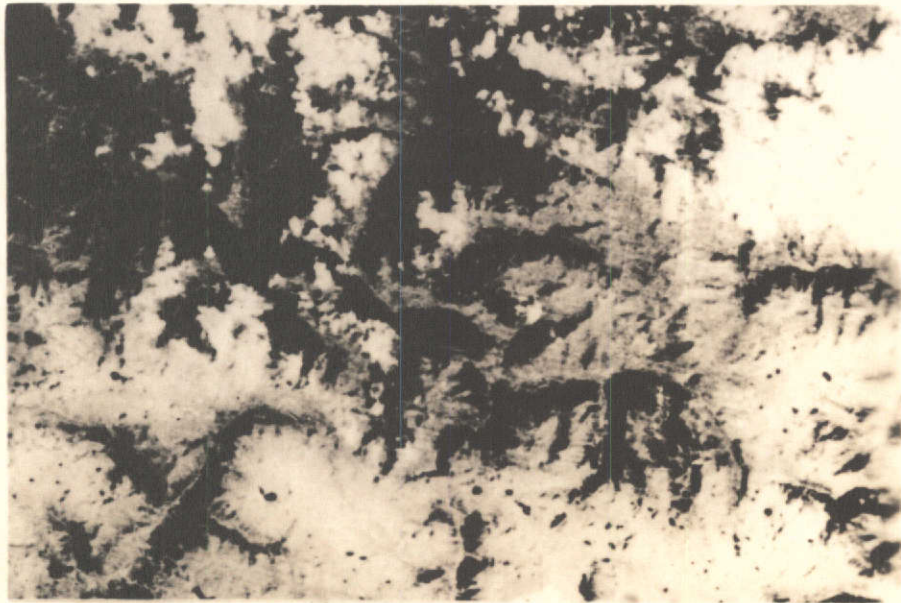
Figure 12 : Part of an ERTS photograph (MSS 5)

Figure 13 : Test zone on the Vegetation Map

Figure 14 : Numerized map of the test zone. Each symbol
represents an 80 x 80 meter area. Firs are
shown in dark gray, pines in medium gray,
and moors in light gray.

Chapter 4.

METHOD FOR LOCATING SAMPLES
ON ERTS IMAGERY

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I. SCIENTIFIC JUSTIFICATION

When digitizing the ERTS imagery using the
Scandig (Joyce Loebl) microdensitometer, it is
impossible to line up the digitalization axes
(sweep lines and columns formed by each digita-
lization step) systematically with the image's
reference axes, which are defined by a system
of 4 crosses.

In order to locate the same samples in a set
of 4 ERTS photographs taken simultaneously with
the Multispectral scanner (bands MSS 4, MSS 5,
MSS 6, MSS 7), it is necessary to define the
reference system on each photograph.

II. METHOD

II.1. Locating crosses

First, the crosses on the photograph must be
located automatically. The points making up these
crosses do not give a specific response, since
their optical density range differs from one
digitized to another, thereby making an automatic
referencing of crosses valid for a whole set of
imagery impossible.

Figure 1 shows a printout of a white cross on
a black background from an ERTS photographic
negative imagery with a 25μ step. The width of
the features is approximately $4 \times 25\mu = 0,1$ mm.
Thus, when the digitalization step is between 50
and 100μ, the integration effect makes the opti-
cal response of the cross indiscernible.

Figure 2 gives the corresponding numerical
printout. The optical responses of points forming
the cross are included in the range 171–189,
while the surrounding points give an optical
response of over 190.
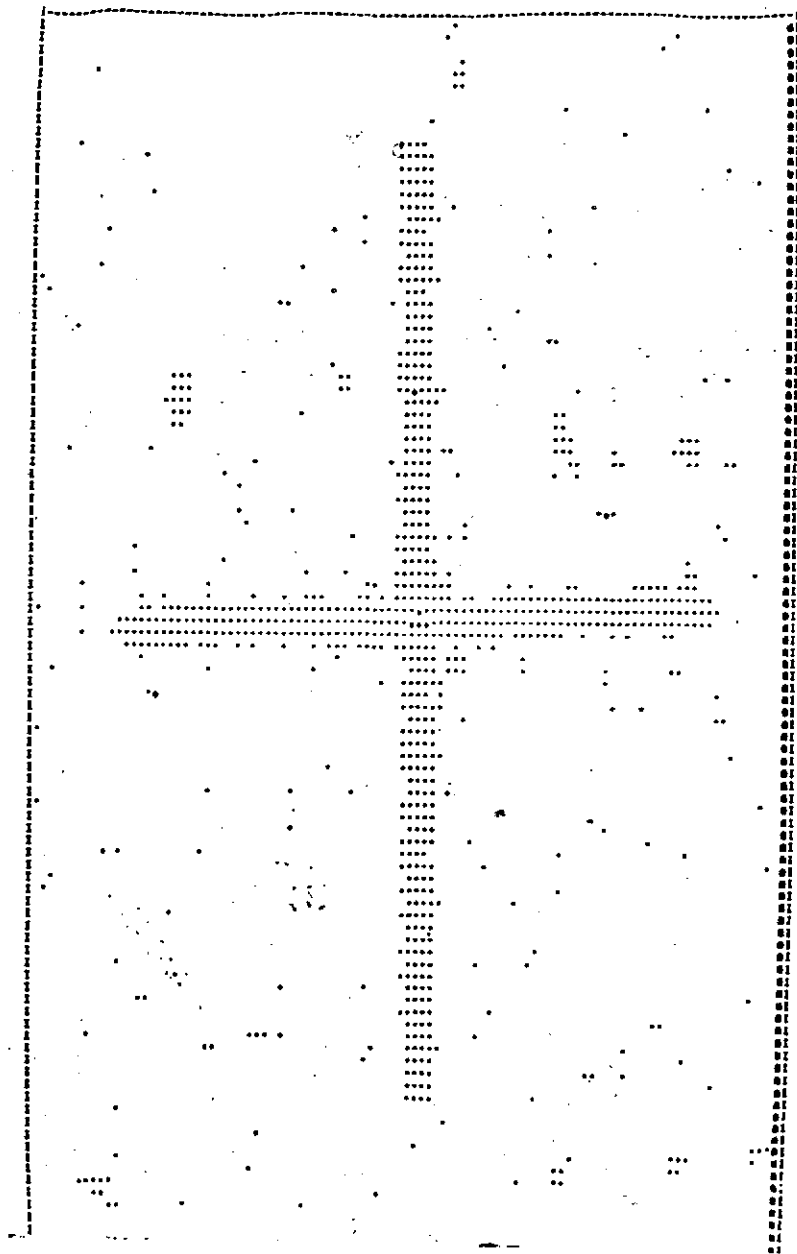
Figure   1

Printout of a cross on ERTS image

Figure 2

Numerical printout of a cross on ERTS negative

In order to obtain specific optical density
values which could help locate the center of the
crosses on all the ERTS photographs, a pinhole
is manually pierced in the center of each cross.
After digitalization this hole appears as a
closed structure with a minimal optical response.

• Definition of the optical density

threshold indicating a hole :

The optical density threshold for a hole
made in an image is determined by a numerical
printout (figure 3). The visual responses are 1,
2, or 3. The transparent part of the photograph
gives an optical density between 15 and 40,
whereas the range from 0-10 indicates a hole in
the photograph.

• Barycenter of a hole :

The diameter of the hole must be more than
4 times the size of the digitalization step in
order to avoid integration effects at each step ;
i.e., for a maximum step of 100μ , the diameter
must be 0,4 mm.

A FORTRAN subroutine determines the
barycenter of all closed structures corresponding
to an optical density of less than 10, regardless
of structural form.

Figure 4 shows a printout of a hole in the
center of a cross. Figures 5 (a, b and c) show
several possible shapes for holes :

Figure 5a : fairly even hole with a
diameter of about 10 × 25μ =
0.25 mm.

Figure 5b : hole whose edges are partially
covered by fragments of film.
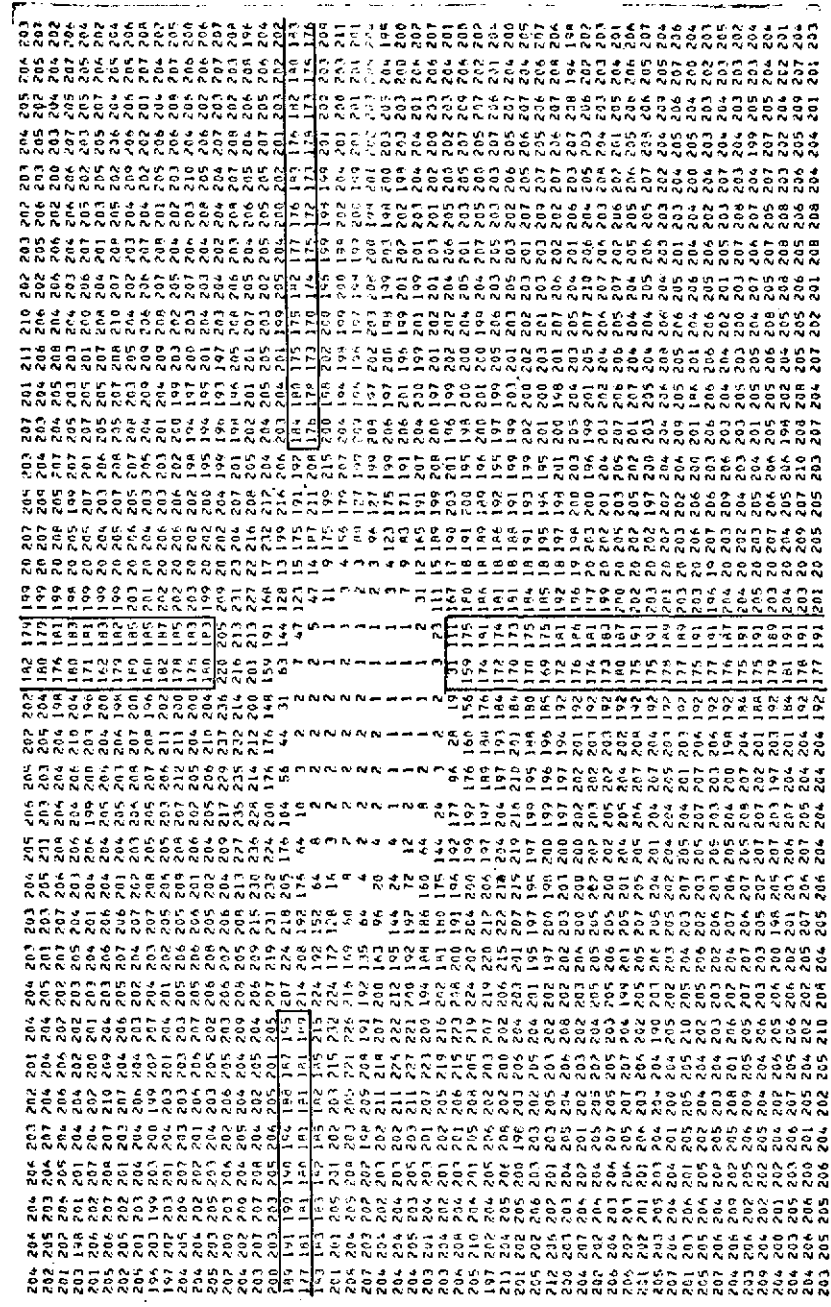
Figure   3

Numerical printout of a pinhole
at the center of a cross.
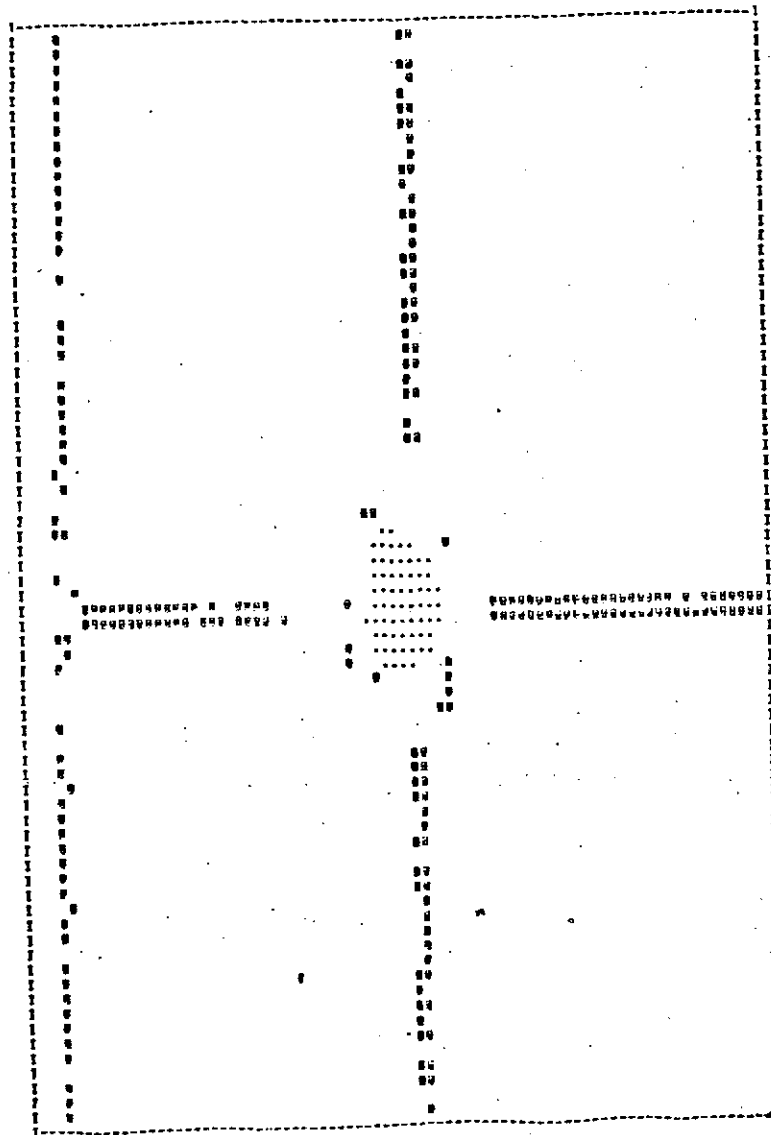
Figure 4

Printout of a pinhole
at the center of a cross.

```
    :...!
    !......
    :.......
    ........
    :.......
    !:........
    !.........
    .........
    :.........
    !....:
```
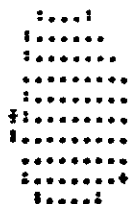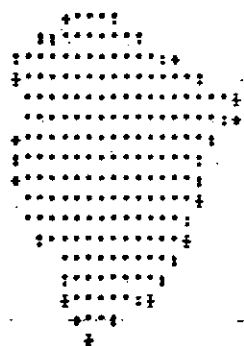
Figure 5 a

```
    +....:
    !:.......:
    :........:+
    !........:
    ..............!
    .........:+
    +..........:
    :..........:
    +..........:
    ..........!
    ..........:
    !..........!
    ..........:
    :......:
    !.....:!
    -+.+.
    !
```

Figure 5 b *

```
    ::+
    !....:
    :.....
    ........
    :.......
    ........
    !...:!:.:
    :.!      +
    !
```
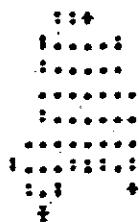
Figure 5 c

Possible shapes for holes

Figure 5c : uneven hole with a diameter
7 x 25μ = 0.175 mm.

. Search Algorithm

The search is done systematically, row by
row following the microdensitometer's sweep on
the photograph. Each closed structure with an
optical density below 10 is tabulated. At the end
of the sweep the structures with definite bary-
centers are thus determined. A first test checks
the orthogonality of each system formed by a
combination of 3 barycenters, so that any acci-
dental holes in the photograph can be eliminated.
An additional test verifying the distance between
each pair of barycenters (the crosses are 58 and
60 mm apart on the ERTS photographs) determines
the position of the set of 3 crosses.

II.2. Transposing the referencing system

A sample defined in the referencing system
formed by the crosses on the ERTS photograph
can be identified in the system of digitalization
axes by a translation followed by a rotation of
the system of axes.

The problem involves replacing x-y coordina-
tes (centered at O)(figure 6) by column and row
coordinates centered at ω , where ω is the
starting point for the digitalization located
either inside or outside the photograph.

In figure 6 a coordinate ωC_1 is calculated
as follows :
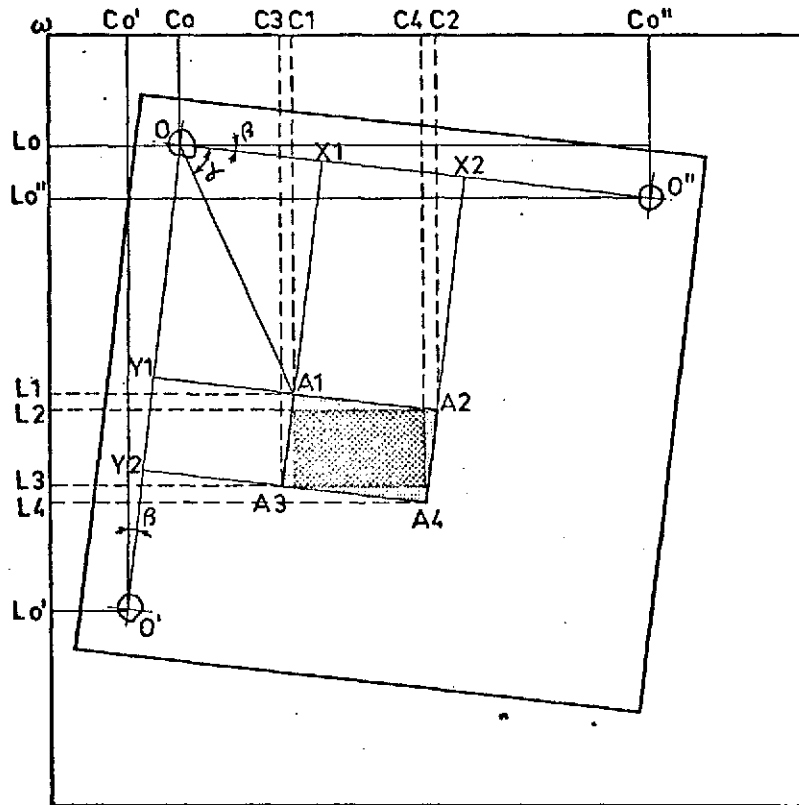
Figure 6

Transposing of referencing system :

The pinholes on ERTS image are materialized by
features at points O, O', O". The external
framework represents the digitalization axes.

$$\overline{\omega C_1} = \overline{\omega C_0} + \overline{C_0 C_1}$$

$$= \overline{\omega C_0} + \overline{OA_1} \times \cos\left(\alpha + \beta\right)$$

$$= \overline{\omega C_0} + \overline{OA_1} \times \cos\left(artg \frac{\overline{C_0 C_0''}}{\overline{L_0 L_0''}} + artg \frac{\overline{OY_1}}{\overline{OX_1}}\right)$$

$$= \overline{\omega C_0} + \left|\sqrt{\overline{OX_1^2} + \overline{OY_1^2}}\right| \times \cos\left(artg \frac{\overline{C_0 C_0''}}{\overline{L_0 L_0''}}\right.$$

$$\left. + artg \frac{\overline{OY_1}}{\overline{OX_1}}\right)$$

Where $\overline{\omega C_0}$, $\overline{C_0 C_0''}$, $\overline{L_0 L_0''}$ are known by means of the pinhole reference.

Only the central values of ωC_1, ωC_2, ωC_3, ωC_4, and ωL_1, ωL_2, ωL_3, ωL_4, are kept to identify the rectangle inscribed in the sample. This "new" sample is slightly smaller than the original sample. In practice, angle β between the two reference systems can be reduced to less than $1°$ by careful framing of the image on the drum of the microdensitometer, so that the loss of information is negigible.

III. RESULTS

Holes are made in the center of 3 crosses, using a needle under a microscope. Possible errors in this procedure stem from the non-standardization of the size and shape of the holes and from problems in locating the exact center of the crosses. An error of 1/10 mm causes a shift of 4 rows or columns for a photograph digitized at 25μ .

In the future, a better perforation process
will be used (laser, microperforator ...) in
order to make the best possible use of automatic
referencing on a digitized photograph.

Figures 8, 9, 10 and 11 illustrate the
results of the above procedure. A test site in
the Aran Valley was located in this way on 4
ERTS images taken on August 19, 1972.
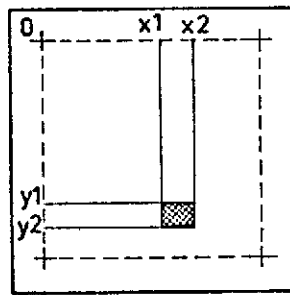
The test-site is an
area defined by lining
up reference crosses
on a set of photo-
graphs :

X_1 = 25,85 mm
X_2 = 29,02 mm
Y_1 = 35,91 mm
Y_2 = 39,01 mm

Figure 7

Figure 8 shows the printout of the site made
from the photograph E-1027-10135-4-01, taken by
the multispectral scanner, band MSS 4. Three
optical density ranges were coded to represent
3 types of vegetation on the ground.

Figure 9, 10 and 11 show the same zone from
photographs E-1027-10135-5-01 ; E-1027-10135-6-01 ;
E-1027-10135-7-01 taken in multispectral scanner
bands MSS 5, MSS 6, and MSS 7.
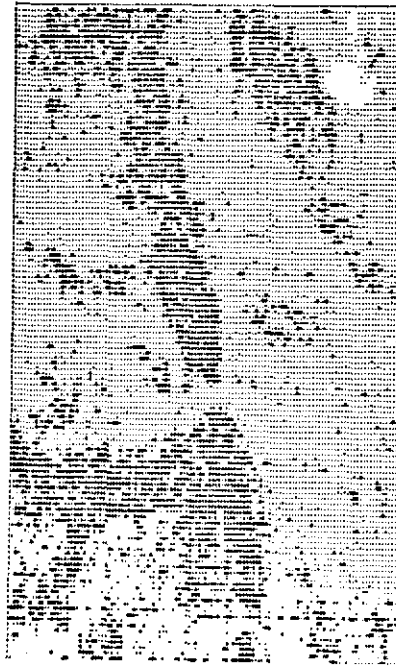
```
TABLE DE CODAGE
--------------------
  166 - 167   8   ≡   X   V   0   14
  168 - 169   8   ≡   X   V   0   14
  170 - 171   8   ≡   X   V   0   14
  172 - 173   8   ≡   X   V   0   14
  174 - 175   8   ≡   X   ^V  0   14
  176 - 177   8   ≡   X   V   0   14
  178 - 179   +   :   -               6
  180 - 181   .   .                   2
  182 - 183   .   .                   2
  184 - 185   .   .                   2
  186 - 187   .   .                   2
  188 - 189   .   .                   2
  190 - 191   .   .                   2
  192 - 193   .   .                   2
```
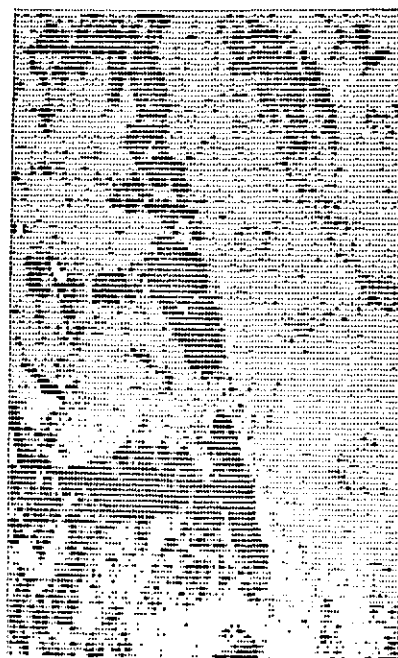
Figure 8

Printout of the test-site from MSS 4 image
using a 3 ranges coding table.
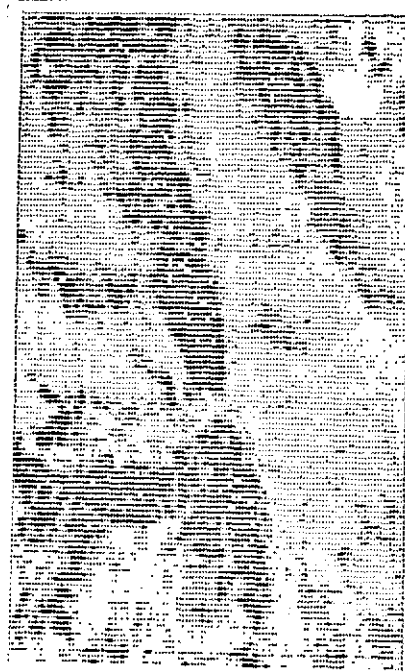
```
TARLE DE CODAGE
------------------
- 140 - 143   ▇  ≡  X  V  0  14
  144 - 147   ▇  ≡  X  V  Q  14
  148 - 151   ▇  ≡  X  V  0  14
  152 - 155   ▇  ≡  X  V  0  14
  156 - 159   ▇  ≡  X  V  0  14
  160 - 163   +  !  -        6
  164 - 167   +  !  -        6
  168 - 171   +  !  -        6
  172 - 175   .  .           2
  176 - 179   .  .           2
  180 - 183   .  .           2
```

Figure 9 : Printout of the test-site from
           MSS 5 image.

140 — 159 : Dark gray   : Fir
160 — 171 : Medium gray : Pine
172 — 183 : Light gray   : Moor

```
TABLE  DE  CODAGE
-----------------
170 - 171   ■  ≡   X   V   O   14
172 - 173   ■  ≡   X   V   O   14
174 - 175   ■  ≡   X   V   O   14
176 - 177   ■  ≡   X   V   O   14
178 - 179   ■  ≡   X   V   O   14
180 - 181   ■  ≡   X   V   O   14
182 - 183   ■  ≡   X   V   O   14
184 - 185   ■  ≡   X   V   O   14
186 - 187   +  :   -           6
188 - 189   +  :   -           6
190 - 191   .  .               2
192 - 193   .  .               2
194 - 195   .  .               2
196 - 197   .  .               2
198 - 199   .  .               2
200 - 201   .  .               2
```

Figure 10 : Printout of the test-site
            from MSS 6 image.

170 — 185 : Dark gray   : Fir
186 — 189 : Medium gray   : Pine
190 — 201 : Light gray   : Moor

```
TABLE DE CODAGE
-----------------
172 - 173  ▓  ≡  X  V  O  14
174 - 175  ▓  ≡  X  V  O  14
176 - 177  ▓  ≡  X  V  O  14
178 - 179  ▓  ≡  X  V  O  14
180 - 181  ▓  ≡  X  V  O  14
182 - 183  ▓  ≡  X  V  O  14
184 - 185  ▓  ≡  X  V  O  14
186 - 187  ▓  ≡  X  V  O  14
188 - 189  ▓  ≡  X  V  O  14
190 - 191  +  :  -         6
192 - 193  +  :  -         6
194 - 195  .  .            2
196 - 197  .  .            2
198 - 199  .  .            2
200 - 201  .  .            2
```

Figure 11 : Printout of the test-site
                 from MSS 7 image.

172 — 189 : Dark gray   : Fir
190 — 193 : Medium gray : Pine
194 — 201 : Light gray : Moor

Chapter 5.

RESPONSES OF DIFFERENT TYPES OF SOIL OCCUPATION DEFINED FROM HOMOGENEOUS SAMPLES

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I. DETERMINING HOMOGENEOUS SAMPLES

In order to recognize structures on an image, one must first define characteristics of the well known homogeneous structures to be found on the image.

In the Aran Valley study, surfaces occupied by homogeneous vegetation types, called samples, are defined by the Service de la Carte de la Vegetation, aided by ERTS image, and the Vegetation Map of the corresponding zone.

The correspondence between the Vegetation Map of the Aran Valley zone and the ERTS image E-1027-10135-01 taken August 19, 1972, in the visible spectral band MSS 5, makes it possible to take samples on the ERTS image. Each sample is determined by its coordinates in mm, in the reference system found on each ERTS image, defined by 4 small crosses (Cf. Method for locating samples on ERTS Imagery).

The samples selected correspond to surfaces occupied by firs, pines and moors, which are the major types of vegetation in the region.

In this way, 14 samples were selected from the ERTS image.Figure 1 shows the vegetation map of the Aran Valley and the samples taken from the study sites, 1 to 14, well known by the Service de la Carte de la Vegetation. In Figure 2 the corresponding sub-test zone on the ERTS image is shown with the location of the test-sites.

A Fortran routine transforms these coordinates in mm through a rotation plus a translation into digital coordinates (Cf. Method for locating samples on ERTS Imagery).

Figure 1
Vegetation map of the Aran Valley with
location of 14 selected samples.
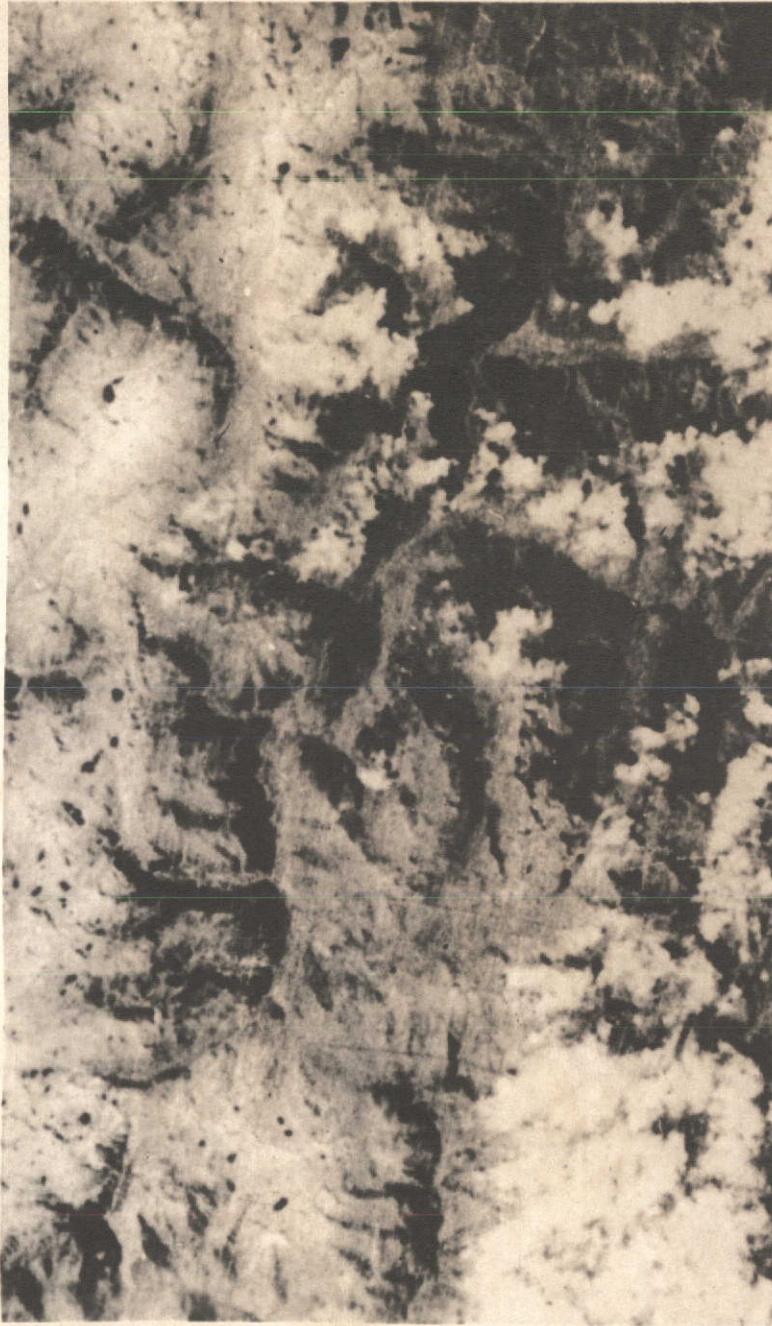
Figure 2

Part of ERTS image with samples location.

The preliminary study of these samples using
the data restitution and treatment routine (Cf.
Image Display Problem) gives the histograms of
the optical responses in the MSS band 5 for fir,
pine and moor classes of vegetation (Figure 3).
It can be pointed out that there is a discrimina-
tion between optical density ranges characterizing
each class of vegetation. The minimum and maximum
values of each range correspond to the mean plus
or minus the standard deviation. Using these
optical density ranges one can choose a coding
scale for the image printout of the test zone.
Firs are shown by dark gray symbols, pines by
medium gray, moorlands by light gray on Figure 4.

The position of fir forests is taken as
reference mark for the selection of homogeneous
areas occupied by pitch pines, high altitude
grasslands, all of which are not large enough for
identification on an original negative.

A total of 32 samples were chosen, the size of
which varies from 40 to 200 digitized points. For
a digitization step of 25 μ , each point corres-
ponds to an elementary surface of :

$$79 \text{ m} \times 79 \text{ m} \simeq 6200 \text{ m}^2 = 0,62 \text{ ha}$$

on the ground. Thus, the samples represent land
areas varying from :

$$40 \times 0,62 \text{ ha} = 24,8 \simeq 25 \text{ ha to}$$
$$200 \times 0,62 \text{ ha} = 124 \text{ ha.}$$

II. STUDY OF THE SAMPLES

A Fortran routine gives row and column
coordinates of studied samples on MSS 4, MSS 6,
MSS 7 images using coordinates on MSS 5.
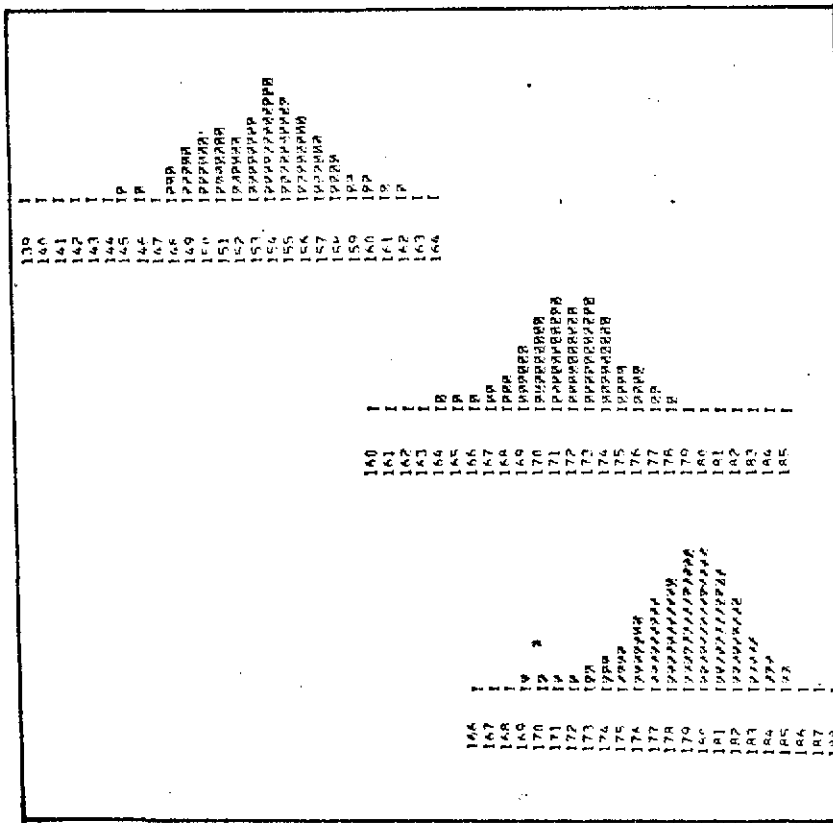
Figure   3

Histograms of MSS 5 responses of fir,
pine and moor classes
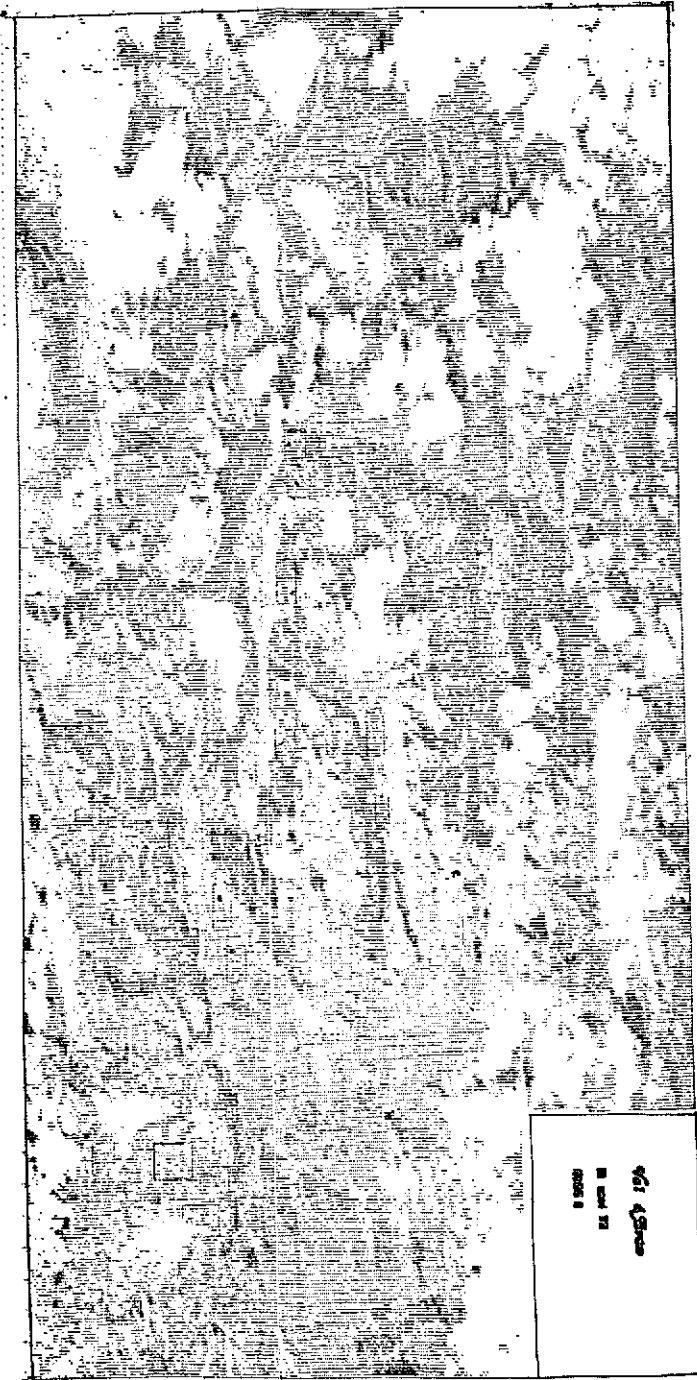
Figure 4
Printout of the Test-zone
part of digitized image

The Fortran data processing routine can be
used to obtain histograms of these samples in the
4 bands. The study of these distributions of
points according to their optical density makes
it possible to determine the homogeneity of
samples.

Table (1) shows the characteristics of
samples selected from the set of ERTS imagery
(MSS 4, MSS 5, MSS 6, MSS 7). Each sample is
characterized by the mean response and the
standard deviation of the distribution.

Figure 5 gives the responses of classes :
fir, pine, moor and grasslands in 4 spectral
bands. The minimum and maximum values of the
optical density range of each class of vegetation
correspond to the mean plus or minus the standard
deviation. It can be pointed out that fir class
(sapins) can easily be distinguished from the
others in band MSS 5.

Figure 6 shows the responses of these vegeta-
tion classes in bands MSS 5 and MSS 7. The graph
shows the clustering of the responses of each
class, particularly the separation of the fir
response from the others. However, the two types
of pine, sylvester and pitch pine, as well as
moors and grassland cannot be separated high
mountain grasslands can however, be separated
from moors and valley grasslands.

The separation of fir response can be seen in
MSS 4 – MSS 7 graph (Figure 7). But the other
vegetation cannot be distinguished from one
another. Band MSS 6 gives results comparable to
those of band MSS 7 but the separation between
classes in less evident.

In conclusion, spectral bands MSS 5 and MSS 7
seem best for discriminating between classes of
vegetation.

TABLEAU   MSS4. MSS5. MSS6. MSS7.

Echantillons		MSS4		MSS5		MSS6		MSS7	
		Moyenne	Ecart type	Moyenne	Ecart type	Moyenne	Ecart type	Moyenne	Ecart type
Sapin	2	177.43	3.25	152.62	5.38	182.05	7.62	183.60	5.60
	3	179.5	3.35	156.30	7.24	181.77	6.45	185.5	6.65
	4	177	3.32	153.98	5.99	184.09	4.38	188.7	4.64
	6	176.5	3.64	155.73	9.78	182.99	6.45	185.52	6.20
	7	176.63	3.30	151.54	5.29	181.29	5.74	186.31	5.09
	8	177.44	3.55	153.71	9.02	185.33	5.70	189.81	5.88
	10	177.3	4.00	155.62	7.66	185.02	3.70	187.29	4.09
	12	178.52	3.62	159.52	9.57	187.12	6.16	192.28	5.53
	13	175.78	4.08	154.45	5.33	181.27	5.49	186.20	5.21
Pins sylvestres	14	182.78	3.07	171.43	4.44	187.65	3.15	193.69	3.63
	16	182.53	3.42	170.85	7.41	190.29	3.98	195.09	3.00
	17	181.96	3.94	163.92	4.70	189.62	5.11	193.29	7.00
Pins à crochets	21	181.43	4.04	169.66	6.24	190.96	4.05	193.90	4.41
	22	181.99	3.11	174.21	5.21	191.04	3.24	195.32	3.32
Landes	24	184.07	2.35	178.49	3.93	192.73	2.89	197.80	5.50
	26	183.73	2.85	178.52	4.56	192.06	3.28	196.10	2.84
Prairies	28	184.72	3.57	176.31	3.80	——	——	195.28	2.60
	31	185.18	2.78	179.44	3.89	——	——	198.24	2.87
Pelouses	32	185.03	4.84	181.42	4.66	——	——	193.58	5.12
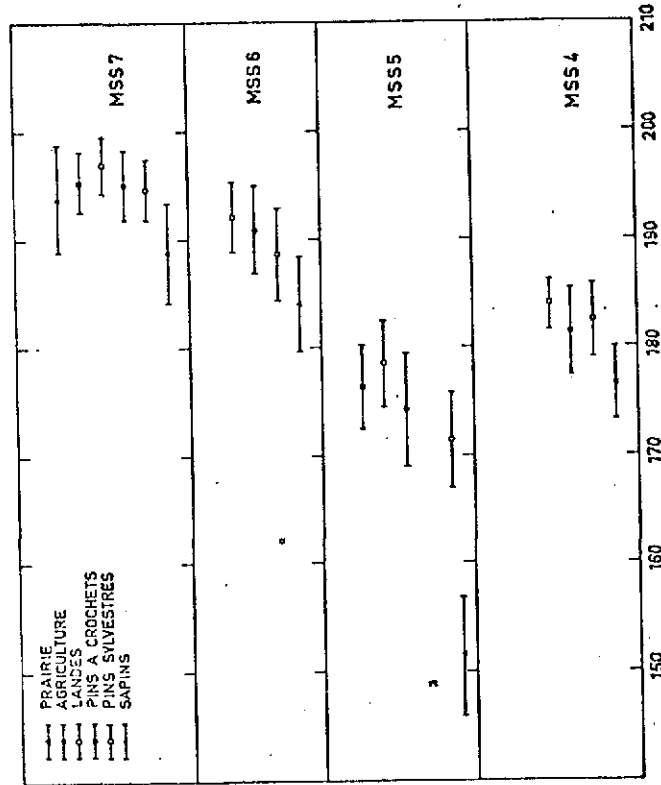
Figure 5

Optical density range of vegetation
classes in 4 MSS bands

├──△──┤ Grassland
├──▪──┤ Agriculture
├──○──┤ Moors
├──●──┤ Pitch Pine : Pinus uncinata
├──□──┤ Sylvester Pine : P. silvestris
├──▲──┤ Abies pectinata
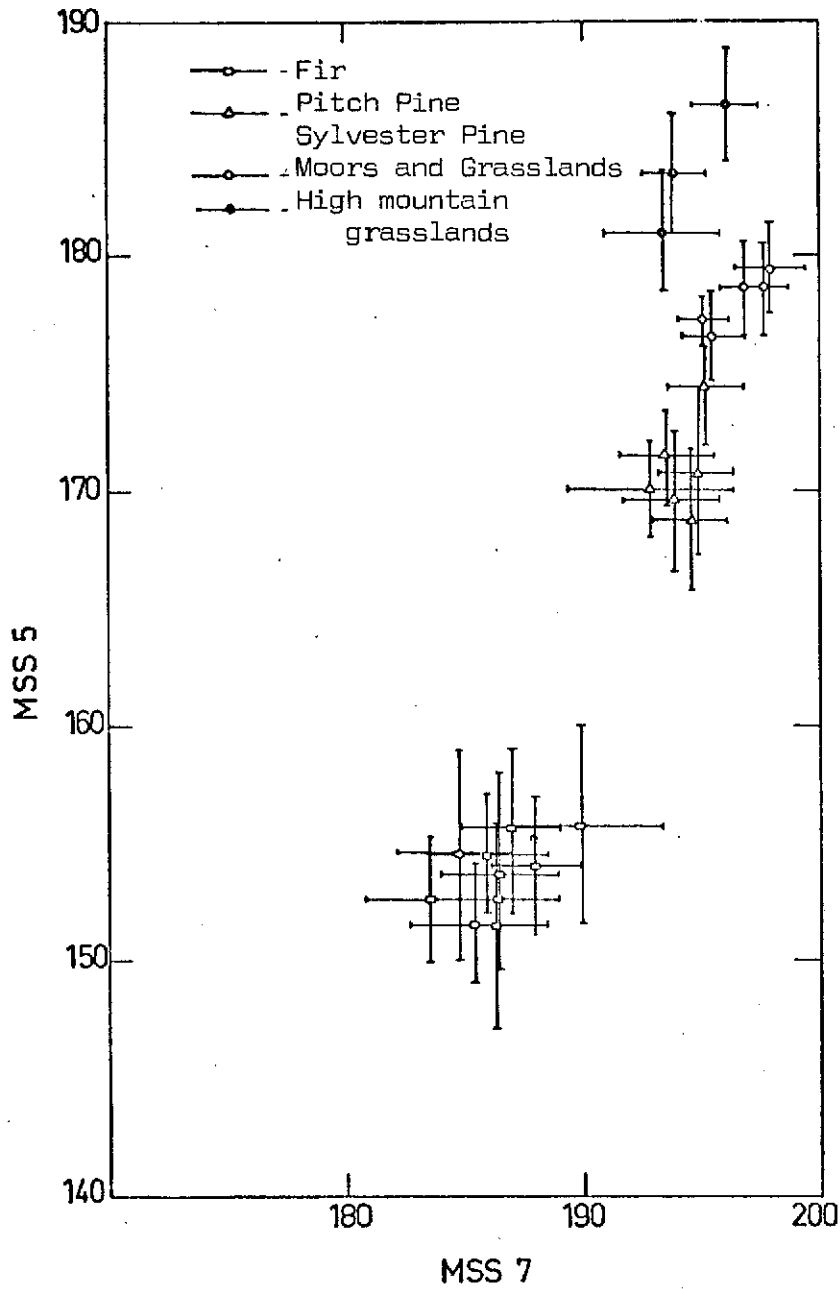
Figure 6

Responses of vegetation classes
in MSS 5, MSS 7 bands
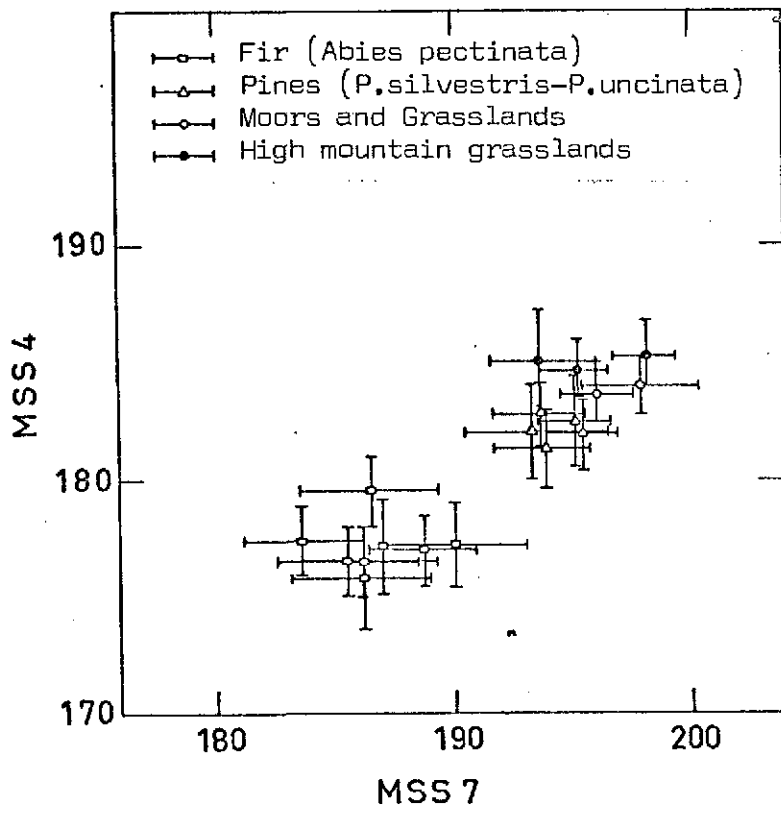
Figure 7

Responses of vegetation classes
in MSS 4, MSS 7 bands

LIST OF ILLUSTRATIONS

Chapter 5.