CORINE land cover

Part One - Methodology

Part Two - Nomenclature : illustrations

1. Introduction

1.1. The CORINE programme

If our environment and natural heritage are to be properly managed, decision-makers need to be provided with both an overview of existing knowledge, and information which is as complete and up-to-date as possible on changes in certain features of the biosphere.

To this end, the three aims of the CORINE (Coordination of information on the environment) programme of the Commission European are:

* to compile information on the state of the environment with regard to certain topics which have priority for all the Member States of the Community;

* to coordinate the compilation of data and the organization of information within the Member States or at international level;

* to ensure that information is consistent and that data are compatible.

On 27 June 1985 the Council, on a proposal from the Commission, adopted a decision on the CORINE programme. This Commission work programme concerns 'an experimental project for gathering, coordinating and ensuring the consistency of information on the state of the environment and natural resources in the Community' (Official Journal L 176, 6.7.1985).

In order to determine the Community's environment policy, assess the effects of this policy correctly and incorporate the environmental dimension into other policies, we must have a proper understanding of the different features of the environment:

* the state of individual environments,

* the geographical distribution and state of natural areas,

* the geographical distribution and abundance of wild fauna and flora,

* the quality and abundance of water resources,

* land cover structure and the state of the soil,

* the quantities of toxic substances discharged into environments,

* lists of natural hazards, etc.

A further objective of the CORINE programme is to bring together all the many attempts which have been made over the years at various levels (international, Community, national and regional) to obtain more information on the environment and the way it is changing.

Two main types of complementary action have been taken to meet the programme's objectives:

* devising procedures for collating, standardising and exchanging data on the environment in the EC Member States;

* creating a geographical information system to provide the information on the environment which is essential when preparing and implementing Community policies.

Figure 1.1. Organization of the project

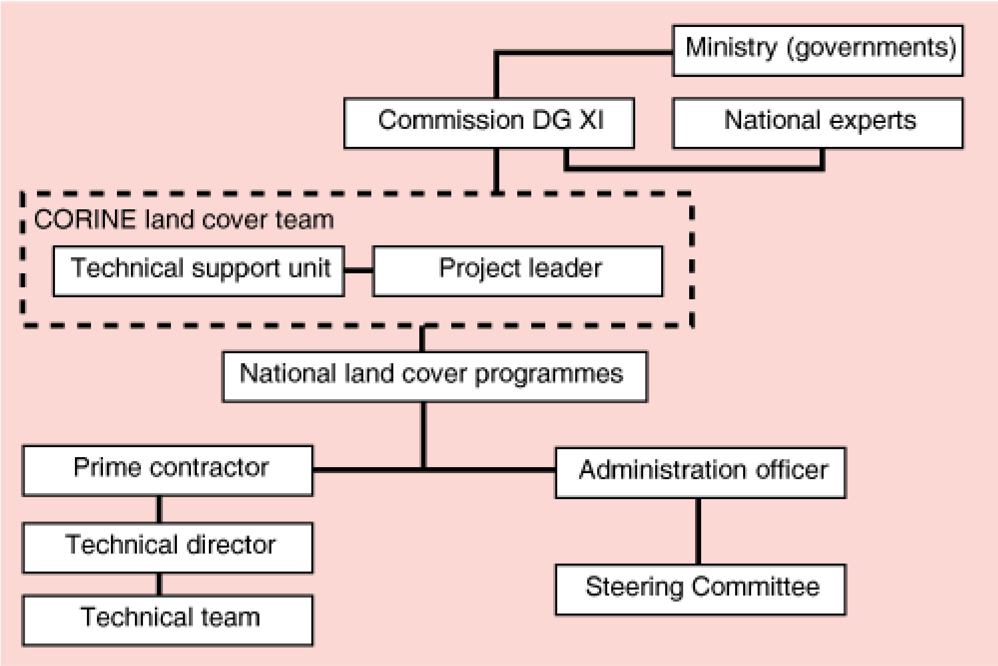


Table 1.1. The CORINE land cover project in figures

Area covered: 2.3 millions km ^{2}

* 12 countries
* from 62° N (The Faeroes) to 28° S (Canary Islands)
* from 14' W (Canary Islands) to 29° E (Kastellorizon)

Working scale: 1/100000

* i.e. 1 500 standard map sheets produced using 10 different projection systems

Area of the smallest mapping unit: 25 hectares

* i.e. more than 700000 basic unit (polygons) or a vector data-base around of 1 gigabyte

Land cover nomenclature with three levels

* First level: five headings

* Second level: 15 headings

* Third level: 44 headings

National teams

* DP specialists, geographers, photointerpreters and cartographers working on the production of satellite images, computer-aided interpretation and the digitization and integration national results into the CORINE land cover database.

A central technical unit consisting of four specialists:

Michel Bossard: Photo-interpretation
Yves Heymann: Project leader
Michel Lenco: Statistics
Chris Steenmans: Data processing

1.2. The CORINE land cover project

The land cover project is part of the CORINE programme and is intended to provide consistent localized geographical information on the land cover of the 12 Member States of the European Community.

The project is necessary for the following reasons:

* preliminary work on the CORINE information system showed that information on land cover, together with information on relief, drainage systems etc., was essential for the management of the environment and natural resources; information on land cover therefore provides a reference source for various CORINE database projects;

* in all the countries of the Community, the information on land cover available at national level is heterogeneous, fragmented and difficult to obtain.

At Community level, in the CORINE system, information on land cover and changing land cover is directly useful for determining and implementing environment policy and can be used with other data (on climate, inclines, soil, etc.) to make complex assessments (e.g. mapping erosion risks).

The benefits of using a single joint project to meet both Community and national (or even regional) needs considerably influenced the general features of the land cover project: scale, area of the smallest mapping unit and nomenclature.

1.2.1. Information on land cover project

1.2.2. Origins of the project

1.2.3. Feasibility study

1.2.4. Implementing the project

1.2.5. Updating the database

1.2.1. Information on land cover

Until recently, it was generally assumed that in the long term human activity had little lasting effect on the land thanks to nature's ability to restore itself. This view remained prevalent for a long time despite the fact that farming practices have been causing irreversible damage in certain areas for centuries.
Over the last few decades, the effects of certain phenomena have shown that we do need to look after land cover and all its various components. These include:

* the gradual desertification of certain regions,

* the rapid disappearance of vast areas of forest,

* the wholesale of poor farmland,

* the gradual drying-up of wetlands,

* continuous urban development along coastlines, etc.

If the aim is to do more than resort to basic emergency action in the face of disaster and instead manage vast areas of land rationally, information on land cover is essential. Yet, despite the urgency and the scale of the problem, confirmed by all the studies, progress in this area is limited and often disappointing.

Those industrialised countries which have devoted considerable resources to producing large-scale maps of national territories and keeping up-to-date inventories and maps of land ownership have never seriously considered the problem of making and updating land cover inventories. This may be because the serious nature of the effects of some of man's actions on the biosphere has only recently been fully understood, or because data compilation and management techniques did not previously lend themselves to this type of operation.

As a result, information on land cover has been available only for small areas affected by urban development, agricultural development, major infrastructure projects, etc.

Against this background, the CORINE land cover project launched by the Commission of the European Communities sets out to meet a new need and provides support for the Commission in its efforts to use and develop advanced datacompilation and management techniques in carrying out its policies.

Over the last decade, awareness of serious environmental problems has lent new urgency to the question of land cover inventories.

We can no longer rely on thematic information from topographic maps which are updated every 10 or 15 years, and even less use can be made of statistical assessments which are the by-products of agricultural and forestry inventories and surveys, when attempting to cope with the following:

* disappearance of areas of wetlands,

* destruction of Mediterranean woodland by fire,

* intensification of agriculture in vulnerable areas,

* development of tourism along coastlines,

* emergence of scrub on farmland,

* disappearance of species deprived of their biotopes, etc.

For environmental management purposes, land cover information will have to meet special requirements: it must be cartographic as well as statistical and it must be possible to reproduce the information at different scales to be useful at various decision-making levels.

The following table gives a summary.

Table 1.2. Map inventory: relationship between scale and needs met

Scale	**Needs met**	**Type of decision**
1:1000 000	Main long-term trends in land cover International comparison of land cover patterns	Guiding national and Community programmes and preparing major development programmes
1:1 00 000	National management of the environment: identifying and locating major problem areas National land use policy: deciding which areas to protect	Monitoring the implementation of Community and national policies
1:25 000	Monitoring regional land use Managing sensitive areas	Local management

The nomenclature used at the various scales must enable decision-makers to identify, analyse and monitor land use in the areas under their responsibility.

lt must be possible for decision-making bodies to update the information on their areas easily and quickly.

1.2.2. Origins of the project

Previous projects in certain countries have shown how difficult it is to delineate, categorise and map types of land cover even in small areas. This is particularly evident when attempting to compare the land cover statistics of several countries or to collect all the information available on land cover in one single country.

However, over the last 15 years or so, the launching of Earth observation satellites seems to have improved the chances of success in compiling land cover inventories of vast areas. The marketing of geographical information software has also made it easier to use the information from these inventories and to update them more rapidly. In fact the Council's recommendation to use satellite data is well justified in the particular case of the CORINE land cover project.

Earth observation satellite data have the following characteristics:

* they are available on a regular basis for all points on the globe (subject to there being no cloud cover); data may be acquired every 16 days in the case of Landsat and every 26 days in the case of SPOT; with the satellites currently in service, and taking account of cloud patterns over certain countries, it is estimated that all the countries of the can be covered twice a year;

* they are inexpensive:

Table 1.3. Cost of acquiring data (CCT) from Earth observation satellites

	(in ECU/km2)
SPOT (HRV XS)	0.5
Landsat (MSS)	0.03
Landsat (TM)	0.14

* they are available for large areas: the data commercially available cover large areas: 35 000 km 2 for each Landsat scene (MSS or TM), and 3 600 km 2 for each SPOT scene; it takes 750 1:50 000 aerial photographs (lateral cover 20%, longitudinal cover 60%) and 3 500 1:20 000 aerial photographs to cover the area of a Landsat scene;

* they are objective: the sensor-transmission-reception system involves no human intervention;

* the data collected are related to the Earth surface features;

* they are in digital form, which has a number of advantages due to advances in data processing.

Earth observation satellite data are made available on a commercial basis by the Eosat and Eurimage companies for Landsat satellites and by Spot Image (France) for SPOT satellites. These companies operate the satellites and thus relieve users of all data acquisition problems.

Remote-sensing data constitute one of the data-sets (together with aerial photographs and ground truth surveys) that may be used in the production of land cover maps. The choice of such a data- set is not arbitrary; it is made on the basis of the technical (and financial) specifications appropriate to the needs of users (see Table 1.4..).

When considering the benefits, however, the qualification must be made that remote-sensing data are not directly readable for land cover mapping purposes.

As early as 1985, work done by the Commission Interministérielle des Comptes du Patrimoine Naturel in France clearly demonstrated that Earth observation satellite data are of crucial importance in preparing land cover inventories of extensive areas. But they must be employed in a rigorous systematic manner and they must be used in conjunction with existing land cover data (ancillary documentation).

A feasibility study was carried out in 1985 to examine in detail the conclusions of the Commission Interministérielle des Comptes du Patrimoine Naturel and to identify the practical problems related to a land cover inventory of the entire territory of the European in accordance with the CORINE programme objectives.

Table 1.4. Land cover mapping: costs and benefits of the different methods

The case of France (550 000 km2)

Principal sources of information	Scale	Number of final documents working Existing maps Number-Size		Number of (error documents	Allowable mapping (million FF) 2 mm)	Estimated cost (years)	Completion time	Number of headings
Ground truth survey	1:5 000	75000	50x60cm 2.5x3km		1100 m^2 (0.01 ha)	5 000	100	>100
Aerial photographs	1:25 000	2000		60 000 aerial photographs	2500 m^2 (0.25 ha)	100	1.5	30 to 50 coastal zone inventory
Earth observation satellites SPOT/TM	1:50 000	1100	40x56cm 20x28km	250 SPOT image	10 000 m^2 (1 ha)	40/50	5	25 to 40
Earth observation satellites TM/MSS	1:100 000	74	90x110cm 90x110km	42 TM images	40 000 m^2 (4 ha)	15	2	20 to 40
Earth observation satellites MSS	1:250 000 to 1:1 000 000	16	90x110cm 225x275 km	42 MSS images	25 000m^2 (25 ha)	2.5	0.25	15 (USGS)
NOAA weather satellites	1:2 500 000	1	110x110cm	1 AVHRR image	2 km^2	0.5	0.1	7

1.2.3. Feasibility study

The feasibility study comprised I 0 test areas (average area 2 400 km 2) in nine of the Member States. The areas were selected to provide a representative sample of the major West European landscapes.

Work on these areas was conducted by 10 different national teams selected in part from those who participated in the 'Less favoured areas' programme of the Ispra Joint Research Centre.

The basic elements of the project were:

* a working scale of 1: 1 00 000,

* the possibility of using data from the MSS sensor of the first generation of Earth observation Landsat satellites as basic data,

* the use of a procedure known as 'computer-aided photointerpretation of false-colour images' to analyse the satellite data.

For the process to be really effective it was necessary:

* to clearly characterise the unit area for land cover mapping,

* to formulate a Community land cover nomenclature hierarchically in three levels based on the unit area definition,

* to refine some of the methods tried out in the feasibility study.

1.2.4. Implementing the project

The results of the feasibility study led the Commission of the European Communities and the Portuguese State Secretariat for the Environment to a decision to carry out a pilot land cover project in Portugal (CORINE seminar in Lisbon, Portugal, December 1986).

Following the pilot project in Portugal, it was possible to define the methodology and the CORINE land cover nomenclature. Coordination of national mapping teams ensures consistency of results throughout the .

1.2.5. Updating the database

The reference date for the CORINE land cover database is the date on which the satellite data used as basic data were acquired.

To be of real use such a database must be regularly updated and such action is therefore planned. This can be accomplished in different ways: the interpretation process can be repeated regularly, for example every five or 10 years, or the database can be updated continuously by using an integrated (satellite) image~processing and geographical information system.

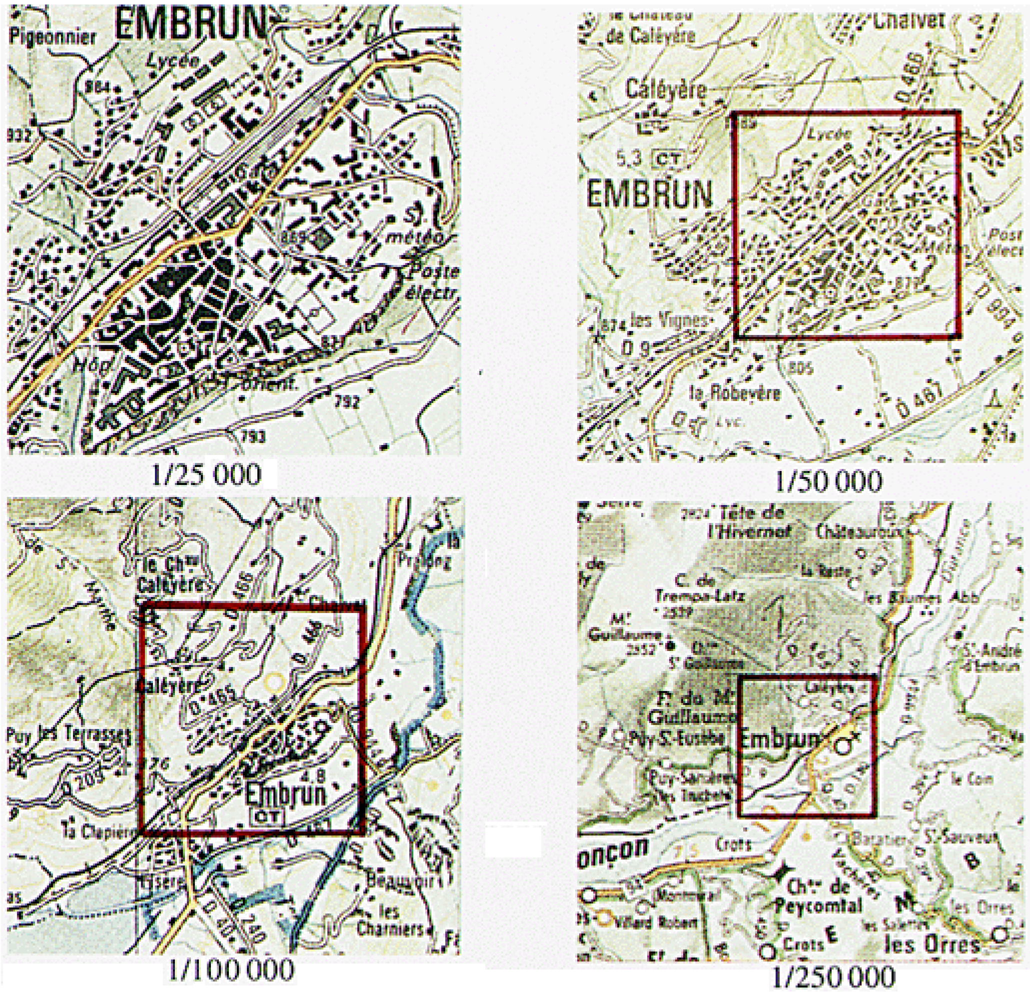
The Institute for Remote-Sensing Applications at the Community's Joint Research Centre at Ispra in Italy has undertaken a research programme to develop a suitable method for updating the CORINE land cover database.

2. Basic principles

2.1. The mapping scale

The scale chosen for the project is 1:100 000.

Figure 2.1. Cartographic scales



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There are several reasons for this choice:

* Land cover data provided on smaller scales (1:250 000, 1:500 000) are not detailed enough to be useful to the Commission. At such scales, the size of the smallest unit mapped is very large and the corresponding nomenclature includes relatively few headings (e.g. level-2 nomenclature, with about 15 headings).

* It is well suited to serve as a basis for specific studies at larger scale within a country, such as preliminary investigations for civil development projects or environmental protection.

* It (e.g. coastal erosion), but it is also compatible with projects which use a smaller scale (e.g. 1: I 000 000), since space-borne remote sensing allows generalisation at that basic cartographic scale.

* It is consistent with budgetary constraints and time limits for carrying out such a programme in the 12 Community countries.

* The maps can be fairly easily updated on a regular basis.

* This is a common mapping scale for most Community countries, albeit with a wide range of projection systems (see Table 2. l.).

Table 2.1. Topographic maps available for use as base maps in the project

Country		Scale	Projection	Number of sheets
Belgium	(B)	1:100 000	Lambert	24
		1:50 000	Lambert	74
Denmark	(DK)	1:100 000	UTM	34
Germany	(D)	1:100 000	Gauss Kruger	
-former Federal Republic of Germany				151
-former German Democratic Republic				115
Greece	(GR)	1:200 000	UTM	54
		1:100 000	UTM	134
		1:50 000	Azimuthal equidistance	333
Spain	(E)	1:100 000	UTM	297
France	(F)	1:100 000	Lambert	293
Ireland	(IRL)	1:126 720	Transverse Mercator	20
Italy	(1)	1:100 000	Gauss Boaga	278
Luxembourg	(L)	1:100 000	Gauss	1
Netherlands	(NL)	1:100 000	Stereographic	8
Portugal	(P)	1:100 000	Bonne	53
United Kingdom	(UK)	1:50 000	Transverse Mercator	204
		1:250 000	Transverse Mercator	17
-Northern Ireland		1:126 720	Transverse Mercator	5
Total number of sheets (1:100000 and 1:126 720)				1 413

2.2. Definition of the unit area and size of the smallest unit mapped

Thematic mapping of the biophysical cover of the Earth's surface may be approached from two different angles:

* Land cover essentially concerns the nature of features (forests, crops, water bodies, bare rock, etc.).

* Land use is concerned with the socio-economic function (agriculture, habitat, environmental protection) of basic surfaces.

Since the aim of the CORINE programme is to provide users with information on the state of the environment, a cartographic inventory of land cover is required: this is the CORINE land cover project.

The feasibility study showed the land cover project's technical unit that the use of satellite data for the land cover mapping of extensive surfaces would not only raise a nomenclature problem, but would also necessitate detailed consideration of the unit area to be mapped.

Remarks on land cover mapping

In many cases thematic mapping is carried out for economic management purposes and is therefore concerned with land use.

Land cover maps often implicitly adopt the cadastral land unit as the unit area. However, the cadastre, a unit area recognized in law, is essentially limited to large-scale land use maps. The cadastral unit is very often heterogeneous in its composition and its area can vary from a few square metres to several thousand hectares.

With vegetation maps, which are a form of land cover map, the problem of the unit area (to be) mapped has not arisen.

The results of certain statistical surveys (areolar surveys of land use/cover) might suggest that the problem of the unit area is not really problematical. However, it must be remembered that these surveys sample points, not surfaces. Nonetheless, in the field it is still possible to classify a point as an item in a land cover nomenclature

2.2.1. The unit area

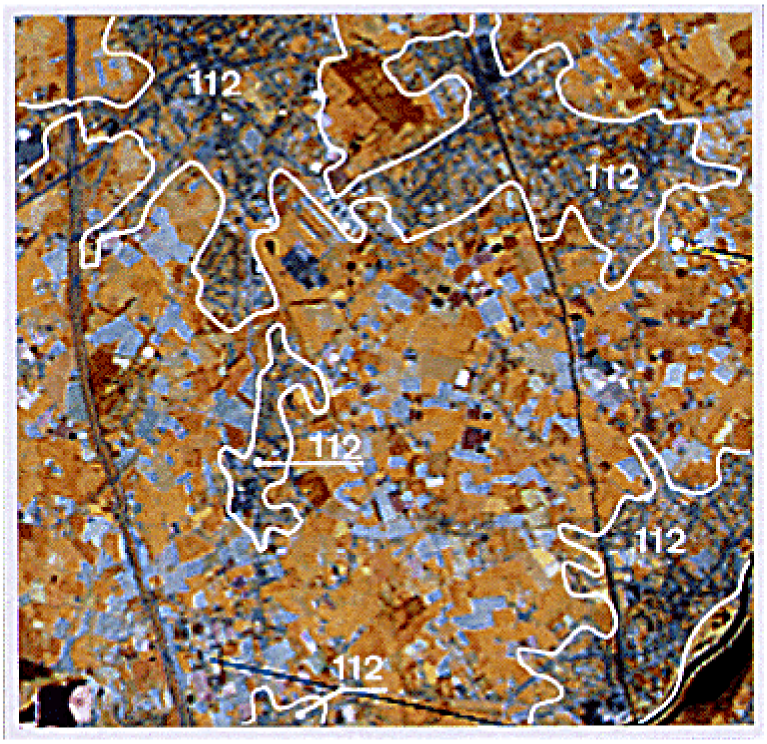
2.2.2. Size of the smallest unit mapped

2.2.1. The unit size area

To assist the understanding and use of this unit, we have decided to define it by listing its main characteristics:

> *** it corresponds either to an area whose cover may be considered homogeneous (grass, water, forest, etc.) or to a combination of elementary areas (homogeneous as defined above) which, in its variations, represents characteristic land cover structures (covering large surfaces which can be considered to constitute a single type of land cover in the Member States of the Community);**
>
> *** given the scale, the unit must represent a significant area of land, it is clearly distinguishable from surrounding units,**
> **its structure in terms of land cover is stable enough to serve as a unit for the collection of more precise information.**

Figure 2.2. Unit area example: 1.1.2 discontinuous urban fabric, Landsat TM image



In the CORINE land cover project the unit area to be mapped has two functions:

> * conceptual tool for land cover analysis;
>
> * a tool for reading and organizing spaceborne remote-sensing data which constitutes - in the images analogue format - a particular representation of the heterogeneity and diversity of the objects covering the Earth's surface.

When defining this unit, it must always be borne in mind that, in reality (in the field) land cover always occurs as a combination of surfaces which are to a greater or lesser degree homogeneous/heterogeneous, whatever the scale used.

Furthermore, irrespective of how they have been processed, data acquired by spaceborne remote-sensing systems do not provide a representation of the actual land cover situation; nor can land cover be mapped in all its complexity/diversity.

Given these circumstances a spatial/statistical unit must be conceived, for all land cover mapping activities, that meets the following two requirements: (a) its content must provide the thematic data required by the users, and (b) it must provide an acceptable representation of reality.

2.2.2. Size of the smallest unit mapped

The surface area of the smallest unit mapped in the project is 25 hectares.

Establishment of the minimum surface area to be mapped must comply with three basic requirements:

* legibility of the printed map, or in the case of the land cover project, easy digitization from the interpretation manuscripts;

* it must provide a representation of the essential features of the terrain in terms that serve the thematic objectives of the project;

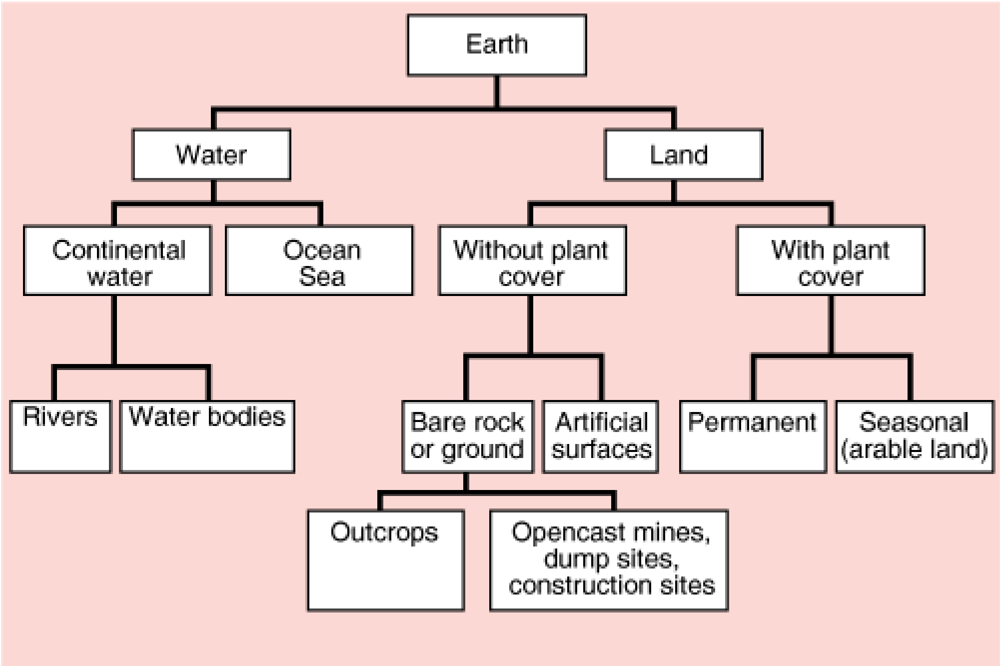
* it must represent a trade-off between project operating costs and provision of land cover information requirements within overall project budgetary constraints.

Taking these requirements into consideration, project managers set the minimum unit mapping size at 25 hectares.

On a scale of 1: 100 000, 25 hectares is represented by a 5 x 5 mm square or a circle with a 2.8 mm radius.

2.3. The nomenclature

Figure 2.3. Theoretical schematic construction of a land cover nomenclature



In any land cover cartographic inventory four elements are inextricably linked:

* the scale,

* the surface area of the smallest unit to be mapped,

* the nature of the basic information used, in this case, Earth observation satellite data,

* the structure of the nomenclature and the number of items it contains.

On the basis of the first three elements listed above and the provisional nomenclature used for the feasibility study, the land cover team has formulated the definitive nomenclature for the project.

This nomenclature and accompanying definitions have been the object of numerous discussions both with the final users of the CORINE database and with various experts in the Member States.

The following diagram (Figure 2.3) sets out the 'logical framework' which was used as a basis for establishing the nomenclature.

Based on this logical framework, the selected nomenclature must meet a certain number of requirements:

* it must be possible to map all Community territory; in other words there can be no heading for 'unclassified land';

* the headings must correspond to the needs of future users of the geographic database, i.e. for the CORINE base, the state of the environment;

* heading terminology must be unambiguous and avoid the vague terms often resorted to by many photointerpreters when encountering uncertain areas.

Moreover, it must be remembered that the nomenclature applies to relatively large units, i.e. 25 hectares or more, and the total number of headings in a nomenclature is always a compromise between the user's needs and the financial constraints affecting the project.

Explanatory notes

(i) Terminology
Most nomenclatures used for mapping or statistics relating to space are land use nomenclatures produced for the purpose of compiling an inventory of human activities.

The terminology available (to designate the items in a land cover nomenclature) therefore relates to land use, so specific terminology for land cover inventories has yet to be developed.

It is fairly difficult, in one project, to establish a nomenclature which encompasses every single aspect of the area unit to be mapped.

(ii) Level of geographical application

The CORINE land cover nomenclature, as set out below, comprises three levels:

* the first level (five items) indicates the major categories (abstract to a greater or lesser degree) of land cover on the planet;

* the second level (15 items) is for use on scales of 1:500 000 and 1: 1 000 000;

* the third level (44 items) will be used for the project on a scale of 1: 100 000.

(iii) National and/or regional nomenclature

The CORINE land cover nomenclature is organized on three levels; a fourth level could be added for some or all of the items, subject to the following requirements:

* additional items must include all the land covered by the corresponding level-3 item (four-figure codes are used for these items only);

* newly created items must not relate to more than one three-figure item;

* the CORINE land cover mapping (three-figure nomenclature) must be completed prior to initiation of level-4 mapping.

Finally, care must always be taken to see that newly created items are compatible with the scale, the size of the smallest area to be mapped and the basic information, i.e. satellite data.

Table 2.2. CORINE land cover nomenclature

Level 1	Level 2	Level 3
1. Artificial surfaces	1.1. Urban fabric	1.1.1. Continuous urban fabric 1.1.2. Discontinuous urban fabric
	1.2. Industrial, commercial and transport units	1.2.1. Industrial or commercial units 1.2.2. Road and rail networks and associated land 1.2.3. Port areas 1.2.4. Airports
	1.3. Mine, dump and construction sites	1.3.1. Mineral extraction sites 1.3.2. Dump sites 1.3.3. Construction sites
	1.4. Artificial non-agricultural vegetated areas	1.4.1. Green urban areas 1.4.2. Sport and leisure facilities
2. Agricultural areas	2.1.Arable land	2.1.1. Non-irrigated arable land 2.1.2. Permanently irrigated land 2.1.3. Rice fields
	2.2. Permanent crops	2.2.1. Vineyards 2.2.2. Fruit trees and berry plantations 2.2.3. Olive groves
	2.3. Pastures	2.3.1. Pastures
	2.4. Heterogeneous agricultural areas	2.4.1. Annual crops associated with permanent crops 2.4.2. Complex cultivation 2.4.3. Land principally occupied by agriculture, with significant areas of natural vegetation 2.4.4. Agro-forestry areas
3. Forests and semi-natural areas	3.1. Forests	3.1.1. Broad-leaved forest 3.1.2. Coniferous forest 3.1.3. Mixed forest
	3.2. Shrub and/or herbaceous vegetation association	3.2.1. Natural grassland 3.2.2. Moors and heathland 3.2.3. Sclerophyllous vegetation 3.2.4. Transitional woodland shrub
	3.3. Open spaces with little or no vegetation	3.3.1. Beaches, dunes, and sand plains 3.3.2. Bare rock 3.3.3. Sparsely vegetated areas 3.3.4. Burnt areas 3.3.5. Glaciers and perpetual snow
4. Wetlands	4.1. inland wetlands	4.1.1. Inland marshes 4.1.2.Peatbogs
	4.2. Coastal wetlands	4.2.1. Salt marshes 4.2.2. Salines 4.2.3. Intertidal flats

Nomenclature definitions

1. Artificial surfaces

1.1. Urban fabric

1. 1. 1. Continuous urban fabric
Most of the land is covered by . Buildings, roads and artificially surfaced area cover almost all the ground. Non-linear areas of vegetation and bare soil are exceptional.

1.1.2. Discontinuous urban fabric
Most of the land is covered by structures. Buildings, roads and artificially surfaced areas associated with vegetated areas and bare soil, which occupy discontinuous but significant surfaces.

1.2. Industrial, commercial and transport

1.2.1. Industrial or commercial units
Artificially surfaced areas (with concrete, asphalt, tamacadam, or stabilised, e.g. beaten earth) devoid of vegetation, occupy most of the area in question, which also contains buildings and/or vegetated areas.

1.2.2. Road and rail networks and associated land
Motorways, railways, including associated installations (stations, platforms, embankments). Minimum width to include: I 00 m.

1.2.3. Port areas
Infrastructure of port areas, including quays, dockyards and marinas.

1.2.4. Airports
Airport installations: runways, buildings and associated land.

1.3. Mine, dump and construction sites

1.3.1. Mineral extraction sites
Areas with open-pit extraction of industrial minerals (sandpits, quarries) or other minerals (opencast mines). Includes flooded gravel pits, except for river-bed extraction.

1.3.2. Dump sites
Landfill or mine dump sites, industrial or public.

1.3.3. Construction sites
Spaces under construction development, soil or bedrock excavations, earthworks.

1.4. Artificial, non-agricultural vegetated areas

1.4.1. Green urban areas
Areas with vegetation within urban fabric. Includes parks and cemeteries with vegetation.

1.4.2. Sport and leisure facilities
Camping grounds, sports grounds, leisure parks, golf courses, racecourses, etc. Includes formal parks not surrounded by urban zones.

2. Agricultural areas

v2.1. Arable land
Cultivated areas regularly ploughed and generally under a rotation system.

2.1.1. Non-irrigated arable land
Cereals, legumes, fodder crops, root crops and fallow land. Includes flower and tree (nurseries) cultivation and vegetables, whether open field, under plastic or glass (includes market gardening). Includes aromatic, medicinal and culinary plants. Excludes permanent pastures.

2.1.2. Permanently irrigated land
Crops irrigated permanently and periodically, using a permanent infrastructure (irrigation channels, drainage network). Most of these crops could not be cultivated without an artificial water supply. Does not include sporadically irrigated land.

2.1.3. Rice fields
Land developed for rice cultivation. Flat surfaces with irrigation channels. Surfaces regularly flooded.

2.2. Permanent crops
Crops not under a rotation system which provide repeated harvests and occupy the land for a long period before it is ploughed and replanted: mainly plantations of woody crops. Excludes pastures, grazing lands and forests.

2.2.1. Vineyards
Areas planted with vines.

2.2.2. Fruit trees and berry plantations
Parcels planted with fruit trees or shrubs: single or mixed fruit species, fruit trees associated with permanently grassed surfaces. Includes chestnut and walnut groves.

2.2.3. Olive groves
Areas planted with olive trees, including mixed occurrence of olive trees and vines on the same parcel.

2.3. Pastures

2.3.1. Pastures
Dense, predominantly graminoid grass cover, of floral composition, not under a rotation system. Mainly used for grazing, but the fodder may be harvested mechanically. Includes areas with hedges (bocage).

2.4. Heterogeneous agricultural areas

2.4.1. Annual crops associated with permanent crops
Non-permanent crops (arable lands or pasture) associated with permanent crops on the same parcel.

2.4.2. Complex cultivation
Juxtaposition of small parcels of diverse annual crops, pasture and/or permanent crops.

2.4.3. Land principally occupied by agriculture, with significant areas of natural vegetation
Areas principally occupied by agriculture, interspersed with significant natural areas.

2.4.4. Agro-forestry areas
Annual crops or grazing land under the wooded cover of forestry species.

3. Forests and semi-natural areas

3.1. Forests

3.1.1. Broad-leaved forest
Vegetation formation composed principally of trees, including shrub and bush understories, where broad-leaved species predominate.

3.1.2. Coniferous forest
Vegetation formation composed principally of trees, including shrub and bush understories, where coniferous species predominate.

3.1.3. Mixed forest
Vegetation formation composed principally of trees, including shrub and bush understories, where broad-leaved and coniferous species co~dominate.

3.2. Shrub and/or herbaceous vegetation associations

3.2.1. Natural grassland
Low productivity grassland. Often situated in areas of rough uneven ground. Frequently includes rocky areas, briars, and heathland.

3.2.2. Moors and heathland
Vegetation with low and closed cover, dominated by bushes, shrubs and herbaceous plants (heath, briars, broom, gorse, laburnum, etc.).

3.2.3. Sclerophyllous vegetation
Bushy sclerophyllous vegetation. Includes *maquis and garrige.*
Maquis: a dense vegetation association composed of numerous shrubs associated with siliceous soils in the Mediterranean environment.
Garrigue: discontinuous bushy associations of Mediterranean calcareous plateaus. Generally composed of kermes oak, arbutus, lavender, thyme, cistus, etc. May include a few isolated trees.

3.2.4. Transitional woodland/shrub
Bushy or herbaceous vegetation with scattered trees. Can represent either woodland degradation or forest regeneration/colonisation.

3.3. Open spaces with little or no vegetation

3.3.1. Beaches, dunes, and sand plains
Beaches, dunes and expanses of sand or pebbles in coastal or continental , including beds of stream channels with torrential regime.

3.3.2. Bare rock
Scree, cliffs, rocks and outcrops.

3.3.3. Sparsely vegetated areas
Includes steppes, tundra and badlands. Scattered high-attitude vegetation.

3.3.4. Burnt areas
Areas affected by recent fires, still mainly black.

3.3.5.Glaciers and perpetual snow
Land covered by glaciers or permanent snowfields.

4. Wetlands

4.1. Inland wetlands

Non-forested areas either partially, seasonally or permanently waterlogged. The water may be stagnant or circulating.

4.1. 1. Inland marshes

Low-lying land usually flooded in winter, and more or less saturated by water all year round.

4.1.2. Peatbogs

Peatland consisting mainly of decomposed moss and vegetable matter. May or may not be exploited.

4.2. Coastal wetlands

Non-wooded areas either tidally, seasonally or permanently waterlogged with brackish or saline water.

4.2.1. Salt marshes

Vegetated low-lying areas, above the high-tide line, susceptible to flooding by sea water. Often in the process of filling in, gradually being colonised by halophilic plants.

4.2.2. Salines

Salt-pans, active or in process of . Sections of salt marsh exploited for the production of salt by evaporation. They are clearly distinguishable from the rest of the marsh by their segmentation and embankment systems.

4.2.3. Intertidal flats

Generally unvegetated expanses of mud, sand or rock lying between high and low water-marks. On contour on maps.

5. Water bodies

5.1. Inland waters

5.1. 1. Water courses

Natural or artificial water-courses serving as water drainage channels. Includes canals. Minimum width to include: 100 m.

5.1.2. Water bodies

Natural or artificial stretches of water.

5.2. Marine waters

5.2.1. Coastal lagoons

Unvegetated stretches of salt or brackish waters separated from the sea by a tongue of land or other similar topography. These water bodies can be connected with the sea at limited points, either permanently or for parts of the year only.

5.2.2. Estuaries

The mouth of a river within which the tide ebbs and flows.

5.2.3. Sea and ocean

Zone seaward of the lowest tide limit.

NB : When the various national CORINE land cover projects are carried out the above definitions may be tightened up and supplemented in order to make them more operational.

3. The method

The third chapter of the CORINE land cover guide sets out the method used and its conditions of application. There are five main stages:

Figure 3.1. Main stages of the method

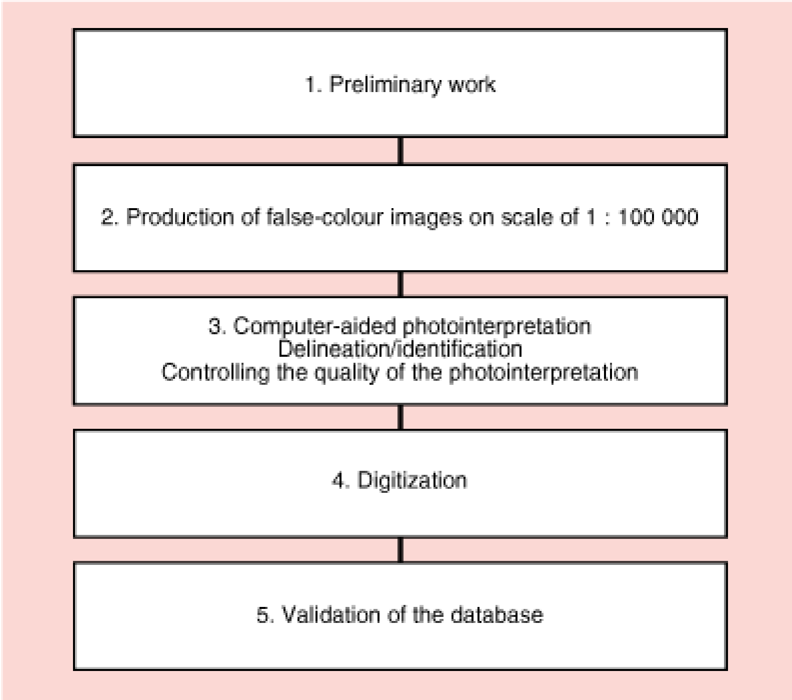


Figure 3.2. The CORINE land cover method

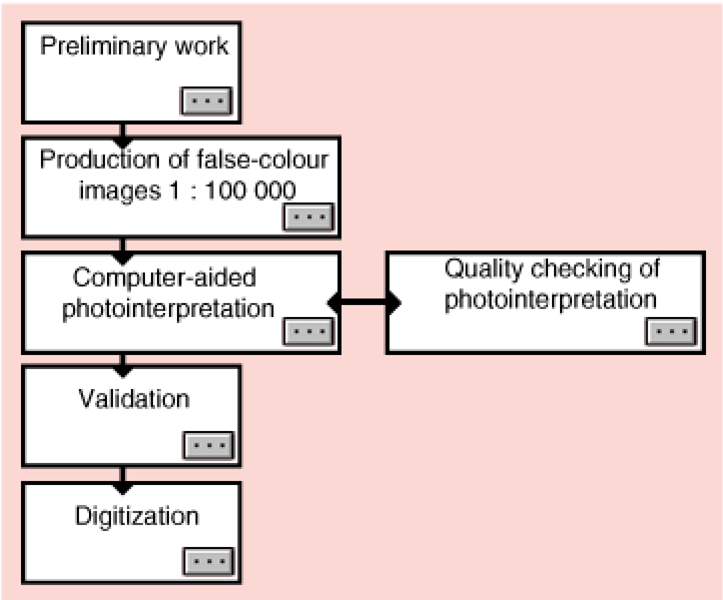


Fig 3.2 a Preliminary work

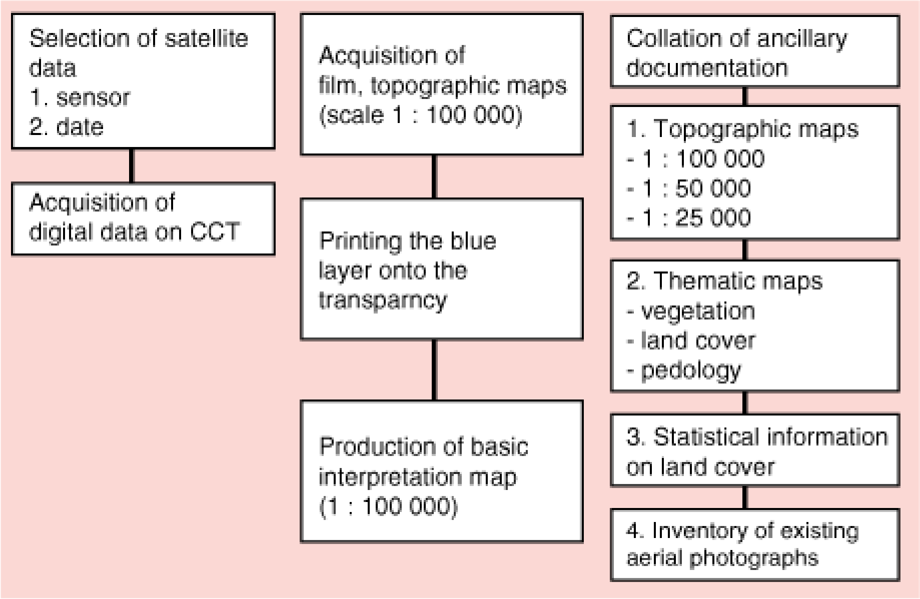


Fig 3.2 b - Production of false colour images 1:100 000

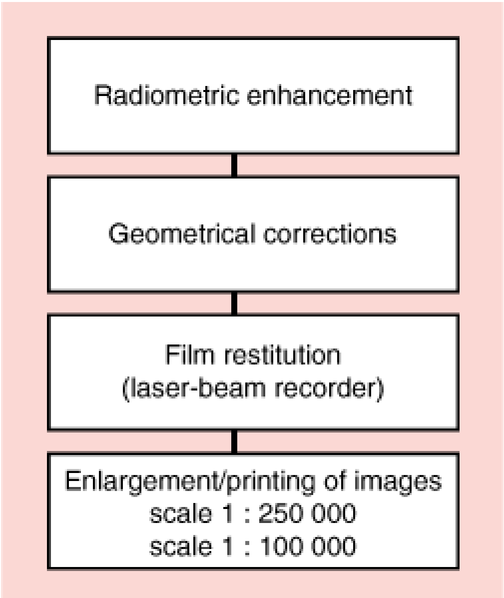


Fig 3.2 c Computer-aided photointerpretation

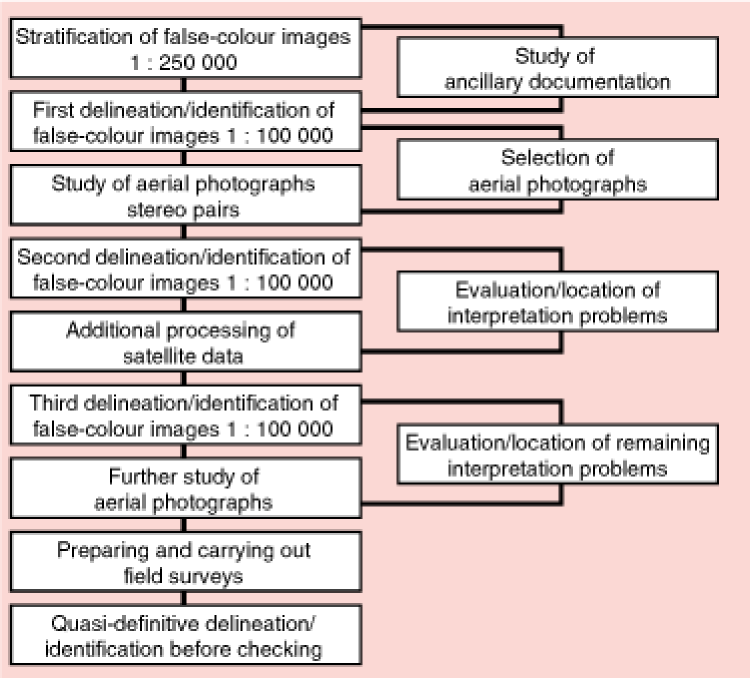
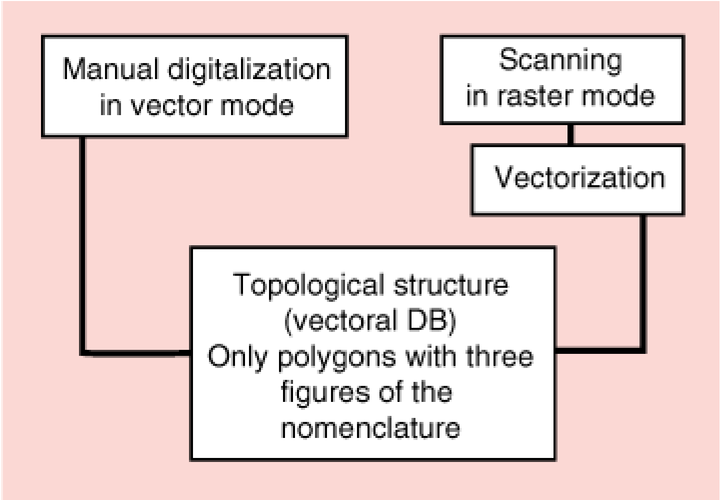


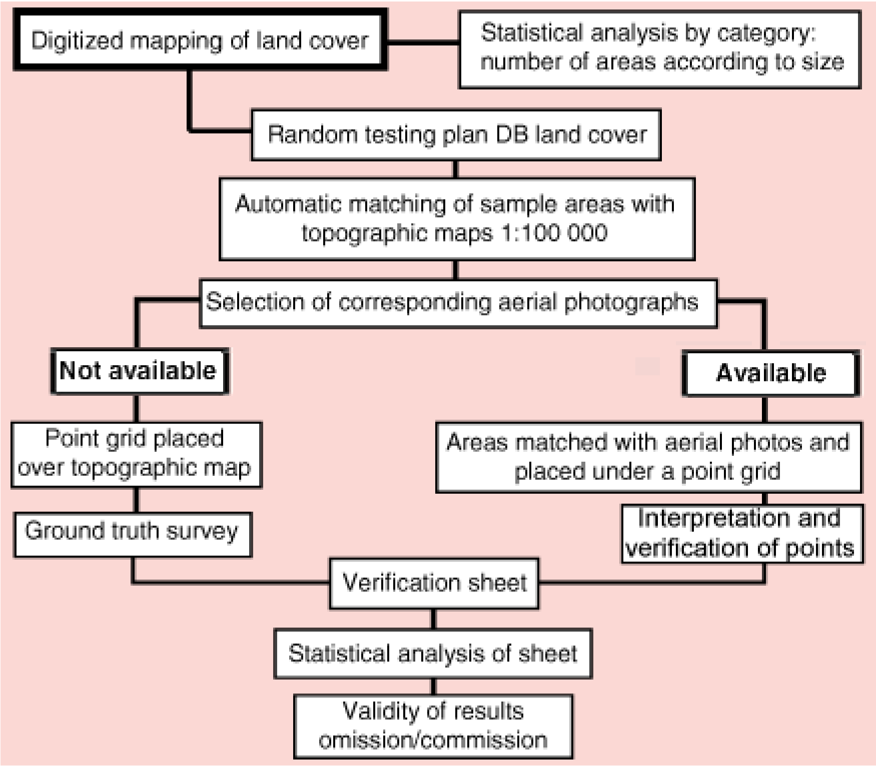
Fig 3.2 d Quality checking of photointerpretation

1. Map documents (transparencies and maps) are properly aligned
2. Consistency of results of the various photointerpretations
3. Quality of the unit delineation
4. Quality of the unit identification
5. Nomenclature of 'complex' categories (e.g. 2.4.1, 2.4.2, 2.4.3 and 2.4.4.)
6. Adjacent maps link up
7. Minimum unit delineation limit of 25 ha
8. Only one code assigned to each unit area
9. Delineation of all units is closed off

3.2 e Digitization



3.2 f Validation



3.1. Preliminary work

3.2. Production of false-colour images

3.3. Computer-aided photointerpretation

3.4. Digitization

3.5. Validation

Practical guidelines

It cannot be that each national project leader must take the utmost care to follow the stages, and the procedures within the stages, in the correct order.

It must always be borne in mind that, in the land cover methodology, although the satellite data (data used to produce false-colour images and data resulting from additional processing) constitute the basic information, they cannot in themselves (no mater how sophisticated their processing is) provide a mapping product to the standards required for the project. It is therefore an important feature of the methodology that ancillary data be collated and utilised.

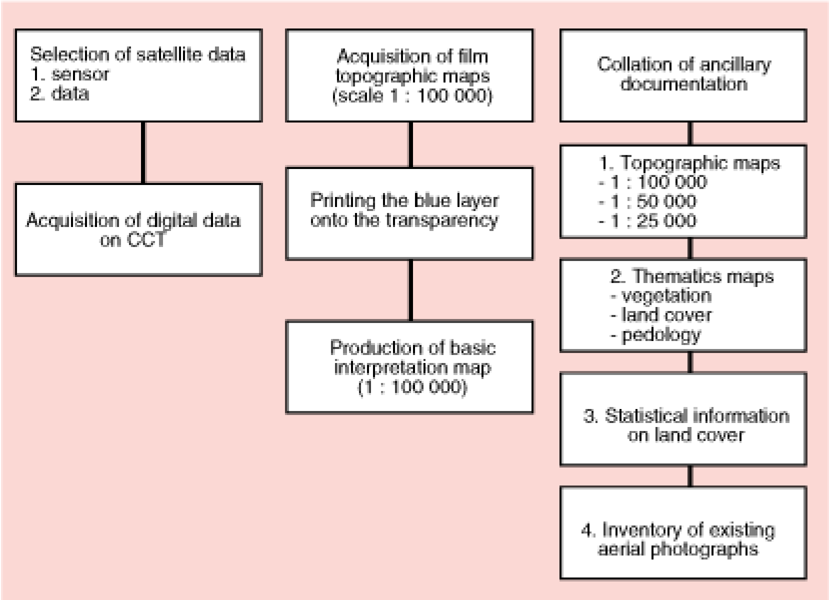
Where national applications include a nomenclature with a fourth level or where the size of the smallest unit mapped is less than 25 ha, it is essential to begin by mapping in accordance with European standards, which will serve as a basis for mapping in accordance with national standards.

To facilitate the link-up between the various national databases, it is recommended that photointerpretation be extended 5 km beyond national frontiers.

The national team in charge of the project must include highly qualified photointerpreters who are familiar with multithematic interpretation combining satellite data and aerial photographs. Where necessary, the team must also include an interactive image-processing workstation operator.

3.1. Preliminary work

Figure 3.3. Preliminary work stages



The preliminary work comprises all the operations which have to be carried out prior to the production of false-colour images, namely:

(i) Selection of satellite data to produce false-colour images on a scale of 1: I 00 000.
This relates to the following decisions:

* choice of sensor (Landsat: MSS, TM; SPOT: HRV) which has acquired the multispectral data;

* selection of data acquisition dates.

On this basis, digital data (CCT) is acquired from the distributor.

(ii) Collection and preparation of ancillary documentation.

(iii) Production of background maps for computer-aided photointerpretation.

3.1.1. Selection of the data-sets

3.1.1.1. Choice of sensor

The task of choosing a satellite data sensor system occurs twice during the land cover project:

(I) for producing false-colour images, which are the basis of the computer-aided photointerpretation;

(ii) in the course of processing additional data.

This section deals with the selection of a sensor system whose archived data are used to generate false-colour images on a scale of 1: 1 00 000. These data constitute the fundamental data source for the project since they become the interpretation base for the production of the CORINE interpretation sheets.

Today, if one wishes to buy digital data (CCT) acquired by Earth observation satellites, there is a choice of data obtained by three different sensors.

The main spatial and spectral characteristics of these sensors are:

Table 3.1. Earth observation satellites

Satellites	**Landsat 1, 2, and 3**	**Landsat 4 and 5**	**SPOT 1, 2 and 3**
Sensor	MSS	TM [1]	HRV
Launching date	1972, 1975, 1978	1982, 1984	1986,1990,1993
Spectral bands	0.5 to 0.6 µm 0.6 to 0.7 µm 0.7 to 0.8 µm 0.8 to 1.1 µm	0.45 to 0.52 µm 0.52 to 0.60 µm 0.63 to 0.69 µm 0.76 to 0.90 µm 1.55 to 1.75 µm 10.4 to 12.5 µm 2.08 to 2.35 µm	multispectral 0.50 to 0.59 µm 0.61 to 0.69 µm 0.79 to 0.90 µm or panchromatic 0.50 to 0.90 µm
Pixel size	57 x 79m	30 x 30m 120 x 120m (thermal infra-red	20 x 20m (multispectral) 10 x 10m (panchromatic)
Temporal resolution	18 days	16 days	26 days 3 days with side vision
Altitude (km)	919	705	822
Scene size	185 x 185km	185 x 185km	60 x 60km

[1] Landsat 4 and 5 also include MSS sensors.

Table 3.2. Scales for work with satellite data

Sensor	**MSS**	**TM**	**HRV XS**	**HRV P**
Scale 1	1:250 000	1:120 000	1:80 000	1:40 000
Graphic limit	0.25 mm	0.25 mm	0.25 mm	0.25 mm
Surface of the smallest element in m^2 (pixel)	2 500	900	400	100
Scale 2	1:100 000	1:55 000	1:37 000	1:15 000
Graphic error	0,27 mm	0.27 mm	0.27 mm	0.27 mm
Field error	35 m	15 m	10 m	5 m
Scale 3	1:250 000 to 1: 1 00 000	1: 1 20 000 to 1:55 000	1:80 000 to 1:37 000	1:40 000 to 1: 15 000

Source: IAURIF.
NB:
Scale 1: minimum scale on which the smallest element can be represented.
Scale 2: maximum scale for a standard map.
Scale 3: possible scale.

Work carried out thus far on the project using data from these various available sensors shows that:

* The objectives of the project can be achieved using data from any one of the sensors currently in operation to produce basic images. This is not surprising, since the scale used - 1: 100 000 - does not require a very high spatial resolution and, therefore, all the sensor systems offer a similar capability.

* In these circumstances, the choice of sensor - which must be made at the outset of each national project becomes a matter of trade-off between anticipated computer-processing time on the one hand and manpower input on the other and including the data acquisition cost of the different sensors.

Data from second-generation sensors (TM/HRV) are easier to interpret but purchasing costs are higher and processing times are longer, while MSS data - which cost less and are more quickly processed - take longer to interpret and involve greater systematic use of ancillary documentation, particularly aerial photographs.

Thus for a given country the choice of sensor should be guided by the following factors:

* Financial resources available: if these are sufficient, it is preferable to opt for second-generation sensors which are faster and easier to use.

* Size of the country: for small countries, purchasing and processing costs will be low in any case, so second-generation sensors should be used.

* Availability of specific image-processing and analysis equipment: if funds are limited, it is better to use MSS data which can be processed using low-capacity equipment.

* Availability of recent small-scale aerial photographs.

* Availability of teams of experienced photointerpreters trained and competent in the use of satellite images.

* Availability of satellite data previously acquired for other work.

3.1.1.2. Selection of the acquisition dates of basic data

Once the sensor has been chosen, it must be decided which of the archived data available will be used to produce false-colour images. Establishments which supply satellite data will provide, on request, a list of the data available. The list is drawn up on the basis of each satellite's geographical reference grid. lt gives the exact geographical position of each scene (basic data diffusion unit; a scene covers 35 000 km2 for Landsat satellites and 3 600 kM2 for the SPOT satellite), the acquisition date, the cloud cover percentage and the radiometric quality of the data.

From this list, the basic data are selected according to the following criteria:

* the data should be as recent as possible, obtained the same year. If this requirement cannot be met gaps may be filled with data from previous years;

* to facilitate photointerpretation, it is better to use data obtained during the summer, when the natural vegetation reflectance is at its peak. Adjustments should be made to take account of climatic conditions specific to certain areas of southern Europe (the optimum period for southern Europe is from I July to 30 October). When this is not possible (data available only in winter, late autumn or early spring) it is often essential to use multitemporal data-sets obtained the same year.

Note

Before placing a definitive order for the selected scenes, it is advisable to ask the supplier for the 'quick looks'. Quick looks are sample black and white images (representing a single spectral band) which allow a scene-by-scene precise evaluation of ground coverage and cloud cover distribution.

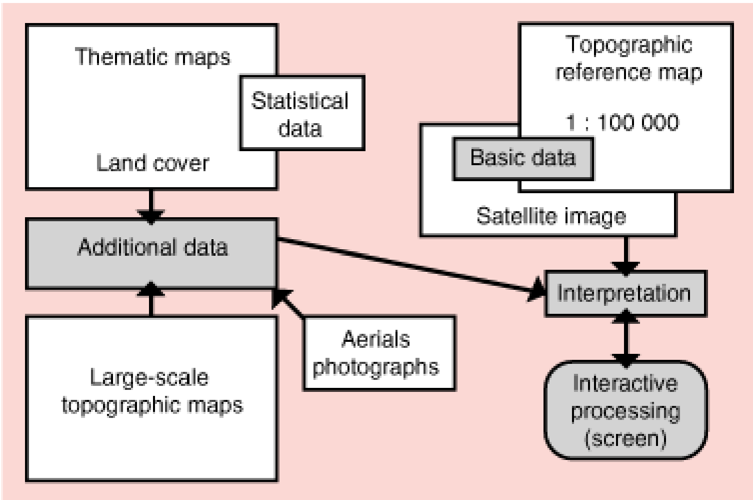
3.1.2. Collection and organization of ancillary data

'Ancillary data' is any information on land cover which does not come directly from the satellite data selected for use as basic or additional data in a national land over project.

Such data essentially comprise:

* topographic maps,
* thematic maps relating to land cover,
* statistical information,
* aerial photographs.

Figure 3.4. Organisation of the data



3.1.2.1. Topographic maps

The topographic map is the reference document for national mapping. It assembles and pinpoints spatial information on places, borders, administrative boundaries, relief, geodetic reference points, etc., and establishes toponymy.

Standard topographic maps are essential to the land cover project. They are used at various stages of the production of the thematic land cover database:

* They are used to prepare the transparency overlays for the interpretation work, and thus establish the geometry of the interpretation.

* They are essential for the geometric correction of satellite data and the production of false-colour images.

* They constitute the reference document for controlling the geometry of the digitization of the interpretation sheets.

* They are a very important source of ancillary information on land cover.

Each country has a mapping system which includes a number of scales, with a basic scale series (usually 1:25 000) and other map scales derived therefrom. For example, the French system uses the following scales:

1:25 000 to 1:50 000	Large scale
1:100 000	Medium scale
1:500 000 to 1: 1 000 000	Small scale

Clearly, the regular 1: 100 000 topographic map is the document most essential to the land cover project.

However, it is also recommended that the interpreters be provided with existing maps on larger scales: 1:25 000 and 1:50000, which usually contain more thematic detail than 1:100000 series. Moreover, standard maps are not generally revised simultaneously.

Thus, depending on the region, the most recent thematic data (resulting from the revision programmes of standard maps) may be found on maps of different scales.

Note

For photointerpretation, it should be remembered that on 1: 1 00 000 maps many line features (railways, roads, etc.) are not drawn to scale: mapping conventions must therefore be observed and the outlines of features which are not represented to scale must not be transferred unadjusted to the interpretation transparency.

3.1.2.2. Thematic land cover maps

Every country produces a large number of medium-scale (1:50000 to 1:250000) thematic maps of all kinds (geological maps, pedological maps, forestry maps, etc.). A number of principles need to be followed with regard to such maps:

* The time taken to collect and collate the documentation should not exceed three man-months for a country with a surface area of 400 000 to 500 000 km2 (Italy, Spain, France).

* The following should be successively acquired:
the most general documents relating to the country as a whole, beginning with those which provide interpreters with contexted information, e.g. geological maps, pedological maps, etc.; next, maps which relate more directly to the project, i.e. vegetation, land use, agricultural (including potentiality), forestry, etc.;

* documents covering areas of more limited geographical extent; however, it is better (for a country of *500* 000 km 2) not to use maps covering areas of less than I 0 000 km2, and to use land cover maps only;

* for land cover or land use documents (agricultural or forestry maps, vegetation maps, etc.) it is essential to prepare methodological summaries for the interpreters in order to prevent any misinterpretation of the map content. For instance, it should be pointed out that most maps showing natural vegetation in fact show what the vegetation would be like in the absence of human activity;

* the maps thus collected must be grouped on a regional basis together with any corresponding statistical data before being given to the interpreters.

Examples:

covering all the Community countries:

* vegetation map,
* soil map;

covering national territory:

* 1:250 000 vegetation map of France,
* 1:50 000 agricultural map of Portugal;

covering a particular geographical zone:

* 1:25 000 continuous inventory of the French coast.

Examples of the use of these documents in the land cover project will be given in Section 3.3.3, 'CORINE land cover Marseilles'.

See also

3.1.2.3. Statistical information on land cover

All European Community countries possess advanced statistics systems which provide information on land cover/ land use. This information will have been processed to varying degrees, depending on the country, and will not always provide the same amount of detail.

As a rule, such information is a by-product of routine periodic statistics on agricultural production. These statistics provide a general perspective for the project. They provide a comprehensive picture of land cover, and thus serve as a guide for the photointerpreters. They are also a means of verifying the land cover results, although great care must be taken when making comparisons, because different nomenclatures are used.

Like all ancillary data collected for the project, statistical information must be made available to the photointerpreters in an integral and user-friendly form.

Land cover statistics vary appreciably from one country to another. They derive from the following:

* general population censuses,
* annual surveys of agricultural production,
* forest inventories,
* land cover/land use sampling surveys.

The results of these operations may be used in the project provided that the surveys cover the whole country and that the results are available for identifiable administrative or geographical areas. The results must also be recent (less than five years old) for rapidly changing land cover categories (urban areas, agriculture, etc.) and not too out of date (less than 15 years old) for natural areas with a greater relative stability.

Grouped by administrative division (see table in the Marseilles example), these statistics provide the interpreter with information on the agricultural land pattern (i.e. major crops, polyculture and livestock), the presence and extent of permanent crops, areas occupied by forest and type of population.

3.1.2.4. Aerial photographs

Distinct from the basic data (satellite data for the production of false-colour images), aerial photographs form part of the ancillary data. Unlike the ancillary data referred to above, however, they should not be collected prior to the start of the photointerpretation. This is because the CORINE land cover methodology requires the use only of a limited number of such photographs (an average of five stereo pairs at 1:30 000 for the interpretation of an image covering 2 500 km^2).

The photointerpreter chooses the geographical location of these paris in accordance with his/her needs.

Along with the standard topographic maps, aerial photographs play a major role in the land cover project. They are used:

* to identify (as a nomenclature item) units delineated on the false-colour images which might be incorrectly classified;

* to determine the exact boundaries of units which are not resolved clearly on the satellite image;

* to verify and validate the results of the land cover mapping.

All the Community countries carry out a systematic vertical aerial photographic survey of their territory at regular intervals (every four to eight years, depending on the size and climatic conditions of the country). The work is performed by one or more public bodies which, *inter alia,* are responsible for archiving and distributing (paper print reproduction) the photographs.

The photographs are on a scale varying from 1: 12 000 to 1:60 000. Black and white panchromatic film is the most commonly used, but some coverage is done with natural colour film or black and white infra-red film.

The photographs help to identify and delineate the various land cover categories by their spatial resolution, which is considerably greater than that of Earth observation satellite sensors (1 to 3m, as against 20 to 80m), and by the three-dimensional view they provide through systematic 60% overlap coverage of the successive photos.

Given the mapping scale chosen for the CORINE project, it is more practical to use small-scale aerial photographs (1:30 000 to 1:50 000) where available; if the photographs are on a larger scale many more prints have to be examined to produce the same end result.

Although the aerial photographs themselves are not included with the initial ancillary documentation (since they are used only as needed) the list and flightline index maps of photographs which may be of use, are part of the ancillary data and must be provided to each photointerpreter before he/she starts work.

The following should be indicated for each photograph: the scale, the type of emulsion and the date the picture was taken.

The main contractor is responsible for ensuring that the photographs are available from the bodies which hold them.

3.1.3. The interpretation transparency

The transparency is the sheet of clear plastic film used to produce the interpretation plot before transmission for digitization.

The transparencies are important documents and must be produced with great care. The accuracy of the resulting database will depend on the quality of the transparencies.

A 'matt transparent plastic support, with Kodatrace-type one face' is recommended for producing the transparencies.

Remarks

(i) The geometry of the transparency is the same as that of the corresponding 1: I 00 000 standard topographic map. To obtain a good representation of this geometry:

* place the blank transparency on the hydrographic overlay (the blue layer of the standard topographic map) using either adhesive paper or perforations (locating pins);

* fix the two documents together;

* starting at the corners trace the frame (in ink: Rapido 0.2mm);

* do not forget to label the document outside the frame (naineand number of the map sheet,e.g. 1:100000Marseilles 0-23);

* check that the corners of the transparency are perfectly positioned over the crosses marked for this purpose on the false-colour image of the corresponding area (see Section 3.2.3).

(ii) Use of the blue layer of the 1:1 00 000 map:

This film must be used whenever geographical positioning problems arise during interpretation. The hydrographic network (or coastline) is always very clear on false-colour satellite images. Therefore, the blue layer may always be used to locate on the printed map a unit delineated from the satellite image.

To make better use of the transparency and in order not to forget some urban areas (continuous or discontinuous) during interpretation, we suggest transferring onto the transparency (by means of an overlay, from the most recently updated 1:100 000map), using stickers, the location of groups of buildings covering more than 25 ha.

3.2. Production of false-colour images

The reason for computer-processing digital satellite data is to make geometric corrections and to improve the Landsat MSS, TM or SPOT HRV data in order to obtain images which are easy to interpret and digital data which are easily accessible for visualisation and further processing on an interactive system. These data are in fact a by-product of the production of the basic images.

The production of images for photointerpretation comprises six stages:

3.2.1. Destriping

On Landsat data (MSS or TM) differences in the calibration of the detectors produce a banding effect on the images. Destriping recalibrates the CCDs (couple charge devices) and removes the stripes.

For SPOT data (HRV has 6 000 CCDS) relative calibration is carried out by the body responsible for managing the operation of the satellite.

3.2.2. Removal of artefacts

Owing to occasional malfunctioning of the sensors a number of anomalies in the raw data supplied by the distributors have to be removed. The main anomalies are:

* missing or irregular scanning lines,

* saturated (glasshouses, forest fires, etc.),

* small areas (15 x 15 pixels) of black or white pixels (dithering pixels).

These anomalies must be removed by averaging and filtering techniques.

3.2.3. Geometric corrections

The 'clean' digital data must them be corrected geometrically with reference to the standard topographic maps of each country. The geometrically corrected data will be used to produce images on a scale of 1: I 00 000, in such a way that the image, the topographic map and the land cover interpretation transparency can be perfectly registered one to the other.

Thus, each land cover interpretation sheet - possibly resulting from several images - will be precisely matched to the corresponding stable topographic background.

The purpose of the geometric corrections is to correct the various distortions which may occur (change in satellite attitude and orbit, movement of the Earth below the satellite, panoramic effect, etc.) and to transform the data in order to obtain an image which is matched to the projection system used for the standard topographic map. This transformation is achieved by aligning a set of group control points (GCPs) marked on the map with the corresponding points in the image data. The points must be fixed (road intersections, end of runways, etc.) and easily identified on a display of satellite data.

Note

Account must be taken, when making corrections, of the altitude of each control point; the geometric correction software used must therefore provide for an altitude measurement of the control points. The resultant parallax errors will be serious if the terrain covered by the data is hilly.

Each control point is characterised by its image coordinates, the row and column coordinates in the raw image data, its map coordinates and latitude and longitude (or other reference system peculiar to the projection to be used). These points must be sufficient in number and distributed evenly over the whole image. These data can be used to calculate a transfer function between the grid coordinates of the raw image and the coordinates of each point in the projection to be used. There are two ways of doing this:

* regression using the least-squares method;

* rigid model taking account simultaneously of the image-map coordinate pairs and satellite flight parameters. This method produces the best results.

The transfer function is a polynomial type; it is recommended that low-degree polynomials alone be used in order to avoid local aberrations.

This transformation must of course be tested to validate the quality of the resulting geometry. lt can and must be improved by correcting wrongly positioned control points until accuracy commensurate with the required quality is obtained.

The adjusted transformation is applied to the whole image so that the position of each point in the corrected image can be determined in the raw image. The values of the new points are determined by the chosen resampling method.

3.2.4. Resampling

Resampling is a two-stage operation:

* Initial sampling, by the instruments on board the satellite, is simply the discretization of a continuous measurement into pixels of predetermined dimensions and positions. It is this process which creates the raw image.

* Stage two (resampling) consists of giving a value to pixels whose dimensions and/or positions have been changed in relation to the original pixels (as a result of the geometric correction). The result of the resampling process is the corrected image.

Whereas the initial sampling is fixed, the second operation can be performed using a variety of methods. These are of three main types: simple choice methods, interpolation methods and restoration methods.

Each method gives different results, and the calculation times vary too! Restoration gives the best results: although the geometry of the image is corrected, in contrast to the other methods the (radiometric) information is represented in a physically correct manner. One of the main advantages of restoration is also that it allows oversampling (and hence a reduction in pixel size) by recreating information (very close to the real thing) rather than by simply multiplying pixels.

A simple choice method: the nearest neighbour

This quite simply takes the value of the pixel in the raw image closest to the pixel to be resampled.

The main advantages of this method are:

* the speed and ease of calculation;

* it is the only method which allows resampling of qualitative images (such as a land cover map where the numbers do not designate a measurable quantity but simply refer to a legend item).

Its main disadvantage is that it produces particularly poor quality images:

* the values of original points are retained whereas the relative position of the pixels is changed, giving a distorted image with stepping along parcel boundaries, breaks in lines, mixed and wrongly placed pixels;

* no significant oversampling can be done, which means that pixels cannot be reduced in size (or their number increased) unless there is redundant information.

Interpolation methods

Interpolations take the form of a variety of convolutions: bilinear, cubic, etc., which will take account of a greater or lesser number of points in the neighbourhood of X. Very acceptable values for X can be attained (using the most complex procedures).

The choice of convolution to be used obviously depends on the capabilities of the software, the final image quality required and the computation time available.

The images produced are interesting but unfortunately seem 'averaged'; interpolation takes place in any case at the expense of the high frequencies (i.e. the details), which means that boundaries generally look blurred, line features are blurred and dotted areas tend to take on faded synthetic hues.

Restoration methods

In contrast to interpolations, the restoration method takes account of more than just the radiometric information contained in the raw image.

Since, during satellite data acquisition, observation is convoluted and then discretized by the observation instruments, the general idea is to deconvolute the raw data using a priori knowledge of the scanner's operation, so as to arrive at an optimum estimate of the original information. Thus the original observation is restored.

The aim of restoration is to deconvolute the data using a priori knowledge of the scanner characteristics to develop a set of coefficients which, when multiplied by a table of original radiometric data, will give the best estimate of the point to be resampled.

Further, using the a priori knowledge, the inverse function of the scanner's convolution can be applied to obtain the new point sampled with the desired point spread function (PSF) to replace the original PSF.

The philosophy is that restoration guarantees resampled image quality by a (simulated) physical determination of the radiometric values, while other methods merely approximate these values statistically.

Resampling by restoration is in fact referred to as rescanning rather than resampling.

The method has obviously enjoyed most success in connection with Landsat MSS. It is now operational for Landsat TM, SPOT XS and P, and NOAA.

At a time when multisensor image fusion is increasingly successful, restoration comes into its own; pixel size is changed in a physically correct manner, allowing serious comparisons.

The restored images are of excellent quality, with clear and strong contours and line features, and retention of detail (especially in complex environments such as very heterogeneous natural or fanning land), qualities which are bound to make a substantial contribution to thematic mapping work.

Table 3.3. Number of control points necessary to obtain a geometric error (RMSE) of one pixel according to the size of the pixel after resampling (full scene)

	RMSE (in pixels)	Number of GCPs [1]	Ground resolution (size of resampled pixel)
Landsat MSS	1	50 to 1 00	50 x 50 m
Landsat TM	1	40 to 70	25 x 25 m
SPOT XS	1	40 to 70	20 x 20 m
SPOT P	1	20 to 100	1 0 x 1 0 m

1 The highest and lowest figures correspond to different types of relief.

Note

In Landsat TM satellite data acquired after 1988 there are discontinuities in the recordings of the different scanning lines. There are sometimes displacements of up to three pixels between the 16-line blocks.

If the digital data acquired for the land cover project has been geocoded by the distributor, it is essential to check its accuracy.

3.2.5. Enhancing the image

The table below shows the various combinations of spectral bands which may be used to produce satellite images. Landsat TM and SPOT XS data are usually combined to obtain an image which resembles an aerial infra-red colour photograph.

The best spectral band combination (Landsat TM) for land cover mapping is: TM4 (near infra-red), TM5 (middle infra-red) and TM3 (red) of Landsat TM data.

To produce good quality images the dynamics of the data in each spectral band must be adjusted.

Table 3.4. Production of false-colour images, spectral band combination (additive synthesis)

	Red	**Green**	**Blue**
Landsat MSS	Channel 7 (0.8 to 1.1 µm) near infra-red	Channel 5 (0.6 to 0.7 µm) red	Channel 4 (0.5 to 0.6 µm) green
Landsat TM	Channel 4 (0.76 to 0.90 µm) near infra-red	Channel 5 (1.55 to 1.75 µm) middle infra-red	Channel 3 (0.63 to 0.69 µm) red
Landsat TM	Channel 4 (0.76 to 0.90 µm) near infra-red	Channel 3 (0.63 to 0.69 µm) red	Channel 2 (0.52 to 0.60 µm) green
Spot XS	Channel 3 (0.79 to 0.89 µm) near infra-red	Channel 2 (0.61 to 0.68 µm) red	Channel 1 (0.5 to 0.59 µm) green

The method used (linear, histogram equalisation, etc.) must be adapted to the landscape of the scene.

Lastly, it is recommended that the boundaries be improved by application of bidirectional convolution with the following type of 3 x 3 pixels window:

0	1	0
- 1	6.5	- 1
0	1	0

If there are sharp contrasts in the landscape of the scene being processed extended windows must be applied (up to 51 x 51 pixels).

3.2.6. Restitution on film

The satellite data must be printed on colour photographic paper on scales of 1:250 000 and 1:100 000. Each print must be a few centimetres larger than the corresponding topographic sheet and the corners of the topographic map must appear on the satellite image. If several images are needed to cover the complete map, it is better to work on the images separately without mosaicking them.

lt is better to produce two copies of each scene on a scale of 1: 100000. The first will be used as a working document (interpretation and work in the field), and the second will be kept as a reference document. The 1:250 000 copy is needed for stratifying the image into large polymorphic areas.

The photographic prints must be of excellent quality, which means:

* absence of saturation in parts which are neither too dark nor too bright;

* use of soft paper;

* low intensity is preferable (not too dark).

Two different methods can be used to obtain good quality prints:

3.2.6.1. Enlargement of slides

3.2.6.2. Colour-proofing of screened films

3.2.6.1. Enlargement of slides

Laser beam recorders (e.g. Optronics, Spectrascan, Vizir, Colorfire) are used to produce small-scale transparencies.

To obtain a colour composition, the photographic support is exposed successively by the red, green and blue rays (additive colouring). Each quarter of a Landsat scene or complete SPOT scene is represented on a slide. The printing is done by enlarging (by a maximum factor of five) on colour photographic paper.

Note

lt is vital to check the precision of the enlarged document: this alone will ensure that geometric deformations caused by the optics of the enlarger are kept to an absolute minimum.

Instead of a reversible colour film, three black and white films may be exposed separately. A colour image is obtained by exposing each film through the three corresponding filters. The printing may be done on either glossy or matt paper.

3.2.6.2. Colour-proofing of screened films

The 'proofing' process is used for the direct production of colour images on a scale of 1: 100 000.

A digital laser photoengraver rasters on lithographic film or by ink jet the data in each spectral band on a scale of 1:100000.

The three black and white films thus obtained are converted (subtractive synthesis) to obtain a colour document:

red becomes cyan,

green becomes magenta,

blue becomes yellow.

An additional black film is produced from the three spectral bands to improve the quality of the image.

The four black and white films are then transferred onto the colour support (175 g/M2 paper minimum) for printing on a scale of 1:1.

3.3. Computer-aided photointerpretation

3.3.1. Preparation

Before starting to interpret the first false-colour images, the photointerpreter ensures that all the requisite documentation is at hand.

The basic documents and equipment required are:

* satellite image(s) on a 1:250000 scale;

* satellite images covering the 1: 100 000 map sheet:

  -an image which is larger than the sheet and includes the guide marks (crosses) at each corner of the sheet, or

  -a mosaic of images if the 1: 1 00 000 sheet covers several satellite scenes;

The photointerpreter must cheek the readability (quality) of the image:

* Blank interpretation transparency;

* A hydrographic overlay (blue layer) of the 1: I 00 000 map showing the main urban areas;

* A topographic map produced on a 1: 1 00 000 scale.

3.3.1.1. Ancillary documentation and interactive image-processing workstation

3.3.1.2. The workstation

3.3.1.1. Ancillary documentation and interactive image-processing workstation

The photointerpreter must ensure that:

* all the ancillary documentation provided for in the job specification has been assembled and can be consulted at any time;

* he can have regular access (every two or three days) to an interactive image-processing workstation in order to work on and view the corrected basic data used to produce the false-colour image he is interpreting;

The interactive image-processing workstation used for photointerpretation must provide the following minimum facilities:

* reading of basic data on magnetic tape;

* display on a colour graphics screen of images of any size (zoom);

* false-colours manipulation;

* statistical analysis;

* radiometric transformation (ratio, linear combinations);

* radiometric transformations of neighbouring pixels (filters);

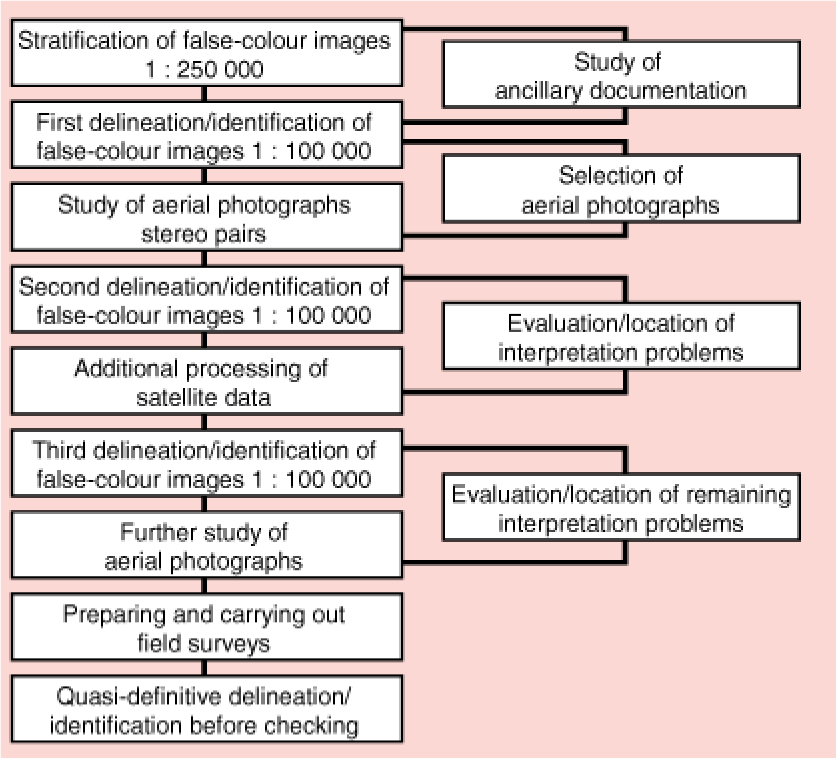
* decorrelation, analysis into principal components;

* automatic classification, supervised classification;

* photocopying of screen displays.

Figure 3.5.

Figure 3.5. Computer-aided photointerpretation stages



3.3.1.2. The workstation

The interpretation of satellite images and the examination of aerial photographs is a delicate task requiring proper lighting to facilitate perception of distinctions between often subtle nuances of colours, grey tones and .

However, the working tools required are extremely simple:

* a very sharp black or coloured pencil for accurate marking of unit boundaries,

* an eraser,

* a magnifying glass to provide a better picture of the details of false-colour images,

* a set of stereoscopes 4 x enlarging capacity for viewing small-scale photos, ± 1:50000, and 2 x for medium scales) for stereoscopic reading of aerial photographs.

3.3.2. Procedure

The photointerpretation of satellite images is a process of extrapolation based on iterative controls.

This process consists of:

* marking on the false-colour image the boundaries of areas representing single land cover units (as defined in Section 2.2) (delineation),

* using interpretation keys, ancillary documentation or aerial photographs to assign to this area a nomenclature heading (identification),

* extrapolating this delineation and identification to all parts of the image expressing similar characteristics (colour, structure and texture).

Iterative controls, which involve constant comparison of extrapolation results with other information such as the ancillary documentation proper, aerial photographs and computerized data displays, are made necessary by the very nature of multispectral satellite data. With a 44-item nomenclature any extrapolation from false-colour images alone is bound to lead to errors, either in boundaries or in classification.

It is clear from the above that no procedural schematic of the computer-aided image interpretation process can convey the conceptual complexity of the interpretation task, because it attempts to represent in linear form a process which in reality is replete with feed-back operations, (see diagram above).

It is also clear that the work involved requires highly specialized skills.

3.3.2.1. Delineation of major landscape units

First of all the photointerpreter must devote a certain amount of time to a general examination of the 1:250000 false-colour image in order to get the feel of the structure and general organization of the document he is about to interpret. This approach should enable him to assess and locate the main difficulties lying ahead of him.

After this initial inspection the photinterpreter uses a special marker pen to trace the major natural regions (or major landscape units) present on the image onto the interpretation transparency. This preliminary delineation will always be possible provided the image covers a large enough surface and is not a single, homogeneous area (e.g. monocultural plains).

Following this intial zoning, the photointerpreter must devote a considerable amount of time to studying the ancillary documentation.

He must first examine the 1: 1 00 000 topographic map, which, irrespective of when it was last updated, will always provide essential information on the relief, the hydrographic network, main town, etc. This map will thus be the permanent point of reference throughout the photointerpretation process.

Other ancillary documents will be examined in a logical sequence according to availability:

* topographic maps (thematic information on scales greater than 1: 1 00 000),

* forestry maps,

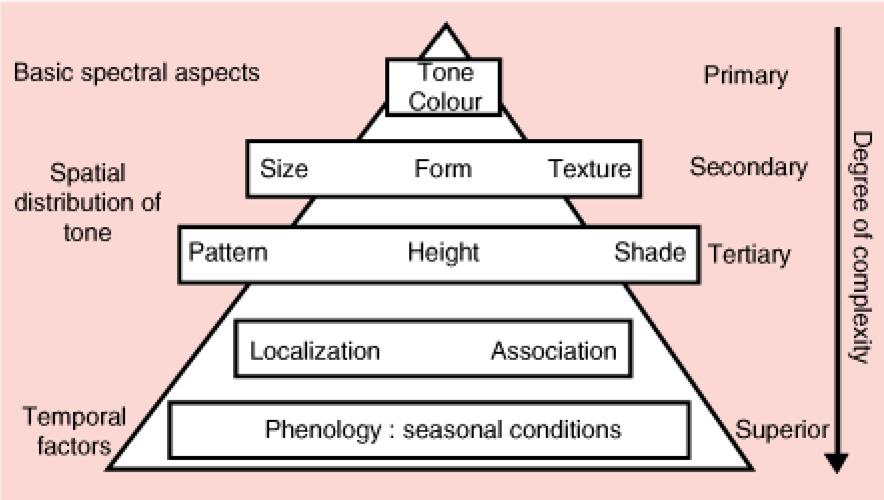
* statistical data on land cover,

* geological maps, etc.

3.3.2.2. First stage in delineation and identification

This first stage of the photointerpretation process chiefly involves the application of false-colour image interpretation key with which all photointerpreters are familiar.

Figure 3.6. Relationship of image elements to the photointerpretation



The photointerpretation of satellite images rests on two basic principles:

(i) Each colour can relate to one class, or a limited number of classes, of features on the ground. The problem arises because there are potentially several million different colours for false-colour images, each image resulting from the superimposition of layers of the three basic colours (blue, green and red) and each layer can itself consist of 256 different shades. In fact, it would be more accurate to think in terms of a whole range of variations of shade around one colour rather than of different colours.

(ii) Areas of different shades (isolated pixels or assemblies of pixels) represent, by their distribution, certain heterogeneous types of land cover (e.g. vineyards or orchards are represented by pinkish patches combined with patches in different shades of grey, although only in early summer).

By way of example, the table below indicates general interpretation keys resulting from the application of the first principle for false-colour images recorded in early summer.

Conditions of validity of interpretation keys

(i) False-colour images produced as follows:

Spectral band used	Colour code
Green	Blue
Red	Green
Near infra-red	Red

(ii) Land areas which are assumed to be homogeneous and which in many cases do not correspond to the CORINE land cover nomenclature

Figure 3.7. Example of interpretation keys based on the tone and colour of false-colour images

Type of landcover [1]	False-colour images
1. Urban fabric	Blue (darker or lighter - or even white - according to building density)
2. Mineral extraction sites, construction sites, bare rock, sand, dunes	White
3. Communication links (roads and railways)	Dark blue, grey
4. Perpetual snow and glaciers (clouds)	White, bluish-white
5. Salines	White, grey, cyan
6. Water bodies	Black (also the shadow cast by clouds), green-blue (darker or lighter according to depth and turbidity)
7. Annual crops	Red (standing crops), grey-pink (harvested crops) and blue-white (ploughed land)
8. Permanent crops	Red-pink
9. Deciduous woodland	Bright red
10. Coniferous woodland	Brown-red
11. Meadows and grassland	Bright pink, light red
12. Wetlands	Black or very dark red
13. Poor pasture and scrubland	Grey-yellow, grey-pink, light brown
14. Burnt areas	Black, dark grey, bluish

1 False-colour images obtained using different coding or using the middle infra-red data of the thematic mapper require other interpretation keys.

The foregoing paragraphs have been concerned with the initial techniques employed to detect and delineate elementary units. The assigning of a nomenclature code to each unit is also subject to a number of rules.

Rules for using the CORINE land cover nomenclature

* **The smallest mapping unit area is 25 hectares.**

* **Only the three-figure nomenclature items are used and only one three-figure code is assigned to each area unit of more than 25 hectares.**

* **Work at national level (assigning four or rive-figure nomenclature codes, smallest mapping : 25 hectares) may only be done after the work has been completed to CORINE land cover standards (see above).**

* **The CORINE land cover nomenclature is a physical and physiognomic land cover nomenclature.**

Analysis of the documents used in the programme (false-colour satellite images on a scale of 1: 100 000, displays of processed numerical data, aerial photographs, ancillary documentation, etc.) makes it possible to delineate, with reference to the topographic maps, the units of more than 25 hectares and to assign a three-digit nomenclature code to them.

Assigning a code is no problem when the land cover of the unit is perfectly homogeneous:

* dense woodland,

dense urban fabric,

* bedrock outcrops, etc.

Where the land cover of the unit is heterogeneous, its classification will depend on:

* either the predominant type of land cover as a percentage of the total area of the unit, e.g. discontinuous urban fabric, poor pasture. (Grassland and in particular low-quality grazing land often includes small areas of arable land, scrub, bare earth, etc.)

* or the land cover which, although not predominant in terms of land area, determines the structure of the unit both in terms of land use and its ecological function, e.g. vineyards.
Even in the main wine-growing regions, the land area actually covered by vines is, in many cases, less than half of the total (because of the nature of the soil and the degree of exposure). Nevertheless, the whole area is affected by the need to maintain the vines and even the other crops are organized as a function of wine growing. In other areas, however, there are vines which, in terms of the size of plots and the percentage of the unit covered, appear to be a form of gardening (irrespective of the economic importance of the grop) and should not therefore be classed as vineyards. In these cases, it is important to take into account the main type of land cover or, where necessary, to allocate the code for complex cultivation patterns (Section 2.4.2).

In those regions where the pattern of land cover is very simple (large areas of monoculture, etc.), it is possible to delineate and identify a large number of units even at the first stage. The interpretation process can then be completed by means of internal confirmation from aerial photographs and additional processing on an interactive display console to pinpoint boundaries and/or define doubtful units.

In most regions, however, there will still be interpretation difficulties, either because the land cover is very complex or because the single image analysed does not provide enough evidence. The photointerpreter should then be able to mark on a map those areas (an average of five per 2 500 km 2) where he judges aerial photographs are required.

3.3.2.3. Second and third stages in the delineation and identification of units: use of aerial photography and additional processing

Aerial photographs can be used to identify complex units and to provide a second partial extrapolation (second delineation and identification). Additional processing of satellite data at an interactive processing station can then serve to complete the interpretation and to corroborate the results obtained.

Additional processing can be carried out on two types of data:

* the basic data used to produce the false-colour images (geometrically and radiometrically corrected);

* additional satellite data, where justified.

The decision to acquire new satellite data should only be taken if, after analysis of the basic data, there are still serious deficiencies in terms of CORINE land cover standards and it is not possible to remedy them more cheaply, i.e. there are no recent aerial photographs or ground inspection would be difficult.

Since the question of using additional satellite data is considered elsewhere, discussion here is confined to the problems of processing the basic data.

In order to keep additional processing time to a minimum, the photointerpreter must prepare the work carefully at an interactive workstation.

This preparation entails:

* identifying on the false-colour image those areas where additional processing is required, marking the areas which have to be checked and the areas where the interpretation has to be completed;

* gathering the requisite ancillary documentation concerning these areas: topographic and thematic maps, aerial photographs, etc.;

* planning the sequence processing stages according to the problems to be solved; in this connection it is preferable for the processing operations required for the different areas on one sheet to be carried out and stored (in a bulk memory) in a log file prior to the interpretation phase at the workstation.

The following five types of multispectral data processing

* adjustment of dynamics,

* vegetation index,

* automatic classification,1

* principal components analysis,

* two-dimensional spatial filter,

are recommended for use at the interactive workstations because:

* experience has shown them to be the best adapted to project objectives;

* they are generally available on commercial interactive processing workstations.

Usually, the results obtained on the display screen can be directly transferred to the interpretation transparency with the help either of the 1: I 00 000 topographic maps or the false-colour image on the same scale. However, in some cases it is better to transfer the results by taking a photograph (paper print) of the display screen.

Time spent on the screen and use of processing

The interpreting team must be very cautious about the time they spend at the interactive processing workstation.

As shown by the following table concerning use of ancillary data, not all the problems remaining at the end of the photointerpretation process (using the basic data) can be solved through the interactive processing of either basic or additional data.

Depending on the type of sensor selected for the data, the interpretation team will have to identify those problems (topics) which can be solved by interactive processing and establish the maximum time to be spent on processing in relation to the degree of complexity of the area to be mapped.

Table 3.5. Use of ancillary data and additional processing-Summary for the different nomenclature headings

CORINE land cover nomenclature		**Additional information which may be used**
1.1.1. Continuous urban fabric	AD:	Topographic maps Aerial photographs
1.1.2. Discontinuous urban fabric	AP:	Vegetation index PCA (Principal component analysis), Filters
1.2.1. Industrial or commercial units	AP:	SPOT data
1.2.2. Road and rail networks and associated land	AD:	Topographic maps
1.2.3. Port areas	AP:	Filter SPOT data
1.2.4. Airports		
1.3.1. Mineral extraction sites	AD:	Aerial photographs Topographic maps
1.3.2. Dump sites	AP:	Improving contrast
1.3.3. Construction sites		
1.4.1. Green urban areas	AD:	Tourist and topographic maps Aerial photographs
1.4.2. Sport and leisure facilities	AP:	Vegetation index Wallis filter PCA
2.1.1. Non-irrigated arable land	AD:	Agricultural statistics Maps of farmland
2.1.2. Permanently irrigated land		
2.1.3. Rice fields	AP:	Viewing images of different seasons Multitemporal vegetation index
2.2.1. Vineyards	AD:	Confirmation from agricultural statistics and large-scale maps
2.2.2. Fruit trees and berry plantations		Identification from aerial photographs
2.2.3. Olive groves	AP:	Vegetation index SPOT data
2.3.1. Pastures	AD:	Topographic maps (in some countries) Agricultural statistics Checking aerial photographs
	AP:	Vegetation index Additional satellite data for spring and winter Supervised automatic cl assification

2.4.1. Annual crops associated	AD:	Agricultural statistics	
with permanent crops		Thematic maps	Aerial photographs
	AP:	Vegetation index	
2.4.2. Complex cultivation patterns	AD:	Agricultural statistics	
		Aerial photographs	
	AP:	Wallis filter	
2.4.3. Land principally occupied	AD:	Topographic maps	
by agriculture, with significant areas		SPOT checks	
of natural vegetation		Aerial photographs	
	AP:	Vegetation index	
		PCA	
2.4.4. Agro-forestry areas		Identification on false-colour images and	
		systematic checking against aerial photographs	
3.1.1. Broad-leaved forest	AP:	Vegetation index	
		Automatic classification	
3.1.2. Coniferous forest		PCA	
3.1.3. Mixed forest	AD:	Forest inventory maps	
		Topographic maps	
		Aerial photographs	
3.2.1. Natural grassland	AP:	Vegetation index	
	AD:	Topographic map	
		Geological map	
		Aerial photographs	
3.2.2. Moors and heathland	AD:	Vegetation map	
		Geological map	
		Aerial photographs	
	AP:	Vegetation index	
		PCA	
3.2.3. Sclerophyllous vegetation			
3.2.4. Transitional woodland/shrub	AD:	Aerial photographs	
3.3.1. Beaches, dunes, and sands plains	AP:	Improving contrast	
3.3.2. Bare rock			
3.3.3. Sparsely vegetated areas	AP:	Vegetation index	
	AD:	Aerial photographs	
3.3.4. Burnt areas			
3.3.5. Glaciers and perpetual snow	AP:	Automatic reconnaissance programme	
4.1.1. Inland marshes	AP:	Displaying the near infra-red channel	
		Improving contrast	
		Satellite data for periods of high water	
4.1.2. Peatbogs	AP:	Vegetation index	
	AD:	Aerial photographs	
		Topographic maps	
4.2.1. Salt-marshes	AD:	Topographic maps	
	AP:	Displaying the near infra-red channel	
		Images for periods of high water	
4.2.2. Salines	AD:	Topographic maps	
4.2.3. Intertidal flats			
5.1.1. Water courses	AD:	Topographic maps	
5.1.2. Water bodies			
5.2.1. Coastal lagoons			
5.2.2. Estuaries	AD:	Topographic maps	
5.2.3. Sea and ocean			

NB: AD = ancillary data, AP = Additional processing.

3.3.2.4. Processing of additional data

As discussed above, it may be useful and occasionally essential to obtain additional information from satellite data other than those used for the database. The additional data are either data acquired by the same sensor but at a different time of the year or data recorded by a different sensor than for the basic data, e.g. the data recorded by the second-generation sensors, Thematic Mapper or HRV (haute résolution visible = high visible resolution) to supplement the MSS (MultiSpectral Scanner) data.

Methods and procedures for using such data differ considerably depending on the end in view.

Note

In most cases additional satellite data are simply displayed on the station console and no new false-colour images are produced. Procedures are as follows:

* If the additional data are MSS data they must be geometrically corrected and resampled to 50 x 50 m before viewing;

* If the additional data are Thematic Mapper data and are being used for strictly local thematic applications (e.g. display window 512 x 512 pixels), it is possible to use the raw data without preliminary processing.

Data acquired at different dates from the same sensor

In the section discussing the principles of establishing the land cover nomenclature it is indicated that certain types of land cover change in the course of the year. In some cases, therefore, it is essential to have data recorded at different seasons in order to identify a unit:

* identification of rice fields;

* delineation of bodies of water or wetlands if the image produced from the basic data was recorded during a period of drought, when water surfaces normally appear as bare earth;

* it is also essential to use images taken on different dates if unfavourable weather conditions made it impossible to obtain basic data for an area on the optimum date.

Data from other sensors

Before considering the problem of using second-generation sensors, it is worth noting that if the original database is derived from HVR or TM sensors, it is economically advantageous to use MSS data as additional seasonal data.

The data from second-generation sensors can be used in two particular situations:

* For thematic purposes to facilitate the identification of certain units.

In such cases, data from TM sensors are of considerable interest since they encompass seven spectral bands, which makes it possible to produce 35 images with different spectral combinations. Not all of these will be of obvious use in this particular project, however.

As its name implies, the Thematic Mapper has a number of wavelength channels, which means that it can be used for different purposes through judicious combinations. Moreover, the better ground resolution of the Thematic Mapper sensor is a valuable aid for the precise delineation of the various land cover units.

* To clarify the boundaries of units with the following features:

lack of sharp distinction with certain other units (zones of gradational change from one cover class to another);

complex land cover consisting of small areas of different types;

particularly rapid changes in land cover.

Data from the HVR SPOT sensor are very useful because the multispectral mode spatial resolution is 20 x 20m.

Note

For all additional processing, it is recommended that a technical information sheet be filled out using a standard model. This will help to speed up cheeks on the quality of interpretation.

Similarly, it is advisable to photograph the results of this processing as they appear on the display screen. Once referenced and filed, these photographs (colour slides) become a particularly valuable by-product of the CORINE land cover database.

3.3.2.5. Field work and quasi-definitive interpretation

After the additional processing (third delineation and identification of units), the process of interpreting the false-colour images is virtually complete. At this stage, the national project leader has to examine the remaining problems in the light of the project standards. This involves identifying those areas which have not been definitively delineated or identified or where there are still outstanding doubts. These areas are then divided into two groups:

* areas where ground truth surveys are the only solution;

* areas where it will suffice to study aerial photographs.

Comments on field studies

Ground truth surveys are the final stage in the preparation of a CORINE land cover map sheet. These surveys are the final stage in the computer-aided interpretation process as such and are carried out at the point where a semi-final manuscript sheet has been produced.

Field surveys are conducted for two different purposes:

* to provide a conclusive answer to any questions of interpretation still unresolved after the additional processing stage;

* to provide a general check on the quality of the results of the photointerpretation.

The work on these two points must be carried out simultaneously. lt is important to ensure that the cost of ground truth surveys does not exceed 10% of the total budget for the national land cover project.

The main problem is planning: to keep the number of field trips to a minimum, particularly in inaccessible areas. Experience shows that it is possible to restrict the number of ground verification points to an average of 25 per 1:1 00 000 sheet. This average takes no account of the particular problems of each map sheet, and the figure can range from 15 (for the simplest regions) to 40 (in the most complex regions).

For each sheet, the number of points required to complete the interpretation and the number of points for checking interpretation will depend on the complexity of the area concerned and how the person responsible for photointerpretation assesses the work of his team.

The practical procedure is as follows:

* Location of observation points on a 1:100000 map (road map, etc.), with access routes and estimated travel time to reach off-road localities.

* Bearing in mind the amount of time required to visit the first group of priority points, other should be selected for verification with a view to including as many as possible of the classes occurring on a map sheet, always minimising travel time. As for previous observations, it is essential to mark the checking points on the map.

* A survey record is to be made (using a standard form).

* The person in charge of photointerpretation examines the survey records in order to

- make the final additions to the interpretation sheet so it can be sent for digitization;

- use the checks to correct the interpretation sheet; and

- carry out some or all of the interpretation process again if the results of the checks are particularly unsatisfactory.

3.3.2.6. Quality control of the interpretationsheet and validation of the geographical database

lt is important to make a careful distinction between checks aimed at ensuring quality of the interpretation sheets and validation of the geographical database (see Section 5: Validation).

Verification is taken to mean all control operations involved in the process of thematic mapping work:

* checking the consistency of the plotting of numerical data (after processing) during production of false-colour images;

* checking the consistency of the interpretations of the different interpretation teams;

* checking the interpretation *per se:*

    -ground truth surveys on the delineation and/or codification of units where interpretation problems arose,

    -ensuring that only a single code has been assigned to each unit (closed polygon),

    -the size limit (25 ha) of the smallest units,

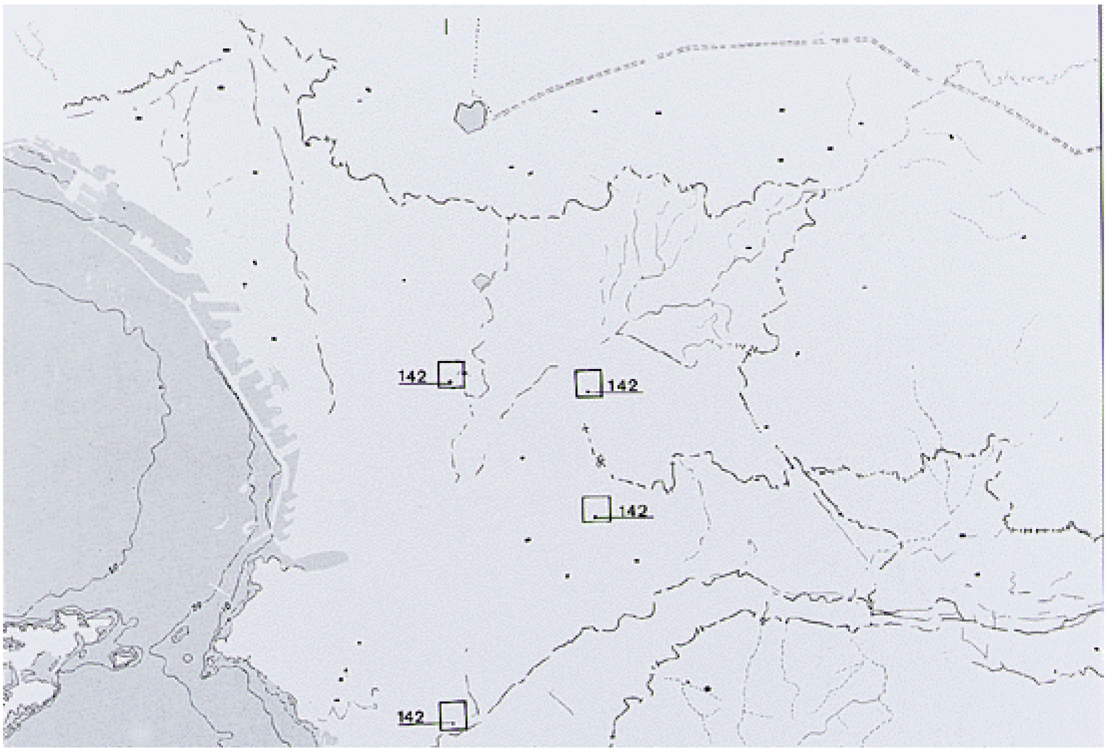
    -consistency of codification of the various units in comparison with the false-colour images.

* checking that interpretation sheets have been properly digitized; checking for polygons which have not been closed, that plotting is consistent with the basic topographic map, arbitrary separation of adjacent units with the same code number, etc.

An important aspect in verifying the interpretation sheets is the carrying out of ground truth surveys. This work is so important that we have decided to consider field surveys as an integral part of the methodology. These have therefore been specified in Section 3.3.2.5 above.

3.3.3. CORINE land cover computer-aided interpretation methodology - Example: Marseilles

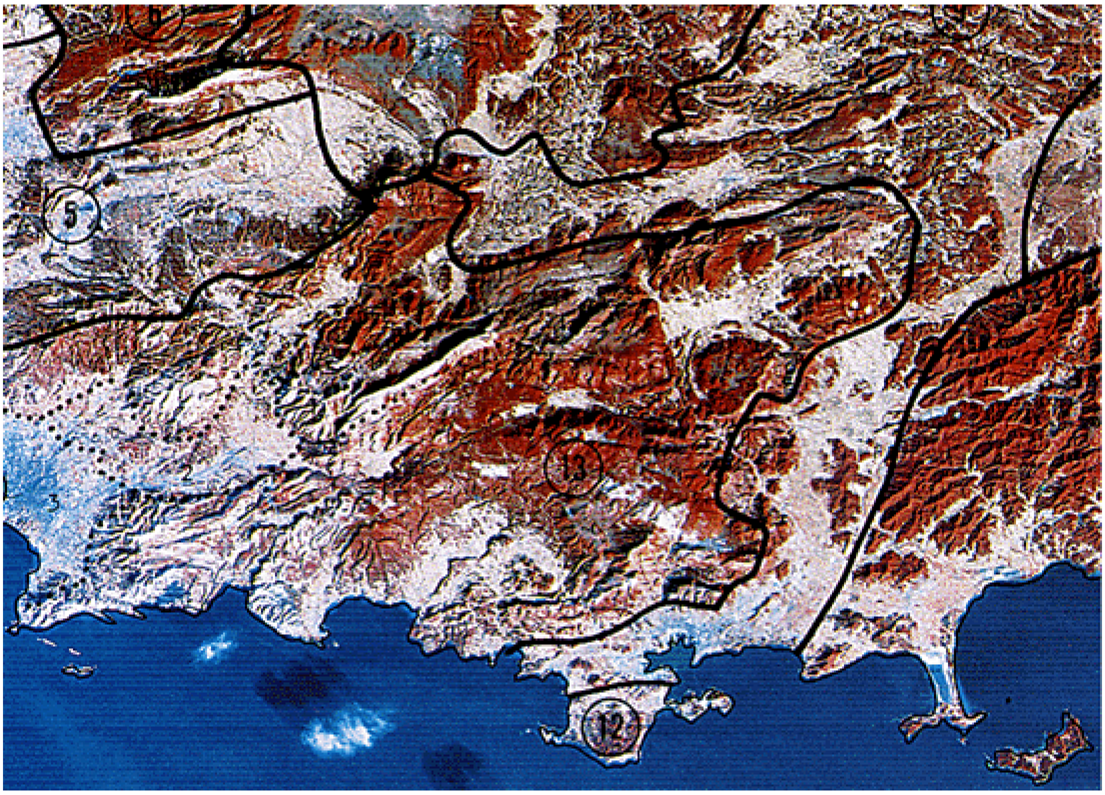
Hydrographic overlay



Features identified on the standard topographic map:

- -village or small town,
- -industrial area,
- -major development or distinctive infrastructure feature,
- -sports and leisure facilities.

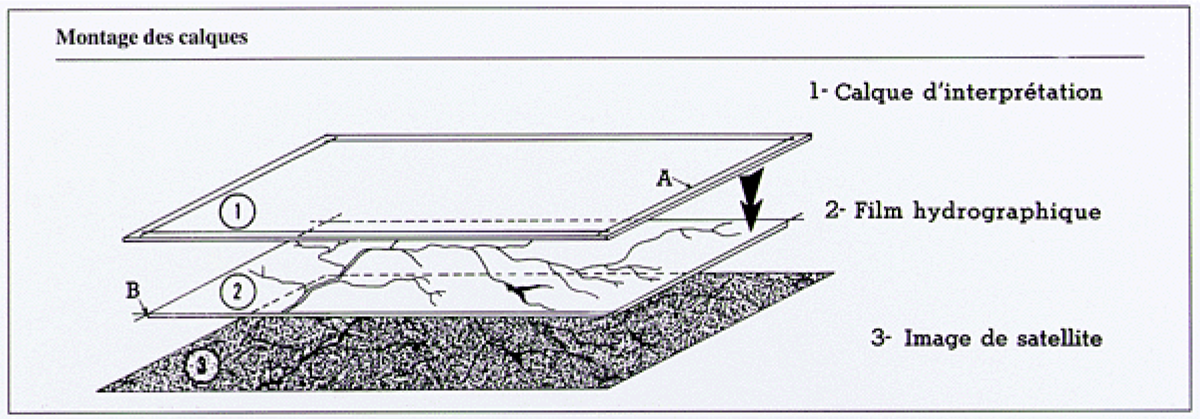
MSS stratification image



Wooded regions

1. Hills of Basse Durance
2. Plateaus of Valensole
3. Pre-Alps of Castellane
4. Pre-Alps of Haute Provence
5. Arc basin
6. Plateaus of Provence
7. Hillocks and plateaus of Haute Provence
8. Plains of Haute Provence
9. Varoise depression
10. Esterel
11. Permian border
12. Moorland and Permian border
13. Southern limestone chains:
    - Sainte Baume
    - Huveaune basin
    - Marseilles urban area

Fixing the transparencies



Indications in the form of symbols are needed to draw the interpreter's attention to features which are sometimes difficult to identify on the image.

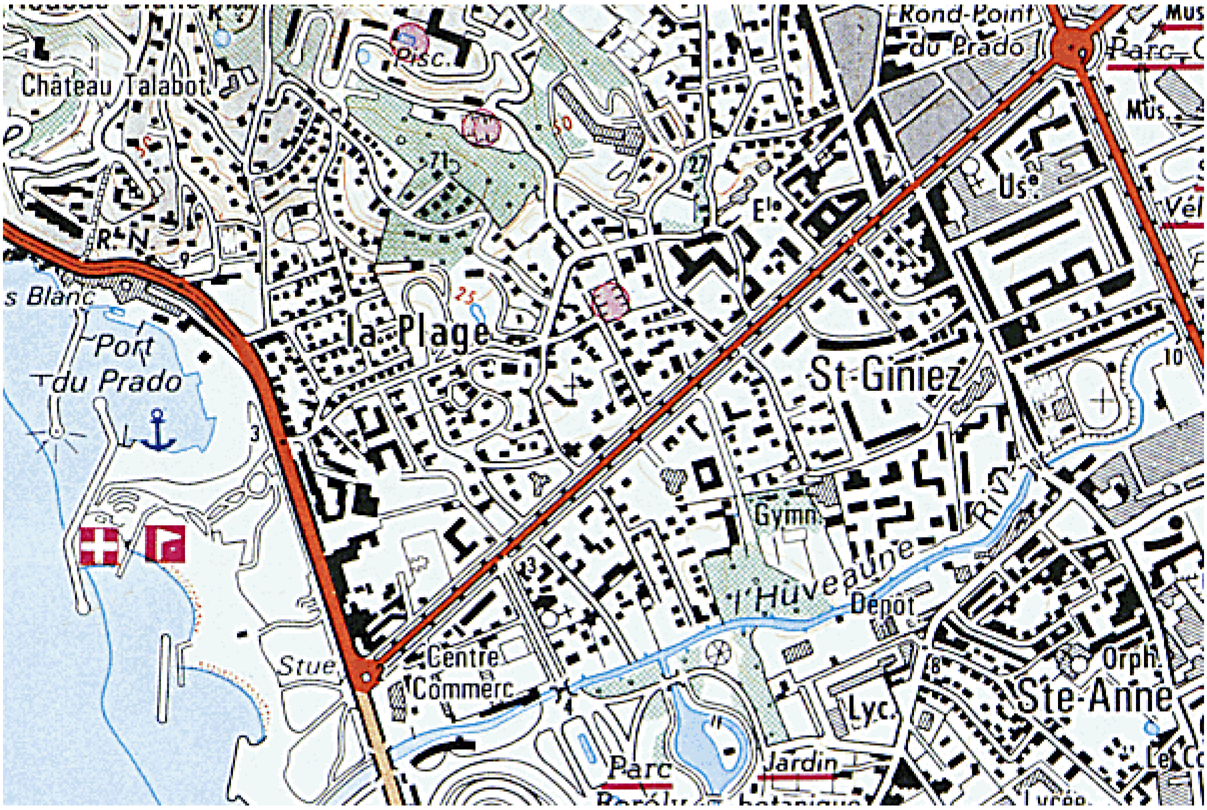
The transparency (1) must be fixed to the hydrographic overlay (2) using strong adhesive tape or by means of studs.

The framework of the map (A) must be marked on the transparency (1) on which the interpretation will be drawn. This framework must correspond perfectly with the corners of the 1: 1 00 000 sheet (B) shown on the hydrographic overlay.

The document (1 + 2) must then be aligned with the satellite image by making the hydrographic network shown on the hydrographic overlay (2) correspond as closely as possible to that visible on the satellite image (3).

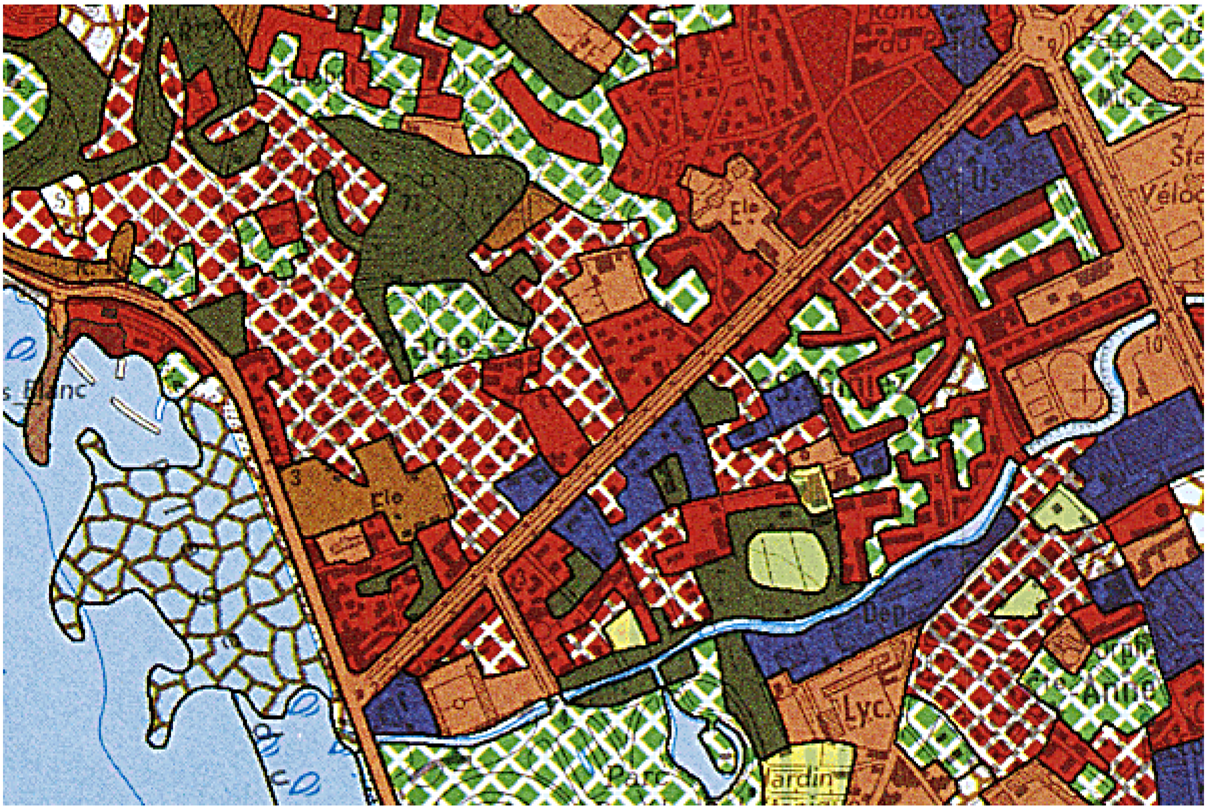
The three superimposed documents must then be placed on an illuminated table to facilitate visual analysis of the image.

Ancillary documentaion Topografphic map (1:25 000)



Ancillary documentation Aerial photograph (1:50 000)

Ancillary documentation Land use



Ancillary documentation

Statistics on land cover

Table 3.6. Breakdown of agricultural land cover per small agricultural region 1979-80

	Maures Esterel **AR NO 247** **TA 88 377 ha**		**Littoral de Provence** **AR NO 469** **TA 106 825 ha**		**Pont Frejus Sollies** **AR NO 248** **TA 44 928 ha**		**Coteaux de Provence** **AR NO 468** **TA 477 693 ha**	
	Total (ha)	**TA (%)**	**Total (ha)**	**TA (%)**	**Total (ha)**	**TA (%)**	**Total (ha)**	**TA (%)**
Agricultural area used (including buildings)	9 489	11	14 454	14	4 501	10	86 856	19
Unproductive wasteland or fallow land	2 261	3	3 592	3	814	2	13 978	3
Productive wasteland or fallow land	440	-	2 098	2	55	-	8 631	2
Permanent grassland	382	-	372	-	148	-	4 178	-
Land for ploughing	329	-	1 774	2	642	1	27 280	6
Permanent crops:: of which:	8 039	9	7 197	7	3 332	7	43 646	9
- vineyards	6 628	7	6 426	6	2 441	5	33 717	7
- orchards	91	-	293	-	397	-	3 942	-

NB: AR = agricultural region.
TA = total area of the agricultural region.

Small farming areas

MSS image
(Used for the CORINE land cover project in the south of France)

The entire area lies in the Marseilles urban district and the surrounding semi-agricultural area.

The boundaries marked on the image are the result of the first visual analysis of the image. The units delineated are those which have the same colour and texture.

At this stage, it is possible to assign a nomenclature code to some of the areas delineated:

unit I - mineral extraction sites code 131

unit 2 - construction sites code 133

unit 3 - port areas code 123

unit 4 - continuous urban fabric code 1 1 1

unit 5 - body of water in continental waters code 512.

However, in some cases, it will subsequently to define unit boundaries with neighbouring units more precisely:

* the boundary between a port area and continuous urban fabric or industrial area;

* the boundary between continuous urban fabric and discontinuous urban fabric and industrial area.

Some boundaries correspond to the clear limits between the different environments corresponding to level I of the nomenclature, e.g. the boundaries marked with an arrow - A and B - correspond to a demarcation line between a mixed agricultural area and discontinuous urban fabric and an environment dominated by natural vegetation.

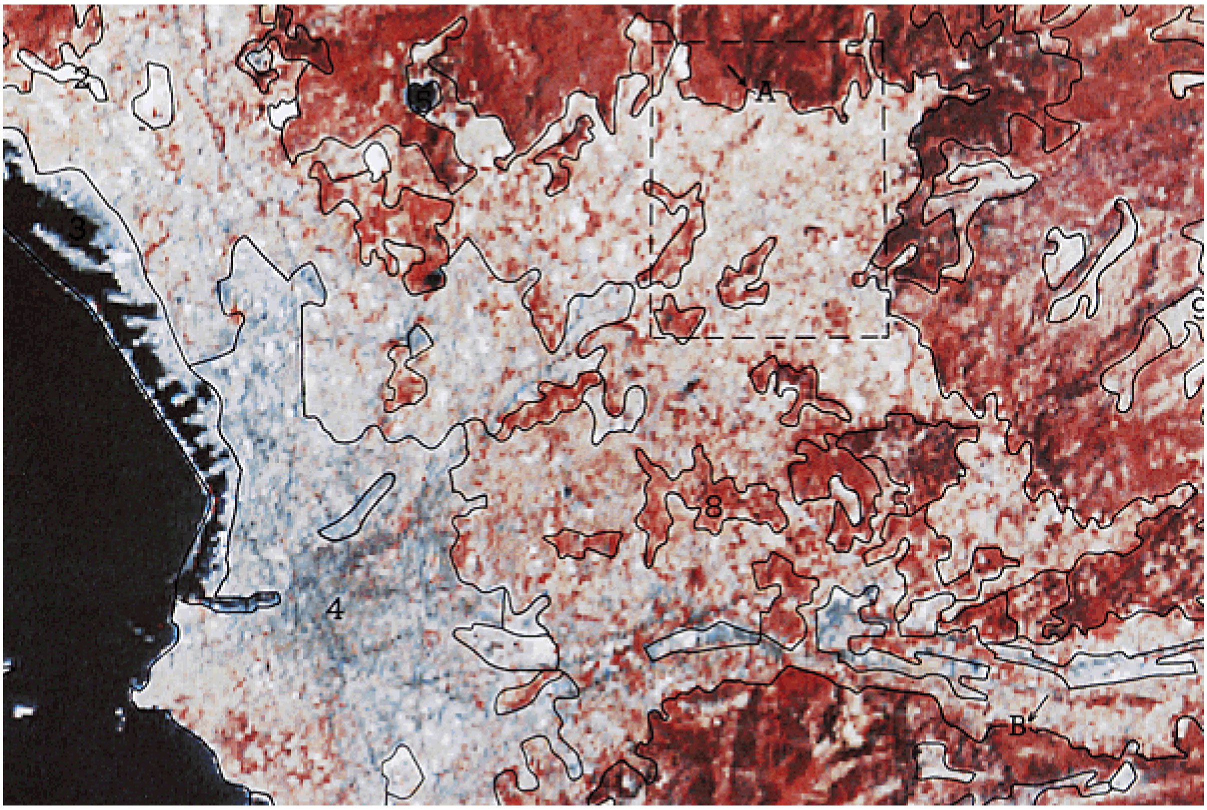
Other boundaries define units (clearly visible on the image) which are included in the major landscape units which also correspond approximately to nomenclature level 1. However, it is impossible for the photointerpreter to assign a precise nomenclature code to these units at this stage: e.g. units 6, 7 and 8.

Moreover, some of these boundaries will later disappear because they separate environments which belong to a larger unit. These boundaries are therefore unnecessary.

Following this analysis, the photointerpreter identifies on a map those stereoscopic pairs of aerial photographs which he feels he needs to continue his work.

The rectangle on the illustration opposite indicates an area where the photointerpreter requests a stereoscopic pair for the second photointerpretation stage.

Preliminary analysis of the image



Use of aerial photographs Stereoscopic pair + interpretation

Use of aerial photographs

Examination of the stereoscopic pair makes it possible to identify the following categories of land cover:

Natural vegetation

3.1.2. **Forest:** clearly visible by the height and shape of trees. The colour on the satellite false-colour image suggests that it is a coniferous forest.

3.2.3. **Sclerophyllous vegetation:** this can be identified from the density and height of the shrubs visible on the photo.

3.2.4. **Transitional woodland/shrub:** in this case, the regeneration of woodland in a previously burnt area. Stereoscopically it is possible to identify individual trees and low vegetation.

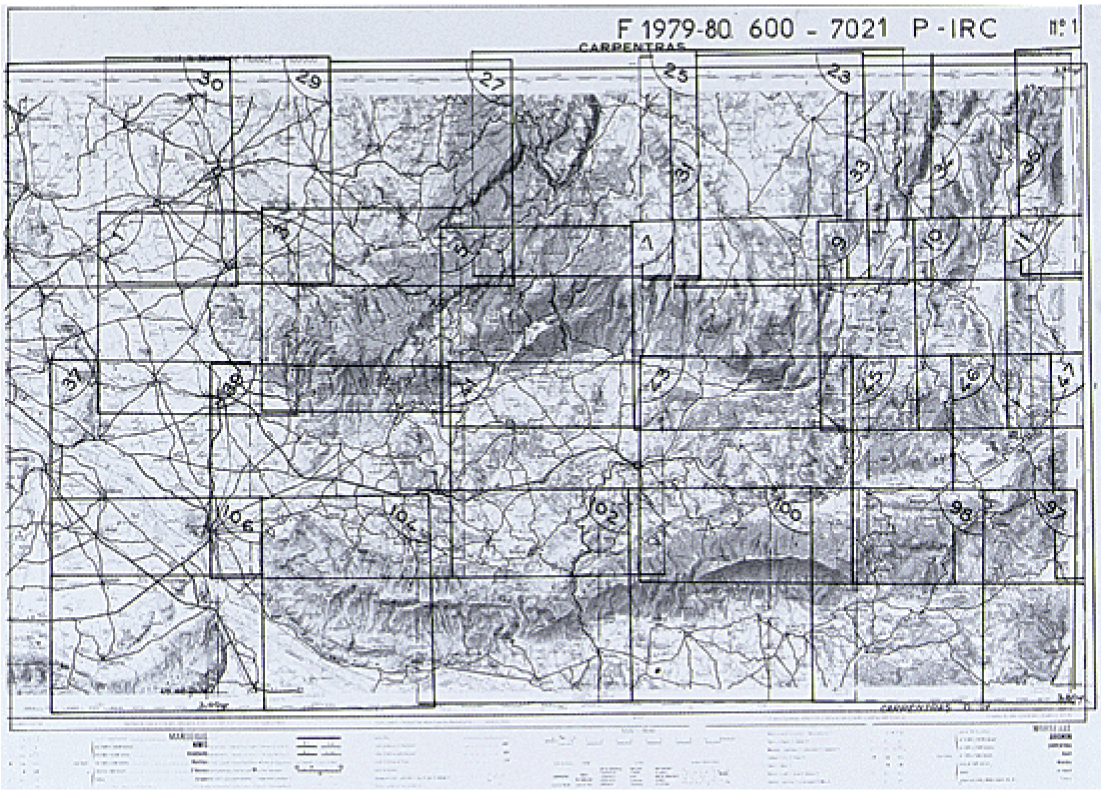
1.1.2. **Scattered habitation:** easy to identify.

2.4.2. **Complex cultivation patterns:** the air photos clearly depict the complexity of the field pattern and the occurrence of grassland, orchards, vineyards and crops.

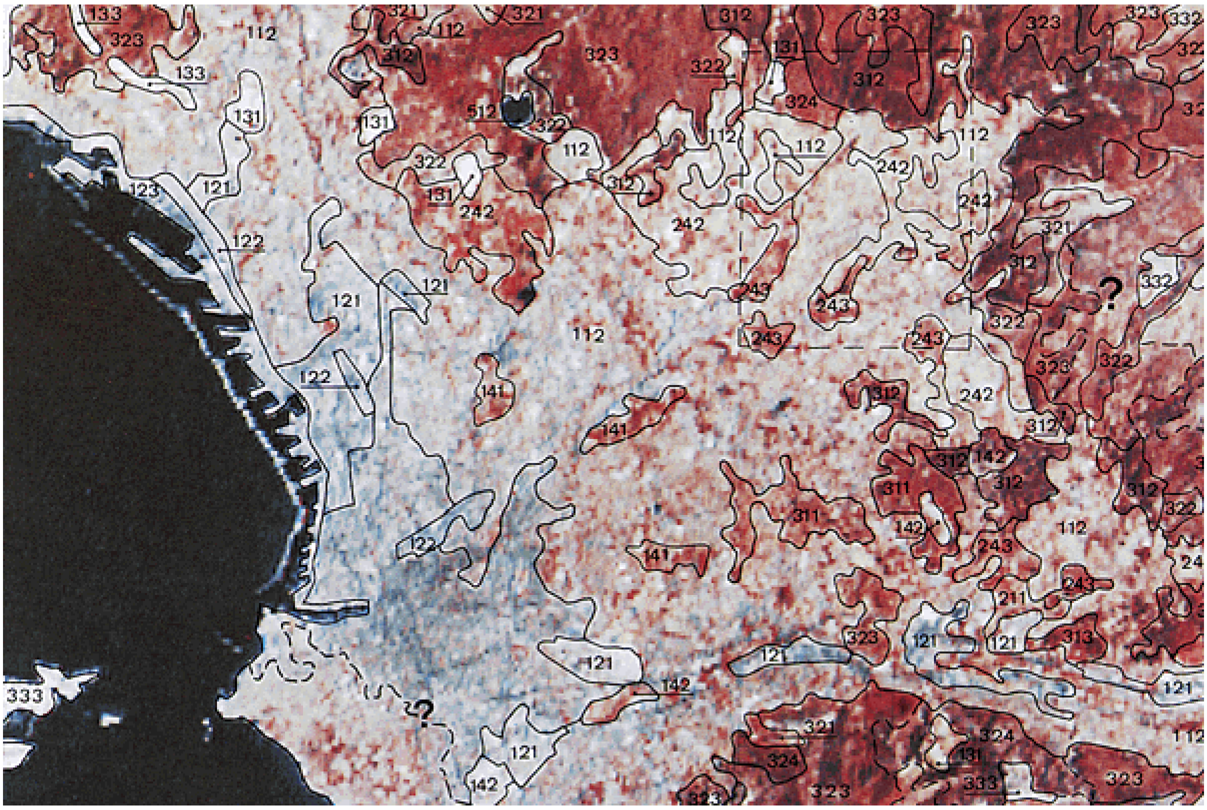
2.4.3. **Land principally occupied by agriculture, with areas of natural vegetation:** while the image suggests a wooded area, the photographs show overlapping agriculture and forestry.

By matching the image with the photo it is possible to establish specific interpretation keys for each image.
NB: The use of photographs is essential to distinguish discontinuous urban fabric from complex cultivation patterns.

Plan showing the assembly of photographs

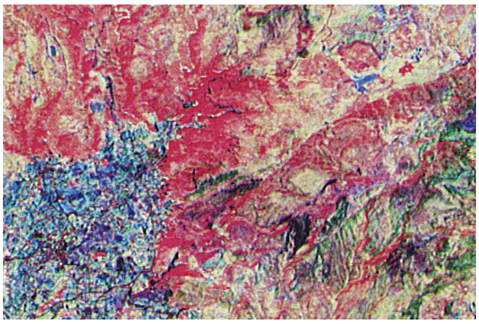


Second delineation/identification following examination of aerial photographs



Processing of additional data Laplace filter on SPOT XS image

Principal component analysis



Technical sheet

CCE–DG XI	Projet « CORINE land cover »	Portugal
Fiche technique	Traitements complémentaires	Fiche n°

Image						Fichier (taille)	
Date	K. J.	Type				Lignes	Colonnes
19		MSS		TM	SPOT		

Matériel de traitement	Type	Logiciel	Écran	Capacité

Opérateur informatique		Opérateur thématicien	

Traitement	Standard			Autre	Canaux utilisés
Date	CC	ACP	IV		1 2 3 4 5 6 7

Objectifs	Codes

Photo n°	
Pellicule n°	

Carte 1/100 000	
n°	Nom

Situation carte

	1	2	3	4	5	6	7	8	9	10
A										
B										
C										
D										
E										

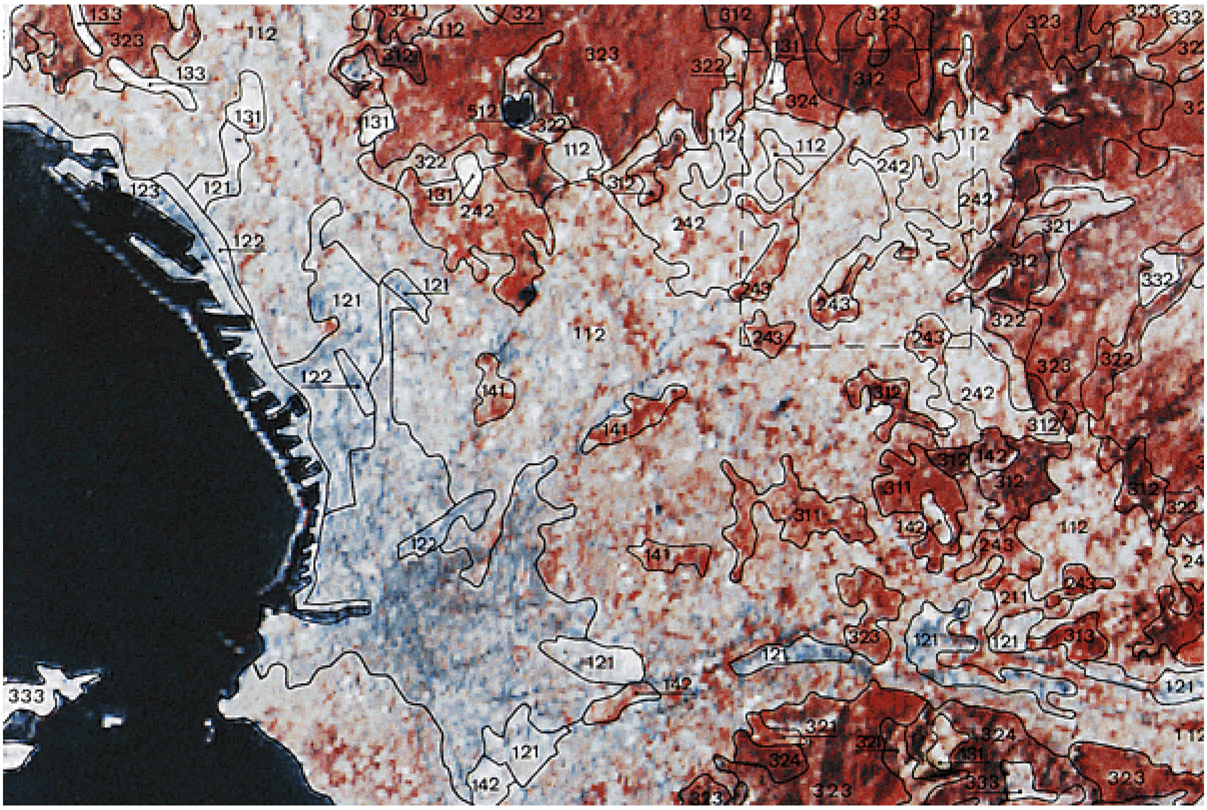
Situation carte	
Ligne	Colonne

Photo écran	
Diapo.	Négatif c.

Résultats et commentaires	Codes	

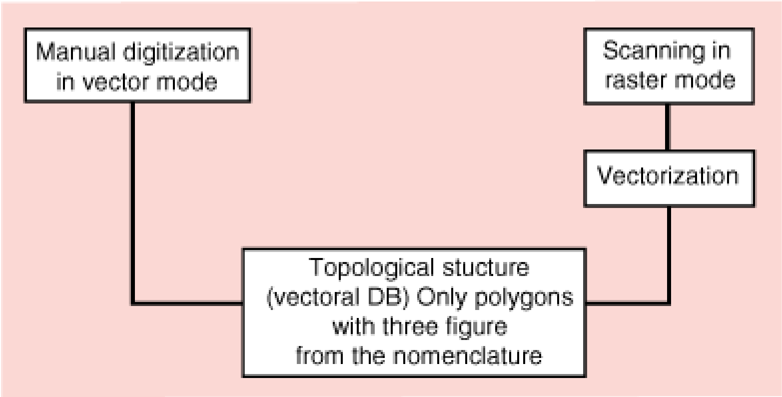
Acquis techniques

Third delineation/identification following additional processing



3.4. Digitization

3.8. Digitization



The results of the national CORINE land cover projects have to be provided in digital form for the following reasons:

* for incorporation into the CORINE database for direct use or cross-referencing with other thematic databases;

* use in the national databases on natural resources;

* production of thematic maps at varying scales and with different levels of generalisation.

The following paragraphs describe the establishment of the land cover cartographic database, including procedures to be used to digitize the boundaries of land cover units appearing on the interpretation transparencies and the essential format for exchanging digital land cover data between the various Member States.

The CORINE central team wishes to receive the digitized data on the cartographic projection systems used for national standard maps. The team will be responsible for converting this data to the projection system used by the CORINE geographical database (Lambert azimuthal equal area projection).

There are two possible approaches to digitizing the land cover interpretation transparencies. The first consists in digitizing the boundaries of each land cover unit using a series of vector coordinates, with the aid of a digitizing tablet or other suitable peripheral system. During or after digitization, the identifier corresponding to each polygon must be recorded.

The second approach consists in using a scanner to generate a high-definition raster image of the land cover map, and converting this into a vector image using a program for converting raster data into vector data. The different land cover units can be identified either by editing the vector image manually or by creating a transparency for each land cover category class and scanning each of these in turn. Section 4.3 deals with scanning methods.

All of these methods are acceptable provided that the final data are vector data, and are sufficiently accurate and structured to comply with the standards set out in Section 4.4.

3.4.1. Topological structure and types of cartographic features

The digitization of the landcover interpretation must be compatible with the overall structure of the CORINE database. The ARC/INFO software GIS (geographical information system) was chosen for the purpose. ARC/INFO is a vector GIS with a topological structure. This means that the structure and the relationships between unit areas such as points, arcs and polygons are explicitly or implicitly stored in the database. Accordingly, whether the data has been gathered manually or by scanning, the land cover data must be transferred to the CORINE database using topologically structured vector files.

As previously mentioned, only units with a minimum surface area are captured in the land cover project. The smallest surface area mapped is 25 ha. The only linear features covered are those exceeding 100 metres in width (1 mm on a scale of 1:1 000 000). On this basis, point features are not recognized, and the linear features of the CORINE land cover interpretation which have a certain width have to be digitized and their limits defined as elongated surfaces, i.e. like polygons.

For the land cover information, the basic topological elements of the ARC/INFO structured cartographic file are polygons. These are elements represented by surfaces on the interpretation transparencies (land cover unit areas). They are made up of arcs which define their boundaries. The boundaries of the polygons are digitized as arcs and each polygon has a corresponding label point, an arbitrary point located inside the polygon. ARC/INFO creates a polygon by assigning codes to the arcs which define its boundaries. These codes (arcs) describe which polygon is to the left and which is to the right of each arc.

Each feature has a corresponding geocoded value and a thematic value. For example if the feature is a forest, its geocoded value can be expressed in longitude/latitude and its thematic value might be conifers.

Using this topology, three types of spatial relationship between cartographic features are possible:

* surface: rather than all the coordinates on the curve marking the polygon being recorded, it is defined by all the lines which contain it;

* contiguity: the identification of the adjacent polygons;

* connection: identifying how the arcs interconnect.

Two other types of topological element exist:

* TICs (TIC points or 'calibration' points), which are used to convert the coordinates of the data set out on the plane of the digitizing tablet into latitude/longitude coordinates.

* Nodes, which are points created when arcs or polygon boundaries intersect. They are also created when an arc or the boundary of a polygon overlaps with the edge of a map sheet.

Only the following categories of element are found in the CORINE land cover digitization: Polygons, Nodes, TICS.

Within each of these classes, various types of features are distinguished by an external identifying number (feature ID).

In the case of the label points, the identifier is the number of the land cover category in the land cover nomenclature. The external identifier is this number made up of three integers without decimal points between them (e.g. 2.4.4 agro-forestry areas, for which the external identifier is 244).

3.4.2. Digitization of arcs

This section describes the sequence of activities involved in the recording of features during digitization of the land cover interpretation transparencies. As there are numerous geographical information systems and digitization software packages, it is advisable to contact the CORINE central team in order to finalise the digitization procedures, indicate the format used and agree on the arrangements for data storage.

Preparation of maps

The preparation of the maps is an essential step in the process. If carried out correctly, it makes digitization much easier and produces better results. The main task is to ensure that the polygons are properly closed and that each polygon has a corresponding code. However, a check must be made beforehand to ensure that the areas of overlap between adjacent sheets have been identified and validated. Digitization is usually carried out using a transparent sheet corresponding either to a single map sheet or to part of a satellite image. The adjacent sheets must be examined to see whether they match up exactly, or whether there is a degree of overlap. In the latter case, a particular sheet must be chosen and the area of overlap with the other sheet identified. A line is then drawn defining the exact boundary between the two sheets. All the elements up to that line must be digitized.

Identification of features

The way in which the graphic features are identified depends on the design of the digitization software used.

If necessary, the operation is carried out on the interpretation transparency used before digitization proper. Identification of the features before digitization is a delicate operation. Each feature is represented by a single number and pinpointed by its external identifier (feature ID).

The external identifier corresponding to the label point already appears on the transparency following the interpretation. While it is not essential to define all the TIC points, arcs and nodes on the transparency, it makes the task of digitizing easier.

Identification of control points

A minimum of four known latitude and longitude control points or four reference points on the national grid must be chosen on the topographic map and transferred to the interpretation transparency. The latitude and longitude coordinates of each control point must be recorded exactly and edited in a separate documentation file.

Digitization of features

As various data-processing centres use different digitization software, only general guidelines can be provided here. Each team must therefore provide details concerning its own operating package.

The results of digitization are recorded in tables. Whether the coordinates are metric or imperial is of secondary importance, but the digitizer must in either case be accurate to about 0.05 mm.

If no software is available for converting the projection, the data must be recorded as table coordinates and converted to latitude/longitude values by the CORINE central team upon receipt of the data. In order to change the projection system, information is required conceming the projection of the original maps and the latitude and longitude of the control points.

If the projection system has been changed before the data is sent to the central team, a detailed account must be submitted of the operations carried out.

In order to convert the table coordinates accurately into latitude/longitude, the first step in digitization is to record the control points which feature on the interpretation transparency.

These must be recorded as accurately as possible, as serious problems are likely to arise otherwise, for instance in assembling adjacent map sheets. The control points must be re-recorded each time the cor-responding transparency is laid on the digitizing tablet.

A file of digital data must contain the results of a single digitizing session: in this way all the data in the file relate to the same ground control points defined in terms of table coordinates.

As each file must be converted separately, it is essential to complete the digitization of each sheet in the minimum number of sessions. Provided each transparency remains firmly fixed on the digitizing tablet, it is always possible to interrupt and resume the session. The final file of coordinates can be added, as they have the same control points.

Digitization of control points

At the start of each digitization session, it is necessary to check that the interpretation transparency is properly fixed and lies perfectly flat on the digitizing tablet. The latitude and longitude of the points chosen as control points (see above) must be recorded.

If the digitizing software so permits, the identifiers should also be recorded, i.e. the serial number and/or the external identifier. If the software cannot perform this operation, the information must be edited later in a coordinates file.

The latitude/longitude coordinates of the control points and the information on the projection (projection system, origin of the projection, standard parabolas, etc.) for each map corresponding to the transparency used will then be transferred to an attribute file.

Digitization of arcs, nodes and label points

Once the characteristics of the map and the control points have been recorded and the features identified on the interpretation transparency (arcs, nodes, label points), a serial number and an external identifier should be assigned to each feature (e.g. the code number from the CORINE nomenclature linked to each label point) if the digitization software permits. Otherwise, this information can be entered at a later stage.

The arcs can be digitized either as a continuous unit, or point by point. In either case, deviation from the original transparency may not exceed 0.4 mm.

Specirication of required topology and digitization accuracy

1. The boundaries of the land cover units (polygons) must be digitized in the form of arcs rather than as a list of coordinates defining the polygons.

2. The nodes must correspond to the intersections between arcs.

3. The points must be recorded with a deviation of no more than 0.4 mm from their actual position on the base map; at least 95% of all the points must be less than 0.2 mm from their original position.

4. No point or line may figure more than once on the digitized map.

5. The polygons must be coded by reference to the label point of each polygon, which is not necessarily the centre of the polygon. The external identifier must correspond to the CORINE landcover nomenclature.

6. The number of land cover units must be the same as the number of label points.

7. All the polygons must be closed. There should be no 'open' arcs.

8. Features situated at the edge of the map sheet must be matched up exactly in the final file.

9. No line-smoothing procedure may be used.

3.4.3. Digitization by scanning

Another method of producing a digitized file of the land cover units is to use a scanner. Automatic scanners produce raster data. Before opting for this method, it is necessary to check that a software package is available which can convert raster data into vector data with sufficient accuracy.

The digitization procedures depend on the hardware and software used, but the final product must be a topologically structured vector file (made up of arcs, nodes and label points) which is compatible with the interchange formats supported by ARC/INFO and accepted by CORINE (e.g. DLG, ARC/INFO export format). In the event of a problem the CORINE central team should be consulted.

3.4.4. Consolidating the data

The CORINE central team will receive digital databases from each Member State, which it will then incorporate into a single land cover base for the whole Community.

In order to simplify this task, it has been decided to limit the number of formats which can be used in each Member State. The formats in question are export formats which can be supported by a limited number of geographical information systems, including the standard interchange format (SIF) and the ARC/INFO export format.

lt is advisable to consult the central team to ensure that the format to be used and the specifications for recording the data conform to the CORINE standards.

For the purposes of producing maps and other types of output data using the CORINE land cover data, the central team is drawing up standards for legends in a bid to make it easier to assemble the data collected from different map sheets and to compare the data from different countries.

3.4.5. Standardizing the cartography

Recommendations and specifications conceming the format of the maps (size, shape, etc.) may also be furnished if they are not laid down by the national cartographic systems.

Specifications for projection systems of basic maps

1. Country

2. Description of topological maps used: * Title

* Scale

* Number of sheets

3. Projection system

* Origin: Name:

* Ellipsoid: Name:

* X axis:
  Y axis:

* Projection:
  -Name:
  -Geometry:
  -Cylindrical: Equal area
  -Conic conformal
  -Plane equidistant
  -Other

* Parameters

  -Central parallel
    Longitude
    Latitude

*Origin of geographical coordinates
  -Longitude
  -Latitude

* Plane of origin of coordinates
  -Longitude
  -Latitude

NB: If the national series used is divided into different projection zones, a form must be filled out for each zone.

3.4.6. Integration of data

As mentioned previously, the integration of the satellite data is carried out using images which have been geometrically corrected using the various national projection systems for the maps on a scale of 1:100000. Digitization of the interpretation transparencies produces a digital cartographic file which echoes the characteristics of the maps.

However, as projection systems vary from one country to another, it would be impossible to generate a single land cover file for the whole Community without supplementary processing.

Furthermore, it is likely that the content of the various headings in the nomenclature will be interpreted differently from one country to another. Such variations would result in a lack of continuity between the land cover maps of neighbouring countries. These defects and differences of interpretation will have to be removed from the Community database.

Creating an integrated Community database from separate national data therefore involves two stages. In order to meet the requirements of a land cover database covering the Community on a scale of 1: I 00 000, these stages have to be completed before any other generalisations at smaller scale.

First stage: conversion of the national projection system to that adopted for CORINE (Lambert azimuthal equal area projection). Second stage: assembling of maps from the different countries, followed by pinpointing and correction of anomalies, with the help of the national teams.

At this time other activities may be considered:

- production of small-scale generalisation (1: 1 000 000)maps;
- adjustment of the boundaries of the land cover units to harmonise with those of the thematic units of the CORINE database;
- reorganisation of the database into a map library to improve data access.

The process of integrating the national files into a genuine Community database on land cover will be carried out centrally in co-operation with the various national teams.

3.5. Validation

3.5.1. Validation

Validation is a statistical operation (usually sampling), analogous to manufacturing controls in industry.

Like all information obtained by a complex process, the information contained in the CORINE land cover database contains errors (of omission or commission).

The purpose of validation is to gauge the reliability of the results supplied to the end user. For CORINE land cover this concerns:

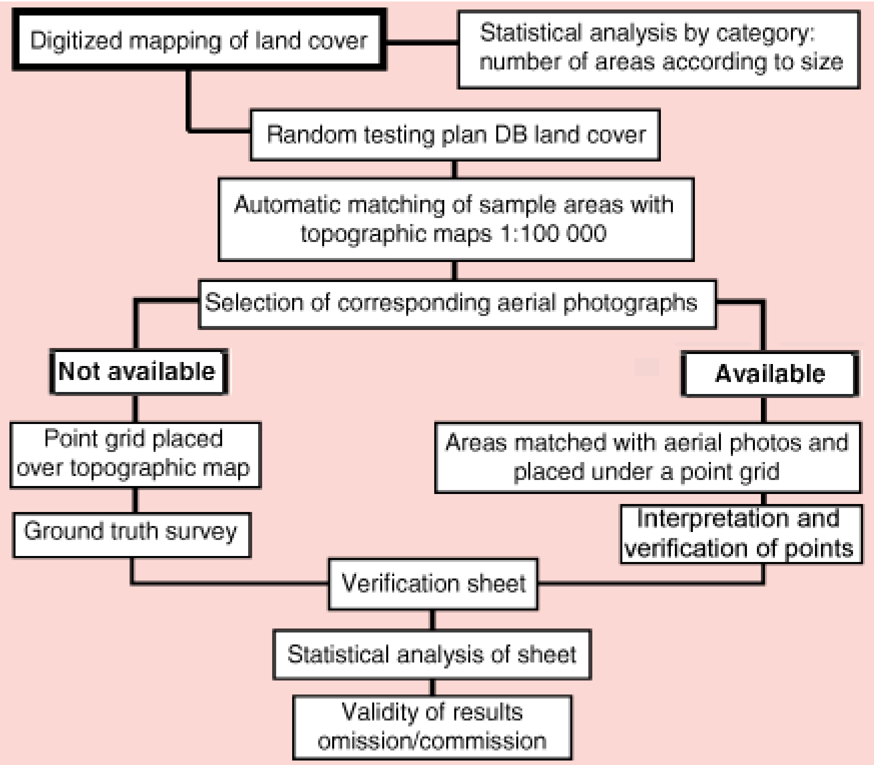
* unit boundaries;

* classification under the nomenclature.

It applies either to a geographical area (country, region) for all categories of land cover, or to each category for the whole of the area considered.

The validation procedure consists of comparing the information on the database with the information obtained from data not used previously (in this case the information comes from field surveys or aerial photographs).

Figure 3.9. Validation



3.5.2. Setting up a validation survey

It should be that the cost of the validation survey must remain reasonable compared with that of the CORINE land cover database. If possible, the survey should be carried out shortly after completion of the database by a team which has not participated in the national photointerpretation work.

Given the nature of the CORINE land cover database, validation must be carried out on a representative sample of units obtained by random selection.

Random selection plan

Firstly, statistical application of the database to the study area produces a table giving a breakdown of units by item of the nomenclature and size of area.

Table 3.7. Breakdown according to unit size and type of land cover

		Unit size (ha)		
	0 to 50	**50 to 250**	**250 to 1 000**	**etc.**
1.1. Urban fabric				
1.1.1. Continuous urban fabric,				
etc.				

Analysis of this table allows a sampling rate to be determined for each stratum (type of land cover/area of surface). For strata comprising a sufficiently large number of units, this rate may be between I /1 0 and 1/20 of the total number of units.

For complex categories which comprise only a very small number of units, validation could be exhaustive and be carried out on all units in the stratum. Categories comprising a large number of areas could possibly be stratified.

Each unit in a stratum is numbered from I to n and the random selection applied to this stratum gives: n . sampling rate = x control units.

Geographical location of units selected

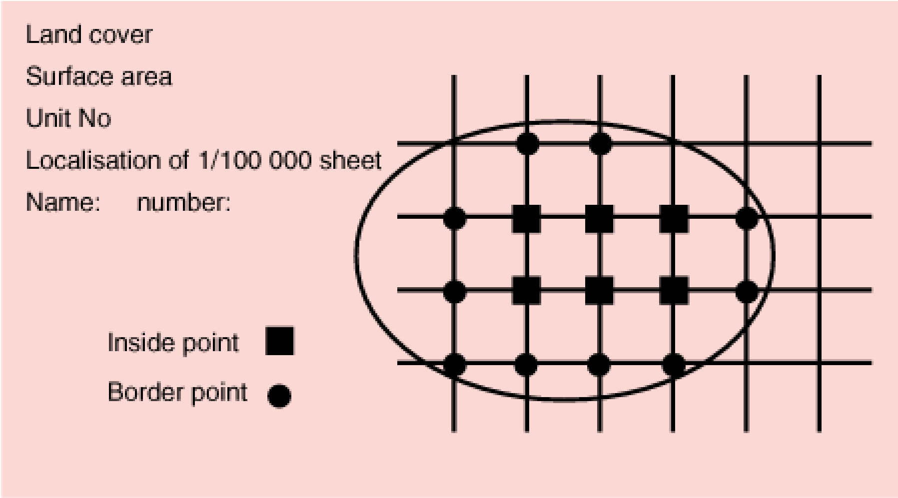
Each of the units thus selected must:

* be located in its geographical environment either using a 20 x 20 km geographical printout (tracer or printer) or by automatic plotting on the corresponding 1: 1 00 000 map;

* be printed out on a large scale (1:50000 or 1:25000) on a stable transparent support.

For each of the units traced on the transparent support, a grid will be superimposed (see figure below). The spacing of the grid depends on the size of the unit and must provide at least nine points within the unit boundaries.

Figure 3.10 Validation grid



Validation comprises the following stages

(a) Determination of the nature of land cover corresponding to each intersection on the grid

This identification may be obtained:

* by use of aerial photographs (if these have not been used for the photointerpretation of the area). In this case, the unit boundaries are plotted on photos manually or by optical projection onto a transparent support;

* by field survey if the aerial photographs are too old or too difficult to use for the item of the nomenclature under consideration.

For this identification, the land cover nomenclature used will be as close as possible to the CORINE land cover nomenclature adapted for a points survey (different diameter from the area surveys).

(b) Application of results

* Firstly, analysis of the results for all the points of the unit will show whether or not the unit has been correctly classified. For complex categories of land cover, the decision rule must take account of the heterogeneity of the unit;

* secondly, a sub-sample can be put together with the results obtained for the points on the border. Analysis of the results for these points will show whether the delineation of the unit is correct or not.

(c) Application of the statistics for all the results relating to unit classification, which shows:

- the reliability of the database (percentage of units correctly classified) for each category of land cover;

- the overall reliability (weighted index given the percentage of the total surface covered by each category) of the base for all the territory considered.

It should be emphasised that the validation procedure described above produces qualitative and quantitative information on the composition of the units corresponding to each item of the nomemclature. Overall reliability must be 85 % or more.

Note

The following section describes a complete validation operation covering both classification and unit delineation. It is clear that, initially and owing to financial constraints, it is possible to limite the operation to unit classification only, the most important aspect for users.

3.5.3. The Portuguese example

Since Portugal was the first Member State to carry out the CORINE land cover operation, it was felt to be methodologically useful to launch a validation survey to test the accuracy of the operation, thereby providing useful information for the various Portuguese users, and to pinpoint weak spots or problems of interpretation and try to remedy them.

The CORINE land cover Portugal preliminary database comprises 9875 units (not including islands) divided into 42 categories; 1069 of them measure 10 to 100 km2 and 115 of them measure over 100 km2.

In view of the available funding, deadlines and distribution of units, the following test rates were selected:

1/20 for 16 categories comprising between 188 and 1 597 units;

1/10 for 7 categories comprising 32 to 132 units;

1/1 for 18 categories comprising 30 units or less.

Since the units of 10 km 2 and above tested at a rate of 1/20 were mainly concentrated in certain categories, it was decided to give more attention to these large units by increasing the checks on areas of between 10 and 100 km2 to 1/10 and on those of 100 km or more to 1/1. The check sample comprised a total of 850 units.

Prior to the systematic random selection of the sample, the units in each category were classified as north-region or south-region and by surface area in ascending order into five unit sizes:

less than 0.5 km^2,

0.5 to 1 km^2,

1to 10 km^2,

10 to 100 km^2,

100 km^2 or more.

Thus the sample was implicitly divided up according to region and size.

Since Portugal possesses a set of medium-scale panchromatic aerial photographs dating from a period close to that in which the Landsat images were obtained, it was decided to use these to check the sample, and to restrict field work.

Table 3.8. Check sample of Portuguese units, by size

Unit size	Number of check points per grid	Average number of points to check	Number of units in sample	Estimated number of check points
< 1 km^2	9	7	271	1 900
1 to 10 km^2	16	12	325	3900
10 to 100 km^2	25	20	119	2400
> 100 km^2	36	30	113	3400

Apart from unit category, the check considered the accuracy of unit boundaries and the internal homogeneity of the units. This involved placing a square grid of basic check points (examined over 2.5 ha, i.e. 25 pixels) over the cheek sample areas placed on the aerial photographs, and then selecting at ramdom:

9 points in the first two unit sizes, only half of them being border points;

16 points in the 1 to 10 km 2 range;

25 points in the 10 to 100 km2 range;

36 points in the 100 km2 and over range.

A form was filled in for each area examined on the aerial photo, with information indicating:

* the characteristics of the sample;

* whether or not the point lay on the edge of the unit;

* whether it had been possible to cheek against the aerial photo;

* whether there had been difficulties in situating the sample and whether recourse to other documents (maps) was necessary;

* whether or not the category tallied with CORINE land cover (giving the likely cause for any discrepancy) and whether a field inspection would be necessary;

* whether it had been possible to make a final decision on maintaining or changing the category.'

The same information was noted on a similar form for points checked by surveyors in the field (around 40% of cases).

Following extrapolation, the land cover category/cheek category results were analysed according to the checking method (aerial photographs or field inspection), the unit size, the interpreter, the region and by border or internal points.

On the material front, the location and boundaries of the sample units were supplied by computer, and point grids placed over them in accordance with the size of the units.

In Portugal, for checking against aerial photographs, the printouts of the check sample units were enlarged to 1: 15 000 and placed over the photographs of regular cover on the same scale.

For the field surveys, the unit contours and the check points of the grid were located on the 1:25 000 maps.

The risk of placing cheek points inaccurately is small on the 1:25000 maps and aerial photographs, but larger in the case of field surveys. However, this has a relatively small impact on the checking operation, since points are chosen by random selection and the final decision will refer to a 2.5 ha square centred on the point.