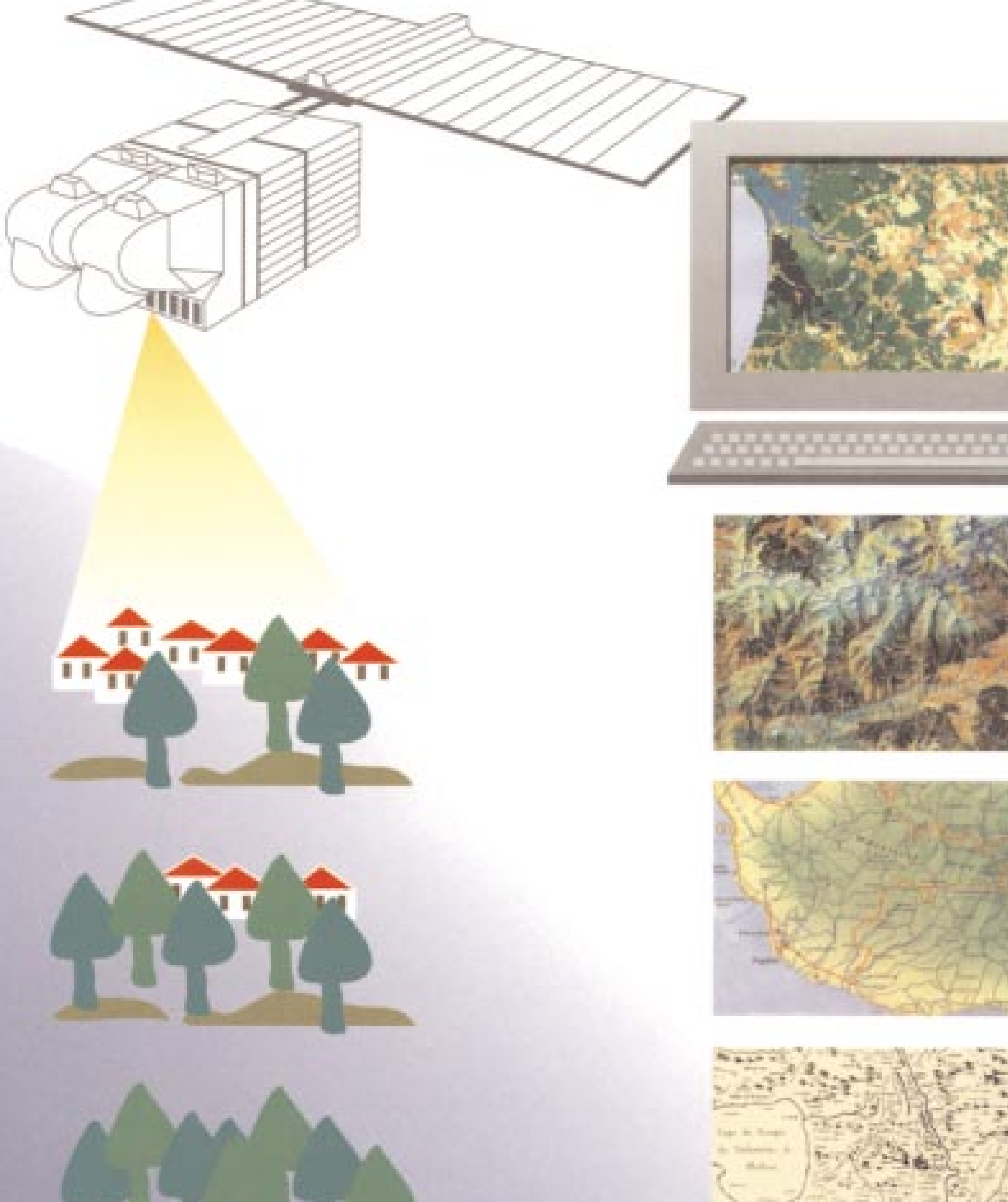
TECHNICAL AND METHODOLOGICAL GUIDE FOR UPDATING CORINE LAND COVER DATA BASE



JOINT RESEARCH CENTRE
EUROPEAN COMMISSION

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1997

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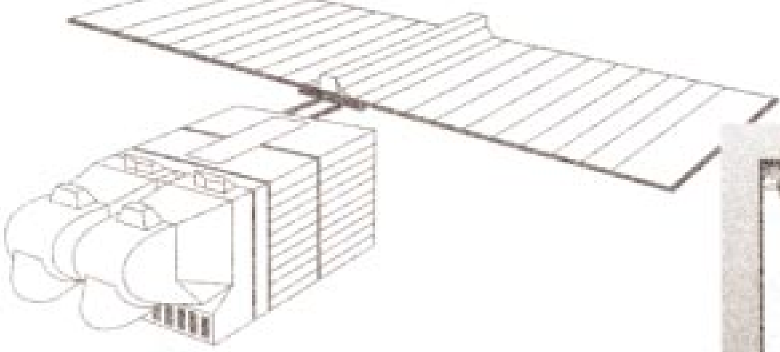
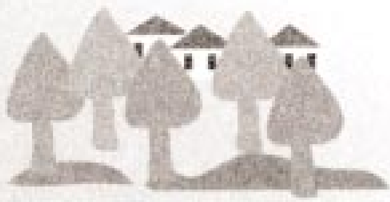


BY

VANDA PERDIGÃO AND ALESSANDRO ANNONI

SPACE APPLICATIONS INSTITUT AIS UNIT



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Après avoir lu ce document, il ne semble pas inutile de rappeler aux auteurs qu'en matière d'occupation du sol:

"è parso più conveniente andare dritto alla verità effettuale della cosa che all'immaginazione di essa" (Machiavelli)

il est même possible d'ajouter que ce qui donne le plus à penser dans le domaine de l'occupation du sol qui donne à penser est que nous ne pensons pas encore l'occupation du sol.

Yves Heymann (°)

(°) the "father" of CORINE Land Cover and first project leader

This guide was prepared by

Vanda Perdigão (°) and **Alessandro Annoni** (°)

(°) European Commission - Joint Research Centre - Space Applications Institute - AIS unit - Ispra

This guide integrates and develops the results of the previous works of JRC and RSDE:

- **"Technical guide for CORINE land cover updating"**. RSDE,1996 (contract n. 9601956).
- **"Provision of prototype demonstration computer system for updating the CORINE Land Cover data-base".** RSDE, 1993 (contract n. 3952 / DJM /DJM).
- **"System definition for updating CORINE Land Cover data-base"**. RSDE, 1992 (contract n. 4435-91-08 ED ISP I).

and the tests carried out by different national teams on the JRC prototype system Co-Pilot:

- "Final evaluation of the prototype system for updating the CORINE Land Cover database". **^{2}GERE**, 1996 (contract. 11467-95-11 F1PC ISP I)
- "Test of the Prototype system for updating the CORINE Land Cover database: The Netherlands test site". **DLO-Winard Staring Centre**, 1994
- "Test of the Prototype system for updating the CORINE Land Cover database: The Andalucia test site". **Agencia de Medio Ambiente - Junta de Andalucia**, 1994
- "Test of the Prototype system for updating the CORINE Land Cover database: The Luxembourg test site". **^{2}GERE**, 1994
- "Test of the Prototype system for updating the CORINE Land Cover database: The Portugal test site". **CNIG**, 1994
- "Technical assistance in the use of the Prototype computer system for updating the CORINE Land Cover data-base". RSDE, 1994 (contract n. 10108-94-03 F1EI ISP I)

All examples in this guide were produced using Co-Pilot system developed by RSDE under JRC specifications (contract 3952 / DJM /DJM). Co-Pilot is based on "Carha for Windows" sw.

Additional information can be found in CORINE Land Cover Technical Guide ISBN 92-826-2578-8 ©ECSC - EEC - EAEC, Brussels. Luxembourg, 1993.

PREFACE

Within the frame of JRC support to the European Environment Agency (EEA), the AIS Unit of Space Applications Institute (SAI) of the Joint Research Centre, is a partner and co-leader of the European Topic Centre on Land Cover, responsible for the Task Research and Development of new Applications.

This Technical and Methodological Guide for Updating the CORINE Land Cover Data Base was produced by AIS, as one of its contribution to this Task regarding the updating of CLC data base. This is a joint publication of the SAI and the EEA.

The content of this Guide is the result of a long experience, first with the creation of the "first generation" CORINE Land Cover data base (CLC), later on with the specific problems linked to its updating, in a context of geo-referenced data base and integrated geographic information systems in general.
What makes the updating of CLC a specific problem, different from the ones GIS experts are used to face is the combination of the four groups of features:

1. the nature of the CLC data base: land cover classes, which boundaries are often fuzzy, with different dynamic rates between classes and inside each class;
2. differences in methodology between the creation and updating as a result of the technological trend;
3. the use of data and information derived from different type of sources, in which earth observation data plays an important role;
4. the European wide dimension and the homogeneity requested.

As a spatial database, CLC is vulnerable to a common misunderstanding about his precision compared to other GIS processing output. In conventional map analysis, precision is usually adapted to accuracy of the data, while the precision of GIS processing exceeds quite often the accuracy of the data used. The ability to change scale and combine data from various sources and scales in a GIS may hide that precision is not always adapted to the accuracy. Still, there are no adequate means to describe the accuracy of complex spatial units.
Even being the present methodology defined for updating the CLC database, its core concept is also valid for the creation or use of any land cover data bases in which earth observation data and GIS are involved.

ACKNOWLEDGEMENT

We wish to acknowledge the four national CLC teams involved in the test of the prototype computer system and of the methodology developed for their practical contribute and exchange of ideas.

We are grateful to A. Arozarena, A. Sebastian, L. Bontemps, Neil Hubbard, for the time they invested improving this Guide with interesting comments and careful reading, in particular Chris Steenmans for his support and exchange of experience on the CLC database all over Europe.

Thanks to Yves Heymann with who many and fruitful discussions on how to conceive the updating of CLC were taking in the past and for several year

This guide had been designed as a working tool for those involved in updating the CORINE land cover database.

In order to justify and clarify the choices for the updating methodology, some chapters discuss the constraints of the creation methodology.

An overview of the possible evolution is given together with typical examples of updating.

The guide is organized in the following sections:

⇒ Chapter 1 shortly introduces the principles of updating and the aim of this guide.

⇒ Chapter 2 provides an overview of the principles for the creation methodology

⇒ Chapter 3 illustrates the basic principles of the updating methodology.

⇒ Chapter 4 further describes the updating methodology.

⇒ Chapter 5 gives some information about validation and quality assurance at the end of updating.

⇒ Chapter 6 discusses how to define the optimum updating frequency.

⇒ Chapter 7 contains a quick-guide for the updating methodology.

⇒ Chapter 8 illustrates possible future improvements of the methodology.

⇒ Chapter 9 includes some useful references and bibliography.

⇒ Annex 1 contains several examples (with changes to be updated or not).

⇒ Annex 2 shows the basic software needs for updating.

⇒ Annex 3 describes Co-Pilot (the JRC prototype system for updating).

In this guide the following symbols were used:

Name	**Symbol**	**Description**
Definition		This is the complete description of a particular item
Method		This is the way to do a particular action
Postulate		This is a rule that must be strictly followed

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1. INTRODUCTION

This Technical and Methodological Guide for updating the CORINE Land Cover (CLC) database is based upon the results of a methodological study concerning the updating of a real Land Cover data set. The study was performed as the JRC's technical support to the CORINE Land Cover project under the responsibility of the Task Force for the European Environmental Agency (DG XI).

To implement the defined methodology, a prototype computer system was developed (annex 3) and tested by four national land cover teams. For each of the four teams, the tests consisted of both an updating, and also a retrospective detection of changes in land cover (known as "downdating"). The tests used a set of the land cover database corresponding to a quarter of TM scene, and followed the proposed methodology using the dedicated software tool. The final evaluation of these tests was done within the framework of the Research and Development Task of the European Topic Centre on Land Cover, under the responsibility of the AIS unit. The suggestions and improvements coming from the general evaluation were already taken into account in producing the guide.

The updating of the land cover database must follow three basic principles:

1. It must take into account the methodology and data sources of the creation phase,
2. It should continue to lead to an harmonised database at national and European level,
3. The process of updating should be faster and more cost-effective than the process of the original creation of the database.

These principles have as a consequence the need for defining a methodology for updating that can be consistently repeated in time in all countries, and by people that may not have been involved in the creation phase. The procedure should be established in all its steps, with defined standards and the subjectivity related to interpretation procedure should be reduced.

With this scope, the present methodology was developed, including the use of an Integrated Geographic Information System in all phases of work, obliging the interpreter to follow the defined rules whilst providing support to respect standards. Several conversion steps linked to different phases of work are now reduced to a single activity, with the consequent reduction of error. In order to fulfil the requirements of the CLC methodology as close as possible, and to keep the homogeneity among the European countries, a customised system with tailored functions is favoured. Such a system has been realised by the JRC, called Co-Pilot (CORINE Photo-Interpretation Land cover Oriented Tool) (see Annex 3). Different systems can also be used but the availability of specific tools can speed up the updating process and facilitate the harmonisation.

The best technical solution when updating is a compromise between cost efficiency and the need of precision for a specific product. The fact that this database is primarily based on satellite data should be kept in mind. This limits the precision that can be obtained, and one temptation to avoid is that of "over-updating". The consequence can be increasing costs to obtain wrong results or a slight improvement which may even be lost when the data is passing through the generalisation procedure for the European database.

The updating can be the occasion to introduce improvements necessary for national applications of the database. However it should be kept in mind that the final product will be also the European database.

Due to this continental scale coverage, the geometry is a specific and complex aspect of the CLC database. In fact, it is a geo-referenced database which uses for its creation and updating data provided by different sources, each of them associated to a different geometric accuracy and which are often time dependent. This is one of the main reasons to give in this Guide an emphasis to the geometric aspect of the database.

A correct identification of a change in land cover and consequent updating is dealing not only with a cost but also with homogeneous and comparable statistics of changes at European level.

Some changes in land cover that can be easily detected with satellite data may not correspond to changes in CLC classes. For example, if oil seeds replace winter cereals, then this is still the same agriculture class. This makes it difficult to use automatic procedures for updating, and justifies the proposed methodology as the only one operational at present. Eventual technological improvements (hard and software) may be considered in the future, when they have proved to be operational.

Land cover mapping units are defined in terms of spatial, thematic and temporal components; the associated error has the three corresponding dimensions. “Error” is used here in its widest sense to include not only “mistakes” but also the statistical concept of error meaning bias.

As a land cover database, the thematic accuracy could be the most important component. It is linked to the process of computer aided image interpretation which is complemented by the use of exogenous data and to the definition of the mapped classes. It means that, for classifying a mapping unit, the interpreter can use all available sources of data; providing they are reliable, the interpreter skilled and with a good reference level, those errors must be minimal and the thematic accuracy different according to the nomenclature class. The available validation at Country level confirms this statement. Important sources of errors will be: (i) differences in difficulty of interpretation for the same class according to the characteristics of each Country, (ii) when assembling national databases, to guarantee that the mapping units along the frontiers are getting the same code in all countries. Thematic accuracy is also not spatially uniform (e.g. relief condition, land cover complexity, radiometric effects of the images); it is time dependent (e.g. recent cut forest at the satellite image date and all classes dynamic enough in time to change category) and it depends to a certain extent on the spatial accuracy.

Spatial accuracy has proved to be the most critical component of error in the CLC database. It has two main aspects: (i) locational accuracy related to the geometric quality of the source data (satellite images and topographic maps used to correct them), (ii) positional accuracy of polygon boundaries, related with the delineation of cartographic units.

Temporal accuracy is not equally relevant for all mapping classes. For the image data, a land cover class or some cartographic units belonging to a certain class may not be identifiable. Another type of temporal error is due to the temporal dynamic of a land cover class. A mapping unit correctly classified can be already occupied by a different land cover class when the validation is carried out. In other words, what is the optimal period for updating land cover classes in a specific geographic region ? Temporal accuracy also interacts with spatial and thematic accuracy.

The first updating is the most critical phase because in most countries it will be in the interface between the database obtained by a different method and the one proposed for the updating. This will be not the case for successive updating events. Nevertheless, updating must not be confused with validation. The validation must be performed at the end of each updating. Also, for the first updating validation must be performed also before updating begins. This is because of the changing methodologies (from creation to updating) as well as the several transformation steps between original mapping and European database compilation, each step producing and propagating errors. The methodology described in this guide is independent from scale. However, the adopted tolerances were established for the updating of a corrected database set up at the scale of 1: 100 000.

The updating of the CLC database can be linked to national applications and consequent updating of other databases. Therefore, the cost and frequency of the updating at the European level can vary according to national programmes and the possibilities of sharing data, staff, etc. Specific European projects like Lacoast (assessment of land cover changes in the European coastal zone) can contribute to the updating of certain zones. It leads to an approach of spatial updating. An alternative approach is the thematic updating, when only selected classes must be considered for updating. This can be relevant when, for example, an European Urban project is launched, or when any land cover class at a certain moment is related to a relevant policy issue. Anyhow, it is most probable that an European CLC database will always have discontinuity in time. How to manage the time in such a database is still a topic for research. It is difficult to define the optimal frequency and precise cost of updating because these are strongly dependent from the land cover evolution “rate” (determined by the nature and man’s activities). A real cost evaluation should be done before starting the updating, based on the relevant characteristics of each site.

This Methodological and Technical Guide has been published when the Technical Guide Vol. 2 and the technical guide on quality assurance and control are in progress. As a consequence, some chapters or items like validation, quality control, the new CLC generalisation rules, metadata are not defined in detail. Further information will be found in these publications.

2. OVERVIEW OF CREATION METHODOLOGY PRINCIPLES

The aim of this chapter is to shortly illustrate the principles of the creation methodology which can be considered important for their consequences on the successive updating.

The term “creation methodology” includes all the activities and data related to the creation of the database.

The following topics of the creation methodology will be illustrated:

- nomenclature,
- definition of spatial unit,
- scale of work,
- process of image-interpretation,
- heterogeneity of the satellite data used (MSS, TM, SPOT, other),
- use of Image Processing systems in creation,
- use of ancillary data.

It must be underlined that some principles for the creation of the CORINE Land Cover database have been now revised. This chapter is mainly related to the definitions included in the first technical guide and applicable to the first countries involved in the project.

For the countries in which the new approach was adopted (use of integrated GIS system directly in creation phase) only a part of the following considerations must be considered relevant.

2.1 CORINE Land Cover nomenclature

The CORINE Land Cover nomenclature is a physical and physiognomic land cover nomenclature comprising three levels (illustrated in table 1).

The nomenclature is strongly related to the process of image interpretation, the working and publishing scale and the smallest cartographic unit.

In fact, it is easy to find, in the 3rd level of the nomenclature, a group of classes for which a deductive analysis is required.

For example, the classes **1.4.2** (*Sport and leisure facilities*), **1.4.1** (*Green urban areas*) and **1.2.3** (*Sea ports*) are not just categories of different land cover, but are classifiable according to their different land use.

This implies that the image-interpreter chooses the class to be updated, taking into account the context in which the unit is placed (i.e. a green space in a town must probably be class 1.4.1 or class 1.4.2) and the additional information available (photos, cartography, ...).

An other example has to do with non homogeneous classes, like:

2.1.1 *(Non irrigated arable land)*
2.4.2 *(Complex cultivation patterns)*
2.4.3 *(Land principally occupied by agriculture, with significant areas of natural vegetation)*
....

In this case the aggregation of primitive objects may be a subjective process based on specific pattern.

In other terms the first consideration to be made regarding the nomenclature and the use of satellite data is the following one: classes in CORINE are not related only to an homogeneous spectral response !

As a consequence of this assertion, automatic updating based on supervised or unsupervised classification, neural networks, fuzzy sets, ... of remotely sensed data cannot be considered exhaustive for all possible classes.

As any land cover mapping CORINE Land Cover creation methodology strongly depends on image-interpreter capability.

Different image-interpreters can sometimes delineate different complex cartographic units when unit is a collection of elementary land cover entities. In this case the way to collect these objects can vary according to the styles and experience of the various image-interpreters.

Some land cover boundaries are fuzzy on the ground. Differences between land cover classes may occur through a gradual transition.

In particular, the classes "*Heterogeneous agricultural areas*": **2.4.1 / 2.4.2 / 2.4.3 / 2.4.4** and the classes "*Scrub and/or herbaceous vegetation associations*": **3.2.1 / 3.2.2 / 3.2.3 / 3.2.4** are easily subjected to different assignments.

A synoptic view is indispensable to identify complex units.

2.2 Definition of spatial unit

Definition 1 - Spatial unit

The spatial unit corresponds both to an area of homogeneous cover (water, forest,...) and to an aggregation of small homogeneous areas that represent a land cover structure.

The following constraints must be respected:

- it represents a significant surface in relation to the work scale,
- it is well distinguishable from other surrounding units,
- it is sufficiently stable in time.

The minimum cartographic unit for CORINE Land Cover at 1:100,000 scale is 25 ha.

2.3 Scale of work for creation

Definition 2 - Scale of work for creation

In the original methodology the image-interpretation was done on 1:100,000 image printouts in which a transparent film was overlapped to the images and digitised at the end of the image-interpretation process.
In the revised methodology (adopting a GIS approach) the scale (and as consequence the precision) can be different.

Table 1 - CORINE Land Cover Nomenclature

Level 1	Level 2	Level 3
1. Artificial surfaces	1.1. Urban fabric 1.2. Industrial, commercial and transport units 1.3. Mines, dumps and construction sites 1.4. Artificial non-agricultural vegetated areas	1.1.1. Continuous urban fabric 1.1.2. Discontinuous urban fabric 1.2.1. Industrial or commercial units 1.2.2. Road and rail networks and associated land 1.2.3. Sea ports 1.2.4. Airport 1.3.1. Mineral extraction site 1.3.2. Dump 1.3.3. Construction site 1.4.1. Green urban areas 1.4.2. Sport and leisure facilities
2. Agricultural areas	2.1. Arable land 2.2. Permanent crops 2.3. Pastures 2.4. Heterogeneous agricultural areas	2.1.1. Non irrigated arable land 2.1.2. Permanently irrigated land 2.1.3. Rice fields 2.2.1. Vineyards 2.2.2. Fruit trees and berries plantations 2.2.3. Olives groves 2.3.1. Pastures 2.4.1. Annual crops associated with permanent crops 2.4.2. Complex cultivation patterns 2.4.3. Land principally occupied by agriculture, with significant areas of natural vegetation 2.4.4. Agro-forestries areas
3. Forest and semi natural areas	3.1. Forests 3.2. Scrub and/or herbaceous vegetation associations 3.3. Open spaces with little or no vegetation	3.1.1. Broad leaved-forest 3.1.2. Coniferous forest 3.1.3. Mixed forest 3.2.1. Natural grassland 3.2.2. Moors and heathlands 3.2.3. Sclerophylous vegetation 3.2.4. Transitional woodland-scrub 3.3.1. Beaches, dunes, sand 3.3.2. Bare rocks 3.3.3. Sparsely vegetated areas 3.3.4. Burnt areas 3.3.5. Glacier and permanent snow-fields
4. Wetlands	4.1. Inland wetlands 4.2. Coastal wetlands	4.1.1. Inland marshes 4.1.2. Peat bogs 4.2.1. Salt marshes 4.2.2. Salines 4.2.3. Intertidal flats
5. Water bodies	5.1. Continental waters 5.2. Marine waters	5.1.1. Stream courses 5.1.2. Water bodies 5.2.1. Coastal lagoons 5.2.2. Estuaries 5.2.3. Sea and ocean

2.4 Process of image-interpretation for creation

After collection of the necessary data, CORINE Land Cover creation methodology suggests to adopt the scheme illustrated in figure 1 (*from CORINE Land Cover Technical Guide - page 50*).

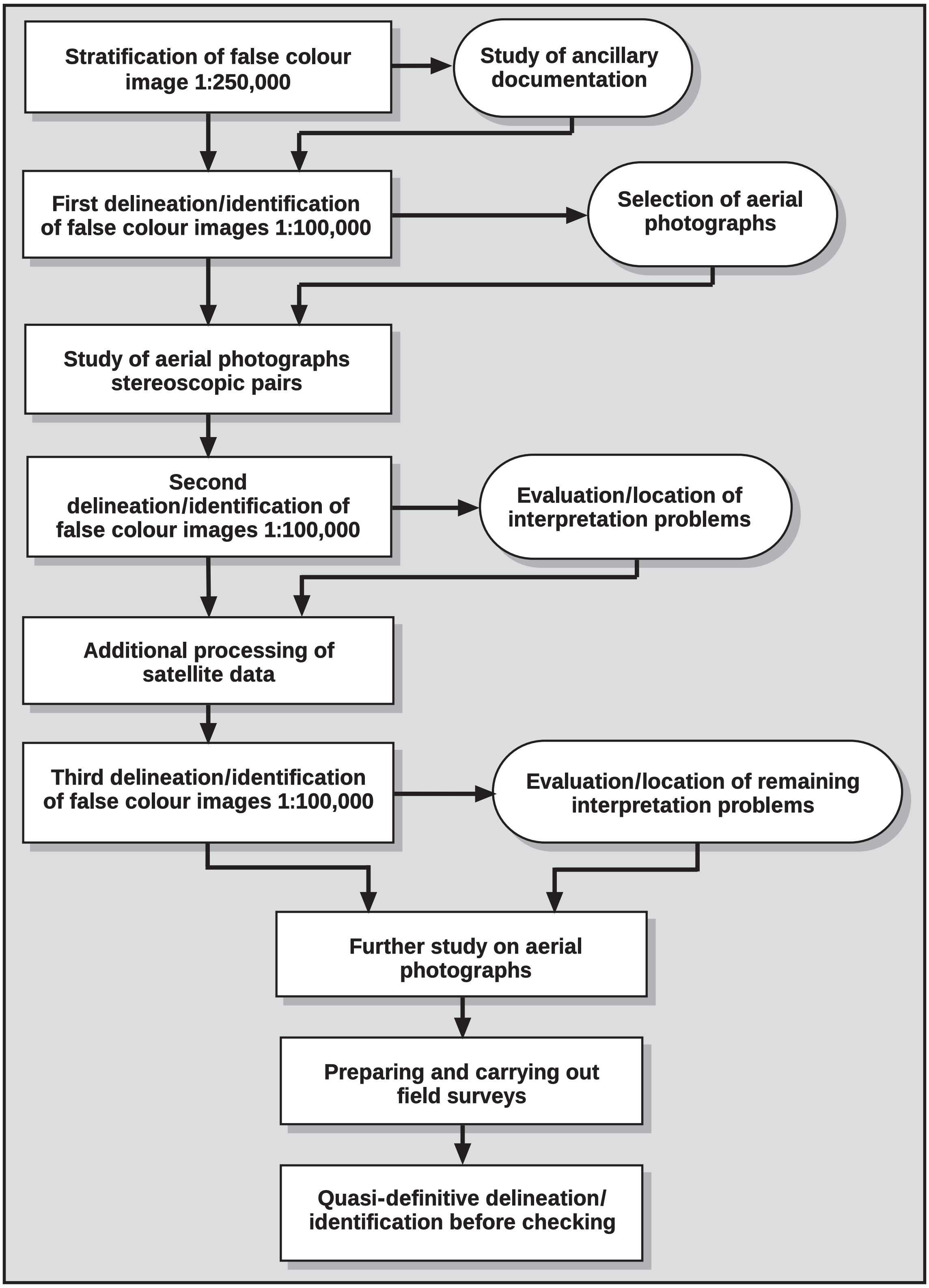


Figure 1 - Image-interpretation schema for creation

Additional important statements reported from the CORINE Land Cover Technical guide *(page 53)* are:

"Additional processing of satellite data at an interactive processing station can serve to:

- *complete the interpretation,*
- *corroborate the results obtained..*

In order to keep additional processing time to a minimum, the image-intepreter must prepare the work carefully at an interactive work station. This preparation entails:

- *identifying on the false colour image those areas where additional processing is required, marking the areas to be checked and the areas where the interpretation has to be completed.*
- *gathering the requisite ancillary documentation concerning these areas.*
- *planning the sequence processing stages according to the problems to be solved.*

The interpreting team must be very cautious about the time they spend at the interactive processing work station. Not all problems remaining at the end of the image-interpretation 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 some problems (topics) which can be solved by interactive processing,*
- *depending on area complexity, establish the maximum time to be spent."*

Nevertheless the image-interpreter can use the image processing system. In this case the guide states:

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

- *the original data used to produce false-colour images,*
- *additional satellite data acquired where justified.*

The following five types of multispectral data processing:

- *adjustment of dynamics,*
- *vegetation index,*
- *automatic classification,*
- *principal component analysis,*
- *two-dimensional spatial filter,*

are recommended for an interactive work station because:

- *experience has shown them to be the best adapted to the project objectives,*
- *they are generally available on commercial interactive processing work stations".*

Resuming the concepts expressed in the CORINE Land Cover Technical guide: image processing must be considered a useful tool to eliminate eventual doubts; the image-interpreter can work only on small areas to detail its first identification.

The final geometric delineation was done using the original image maps or hardcopies of the screen (at 1:100,000 scale).

These choices were related to the status of the market of the image processing systems in 1985 when the methodology was defined. As a consequence, the creation methodology was oriented to minimise the use of very expensive systems, favouring the manual work on paper supports.

Now direct video digitisation capabilities offer better performance and time saving. The cost for purchase of hardware and software has greatly decreased.

As a consequence although the old creation methodology principles maintain their validity from a logical point of view, their original suggested implementation cannot currently be considered the best way to make economy and to speed up the process without loss of quality of the work.

In the past some constraints of the creation methodology were often ignored or not respected.

For example the following constraints (*from CORINE Land Cover Technical Guide - page 43):*

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

- *the geometry of the transparency is the same as that of the corresponding 1:100,000 standard topographic map,*
- *to obtain a good representation of this geometry some simple rules are suggested. To guarantee the quality the image-interpreter must check:*
  - * *that map documents are properly aligned,*
  - * *the complex categories interpretation,*
  - * *that adjacent maps link up,*
  - * *that only one code has been used for each area,*
  - * *that the areas that have been completed are marked off."*

These rules are extremely important to guarantee a good quality of the final database. Ignoring these simple suggestions may produce bad classifications or delineations of some units.

Because of the error propagation it may be difficult to know if all these operations have been correctly performed. Normally the validation process can focus some errors and consequently can show an incorrect application of the methodology taking into account that some errors are intrinsic of the methodology itself. <u>Updating is so sensitive to the original database</u> quality because a correct quantification of changes can be performed only after errors removal.

2.5 Use of Image Processing systems in creation

The use of Image Processing systems was often very low or completely absent in the creation phase.

The Image Processing systems were mainly used:

- to help in interpretation of particular areas,
- to produce additional materials to be used for interpretation,
- to check the interpretation results by over-laying the geocoded satellite data with the land cover vector data.

The first case (mainly used for wetlands), proved very useful to detect differences in some other classes (i.e. broad leaved forest and coniferous forest areas). This kind of solution that can be defined "interactive support to the interpretation by means of Image Processing system" <u>could</u> <u>be</u> <u>higher</u> if Multitemporal images were available or *modifying the methodology* if no image prints were produced (directly performing the video digitisation). These cases describe for example the approach for the creation in some regions of Italy (Veneto, Toscana, ...).

In the second case the image-interpreter used the Image Processing system for production of slides or prints (obtained with particular procedures like vegetation index, principal component analysis, linear combination,...) and used these slides during the image-interpretation session. This situation typically describes a image-interpreter who doesn't have his own Image Processing system and must collect all suitable materials before starting its interpretation session. This type of solution can be defined: "batch use of Image Processing system".

The third case proved to be very efficient for final verification of the database.

2.6 Database structure

The present structure of CORINE DB was influenced by the choice of the "sheet oriented" approach and of the topological structure. In fact, all CORINE objects are polygons, but their storage is organised by coded arcs and labelled points (one for each polygon).

This structure guarantees the topology coherence because <u>the overlapping of two polygons is impossible</u>.

One aspect that must be considered (for its influence on Updating) is the problem of polygons situated on the map limits. *The CORINE Technical Guide established (page 79)*: *"the features situated at the edge of the map sheet must be matched up exactly in the final file"*.

This statement means that a unique polygon is created merging the two original ones (Figure 2).

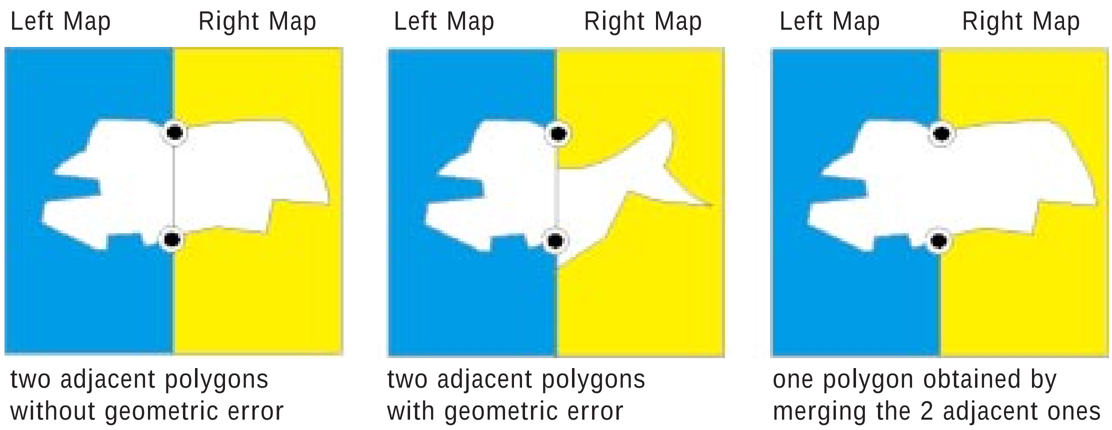


Figure 2 - Polygons on sheet boundary

The figure 3 illustrates the presence of units < 25ha in a "sheet oriented" data structure, which would be merged with neighbouring polygons resulting in land cover units >25ha.

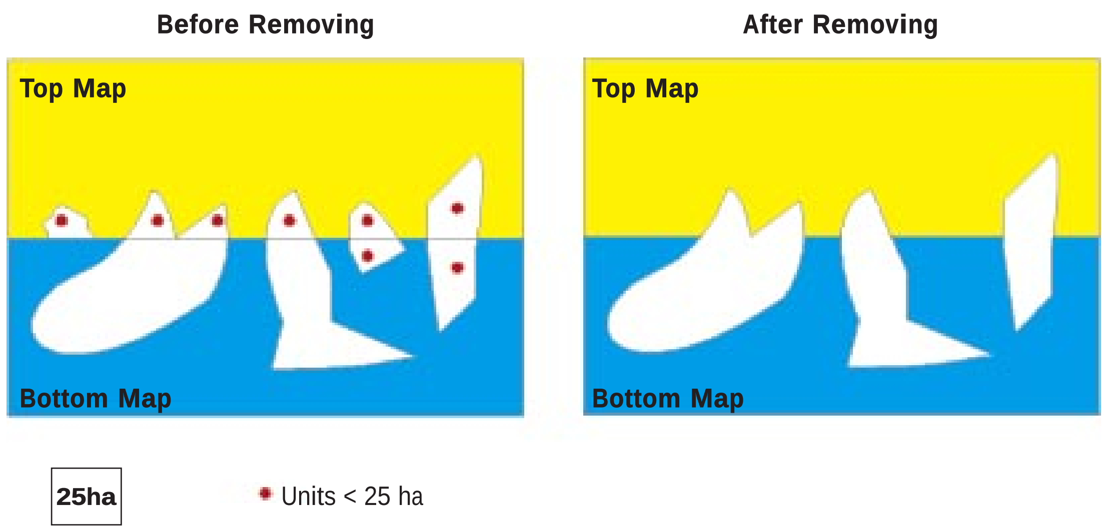


Figure 3 - Small units located on sheet boundary

2.7 Use of ancillary data in creation

Another important aspect is concerned with the use of exogenous data (photos, maps, ..) that can influence the quality of the database (for example according to the presence or absence of photos in the same areas).

The original creation methodology required to store the history of each image-interpretation step (ancillary data used, processing, ...) but sometimes there is not a precise track of the ancillary data used for interpretation on the different areas of each country and different teams. Some of these materials were made available for that purpose and could not be archived.

According to the CORINE Land Cover Technical Guide *"a fact never to be lost sight of is that in the Land Cover methodology, the satellite data may constitute the fundamental database but the required project inventory output cannot be derived solely from them. The methodology is a data integration methodology, wherein the collection and analysis of ancillary data in conjunction with the satellite spectral data provide a convergence of evidence that leads to a reliable identification of the particular land cover class occurring on a given land unit"*.

> *Definition 3 - Ancillary data*
>
> The term ancillary data refers to any documentary, cartographic or photographic information concerning land cover which does not come directly from the satellite database.

As a consequence of this definition a spatial unit is attributed to a class not only on the basis of the satellite imagery, but also through the additional data available for the image-interpreter. This means that in these cases the satellite image is not enough for a satisfactory identification of the class.

Such data essentially comprise: topographic maps, thematic maps related to land cover, statistical information, aerial photographs.

The following list concerns some statements regarding type and use of the main important data in order to evaluate their possible contribution (*from CORINE Land Cover Technical Guide - page 40-42*).

"Standard topographic maps are essential to the Land Cover project. They are used at various stages:

- *to prepare the transparency overlays for the interpretation work, and thus <u>establishing the geometry of the interpretation</u>,*
- *for geometric correction of satellite data,*
- *they constitute the reference document for controlling the geometry of the digitisation of the interpretation sheets,*
- *they are a very important source of information on land cover.*

Statistical information provide a general perspective for the CORINE land cover project:

- *they provide a comprehensive picture of land cover,*
- *they are a means of verifying the Land Cover results.*

The aerial photographs play a major role in the Land Cover project. They are used:

- *to <u>identify</u> (as a nomenclature class) units delineated on the false-colour images which might be incorrectly classified,*
- *to <u>determine the exact boundaries</u> of units which are not resolved clearly on the satellite image,*
- *to <u>verify and validate</u> the results of the land cover mapping".*

The consequences of these statements for the updating process are evident as discussed after.

3. BASIC PRINCIPLES FOR UPDATING

3.1 Definitions of error

We can distinguish 5 sources of error in the existing database:

- errors caused by the material used,
- errors during data integration,
- errors caused by the image-interpretation,
- errors occurred during digitisation,
- errors during data transformation.

3.1.1 Errors caused by the specific material used

The error caused by the used material is common to all objects (polygons) of each sheet and it can so be considered as a systematic error.

Definition 4 - Systematic error

We define as systematic error every error affecting the database or the Images that can be considered as common to the whole data set and can so be modeled and corrected with some techniques of global correction. This type of error must be identified and corrected before any eventual local error correction.

As described in the chapter "geometric correction of the original database" it is possible sometimes to proceed to a global correction of each Sheet data if the error can be classified of systematic type and if the operator provided ancillary information necessary to its evaluation (for example co-ordinates of control points acquired on the geographic reference and on the database to be corrected).

Figure 4 shows an example of bad document (satellite image on paper) used for image-interpretation and its consequence on the interpreted polygons.

3.1.2 Errors during data integration

As often mentioned, ancillary data play a considerable role in the CORINE land cover creation and updating. It is highly recommended to use all complementary information during the interpretation.

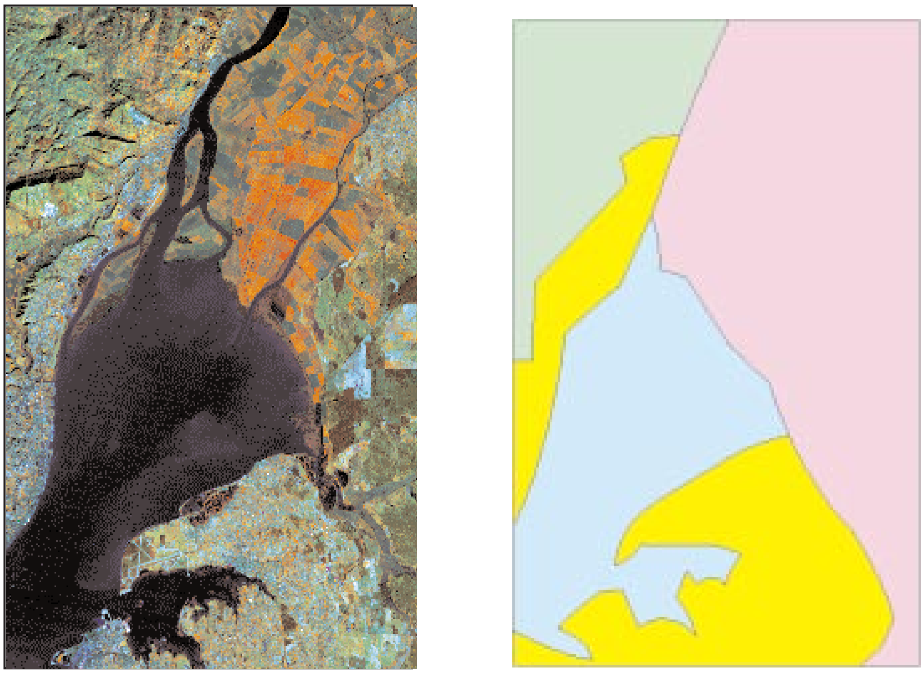
As any kind of information, also ancillary data are affected by random or systematic errors. As a consequence, the ancillary data can provoke a diffusion of their own errors over the CORINE database.

In particular, the two types of errors that can be originated by bad ancillary data are on geometry and in class identification.

For example, the use of distorted topographic maps has as a consequence an incorrect geometric precision or different levels of geometric precision according to the different scale of available cartographic maps.

Instead, the use of bad thematic ancillary data can suggest to the image-interpreter a particular interpretation that is not the correct one.

Correct image geometry



Bad image geometry

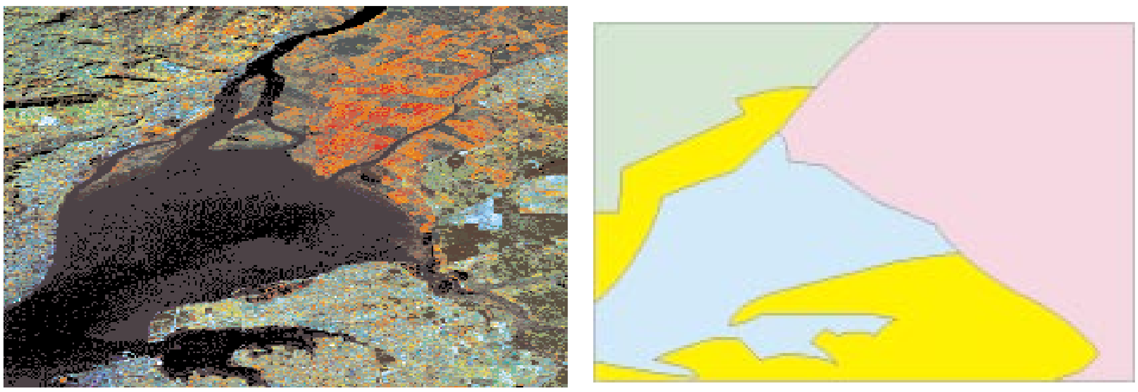


Figure 4 - Bad geometry of the material

3.1.3 Errors caused by the image-interpretation

The errors caused by the image-interpreter can be classified as:

- bad code attribution for a class,
- bad boundary's delimitation for a cartographic unit.

The error in the class identification, when recognised, is easily correctable. The GIS system used for updating must contain some special functions to automatically check the errors caused by no code attribution (NULL or 0 code) and errors caused by the attribution of a not existing code (using appropriate Codes Look up tables).

<u>The errors of bad code attribution as a consequence of a bad interpretation or a data entry error (for example code 311 instead of 312) cannot be automatically detected !</u>

The errors of geometry due to bad boundary delimitation can be caused by various factors and can be of different relevance. For some land cover classes the boundary is fuzzy on the ground. It also happens that a sharp boundary on the ground can appear fuzzy on the satellite data.

A quantification of the error is necessary: overall it must be considered that in the CORINE Land Cover Methodology the smallest unit mapped is defined as a surface of 25 ha that represents at 1:100,000 scale a 5 x 5 mm square or a circle with 2.8 mm radius (see figure 5).

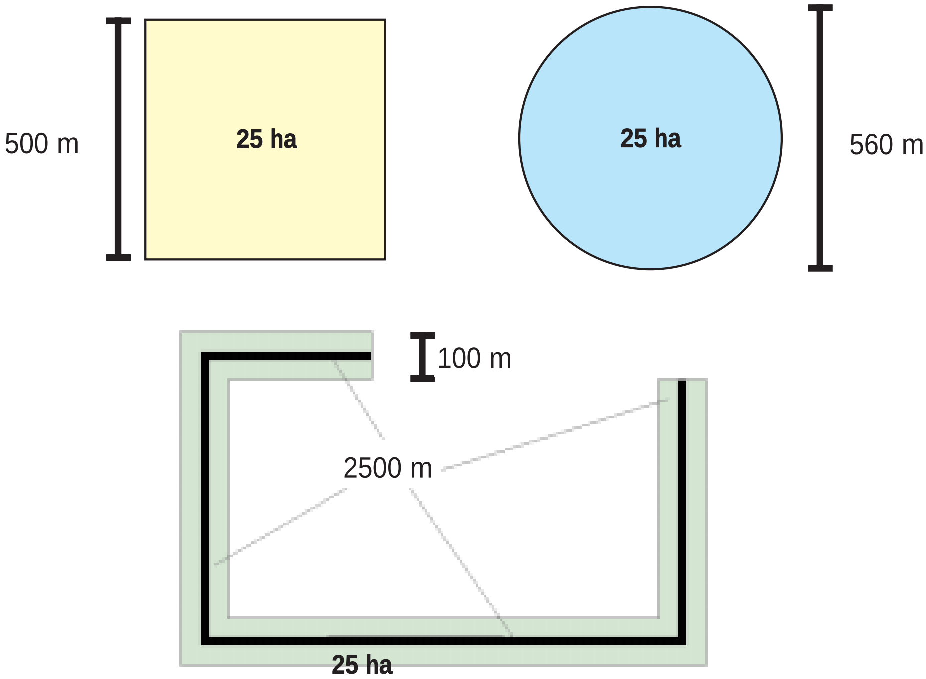


Figure 5 - Minimum cartographic unit

The main aspect concerning geometric precision are given in the CORINE Land Cover Technical Guide (*page 76*):

“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 m in width”.

Not all the elements that can influence the geometric precision were originally defined in a standard way. Two different aspects must be considered concerning geometric precision:

- location,
- surface.

The two aspects are related. In fact in some cases a boundary displacement less than 100 m can introduce errors on area >25ha (as illustrated in Figure 7). In this case due to surface tolerance the unit must be modified.

The constraint in the creation methodology regarding precision of location is to avoid narrowness less than 100 m. Normally 1:100,000 cartography has a geometric precision of about 100 m but in the case of CORINE it is known that this precision was not always respected (due to the use of satellite data).

The updating precision must be a compromise between the maximum precision obtainable with the satellite data (about 1.5 times the Pixel size) and the needs to exploit the existing database, finally to save the image-interpretertime during interpretation/digitisation sessions.

A good criteria to define a judicious precision is to establish that an object cannot occupy more than 50% of the place belonging to a different object. In other terms for a regular shape the centre of the real object must be inside the digitised polygon (as illustrated in figure 6).

As a consequence of this criteria the acceptable error changes according to the shape of the polygons, as illustrated in the following table.

Type of shape	Shape for minimum unit	Maximum acceptable error
Square	side = 500 m	250 m
Circle	radius = 280 m	280 m
Rectangle (W/H rate 1:4)	width = 1000, height = 250	125 m
Rectangle (W/H rate 1:16)	width = 2000, height = 125	62.5 m

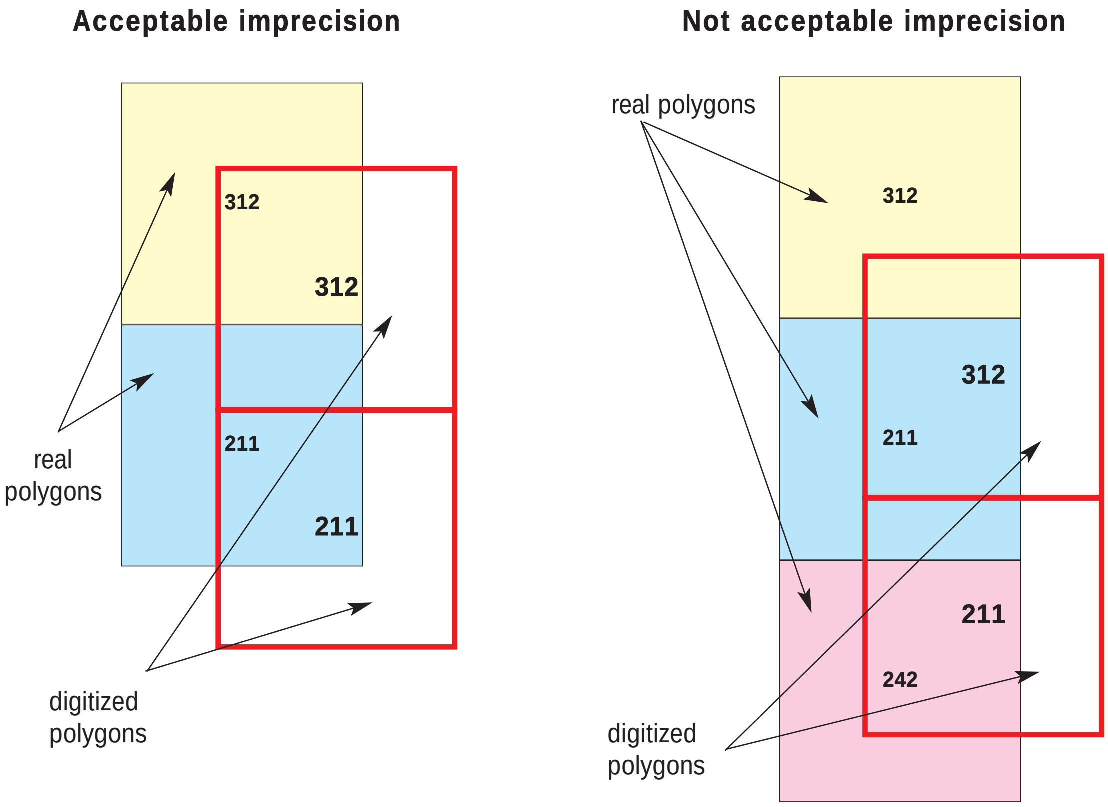


Figure 6 - Errors in polygon location

It is evident that it must be adopted a unique definition for “acceptable” error. The acceptable error (compatible with the precision of CORINE land cover database) is fixed in 100 m (corresponding to 1 mm on 1:100,000 scale map). For linear features, the image-interpreter must check if this threshold is high enough to avoid confusion, if not he must correct the database.

The following table shows the relation between the acceptable error and available satellite data precision:

Type of satellite data	Pixel size (m)	Errors expressed as equivalent number of pixels (100 m)
Landsat MSS	56x80	2
Landsat TM	30x30	3
Spot XS	20x20	4
Spot P	10x10	10

Definition 5 - Error on geometric location

We define error of boundary delimitation as every difference greater than 100 m.

Both errors (area and location) must be considered; figure 7 illustrates the various possible situations.

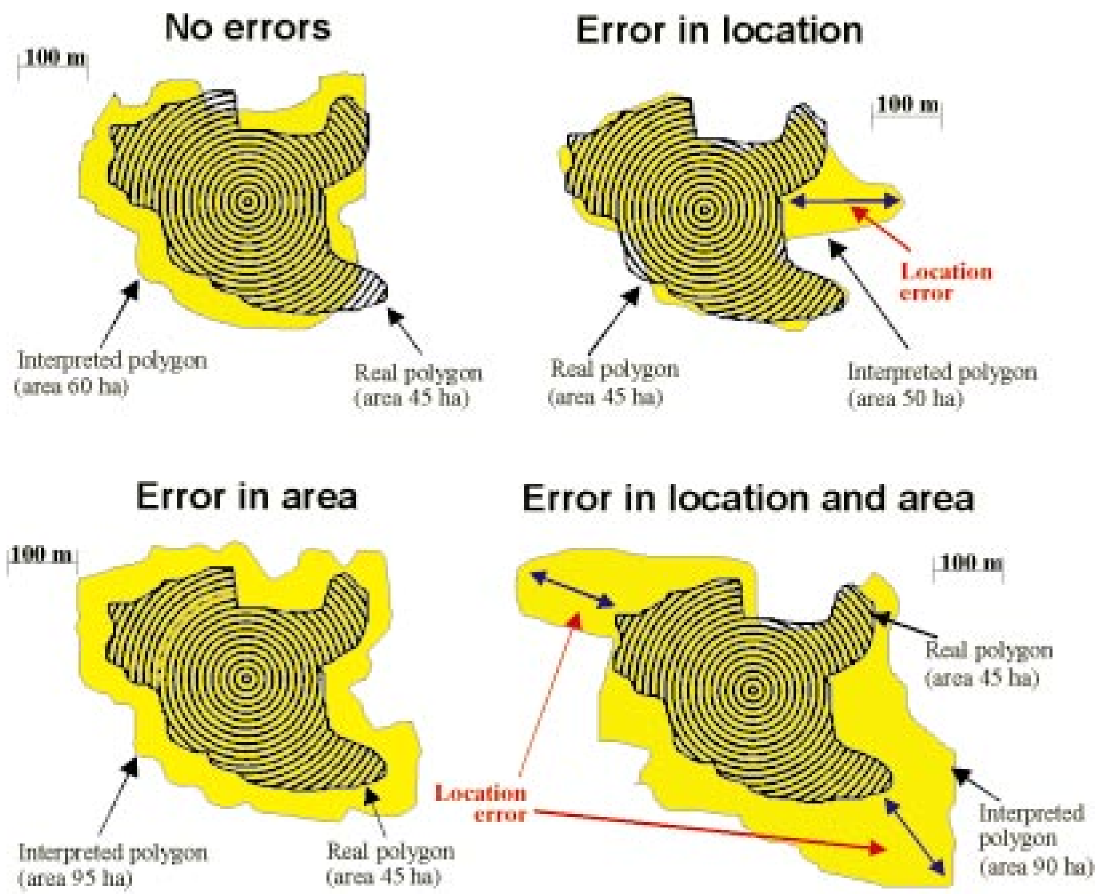


Figure 7 - Errors on geometry caused by the image-interpreter

3.1.4 Errors occurred during digitisation

The last chain of the database creation procedure is the digitisation, that is normally performed manually with a digitiser or by means of scanning. This process can cause errors both on coding and on geometry.

The errors on the geometry can be classified as :

- local errors,
- systematic errors.

Errors necessarily arise because of the width of the pen and when digitising the image-interpreted line, since the operator does not always digitise exactly the middle of the line, as it would be most appropriate. Besides, not every point along the line is digitised but only a sample of them; this generalisation upon the image-interpreted line means another source of error. Both sources should be mentioned in this guide.

In the case of local errors the operator charged with the digitisation could forget a line or move this line some millimeters. These errors cannot be modeled and shall be evaluated only during updating. In that occasion the image-interpreter will observe a modification between the original database and the new imagery and must check if this difference is a real change or instead a remaining error.

The so called “systematic errors” are caused by an incorrect following of the creation methodology or by the bad material used (for example use of films that have deformations, bad calibration of the hw, ...). The approach for the correction of these systematic error is described in chapter “geometric correction of the original database”.

3.1.5 Errors during data transformation

According to the creation methodology principles, each database must be produced in the national geographic system used for a specific country.

When the database is organised at European level the coordinates must be transformed in a common system (for example Lambert azimuthal equal area projection). This transformation is made by some mathematical formulas that can introduce small or significant differences.

In addition some errors can be generated during the integration process to solve all cases of sheet/Region/Country overlapping or lack of information, as illustrated in figure 8.

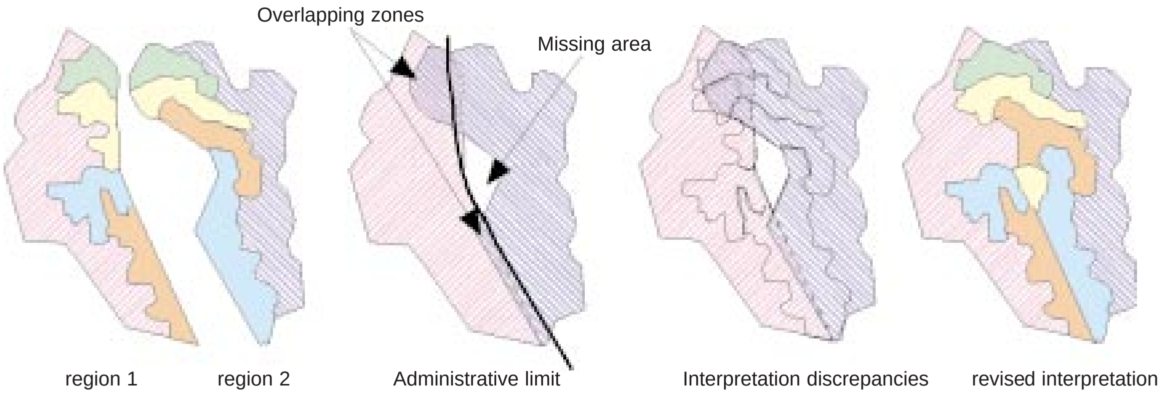


Figure 8 - Errors during data transformation

3.2 Definition of change

Definition 6 - Change

The change is the transition from one or more classes to a new one.

There are only 2 possible situations:

- creation of a new unit,
- boundary modification of an existing unit.

Postulate 1 - Smaller units

Units smaller than 25 ha must not be considered as new units.

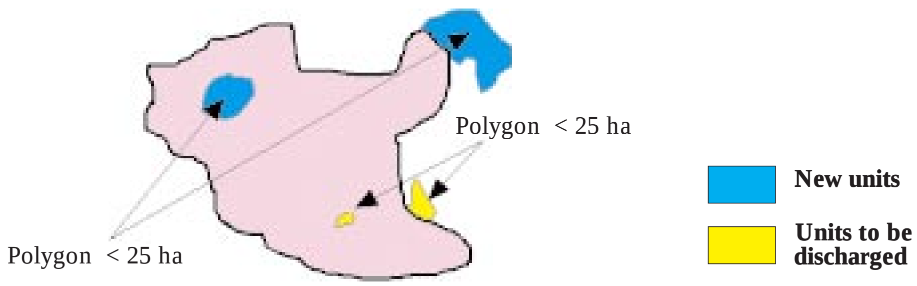


Figure 9 - Small units

> *Postulate 2 - Creation of a polygon*
>
> When a change less than 25 ha provokes the identification of a new unit greater than 25 ha a polygon must be created as new unit.

An example of the application of this postulate is given in Figure 10. The polygon **B** has not been digitised in the original database because it was smaller than 25 ha (15 ha, for example), this polygon then has remained integrated into another polygon **A**, bigger enough to be digitised. Between two updating periods, polygon **B** changed growing 20 ha. Since 20<25 ha **B** must not be updated but the results of this change is to have a polygon of 35 ha neither digitised. This would break the rule of 25 ha as minimum area. To avoid it the creation of a new polygon is obligatory (in this and similar cases).

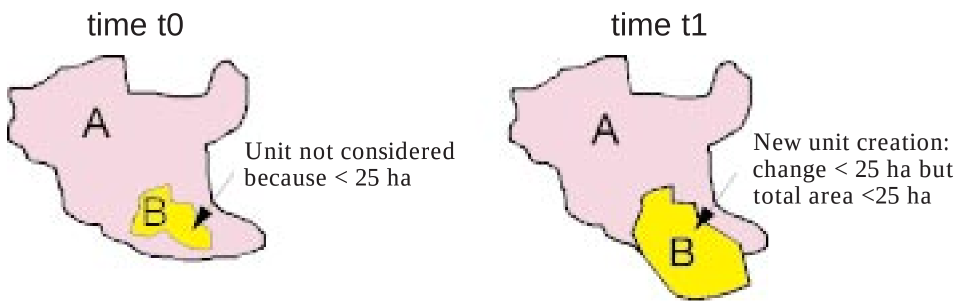


Figure 10 - Changes provoking object creation

> *Postulate 3 - Boundary change definition*
>
> In each unit only variations greater than 100 m must be updated (see figure 11).

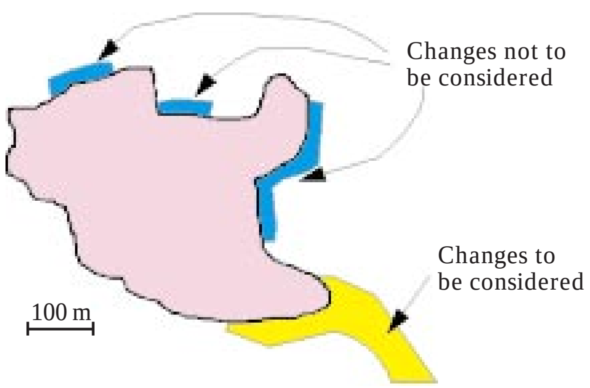


Figure 11 - Boundary changes

In particular figure 12 clarifies the situation when linear changes occur (as for example on the boundary of a big forest area).

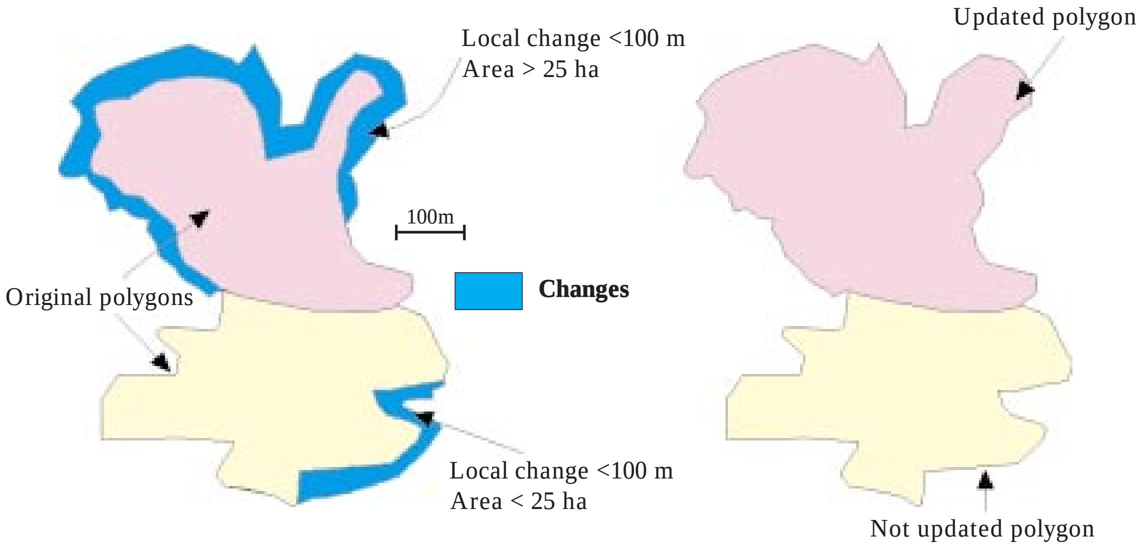


Figure 12 - Linear changes

There is a last case that must be discussed separately, when the sum of the small changes in a selected unit is greater than 25 ha, but each single change is less than 25 ha and with a distance to the old boundaries less than 100 m (see figure 13 and figure 14).

The updating methodology fixes that there is no obligation to update these changes but it is preferable to do it in some cases. In fact, if for example these small changes are related to original imprecision or shift (there is not a real change, then updating is not necessary because the compensation between the different units saves the results (see postulate 3 and figure 14). Instead when only few polygons show this discordance it is probable that real changes occurred, so it may be better to proceed updating the database (see figure 13).

Postulate 4 - Set of linear changes less than 100 m with a total area greater than 25 ha

If for one unit there are several local changes less than 100 m but with a total area greater than 25 ha, these changes could be considered only if they affect a limited number of polygons.
Updating is not obligatory.
It is recommended to not lose time to make these modifications that are not really useful but to proceed to modify the units when very few local cases are encountered.

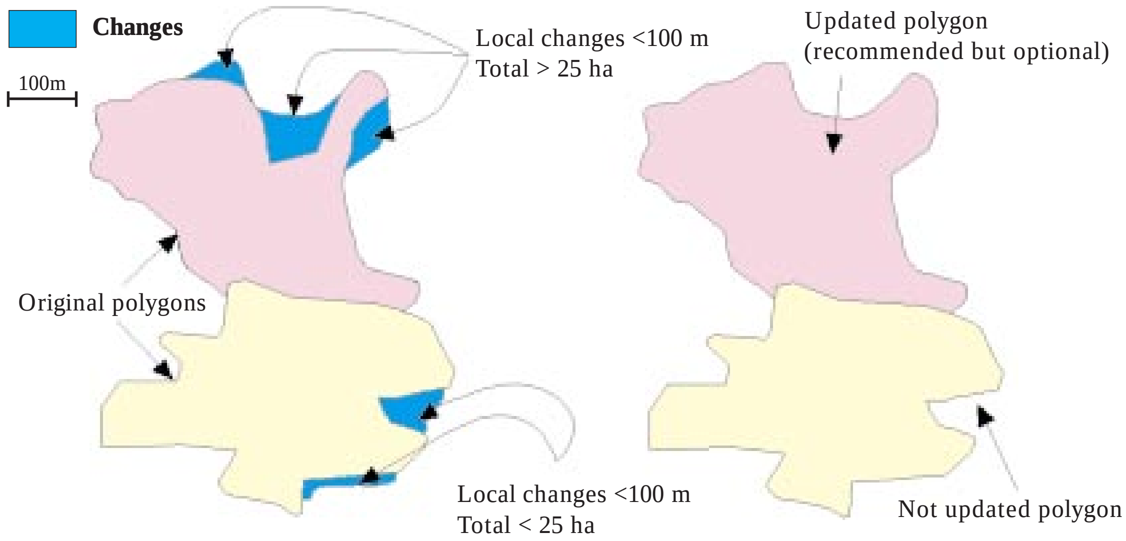


Figure 13 - Sum of small changes to be considered

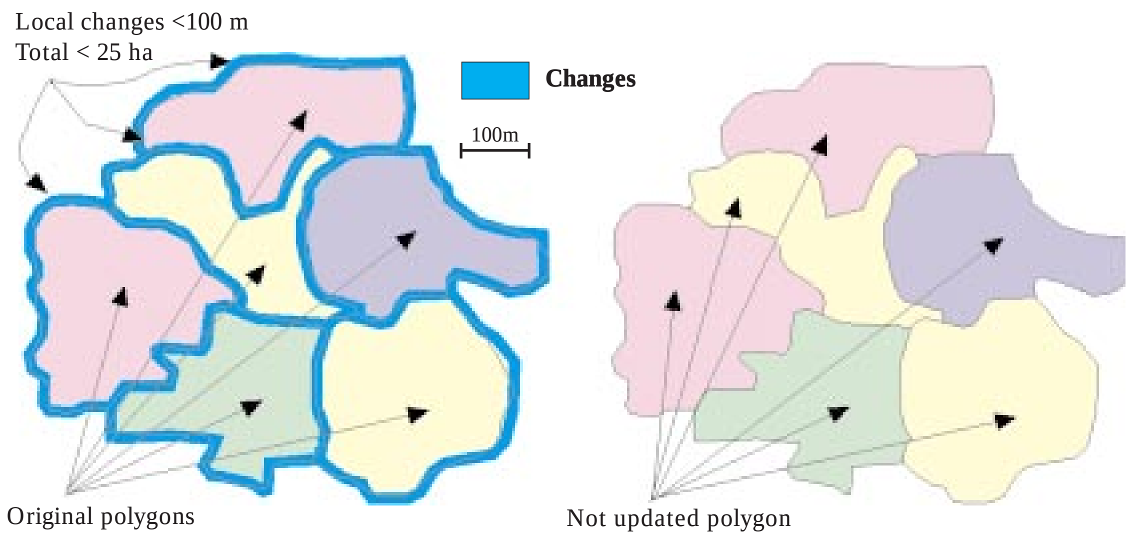


Figure 14 - Sum of small changes not to be considered

The figure 15 and figure 16 show an example of errors on location less than 100 m.

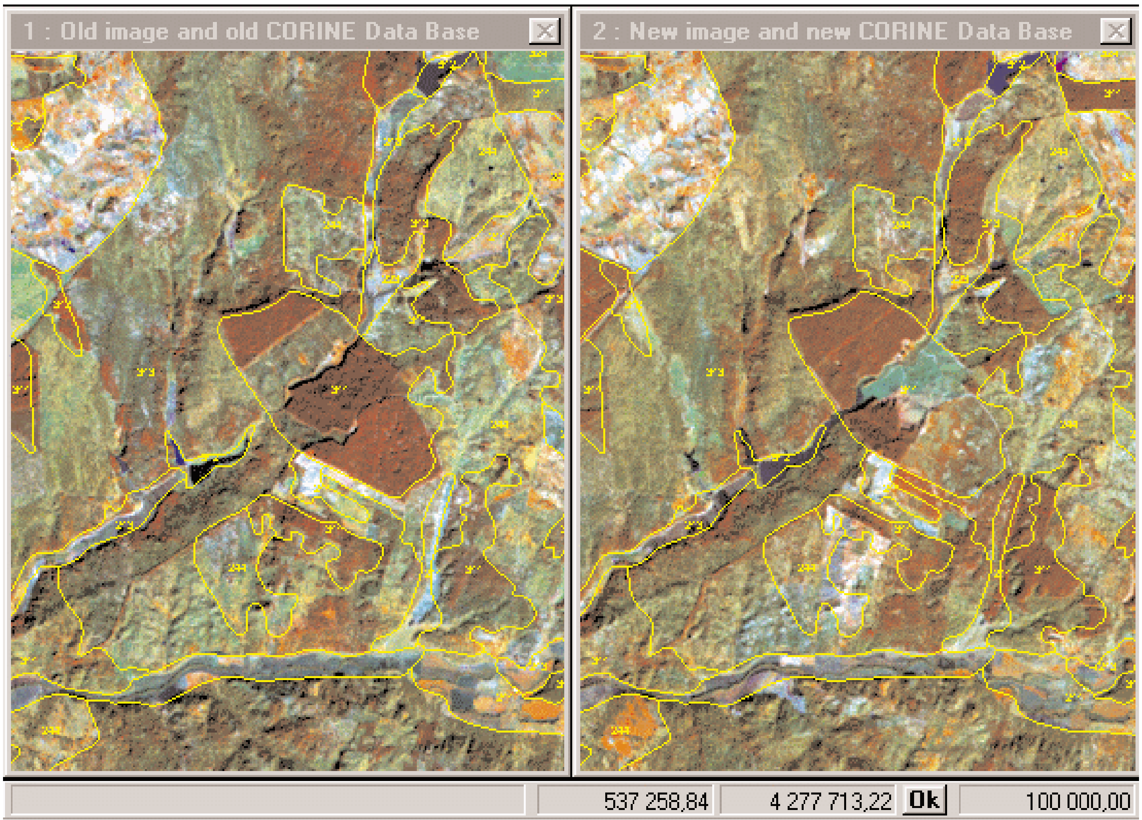


Figure 15 - Land Cover data overlapped to 1985 and 1991 TM images (original video scale 1:100,000)

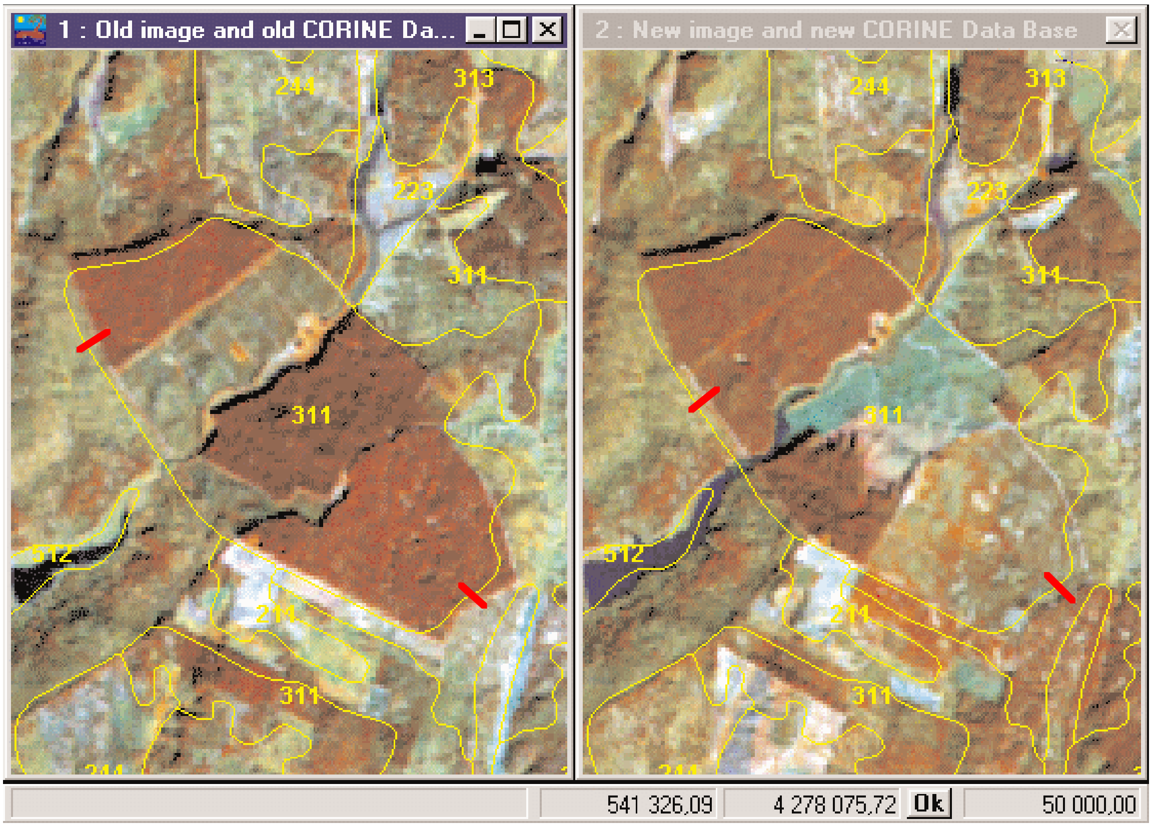


Figure 16 - Land Cover data overlapped to 1985 and 1991 TM images

3.3 Possible sources of ancillary data for updating

As in the creation, some exogenous data can be used as complementary to Remotely Sensed data. In fact there are several information sources scattered in a non homogeneous form, that can be considered useful in the updating phase (road plans, forest management plans, statistics, ...). It is better to distinguish between:

- data to be used in digital form,
- non-digital data useful for interpretation.

The first type of data plays the same role in updating as the hydrographic film in creation. In fact one image containing superimposed additional information acquires a better visibility and helps the comprehension of the various landscape units. This is the case of rivers, roads, ...

A Digital Terrain Model can provide information on slopes and exposition and could be used to partially remove the effects of the shadows. It also can help to identify land cover classes that are linked to a certain slope exposure or to a limit on altitude.

A different use of numeric data can be hypothesised in a multiwindows environment as help for the image-interpreter. For example a rasterised topographic map can be used in a second window instead of obliging the image-interpreter to move for consultation of that information on paper (see Figure 17).

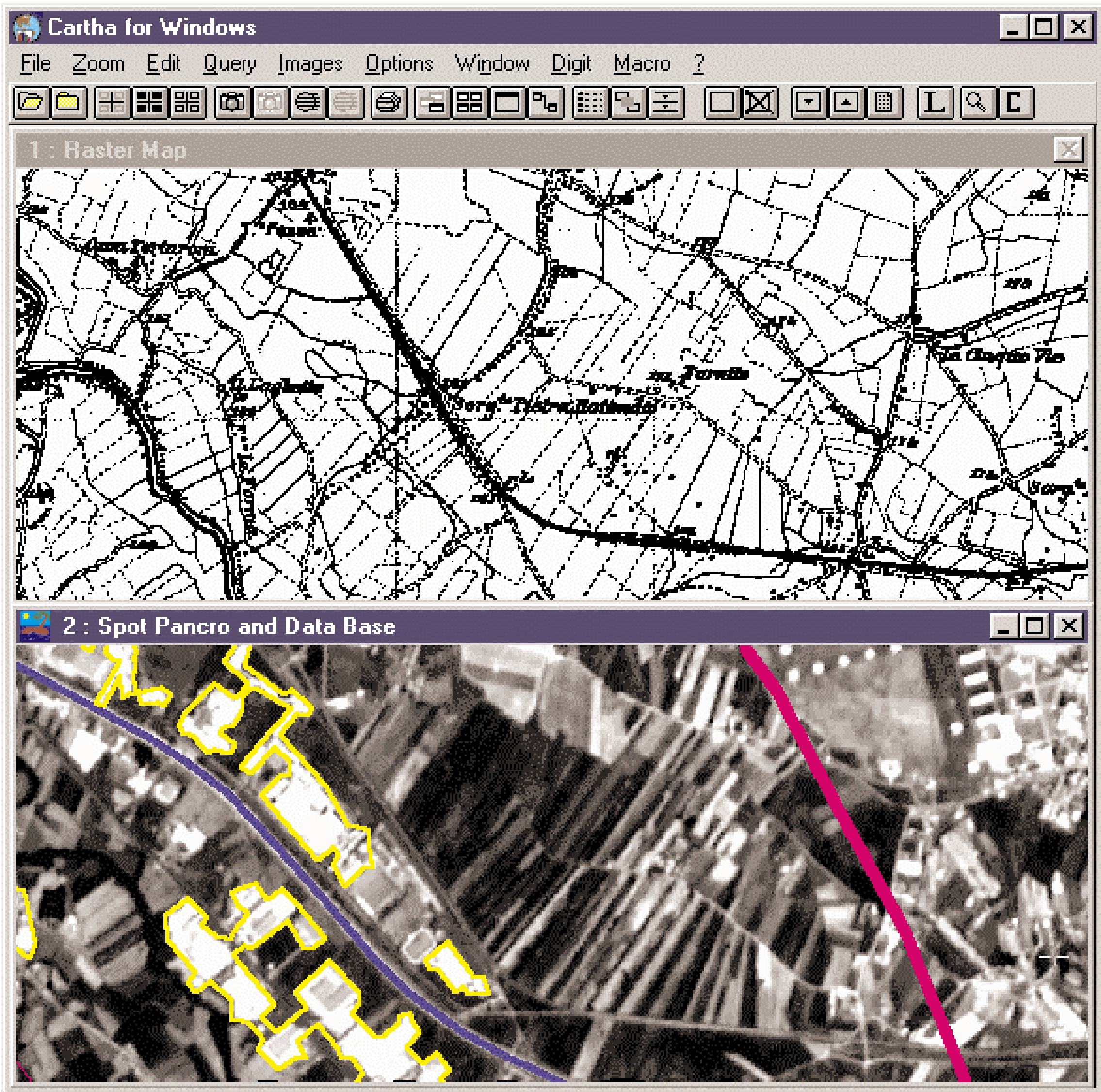


Figure 17 - Raster map and satellite image in a multiwindows environment

When data are not available in digital form the best thing to do is to build a numeric catalogue that could be easily consulted during computer aided interpretation.

A typical example illustrated in figure 18 concerns the use of available aerial photos in which the project co-ordinator introduces on the computer the information concerning the shape and location of each photo (also called "flight plan") and the image-interpreter can consult this plan interactively to know which photo is available for the area currently analysed.

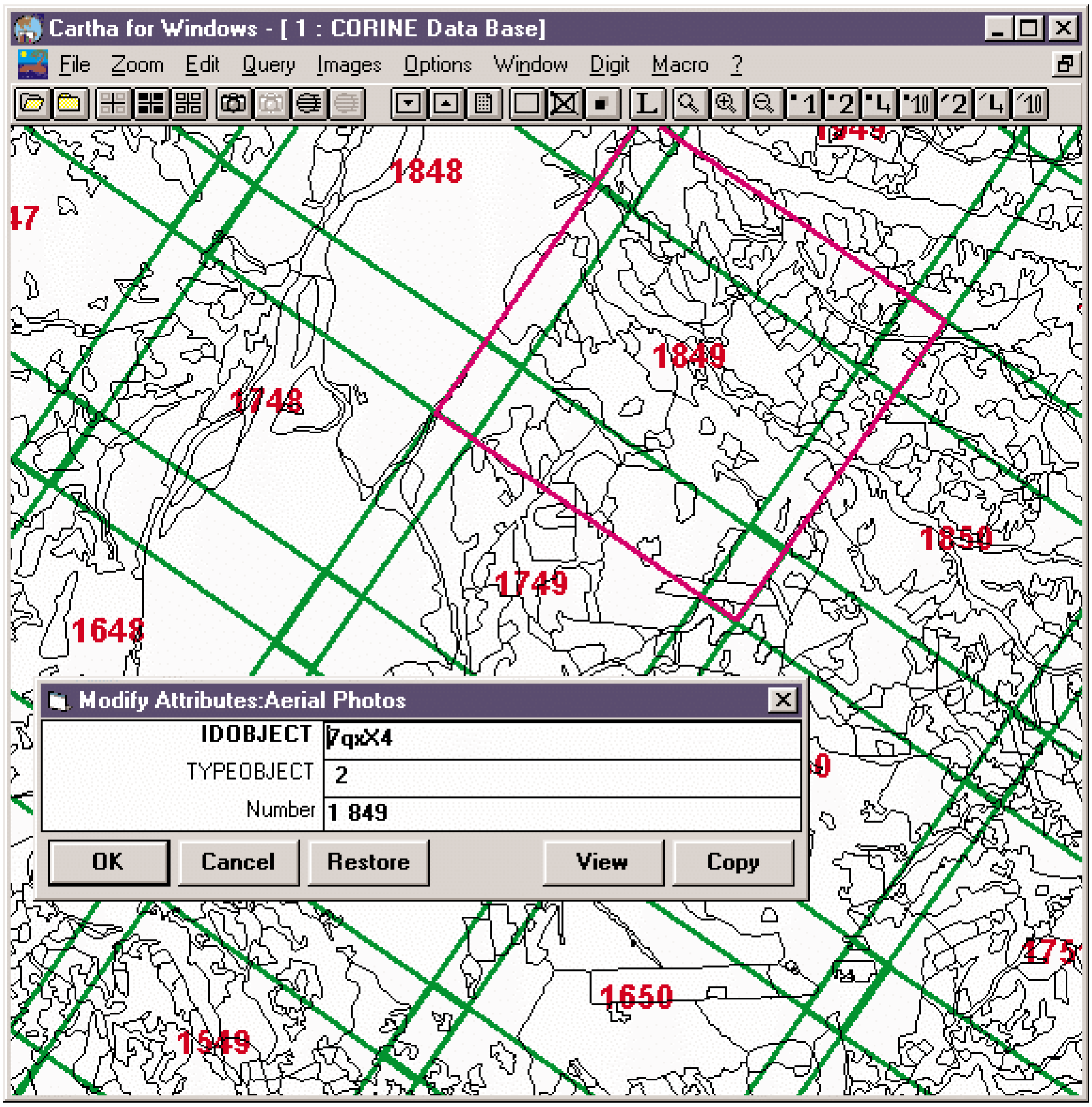


Figure 18 - Aerial photos referenced by means of their flight plan

Postulate 5 - Use of ancillary data in non-numeric form

If the consultation of non-digital data can be considered strategic for the interpretation process (optimising the access, search and saving the image-interpreter time), the creation of a numeric intelligent catalogue is highly recommended. An exhaustive digitisation of the ancillary data is not necessary in that case.

Unfortunately not all these information are available at the moment of the work planning. The GIS system should be able to add this information at any moment of the work if necessary, without disturbing the existing database architecture.

The ancillary data to be used for updating can be catalogued in 3 categories according to their possible contribute.

Table 2 - Ancillary data for updating

Data type	**When not digital**	**When digital**
Aerial photos	Use on paper or film (normally not georeferenced) to support the photo-interpretation. Digital catalogue (flight plan) highly recommended.	Use in digital form (georefererenced) to support the photo-interpretation Possibility of video overlap to the CORINE Land Cover database.
Thematic maps	Use on paper georeferenced to support the image-interpretation. Digital reference (sheets oriented) highly recommended.	Use on digital form (vector form recommended).
Topographic maps	Use on paper georeferenced to support the image-interpretation. Digital reference (sheets oriented) highly recommended.	Use on digital form (raster form recommended).
Tabular data	This includes statistical data to be used in comparison with the statistics derived from CORINE database. Land Cover database is suggested.	Use on digital form not strictly necessary. If yet available the creation of "hot points" as source of information on the CORINE
Documentary images	This includes drawings, photos collected on the ground, ... Digital reference (as information points) highly recommended.	Low resolution scanning with information reference points available during interpretation.

3.3.1 Example of implementation

The following pictures show the implementation of ancillary data consultation under *Co-Pilot* system (see Annex 3).

Two special attributes called "Documentary images" and "Documentary Text" can be associated as attribute of each object.

In particular special objects called "Information points" can be registered in the database located in the geographic area in which documentation is available. When the image-interpreter needs to know this information he clicks on the point and a special image selector shows which data are available. Clicking on the selector the image is enlarged to full screen.

The figure 19 shows the consultation of a photo collected on the ground; the figure 20 instead shows a quick look of the aerial photos available. To save time the aerial photos can be scanned at low resolution (for mass memory economy) and not georeferenced but only geo-located.

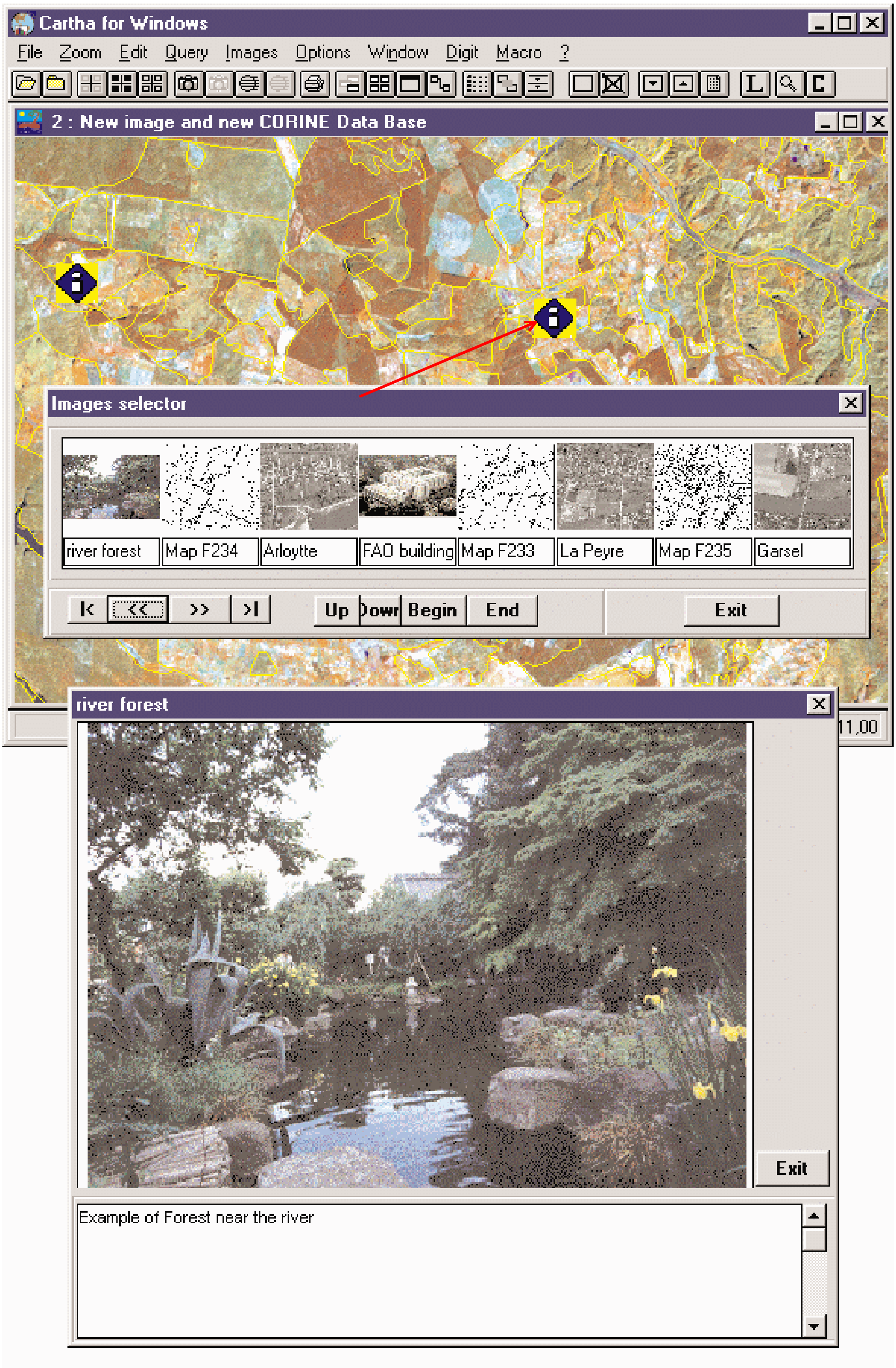


Figure 19 - Consultation of a photo collected on the ground

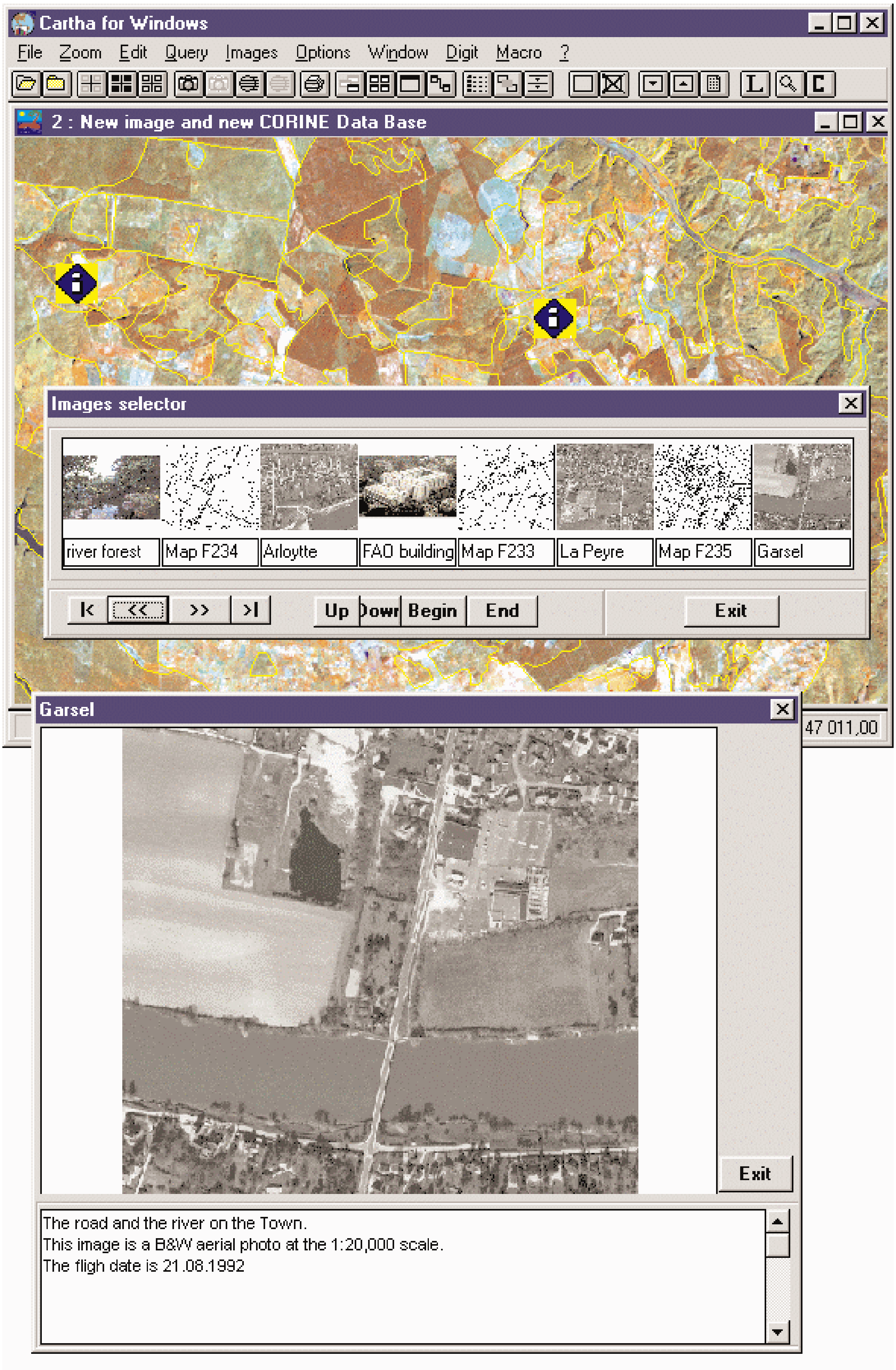


Figure 20 - Consultation of an aerial photo

4. UPDATING METHODOLOGY

4.1 General overview

In the creation phase two different approaches were followed to organise national work:

- centralised,
- regional teams subdivision.

The updating can be carried out by teams who were not involved in the creation.

Both creation and updating require ancillary information and expertise available locally in each country.

The regional solution has some advantages. For example ancillary data are available in the updating phase, may be without the need of digitising, the same image-interpreters responsible of creation could also be used for updating, other data useful for updating could be easily found, ...

In any case the methodology should be unique to guarantee and facilitate the integration of the updating land cover version at National and European level.

To apply the methodology, the availability of a dedicated, easy to use and inexpensive system should be guaranteed to all teams.

The organisational scenarios described here contain some possibilities that should be adapted according to each country's solution.

4.1.1 Specific problems related to the subdivision of the work using regional teams

Both the intellectual property of the databases and the responsibility for the integration of the updated databases are extremely relevant, not only because image-interpreters with incomparable reference levels can be used, but also because the geographical division of a country into several parts is involved.

It also has to be highlighted that, when assignments for administrative units are concerned, the tricky situations illustrated in figure 21 could occur at the moment of integration.

In this example 3 possible cases are illustrated.

Case 1) It may be interpreted either as an error in assignment of one of the two classes, or as a correct situation, where the boundary corresponds to a permanent feature of the landscape. In any case it seems difficult to believe that the boundaries of **C**,**B** correspond to the administrative limits on the left whilst on the right an exact correspondence of **B**,**C**,**B** happens (even though that is possible; see case 3). Additional analysis is recommended.

Case 2) Normal situation: the final result should be a single polygon.

Case 3) In this case either an error (or a different interpretation) in assigning a code to one polygon occurred, or the administrative limit corresponds to a physical limit (e.g., a river or a road that bounds two regions) and the code attribution is correct. When different image interpretations occur, a possible solution consists in a new definition of the boundary.

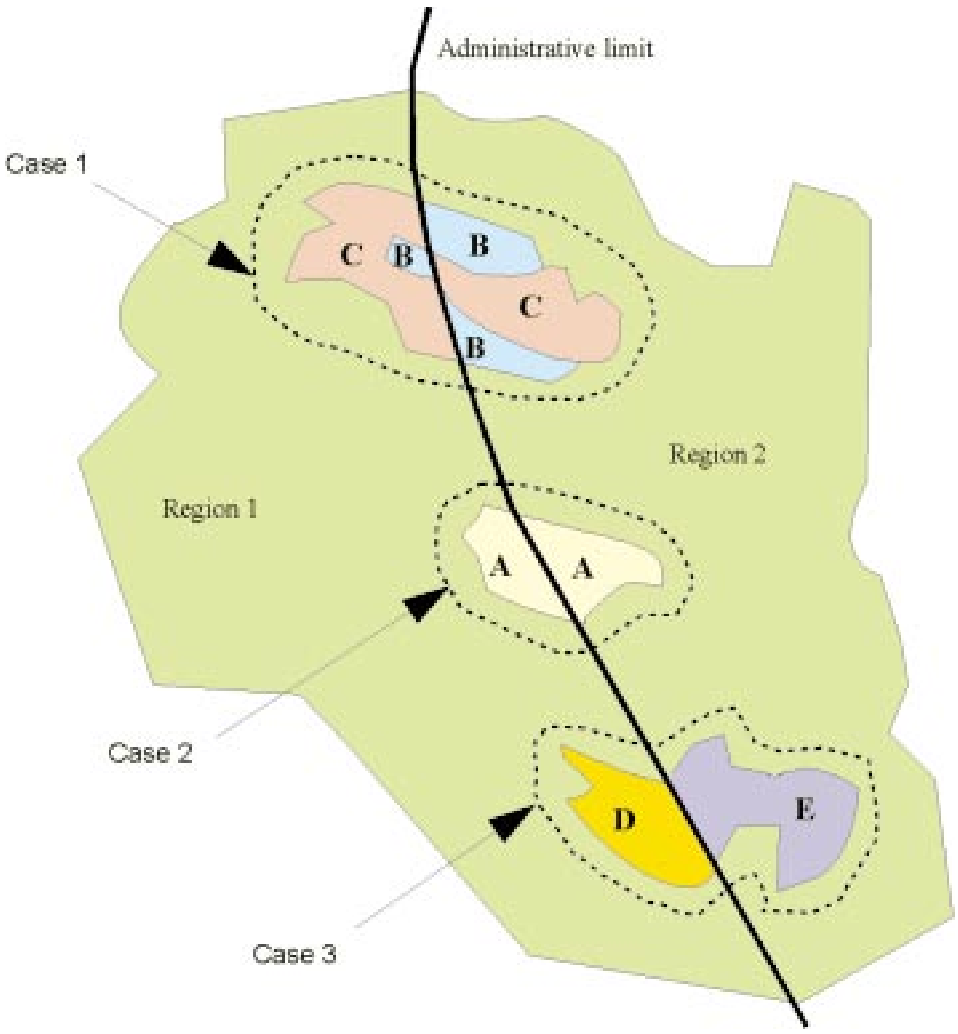


Figure 21 - Merge two regions

> *Postulate 6 - Coding for fragmented territory*
>
> When a fragmentation of the territory is concerned, a specific integration of the different parts analysed has to be planned to solve all problems concerning double coding.

One of the main relevant problems concerning a regional organisation for creation and updating of the CORINE land cover database is the training of the technical staff charged to execute the project.

As has been underlined many times, the technical level of the image-interpreters is very important for the correct application of the methodology. Distributing the work for one country to several teams may cause problems related to different levels of accuracy for the final national database. Nevertheless this solution has the great advantage to benefit from the supplementary additional local databases and from the good knowledge of its own territory.

> *Postulate 7 - Training for fragmented territory*
>
> When a regional solution is adopted, a person responsible for training, co-ordination, supervision and data integration at national level, must be selected.

4.2 Work organisation

4.2.1 Work Planning

The updating methodology is oriented towards Computer Aided Image Interpretation.

Therefore a considerable part of the time will be spent in analysing and eventually modifying the data.

It is necessary to optimise the preliminary work of data collection and preparation in order to provide the image-interpreter with all materials useful for analysis, and in order to provide him with data standardised in a consistent manner for the successive work.

Considering that the image-interpreter must distinguish between Change and Error, he will need the old database and the old images used for the original version of the CORINE Land Cover map. In addition, to fully understand the shape and the code of some polygons which are difficult to identify and/or to delineate using solely the satellite images, he should also have access to the ancillary data used during creation.

Postulate 8 - Material necessary for updating

The old images must be at the disposal of the image-interpreter during updating. If possible, old ancillary data (when previously used) must be also at the disposable (metadata in numeric form are highly recommended). When old images are not available ancillary data become necessary.

Unfortunately, information (metadata) about ancillary data used in creation (aerial photos, statistics, maps,..) is not always stored and teams charged of the updating work could be different from those who undertook the creation.

As a consequence, the retrieval of the ancillary information used in creation could be very difficult or too expensive. The methodology doesn't require these data as strictly necessary but suggests to use them when they are easily available. However, the old satellite images and the old database must be transformed in a suitable way for the updating process because the methodology (Multiwindows oriented) requires that these data satisfy some constraints in terms of precision.

The preliminary work consists of the following steps concerning data:

- data collection,
- data cataloguing,
- data standardisation,
- data correction,
- data distribution.

In addition to data preparation some other activities must be performed, including:

- staff selection,
- staff training,
- work distribution..

Finally a team leader must be identified and the data merging at the end of updating must be correctly planned. A possible planning schema is illustrated in figure 22.

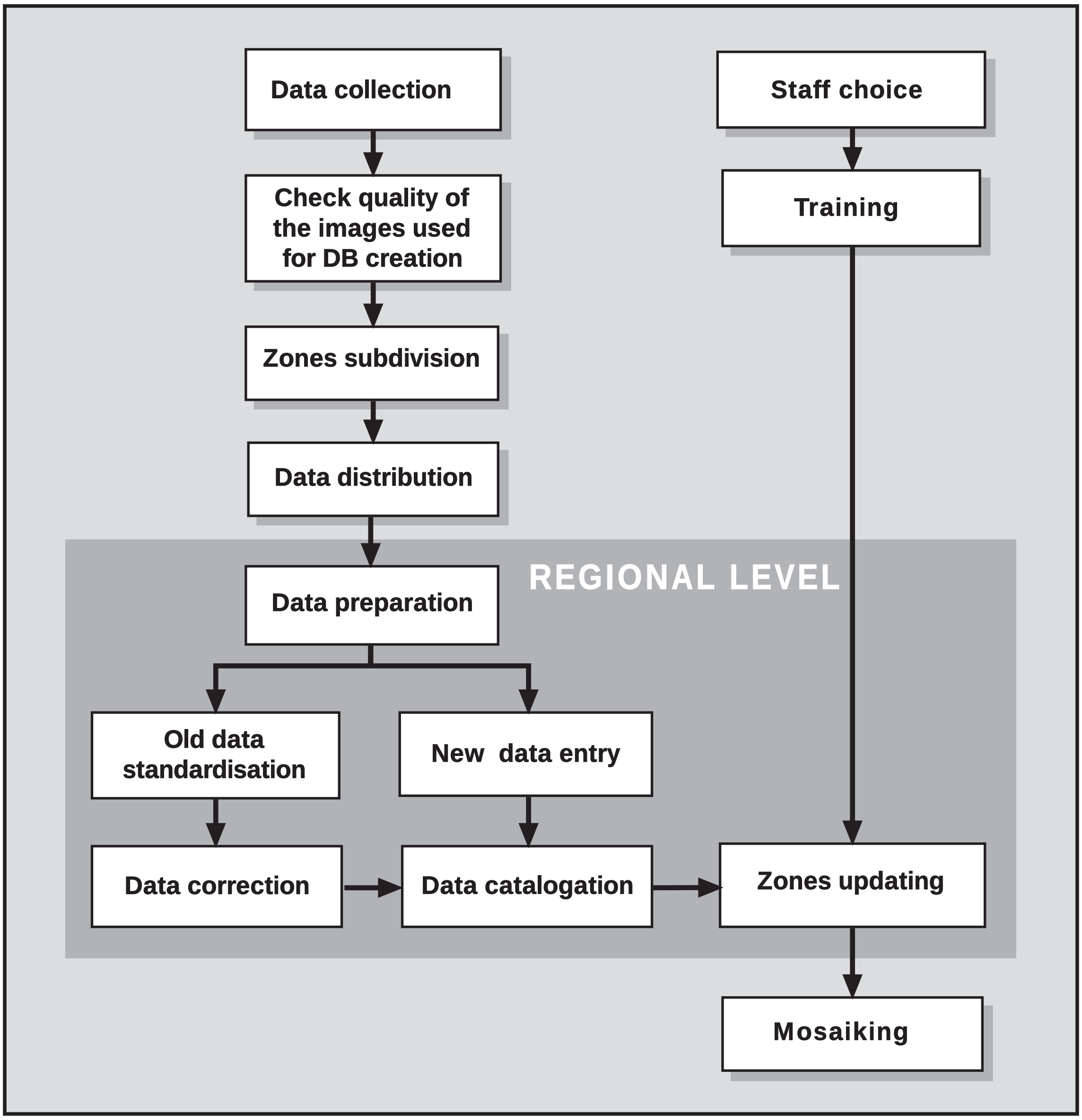


Figure 22 - Work Planning

4.2.1.1 Staff selection

The criteria for staff selection are the responsibility of each country. The selected staff must guarantee the correct execution of the work, in particular, for those aspects concerning image-interpretation.

The choice of the same staff involved on the past for the creation of the CORINE Land Cover is highly recommended but not always possible. This choice should avoid the loss of homogeneity in the interpretation of some heterogeneous and complex classes, and should guarantee the use of the same ancillary data utilised in the previous work. In fact, without these data the interpretation can differ between different image-interpreters (due to the lack of important information). Also, unfortunately, the record of the data previously used (in addition to the satellite images) and the history of the creation process (steps of image-interpretation, ground control points, ground check, ...) are not always available.

Finally, the geographic location of the staff can be considered an additional important advantage because a strong knowledge of the territory to be mapped increases the quality of the image-interpretation and helps to identify real changes that have occurred since the original database creation.

4.2.1.2 Training

Training is an important phase for the correct execution of the project at National and European level to keep the homogeneity of the database. The updating methodology is more restrictive. The use of rules and standards driven by the software will guarantee to better respect them.

In fact in the creation, the respect of some rules was sometimes neglected (for example collection of the GCPs used for geometric correction of the images, use of hydrographic film, precision and tolerance standards, small cartographic unit management, use of aerial photos, ...). The information became numeric only at the end of the image-interpretation process and often no revision by the image-interpreter was scheduled for the digitised data. As a consequence, polygons smaller than the minimum cartographic unit are present and some non-existing codes (or null codes) remain in the database.

In the updating methodology the information is numeric in every phase of the work so all rules concerning quantitative and qualitative aspects must be directly introduced in the GIS system used to perform the work (for example scale of work, precision, tolerance, minimum cartographic unit, nomenclature, ...). The image-interpreter must know about it.

Left to the image-interpreter are the code attribution and boundary identification and delineation. In fact an exchange of codes (for example 311 instead of 312) cannot be automatically detected (unless to use additional automatic procedures for polygons classification/validation or for change detection).

These considerations justify the importance of correct training in order to provide the image-interpreter with all the techniques and rules for his work. Image-interpreters are not traditionally or necessarily used to computer aided work; as a consequence during the training a considerable effort must be done to familiarise them with the additional opportunities of this technology compared to the traditional one, in particular the GIS, database management and cartographic tools.

4.2.1.3 Criteria for work subdivision for several staff

In some cases the work must be subdivided for simultaneous staff working.

Method 1 - How to subdivide the work

When several teams are involved the following criteria must be adopted:

- the work must be divided in the minimum number of contiguous zones ,
- the length of the boundaries between the zones for different teams must be minimised,
- interpretation must be extended in the contiguous regions (a distance of 1 km from the region boundary is required),
- stable limits for region subdivision must be chosen (for example administrative limits) and distributed to all the team in numeric form,
- the staff must be selected according to their knowledge of the available zones and their technical capabilities,
- if the work is subdivided by sheets, the maximum number of contiguous sheets should be attributed to the same interpreters.

Figure 23 - Splitting the work in zones

4.2.2 Data collection

The data collection phase is a very important preliminary activity in which the project manager is charged to plan the collection of all useful and available information related to the project. A particular emphasis must be placed on the collection of all documents used in the past for the CORINE Land Cover database creation and of all new documents available now to help the updating process (new photos, statistics, new maps, ...).

> *Postulate 9 - Old satellite images*
>
> The satellite images used for creation must be identified and must be collected in digital form.

Before proceeding with the data cataloguing and distribution two activities must be executed: data standardisation and data correction.

4.2.3 Data standardisation

In this phase the data must be standardised according to the technical specification of the GIS system that will be used for updating.

In particular the old database must be imported and the images must be transformed in a format suitable to be managed by the GIS.

The present structure of the CORINE database is influenced by the choice of ARC INFO Sw used to manage the data. The aspect to be discussed here concerns the suggested format adopted for import/export of the data of CORINE Land Cover database toward the GIS system used for updating.

ARC INFO offers various possibilities to export data in different formats (ARCDIME, ARCDXF, ARCDLG, ARCMOSS, UNGENERATE, EXPORT, ...) but not all of these maintain the full aspects of topology.

There is no way to define a unique format to be used because the best format changes according to the formats supported by the GIS to be used for updating. Nevertheless the use of ARC INFO EXPORT format is highly recommended (if possible). This format (that is a proprietary format) is supported by several GIS (normally to import the data). Alternatively, to export the data the UNGENERATE format is also a recommended solution.

> *Postulate 10 - Format for data import*
>
> The choice of the format must take into account the possibilities offered by the adopted GIS, but this choice must guarantee no loss of topology coherency.

4.2.4 Data correction

When data don’t satisfy the required standard of precision they must be corrected.

The data that can be corrected are: old images and the old database. The proposed standard methods to evaluate precision and to make corrections are described in the chapter “preliminary operations” .

4.2.5 Data organisation (sheets and zones)

At this point all data are verified and eventually corrected. As a consequence the old information is ready to be used. Before starting the process of subdivision of the work, some additional information must be introduced in the system concerning sheet subdivision and administrative boundaries (if work subdivision is planned).

The sheet is a very important component for project management, whilst the administrative limits are a useful tool for work subdivision.

4.2.6 Data cataloguing

All necessary data must be catalogued before starting the process of distribution to the several staffs. In particular, for data in non numeric form it is fundamental to record their characteristics and the final owner in order to avoid the loss of precious material (for example aerial photos).

4.2.6.1 Data subdivision (sheets and zones)

During this phase the project manager must organise the work subdivision, selecting the zones to be attributed to the different staff and preparing the data to be sent. Sheet limits must be digitised if not already available in numeric form.

It is useful to remember here that the “sheets or zones” subdivision reflects the approach selected for Creation.

In fact, the need for reliability and homogeneity pushed the CORINE Land Cover staff charged with the database maintenance to store ancillary information (year of production, estimated precision, ...) for each sheet or zone.

The “zones” approach was adopted for some countries where the work subdivision was done according to administrative criteria. For example in Italy each Region worked separately and as a consequence the sheet approach was unfeasible as illustrated in Figure 24. In that case the administrative limits of the “Provinces” were chosen as subzones (comparable to sheets) to subdivide the Region.

If only one team will be charged with executing the project then this phase is not really significant. But where more than one team is involved this is considered an important phase. The Table 3 shows in which way the data must be distributed to the different staff. It can be easily observed that some data will be completely accessible by several teams (sheets and zones subdivision), some data are partially accessible and finally, some of the data will be available for one team only (aerial photos).

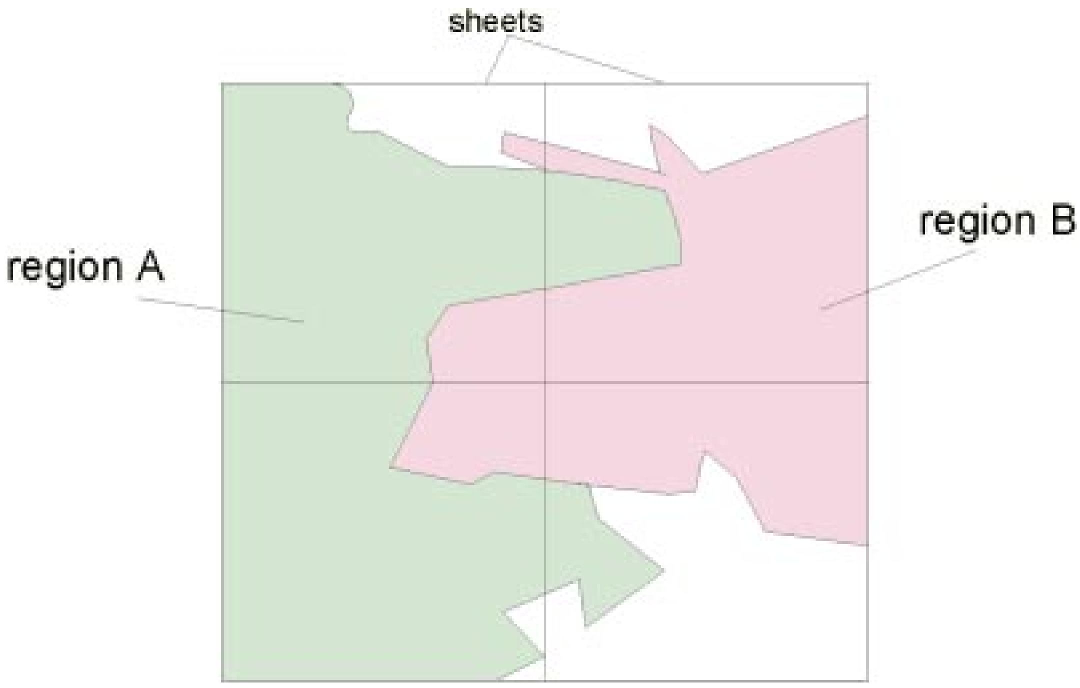


Figure 24 - Zones and Sheets for work subdivision

Table 3 - Distribution of the data

Data type	**Common to several teams**
Old aerial photos	no
Old Thematic Maps sheets	partially
Old images	common / partially
Old database	common / partially
New aerial photos	no
New Thematic Maps sheets	partially
New images	common / partially
New statistics	common
Sheets subdivision limits	common
Zones subdivision limits	common
Database structure	common (*)
Data catalogue	common

(*) <u>Using a common database structure and parameter files (including tolerance, precision, definition, ...) the homogeneity of the final database is automatically guaranteed.</u>

4.3 Preliminary operations

4.3.1 Checking the geometric quality of the original data (database and images)

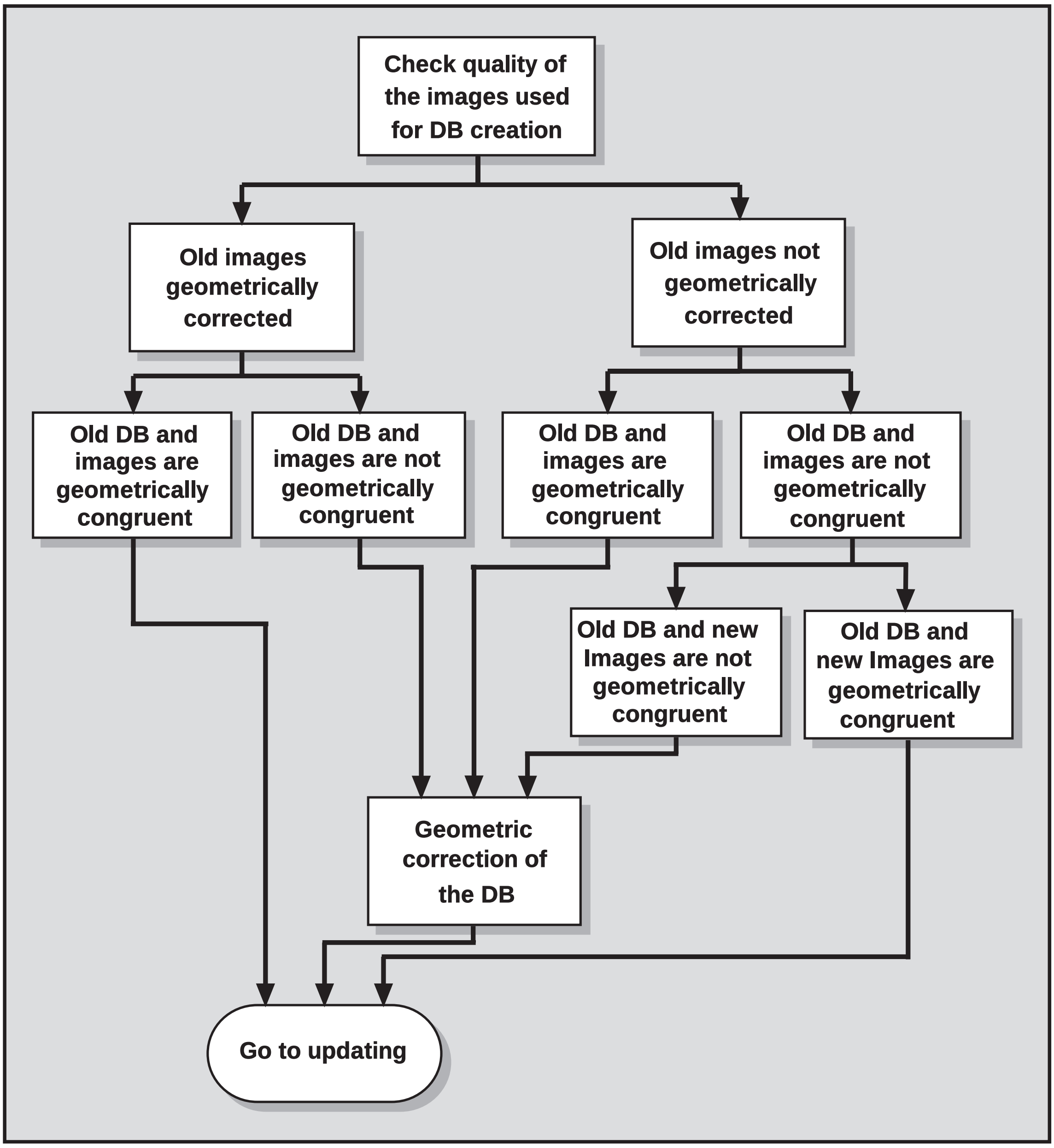


Figure 25 - How to verify the geometric quality of old data

> *Postulate 11 - Geometric correction of old images*
>
> The images utilised for the creation of the database should be used for updating in numeric form. In case of bad geometric quality these images could be corrected in a fast way (4 GCPs) to facilitate the process of image-interpretation in a Multiwindows environment. <u>A best correction is not strictly necessary</u> for the purpose of updating (unless the user intends to partially adopt automatic procedures for change detection) and it could be expensive to re-process all images used for the creation .

Method 2 - How to verify the geometric quality of the old images

To verify the geometric quality of the old images, <u>minimum four Ground Control Points must be identified</u> for each sheet on the image and on the reference map (or on new georeferenced image already verified). The maximum error of the single point cannot be over 200 m, and the average error must be less or equal to 100 m.

Postulate 12 - Geometric correction of the old database

The old database must be corrected when it is not congruent with the new images and reference maps (to be used for updating). The correction must be done <u>before</u> starting the updating process. The average required precision of the corrected database must be less of the defined acceptable error (100 m) . The geometric precision must be evaluated for each sheet.

Method 3 - How to verify the geometric quality of the old database

To verify the geometric quality of the old database, the user <u>must utilise a corrected image</u> (this old or new image has been verified with the reference map to be used for updating). The 1.5 - 2 pixels of RMS must be respected for the new images to be used. The database is overlaid on the image, with a grid (with a cell of 10x10 km). The user must check for the nearest point to the corner of each cell the distance between the point of the polygon and the similar point on the image (see figure 26). The average difference of all points contained in a single sheet must be less than 100 m. If it isn't true the database for that sheet must be corrected.

<u>WARNING</u>
When using new images the user must pay attention to verify if the eventual displacement of the observed point is real or if it is caused by a change on the landscape. In first case the point can be considered for the geometric quality evaluation. If no points are available (in all the corners of the grid for each sheet), the sheet can be considered completely changed and no correction is necessary.

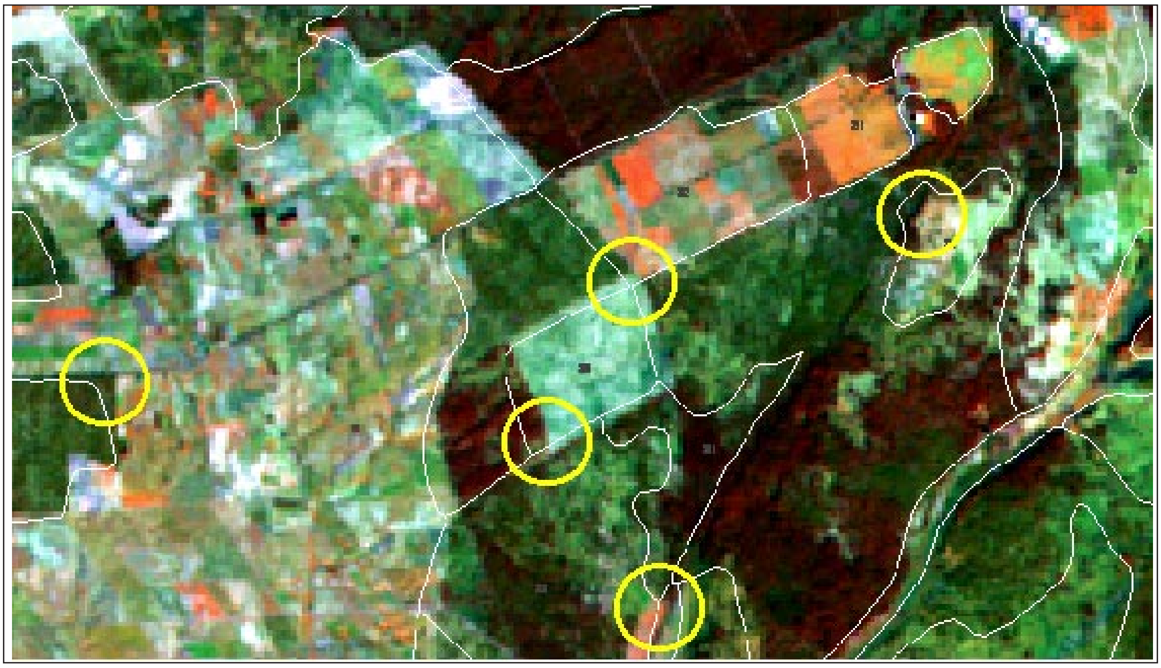


Figure 26 - Example of points to be selected to verify the geometric quality of the old database

4.3.2 Geometric correction of the original database

If the geometric quality of some sheets of the old database doesn't permit its direct use for updating, a preliminary raw geometric correction will be necessary.

The following method must be adopted.

Method 4 - How to correct the geometry of the old database

a) Overlap the database to old or new images. The old or new image must be geometrically congruent with the reference map.

b) Identify similar points. A similar point is a point that is easily recognisable on the two sources: for example an intersection between two polygons, a particular shape, .(see figure 27, figure 28)

c) Using the pairs of co-ordinates of similar points (acquired from the old database and from the reference document) the existing errors (maximum and mean) must be verified. If these errors are higher than the acceptable threshold (respectively 200 m and 100 m), the transform coefficients for geometric correction must be evaluated using the least square estimation. The polynomial degree will be selected according to the number of available points (a minimum of 3 is required). The polynomial degree must not be higher than 2 (to avoid unpredictable modifications).

d) All sheets must be considered before starting correction. If no sheet requires correction a direct copy of the old database must be produced for the successive updating (see figure 29) and this process ends here. Vice versa, all sheets ready to be used must be extracted and copied to the old corrected database. For the sheets to be corrected the user must follow the steps given below.

e) The database objects contained in the sheet to be corrected must be extracted from the database.

f) The co-ordinates of the objects extracted must be transformed using the coefficients calculated for the corresponding sheet.

g) The new corrected sheet must be added to the old corrected database (see chapter "database management").

h) The process iterates until the verification of the last sheet to be updated.

i) At the end of correction process some differences can be encountered on the sheets boundaries. The user must check these differences using automatic procedures (based on a fix clean tolerance of 100 m). If some differences cannot be solved with this tolerance the user must manually correct them.

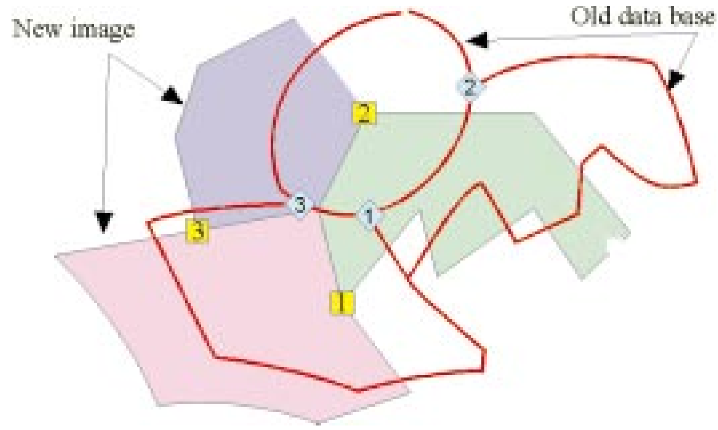


Figure 27 - How to recognise similar points (based on polygons intersections)

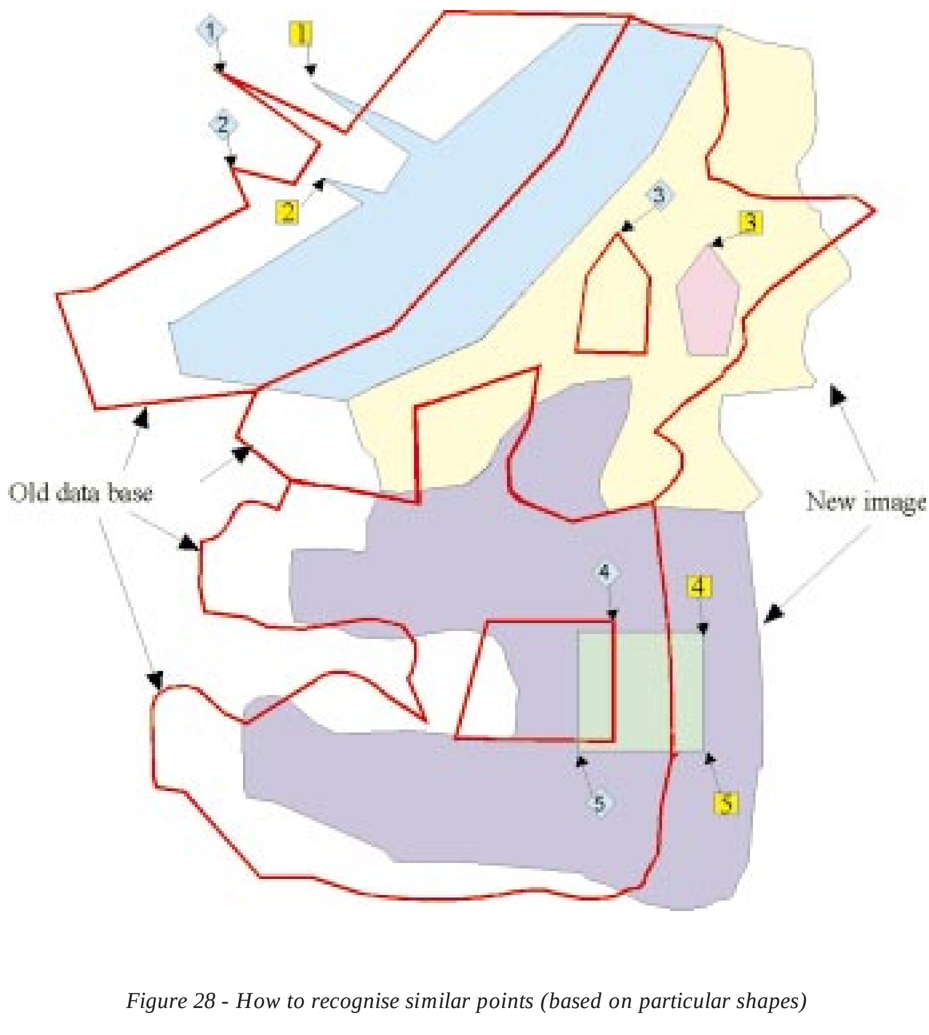


Figure 28 - How to recognise similar points (based on particular shapes)

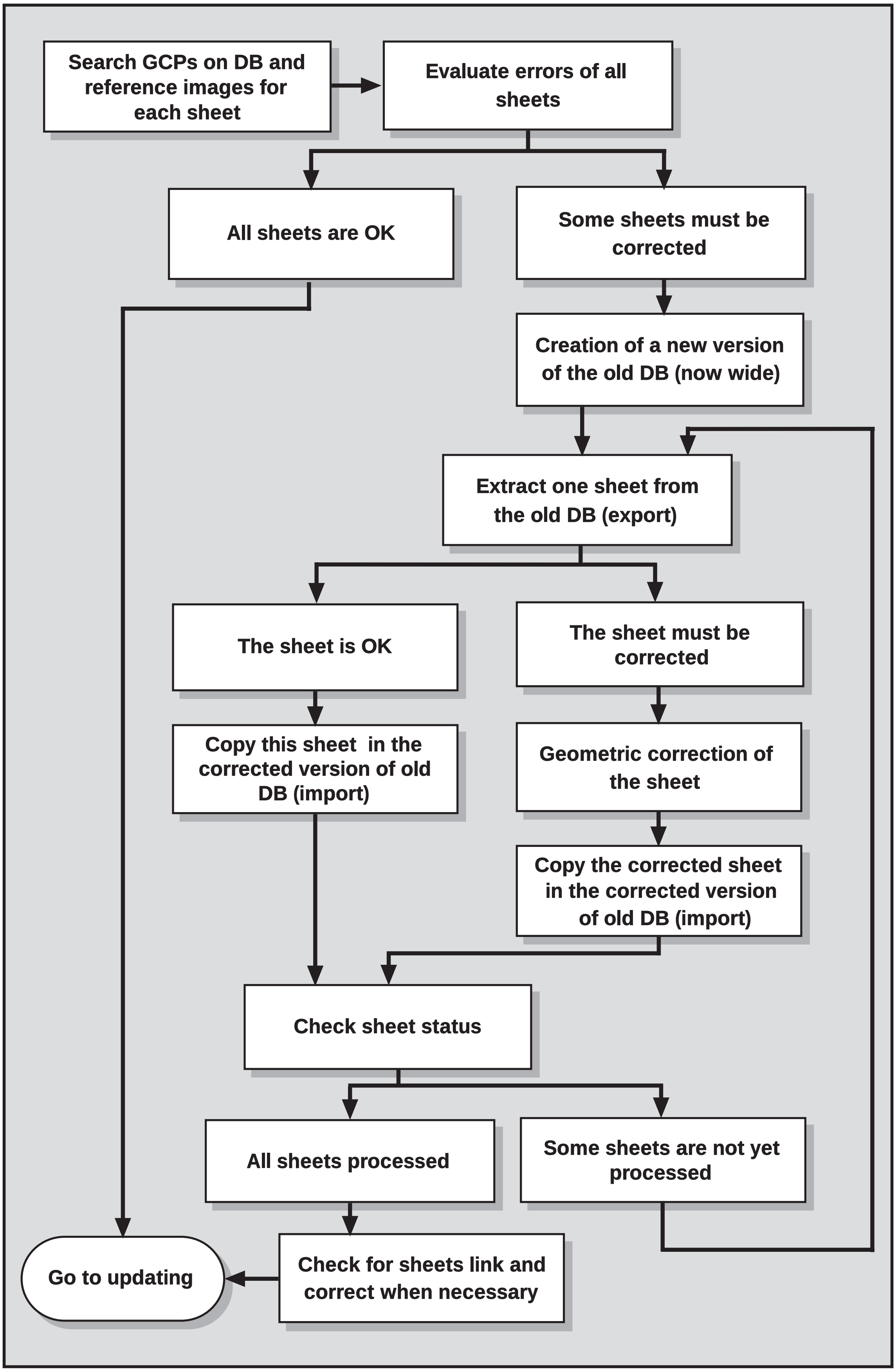


Figure 29 - Geometric correction of the old database

4.4 Changes detection

4.4.1 Image interpretation

The image-interpreter must operate in a multiwindows environment with at least two windows. In the first window the old image (used for creation) is shown with the overlapping of the old database. In the second window the new image is displayed with the database to be updated (see figure 30).

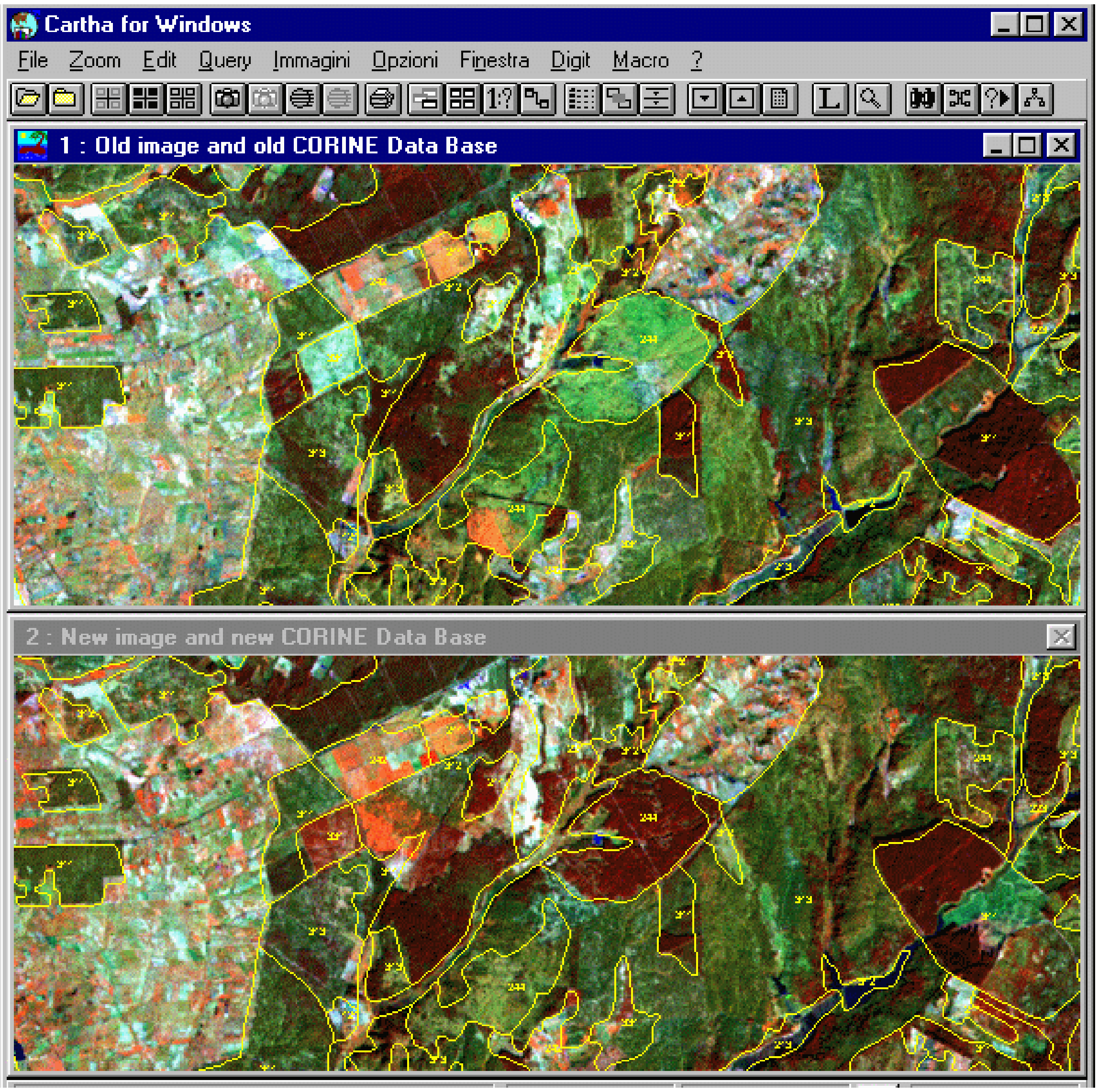


Figure 30 - Old and new images and the database displayed in two different windows at 1:100,000 scale

<u>The suggested scale for a preliminary analysis is 1:100,000</u>. The image-interpreter is thus able to understand if something of significant importance has happened. When necessary he can mark all polygons to be analyzed with the appropriate code. <u>The analysis must be made for a single sheet before passing to the successive step</u>.

In the second step the image-interpreter selects the 1:50,000 scale and proceeds systematically to verify local changes or residual errors (geometric and/or thematic). The polygons previously marked must be temporarily colored in a different way to alert the image-interpreter. The 1:50,000 scale permits a better appreciation of geometric errors and guarantees the visibility of codes and images also for small areas (see figure 31).

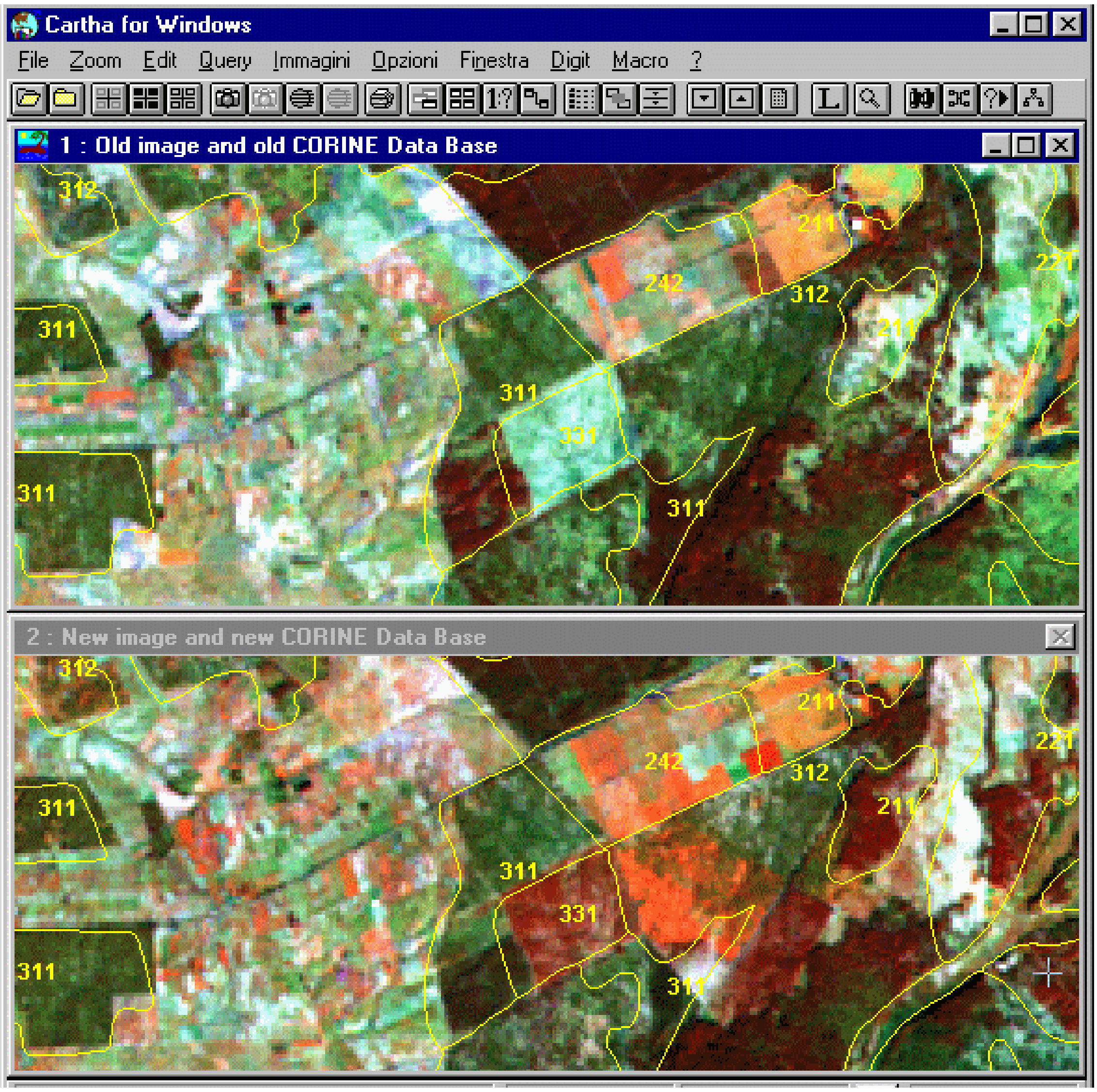


Figure 31 - Old and new images and DB displayed at 1:50,000 scale

The multiwindows environment is very important. Some polygons can be mis-interpreted when only using of the current image. A land cover change sometimes doesn't correspond to a CORINE land cover class change and the verification with the old image can clarify.

In the example shown in figure 32, inside the polygon classed as 311 some areas seem un-forested now. Looking at the old image it can be observed that the same situation occurred in the past. In fact that area is an Eucalyptus forest, subjected to cuts and new plantations; as a consequence the areas that seem not forested are new young plantations and there aren't real changes on land cover.

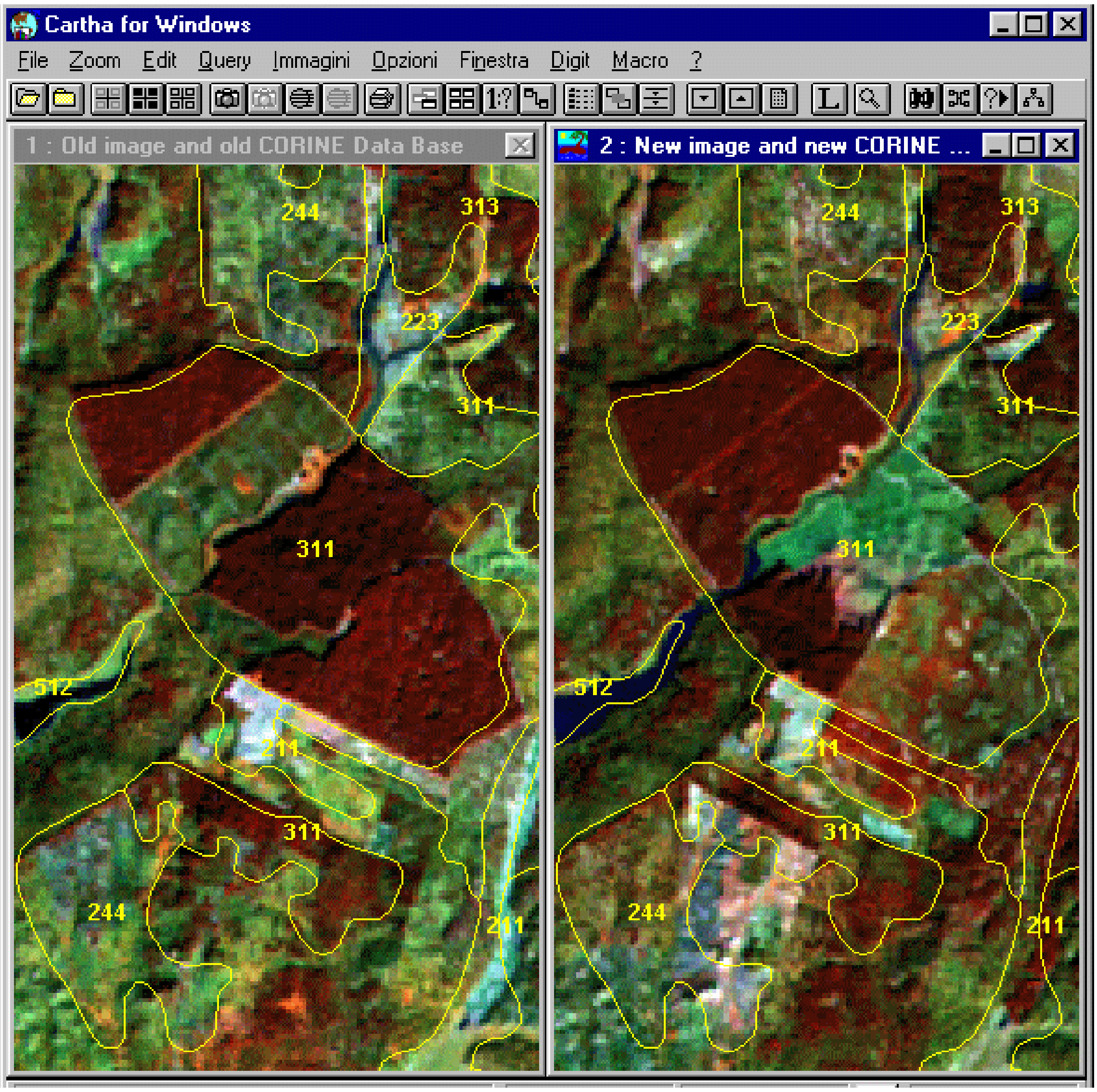


Figure 32 - CORINE unit with not homogenous spectral aspect (311)

The way to delineate a boundary of a land cover mapping unit is often influenced by the image-interpreter's style. For complex classes this is even more relevant.

The multiwindows environment permits to see how this delimitation was undertaken in the past, and if there is not a concrete reason to change it is better to maintain that choice. If old images are not available multiwindows benefits strongly decrease.

Other advantage of the multiwindows environment is to maintain a global view (at 1:100,000 scale) together with a detailed one (1:25,000-1:50,000 scale) looking at the same time for a particular feature without loss of an holistic view of the problem (see figure 33).

Postulate 13 - Use of new and old image for updating during image-interpretation

During image-interpretation the user must check the new and the old image (used for creation) in every phase of the analysis. The use of a multiwindows environment is recommended. The use of a single image (full screen) is suggested only during the geometric updating of a polygon.

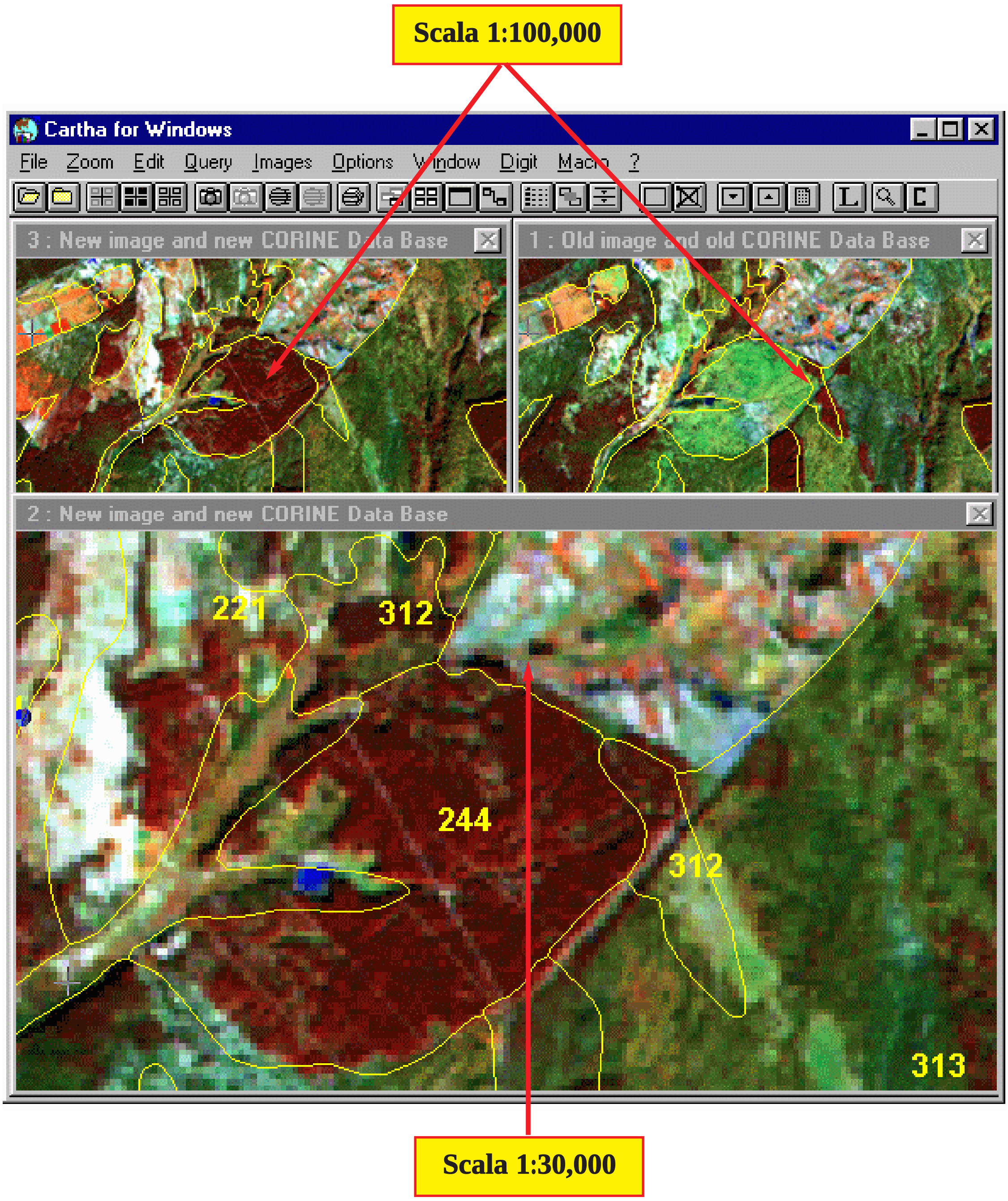


Figure 33 - Multiscale multiwindows analysis

A big advantage of computer aided interpretation is in the possibility to enhance the quality of the image with the best choice for a selected theme. In other terms the image-interpreter can adapt the image display to suit the limitations of the human eyes or of the image itself. As an example additional image processing is indispensable to identify land cover classes of wetlands. To do this the image-interpreter can perform contrast stretch operations, filtering, color composition (selecting different spectral bands), ...

The advantages of these possibilities are evident. The two main disadvantages are: an increase in the costs and a possible negative influence on the image-interpretation. The increasing cost is related to the time consumed to perform these operations during the image-interpretation session. There is not a precise rule to decide if these operations must be done or not. Normally the loss of time of the image-interpreter to analyse a not appropriate image compares the lost of time to ameliorate it.

Method 5 - How to use image processing functions

If some particular processing is considered a real advantage for the updating process (increasing the speed and certitude of the interpretation) it must be preferable to do it at the beginning of work. A new set of pre-processed images (for example using NDVI, PCA, filters, …) must be produced and associated to a window. This window is normally iconised but can be maximised every time that the image-interpreter wishes. This strategy avoids to stop the process of image-interpretation without limiting the system capabilities.

The possible negative influence on the image-interpretation is a more delicate point: an image-interpreter expert in computer aided interpretation likes to have the best image every time that the dynamic of colours of the area changes. To obtain it, he performs a contrast stretch operation to enhance image quality. The most diffused is the Minimum-Maximum linear stretch, in which the minimum and the maximum values of the area displayed on the screen are set to the minimum and maximum values of the used display system to cover all screen dynamic. Our eyes are not able to distinguish small variations of luminosity when luminosity is high (the capacity to detect a change is proportional to $\frac{\Delta \mathbf{i}}{\mathbf{i}}$ where $\mathbf{i}$ is the luminosity).

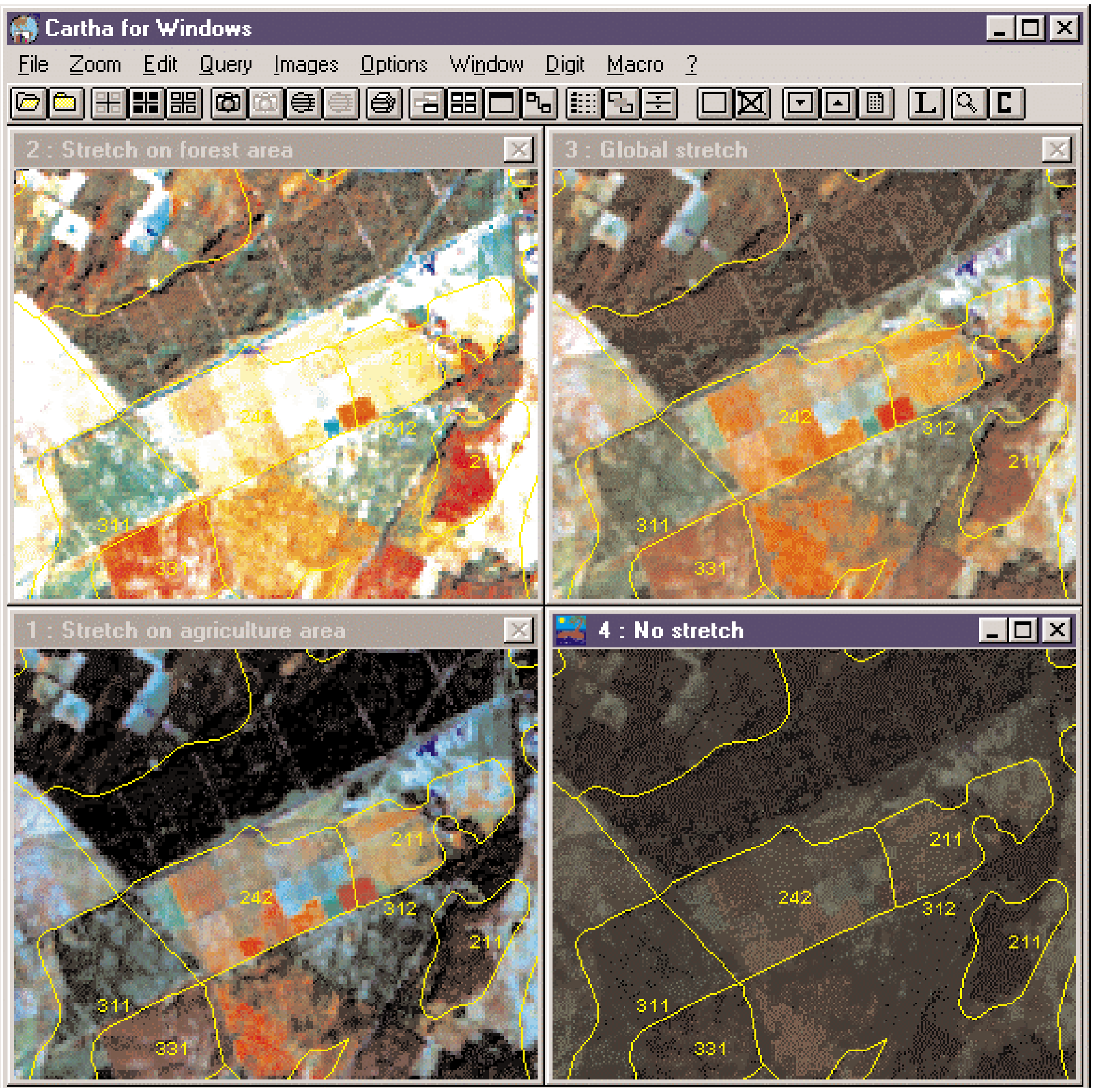


Figure 34 - Different types of stretch

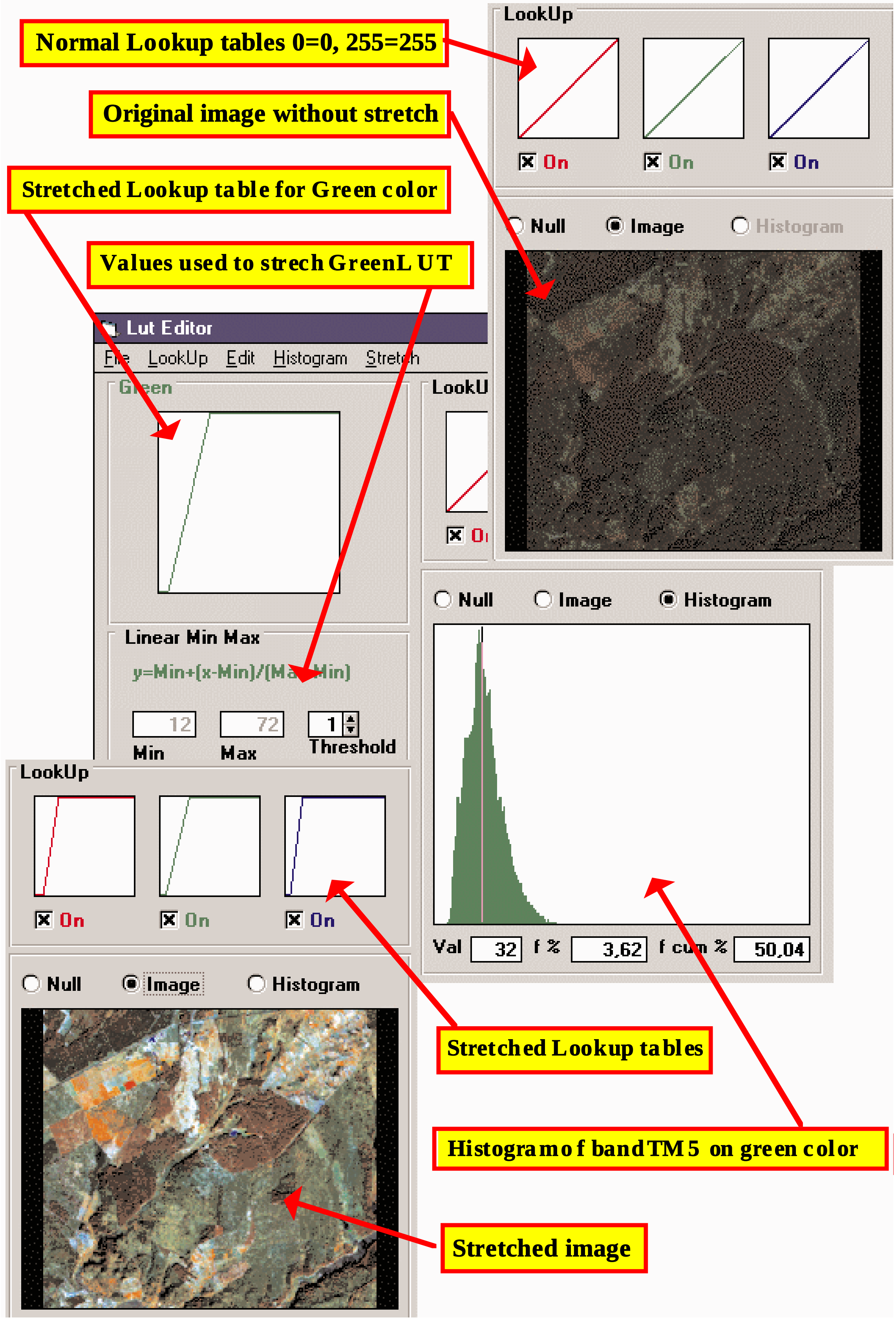


Figure 35 - Contrast stretching

The risk is a loss of homogeneity for some classes (normally the dark and light classes). In fact for the light classes (snow, sand, urban areas, ..) the tendency is to over-evaluate them whilst for dark classes the risk is to not disaggregate them. A typical example are the classes 4.2.1 "Salt marshes" and 4.2.3 "Intertidal flats" that without using an appropriate stretch can be classified as 5.1.1 "Water courses". Another risk concerns the use of image-interpretation keys. During the training phase the image-interpreter must study the typical "color" of some classes in the date of the available used image. If the color changes, the interpretation key must also be redefined. Therefore the contrast stretch possibilities are a very important tool for this work, but the image-interpreter must use them with some precautions (see figure 34).

The best way to manage this possibility is to build a set of look up tables (LUT) to be used for the various classes (water, forest, ...) and a standard LUT to be used for global overview.

The LUT is a table to be used to transform each original value of the pixels in a new value to best display the image. For example if the values of the whole image range from 30 to 130, with an appropriate LUT we can stretch the value 30 to the miminum value (0) of display and the value 130 to the maximum one (255) (see figure 35).

Method 6 - How to use dynamic contrast stretch

- The use of contrast stretch is recommended to improve the image-interpretation quality.
- It is important to define "global" or standard LUTs to be used for training of the interpretation keys and for normal interpretation.
- The image-interpreter must use these LUTs at 1:100,000 scale and at successive scale before making local contrast enhancement of the image.
- The use of a new contrast stretch must be limited to ambiguous cases only.
- A considerable quantity of time must be spent at the beginning of the work to look for the "global" look up table that best represents and distinguishes the present themes.

4.4.2 Scales of work

Postulate 14 - Scales of work

During image-interpretation the user is free to choose the best scale to analyse and study data and images but he must take into account the following rules or suggestions:

RULE : during the digitisation a fixed screen scale of 1:50,000 must be adopted.

RULE: preliminary analysis of the images and databases must be done at 1:100,000 scale.

SUGGESTION: detailed analysis of the images can be done at any possible scale but it is highly recommended to avoid scale larger than 1: 25,000.

4.4.3 How to detect changes

There are two possible ways to detect changes: manual and semi-automatic.

4.4.3.1 Manual interpretation

The manual way consists of the process of image-interpretation in which the image-interpreter observes that the old polygon boundary do not correspond to the limits visible on the new image, or he recognizes that the thematic class of the whole polygon is not the same as the old one.

Method 7 - How to detect geometric changes

The following rules must be adopted:

1) Identify the boundaries that don't correspond to the new image.
2) Check if the difference is over the defined threshold. If not pass to a new boundary.
3) Check if this difference is caused by an error or by a change (optional).
4) Understand the thematic cause of this difference.
5) In case of doubts look for ancillary information.
6) Proceed to make the modification to the database.

Point 4) is important because some class changes can be considered as not really possible. As far as the class change is concerned, it is possible to determine the variation possibilities; for instance, the transformation of a continuous urban land into a coniferous forest is virtually impossible from one year to the following one. It is thus possible to define a scattered matrix of possible events (see table 4) or as matrix of transition probabilities (see table 5).

Table 4 - Matrix of possible events

Original Class	**New possible classes in order of probability**				
111					
112	111				
121	112	111			
122	112	111	131		
......	......	......	......		
211	212	221	222	241	
......	......	......	......	......	
311	321	323	324	334	244
......	......	......	......	......	......

Table 5 - Matrix of possible transitions

Original Class	**New possible classes in order of probability**															
	111	**112**	**121**	**122**	**131**	**211**	**212**	**221**	**222**	**241**	**244**	**311**	**321**	**323**	**324**	**334**
111	100%															
112	50%	50%														
121	5%	25%	70%													
122	2%	7%		90%	1%											
....																
211						50%	20%	8%	8%	4%						
....																
311											2%	60%	20%	15%	10%	3%
....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....

Both tables are only given as examples: the possible transactions vary from one country to another. They are influenced by economic development, territorial and environmental policy of each country,....
<u>The tables can be upgraded using statistical information regarding the changes that have occurred</u> (for example in a region where the forest areas decreased there is a very low probability for each class to be transformed in forest area).

Both tables can be computerised. They provide the image-interpreter with a useful instrument for the attribution of the new class.

The use of this approach is optional but it is highly recommended to compile these tables at the beginning of the updating work on the basis of the ancillary data collected. This preliminary work is very useful to represent the current status of knowledge of the territory and to synthesise the evolution that has occurred (based on the existing documentation). At the end of the updating process it will be possible to compare the expected and the observed results.

4.4.3.2 Contribution of computer procedures for automatic change detection

There are two possible approaches:

- comparison of automatic classification of the data (at different periods),
- automatic recognition of changes in pixels contained in a single "unit" using one image.

The first approach consists mainly in a "raster analysis" of a pixel classification obtained through one of the possible algorithms to be used (supervised, unsupervised, neural network, fuzzy set, fractal, ...).

The main limit of all these systems is that they "extract" classes that can be identified only using satellite images information, referred to as "land cover spectral classes". In the CORINE nomenclature there are many classes that cannot be recognised by analysing only the spectral signature because some of them have the same spectral signature and other ones can be identified using other criteria (patter, context, shape,...). An example of the first case are the classes 5.1.1 "water courses", 5.1.2 "water bodies", 5.2.2 "estuaries", 5.2.3 "sea and ocean", ... that are physically the same entity: water. The correct classification can be achieved by looking to the context of the area or using ancillary data.

In addition, the reliability of these automatic classifiers strongly depends upon the training phase, the quality and date of images (clouds, haze, date, ..), and so on.

The raster approach can be useful only by simplifying the nomenclature to a maximum of 15-20 classes. The vectorial character of the CORINE Land cover database does match well with this kind of solution (see figure 36).

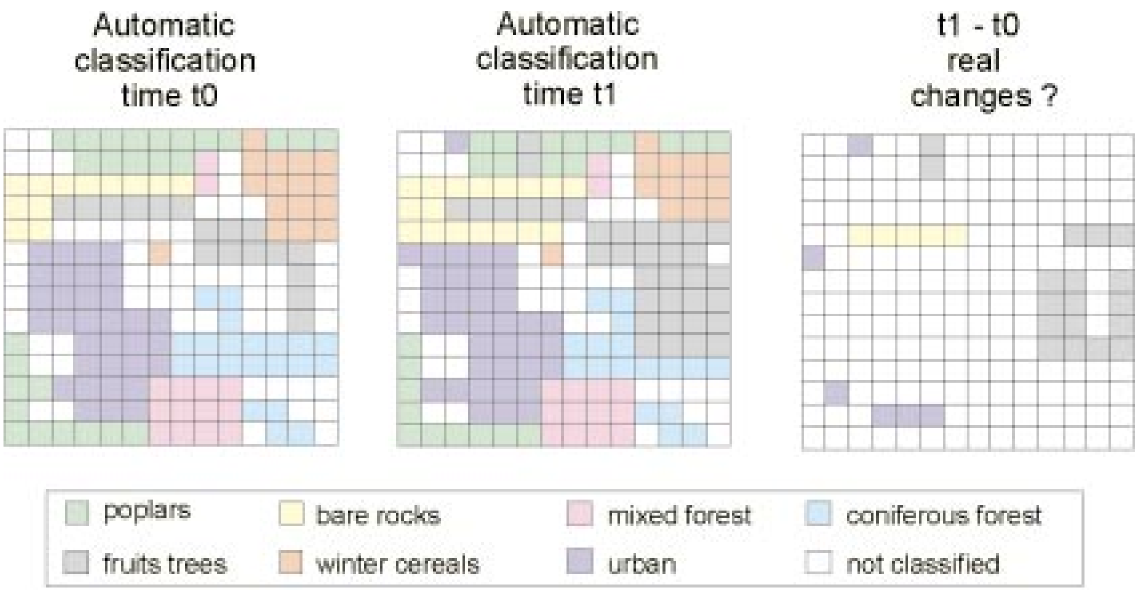


Figure 36 - Land cover change with a raster classification

An example of the second case concerns heterogeneous classes. Those classes have a spectral response strongly depending on the date of image acquisition. For example, a complex agricultural system, observed in two closely spaced dates, appears different according to the phenological calendars and the type of crops present in the area (i.e. winter or summer cereals).

The image-interpreter must thus spend a lot of time in a post-classification phase (see figure 37) consisting mainly in a process of data aggregation (pixels or small areas less than 25 ha must be included in a larger specific unit).

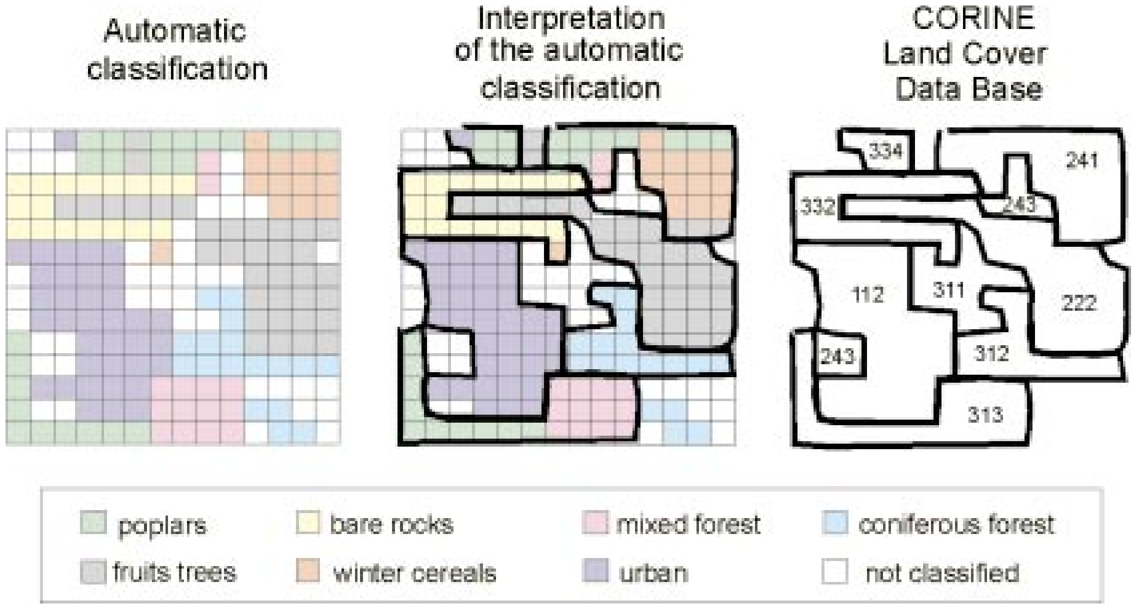


Figure 37 - Post classification of a raster classification

Other possible use of automatic procedures concerns the possibility of automatic detection of changes in pixels contained in a single "unit" (polygon oriented classifiers).

In this case every polygon must be analysed and it must be checked if:

- there are areas inside the polygon that seem anomalous,
- the boundaries must be moved for a best fitting with the image.

The first situation normally occurs when an area inside a unit is changed. If this area is spectrally different from the surrounding this area can be detected. With the term "spectral difference" is intended the collection of spectral properties of the parcel (colour, texture, ...).

This type of approach is really efficient in case of classes with uni-modal gaussian distributions (for example water, coniferous forest with exception of Larch, ...). In this case the area inside the parcel of different classes can be easily automatically detected.

It also important to underline that automatic detection doesn't mean automatic updating because as previously mentioned a cover change doesn't necessarily correspond to a CORINE land cover change (see figure 32). As a consequence the image-interpreter has the responsibility to confirm or to refuse the proposed changes.

The second approach is based on a gradient analysis of the boundaries of a polygon to identify where these boundaries best fit the image.

This approach could avoid the tedious work for a better correspondence of draft boundaries but at the current date no reliable procedures are available on the systems on the market for all classes.

Postulate 15 - Use of computer procedures for automatic change detection

Automatic procedures for change detection can preferably be used as support to the image-interpreter. After the automatic classification / detection of changes the image-interpreter must decide if the proposed data correspond to real change. In this case he can proceed to the geometric updating of the database.

4.4.4 How to update geometric changes

When a change has been detected the image-interpreter must update the geometry.

The choice of the methodology is strongly dependent on the type of data and work to be done. In fact, as illustrated in the figure 38, a change of the boundaries of the left polygon produces also a modification on the limits of the right polygon. This figure provides an example of Arc-Nodes structure. When a change occurs normally nodes move. For this reason, the “polygon digitisation” approach can result more competitive compared to arc-nodes approach.

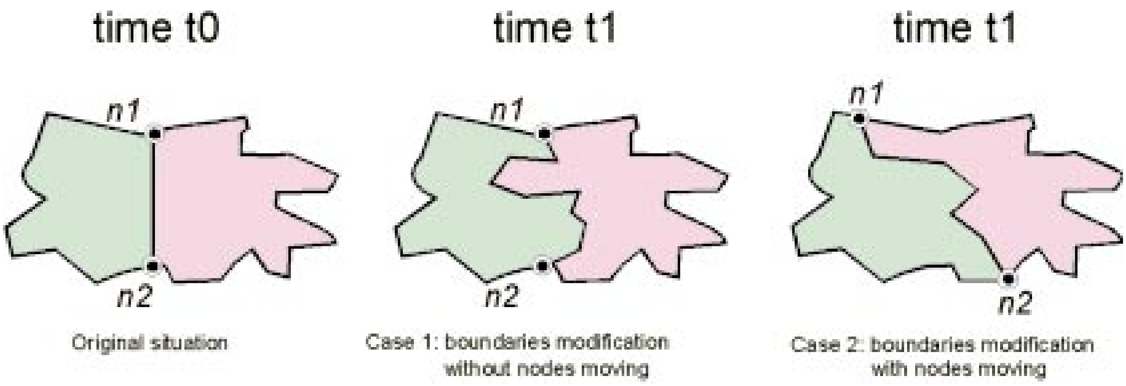


Figure 38 - Change the boundaries of a polygon

Not all GIS are able to support a Polygon Oriented Methodology. So this cannot be considered as strictly a requirement, but the use of this methodology can speed up and simplify the work of the image-interpreter in case of low rates of changes.

Instead, when many changes are expected, a “Spaghetti Oriented Approach” can be preferable as later illustrated.

4.4.4.1 Polygon Oriented Methodology

With this type of approach the image-interpreter works on a single unit and its problem is only to exactly draw it. The GIS must be able to manage the polygon entity and to safeguard the topology after a change.

The work flow is illustrated in figure 39.

The main advantage of this approach is that every polygon is considered and modified in one step only and there is no need to come back to the analysis a second time. In fact all the operations concerning geometry modification, topology rebuild (with Minimum area checking) and Code checking, are made at the same time !

The main disadvantage is when complex polygons are modified. In this case considerable time is necessary to correctly rebuild the topology. This fact can incur a loss of image-interpreter time.

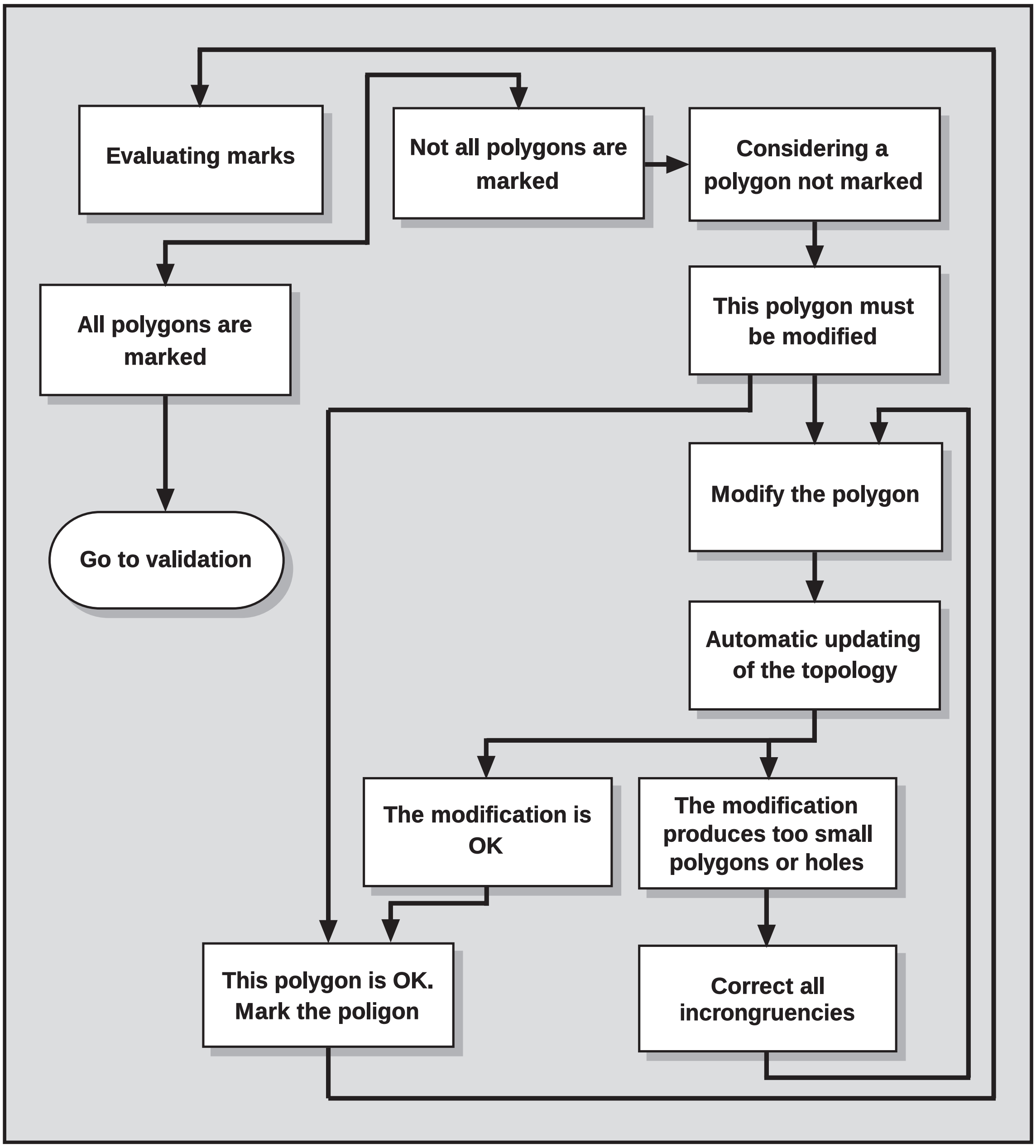


Figure 39 - Polygon Oriented methodology work flow

To implement this approach, the GIS must provide at least the following basic editing functions to permit modifications guarantying the consistency of the topology:

- create a new object,
- modify part of the boundaries of an object,
- delete an object (without leaving holes),
- split an object,
- merge a set of objects.

4.4.4.1.1 CREATE A NEW OBJECT

The creation of an object inside an existing one must insert an island in the original one !

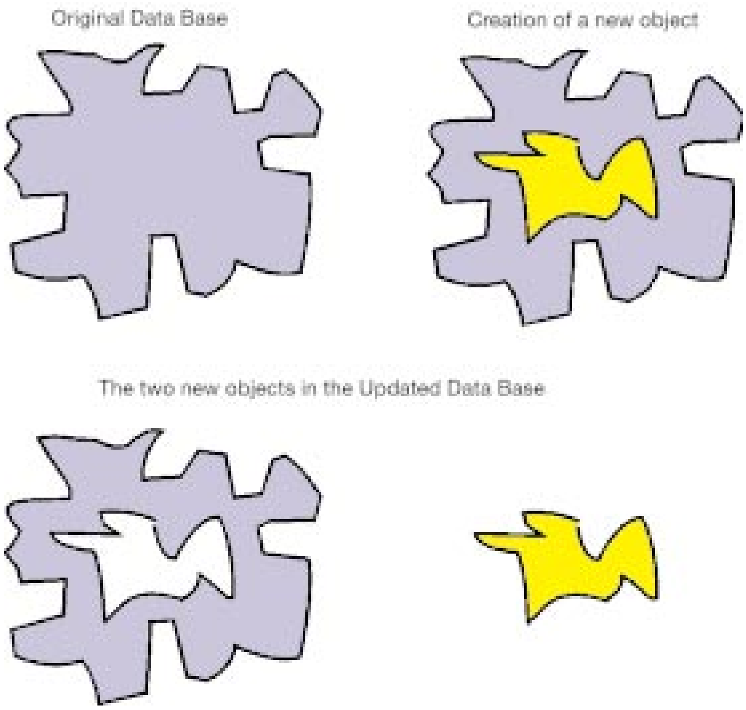


Figure 40 - Creation of a new object

The creation of an object partially covering several objects must not introduce problems in topology !

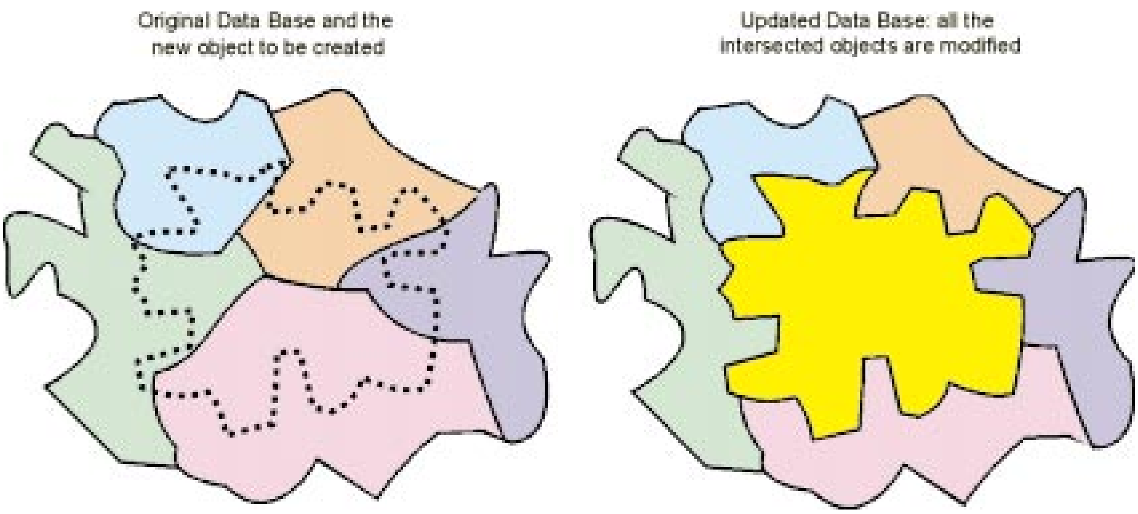


Figure 41 - Modification of intersected objects

Postulate 16 - Accidental generation of objects smaller than 25 ha

When a new object smaller than 25 ha is generated by the new object creation, the system must alert the image-interpreter in order to give him the responsibility to decide how to aggregate the small object (see figure 42).

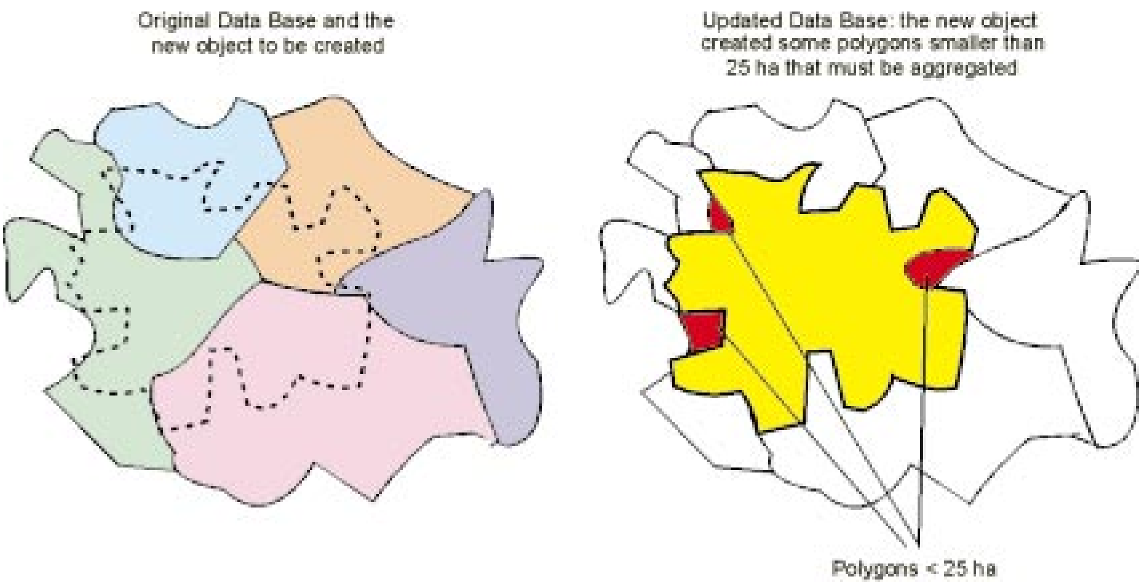
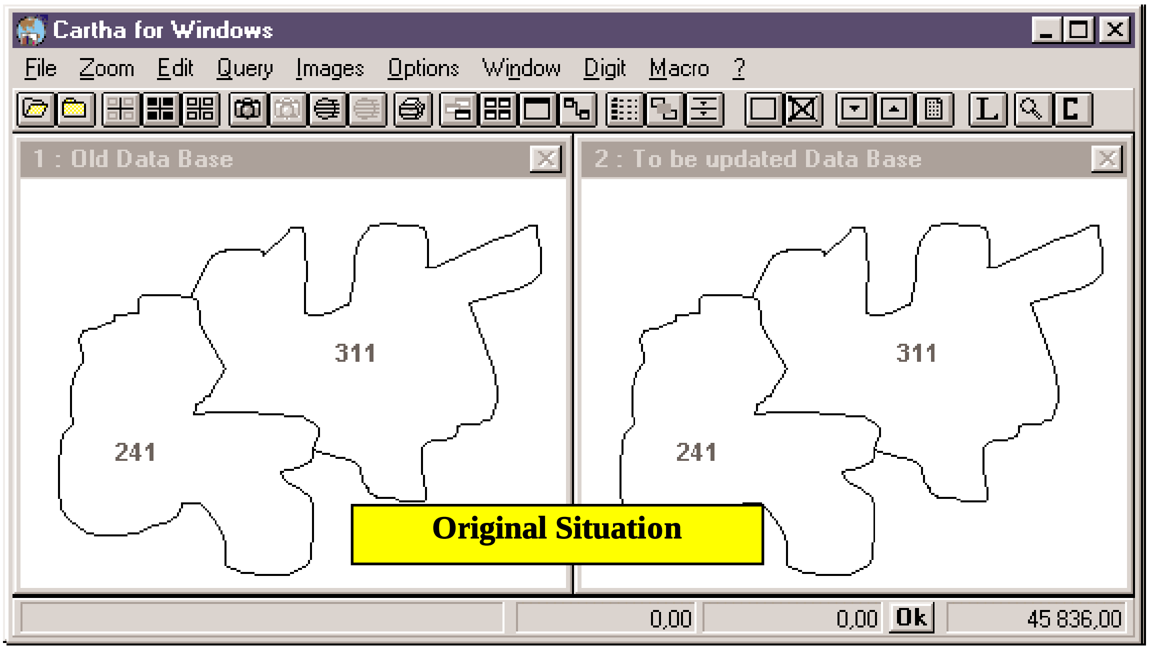
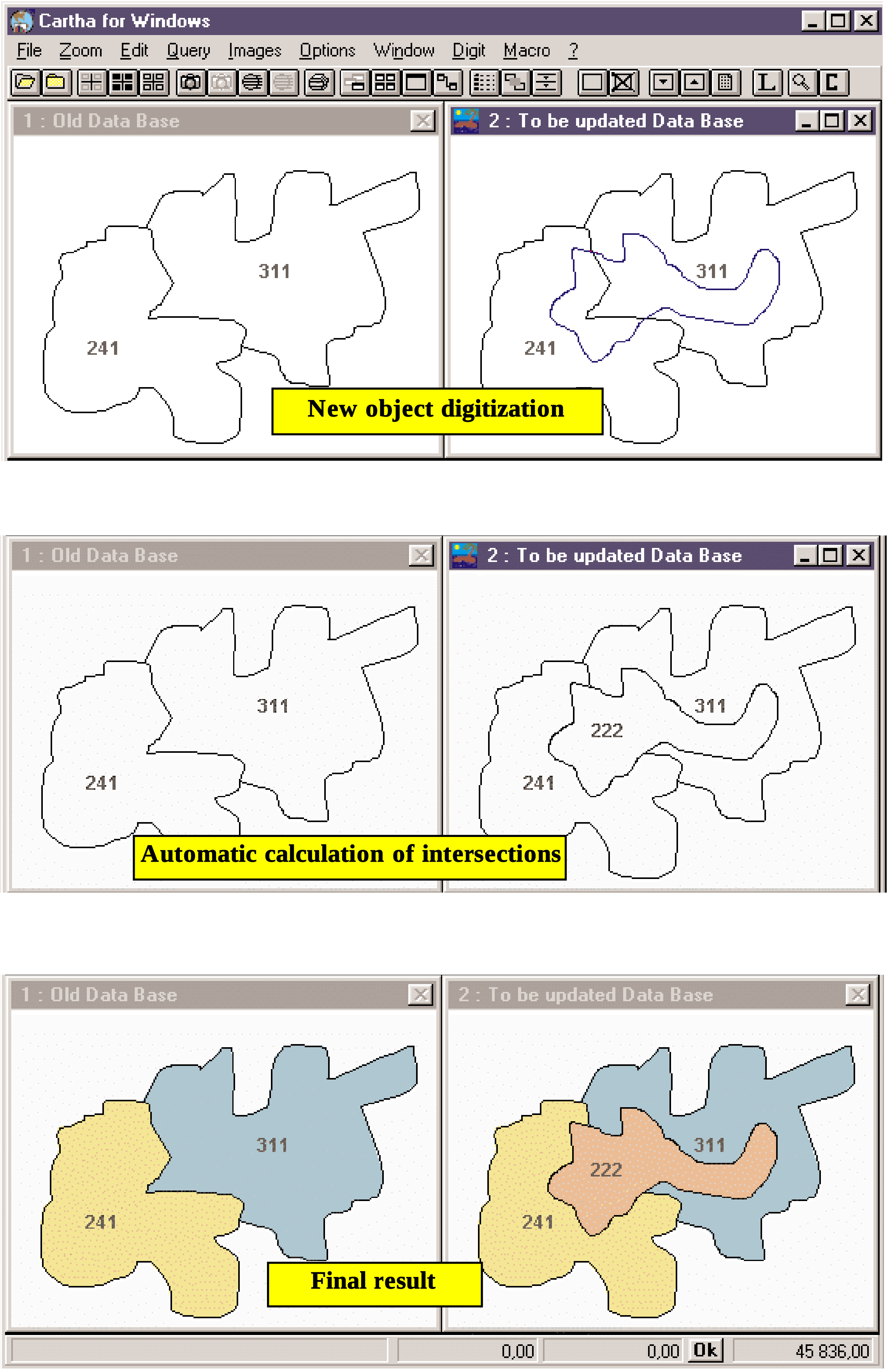


Figure 42 - Small polygons generated by the new object creation

4.4.4.1.1.1 Example of Implementation

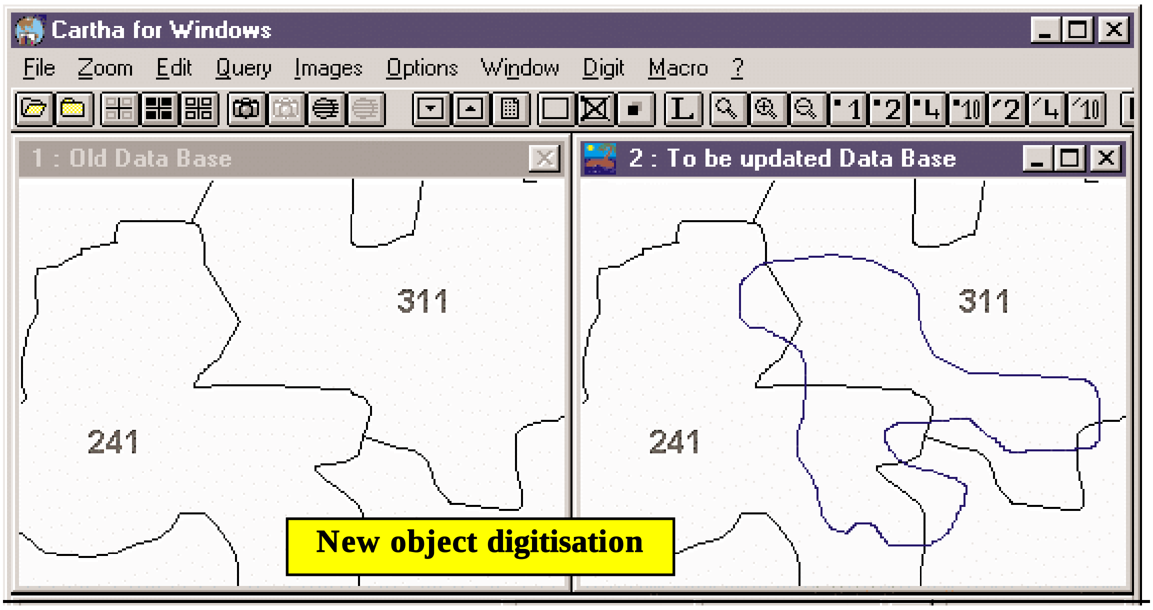
The following pictures show the implementation of new object creation under *Co-Pilot* system.

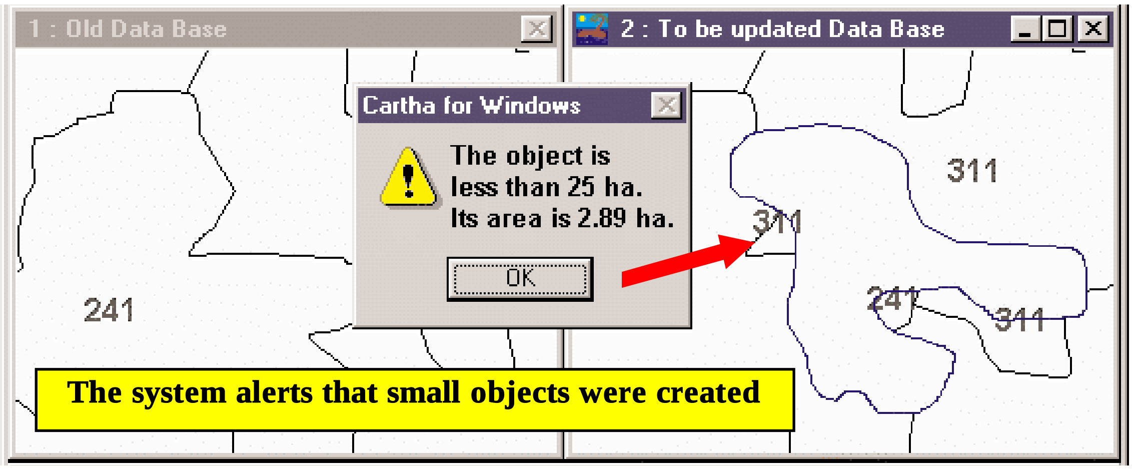


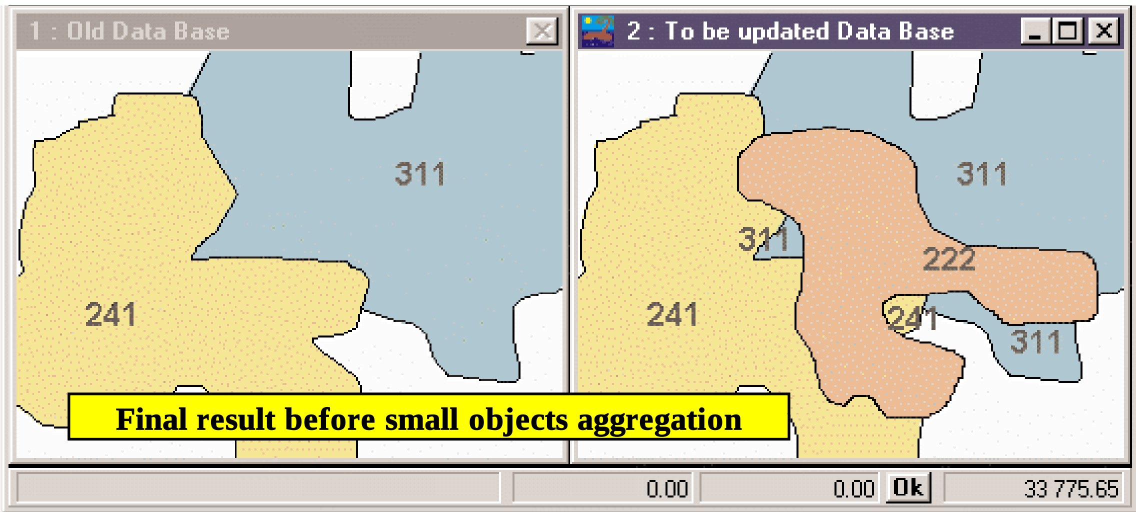


Cartha for Windows
File Zoom Edit Query Images Options Window Digit Macro ?
1 : Old Data Base
2 : To be updated Data Base
311
241
New object digitization
1 : Old Data Base
2 : To be updated Data Base
311
241
222
Automatic calculation of intersections
1 : Old Data Base
2 : To be updated Data Base
311
241
222
Final result
0,00
0,00
Ok
45 836,00

The following pictures show how the system alerts the image-interpreter that objects of too small size were created from the intersection of the new polygon with the old ones.

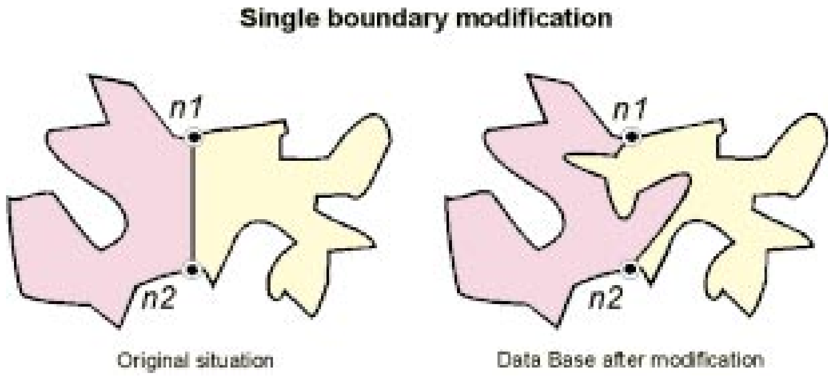




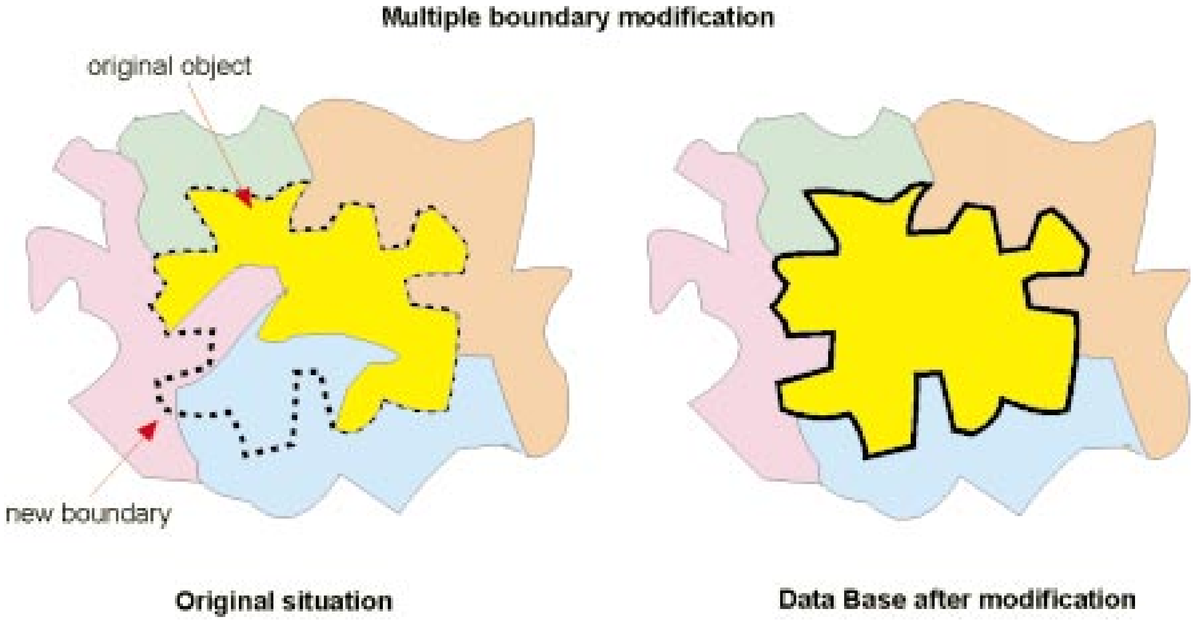


4.4.4.1.2 MODIFYING BOUNDARIES OF AN OBJECT

Every modification on a polygon forces modification of surrounding ones. The modification of a single boundary of an object is a relatively simple process !



The modification of an object covering more objects must not introduce problems in topology, particularly in the case of multiple boundaries modification.

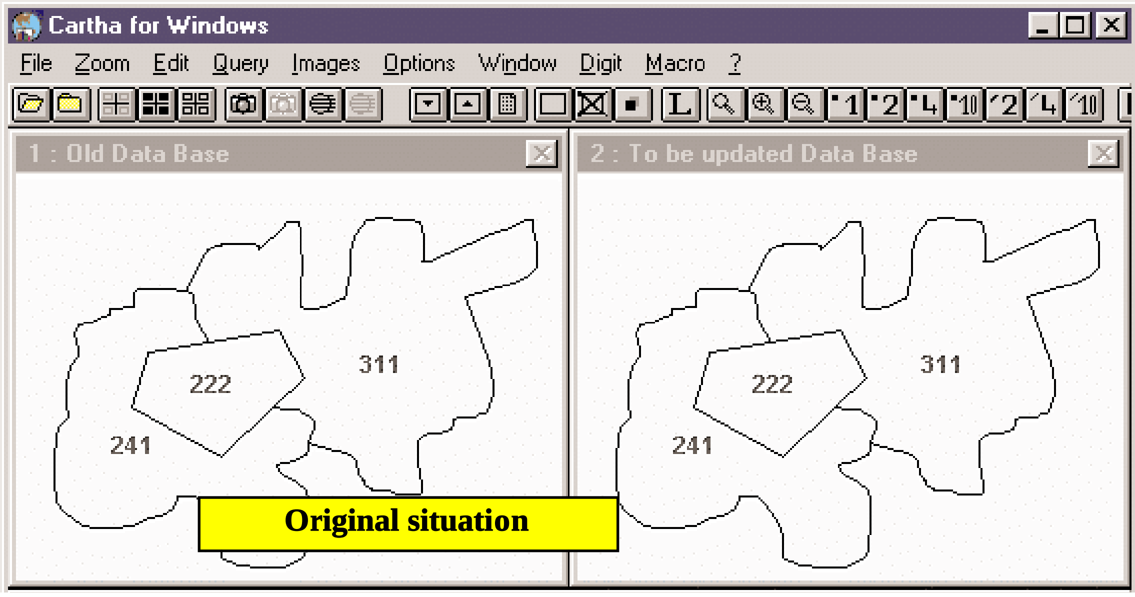


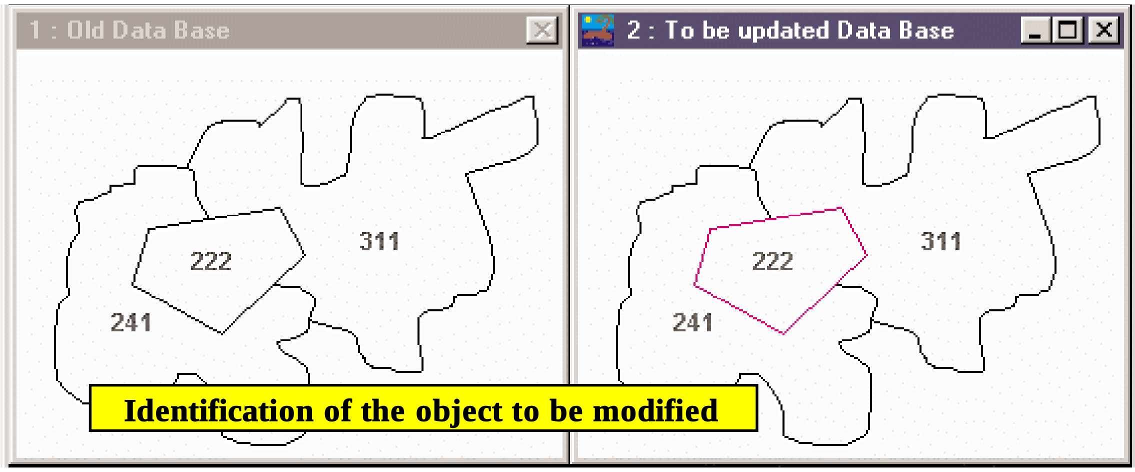
The following steps must be followed:

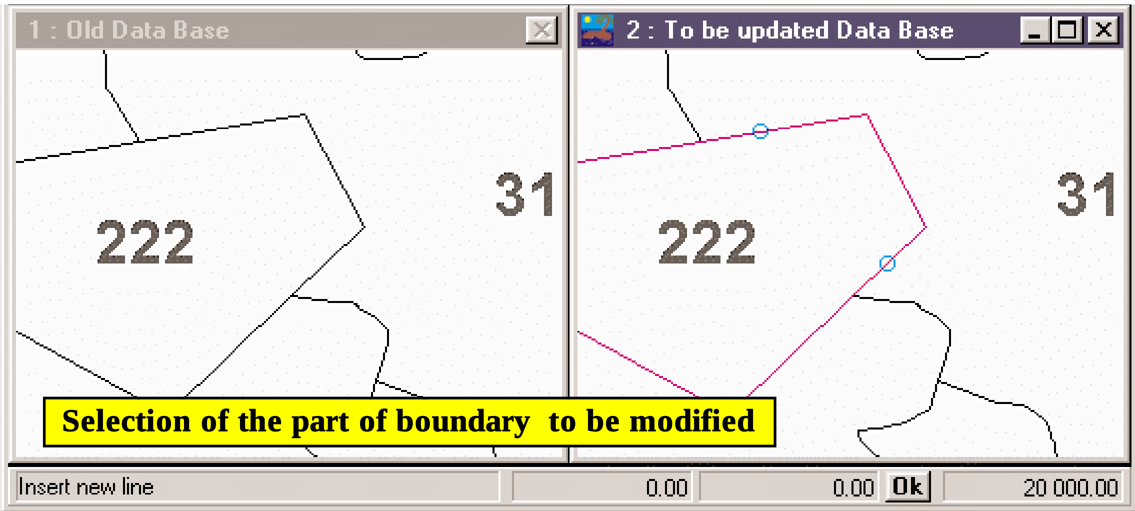
- identify the object to be modified,
- identify part of the contour to be changed,
- start modification: (Digitise new part, Move point, Add point, Delete point, Snap part of contour of an other object, ..),
- calculate Intersections and Rebuild polygons.

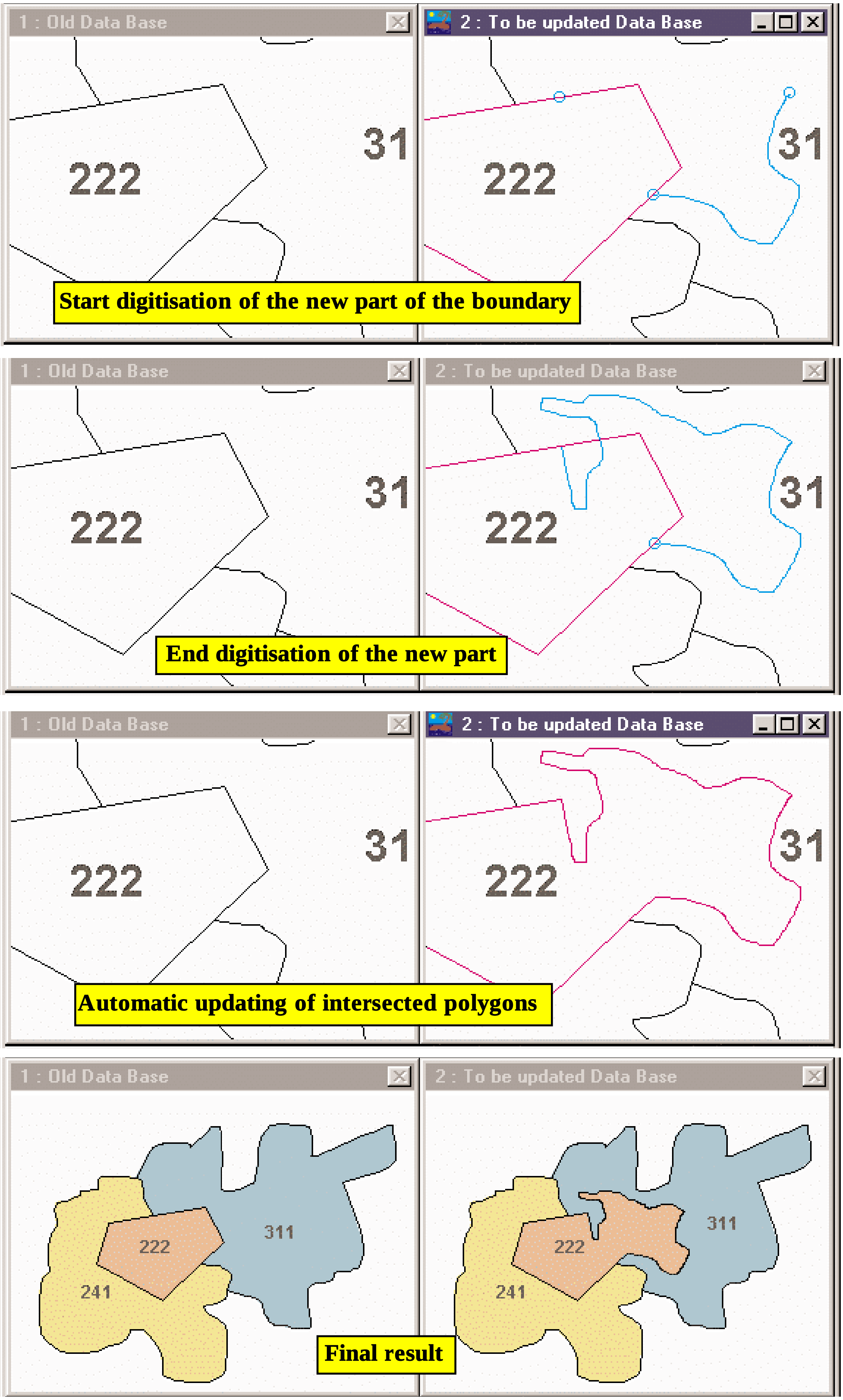
4.4.4.1.2.1 Example of Implementation

The following pictures show the implementation of object modification under Co-Pilot system.

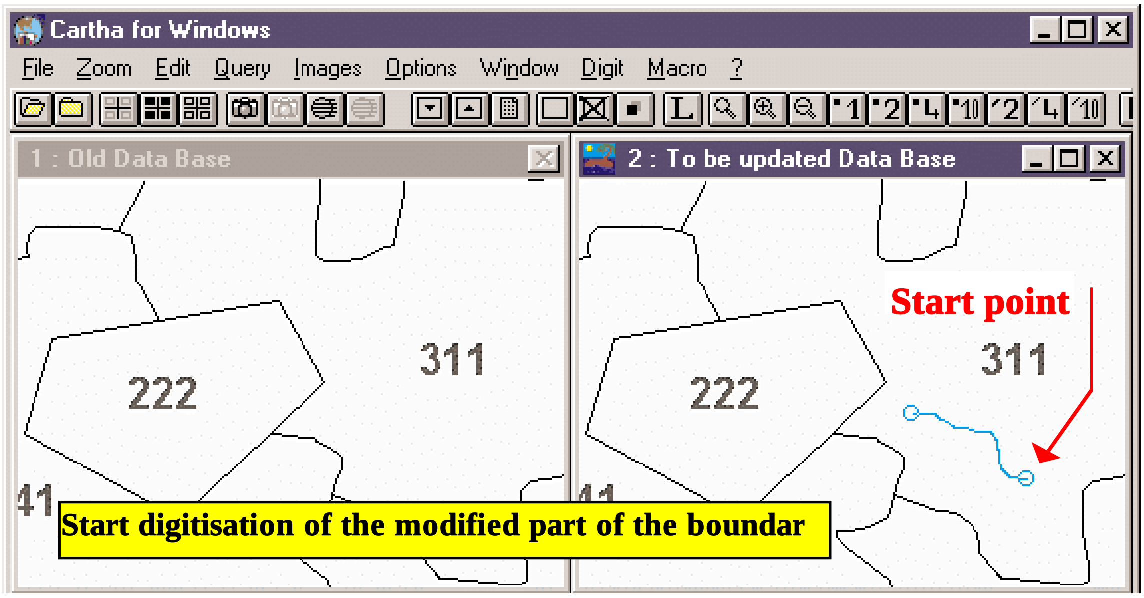


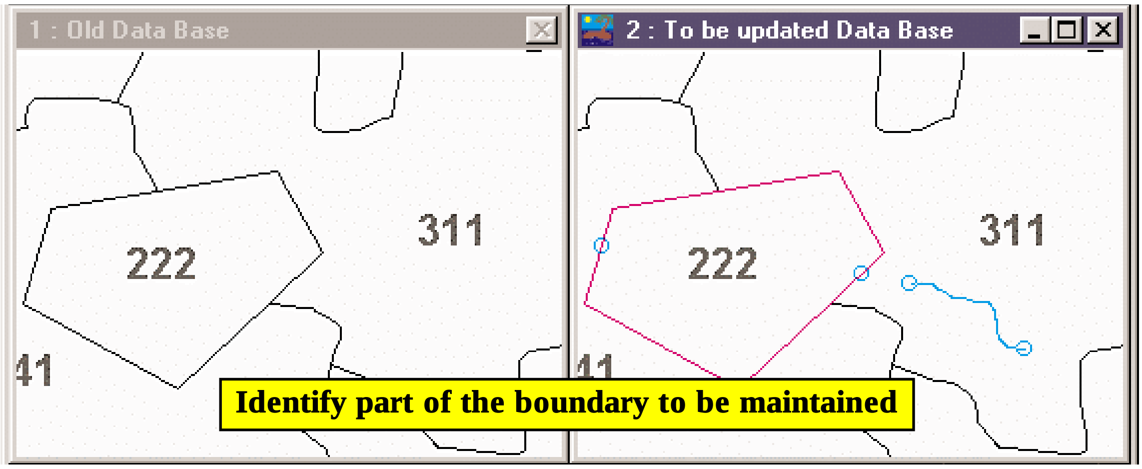


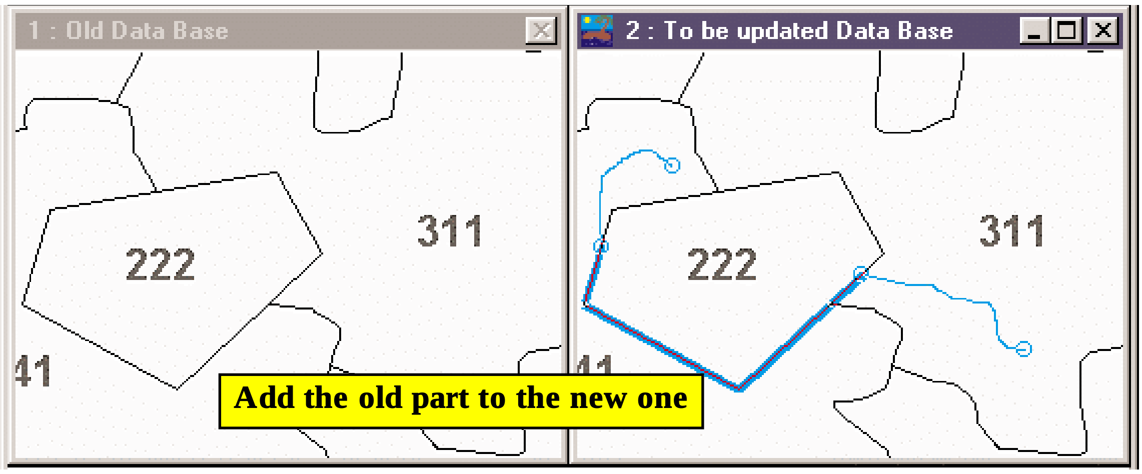


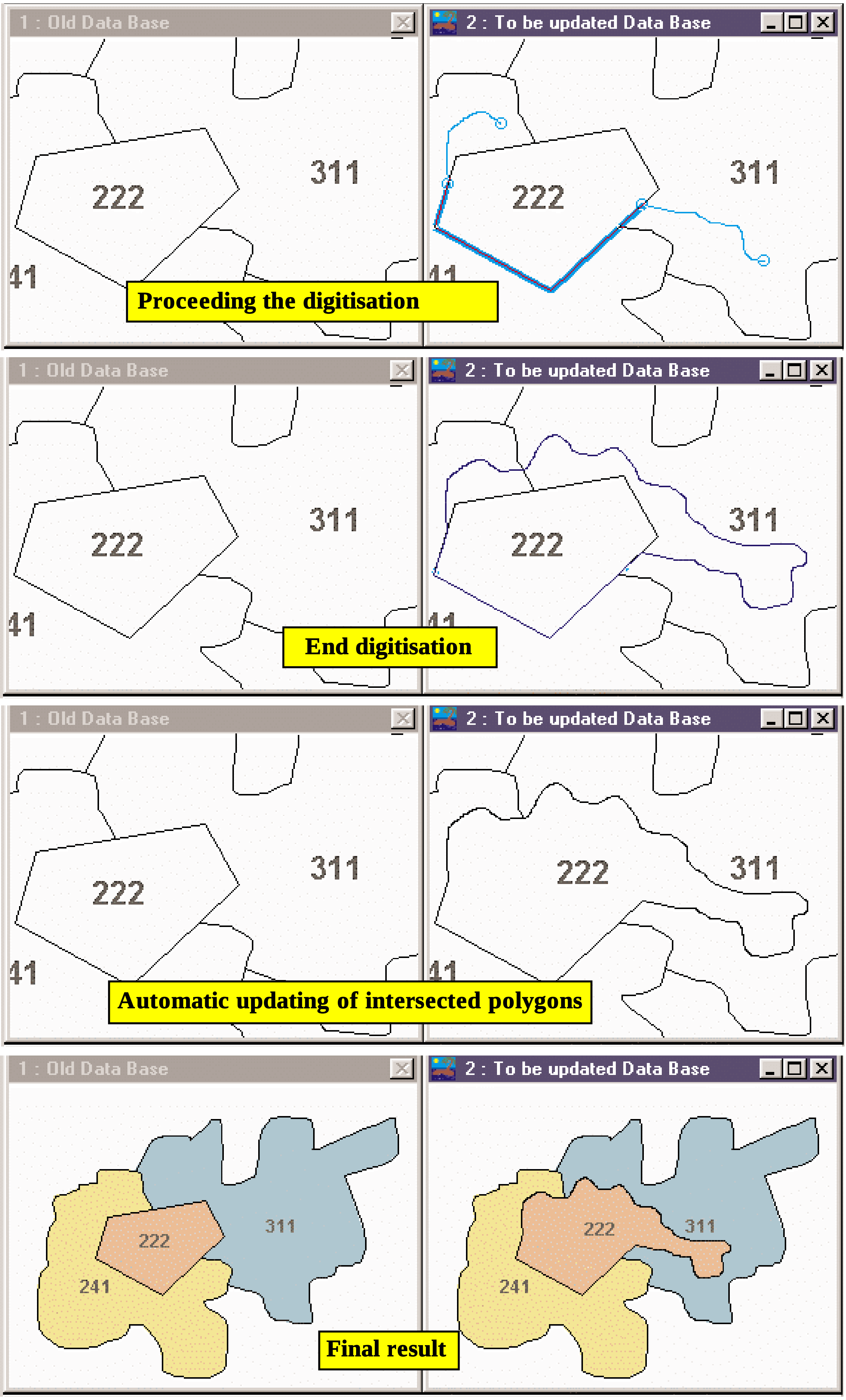

1 : Old Data Base
2 : To be updated Data Base
222
31
Start digitisation of the new part of the boundary
1 : Old Data Base
2 : To be updated Data Base
222
31
End digitisation of the new part
1 : Old Data Base
2 : To be updated Data Base
222
31
Automatic updating of intersected polygons
1 : Old Data Base
2 : To be updated Data Base
222
311
241
Final result

The following pictures show the case of multiple boundaries modification.








1 : Old Data Base
2 : To be updated Data Base
222
311
41
Proceeding the digitisation
1 : Old Data Base
2 : To be updated Data Base
222
311
41
End digitisation
1 : Old Data Base
2 : To be updated Data Base
222
311
41
Automatic updating of intersected polygons
1 : Old Data Base
2 : To be updated Data Base
222
311
241
Final result

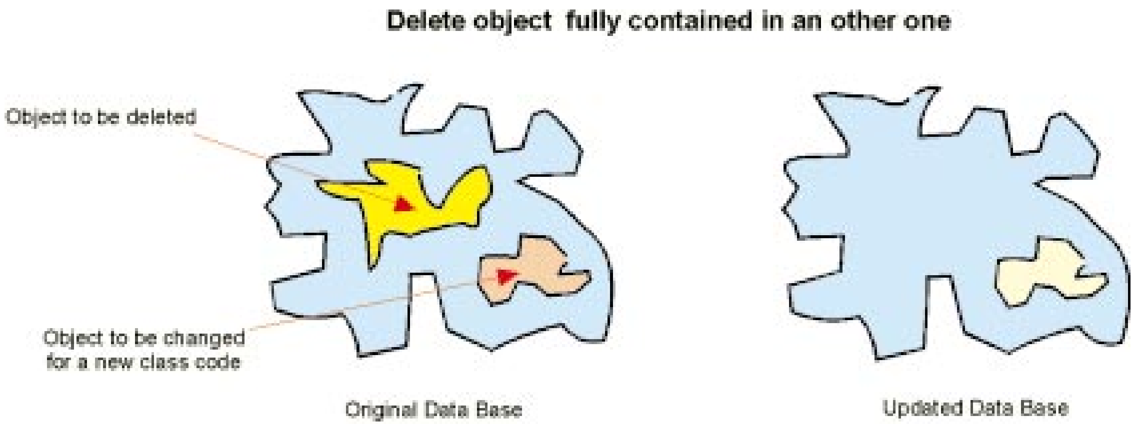
4.4.4.1.3 DELETING AN OBJECT

The deletion of an object must not leave holes in the database.

We can summarise the two possible cases of deletion:

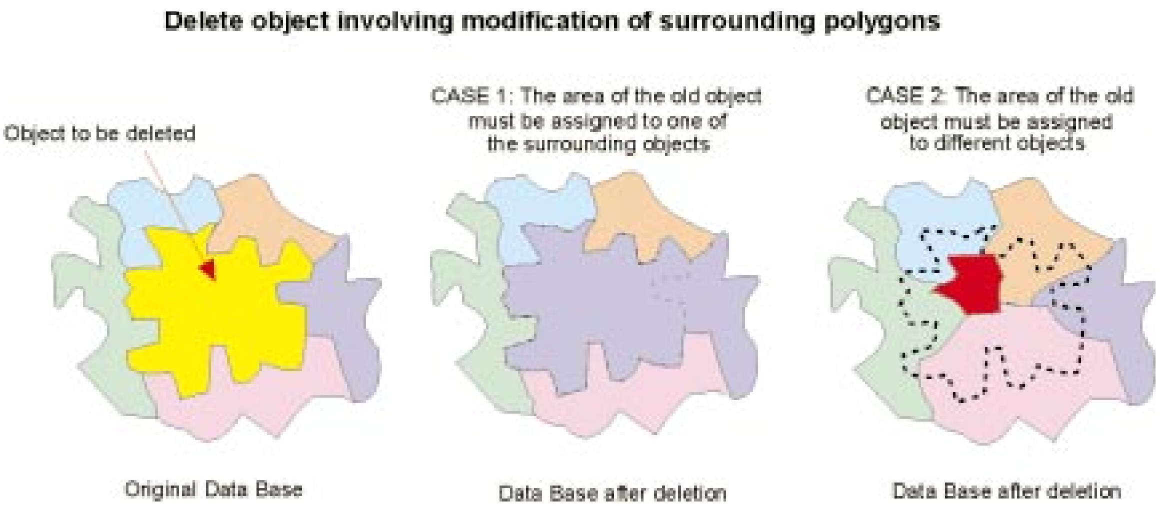
- object completely contained in another one (this object is also called an island),
- object not contained in another one.

In the first case the object is deleted and its area is assigned to the polygon that contained it. If this area must be assigned to a different class it is not appropriate to define it "object deletion" but instead, it is better to call it "class change". In this case the image-interpreter must only change the CORINE code of the old polygon without performing geometric updating.



If the object to be deleted is not contained in another one we can have two sub-cases:

- the object must be assigned to one of the surrounding polygons,
- the object must be split in several parts (some of them to be added to the surrounding existing polygons).

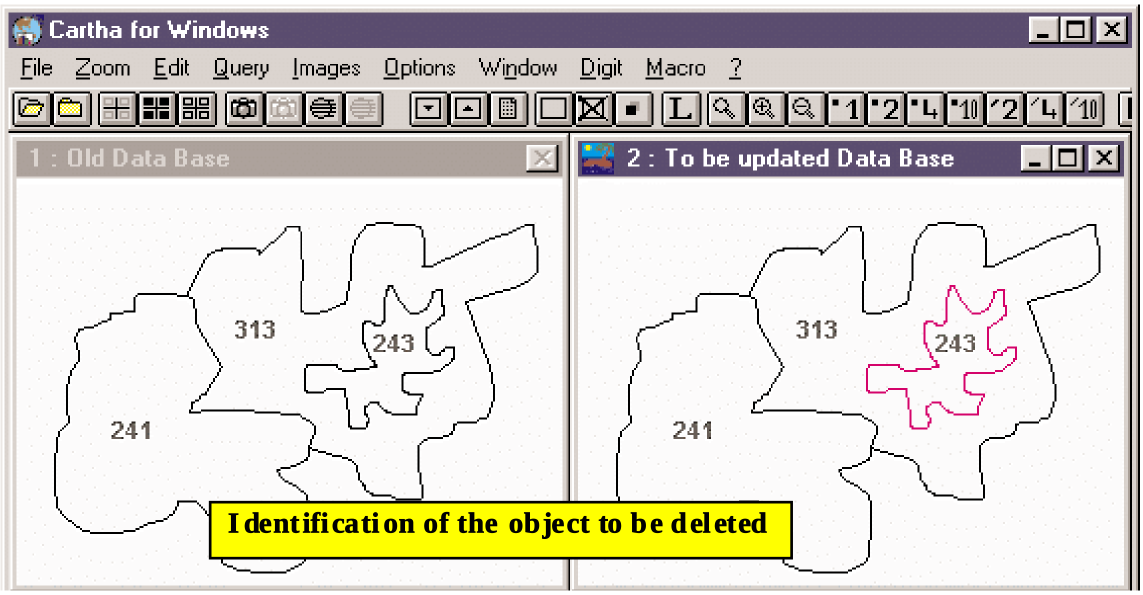


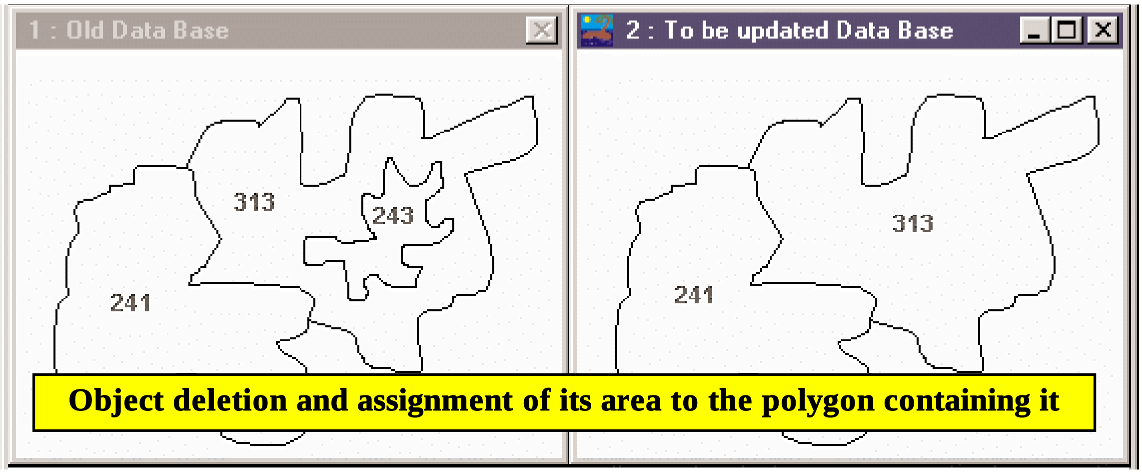
If the old object must be split in several polygons, "Object deletion" must not be used. Old polygons must be directly modified with creation of the eventual new objects.

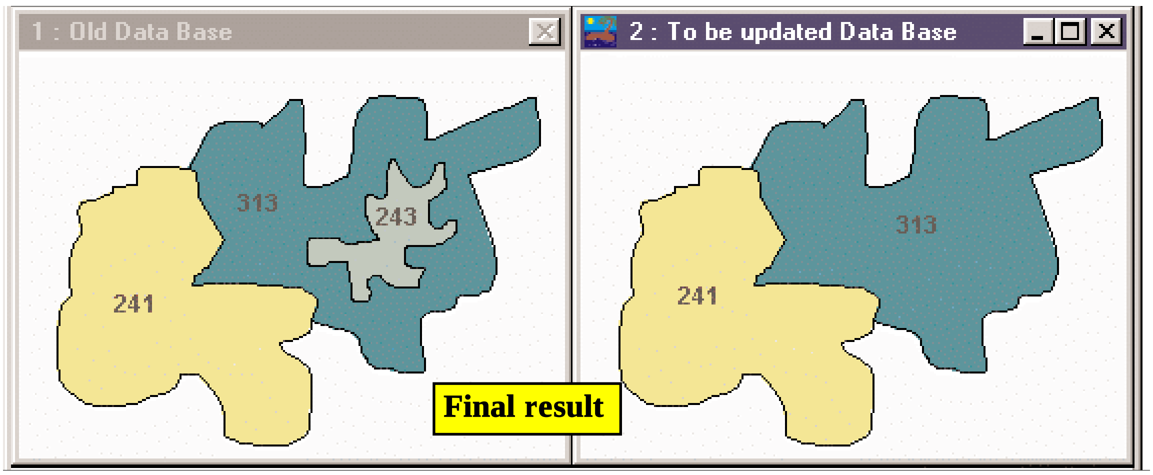
On the other hand, if the area of the old polygon must be assigned to a surrounding polygon its code must be changed and then the "Merge" function must be used. In other words the term "object deletion" concerns only the deletion of islands.

4.4.4.1.3.1 *Example of Implementation*

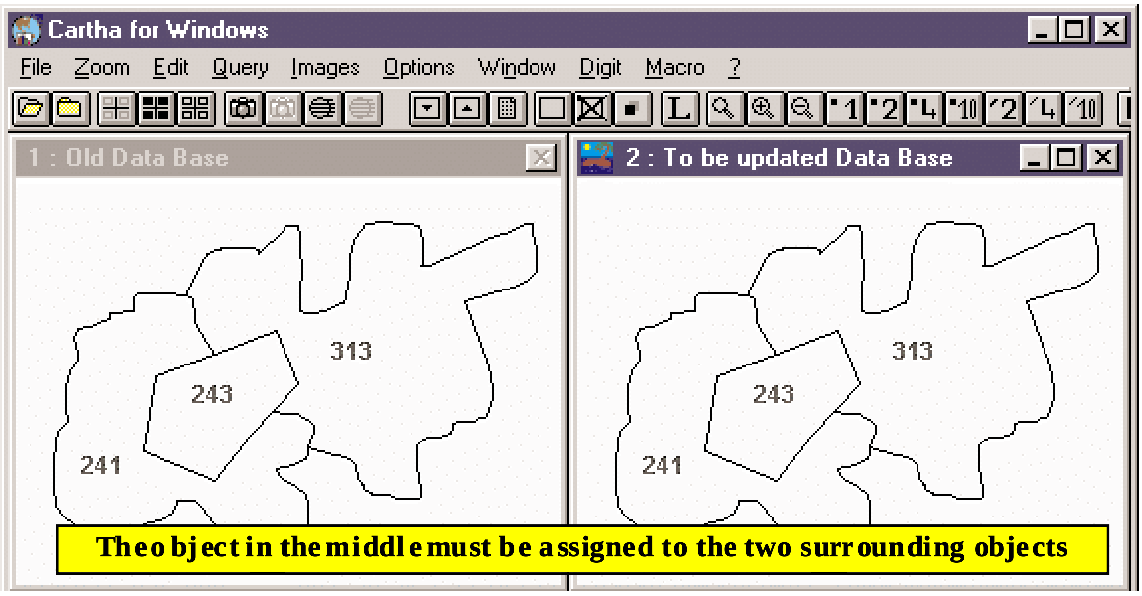
The following pictures show the implementation of island deletion under *Co-Pilot* system.

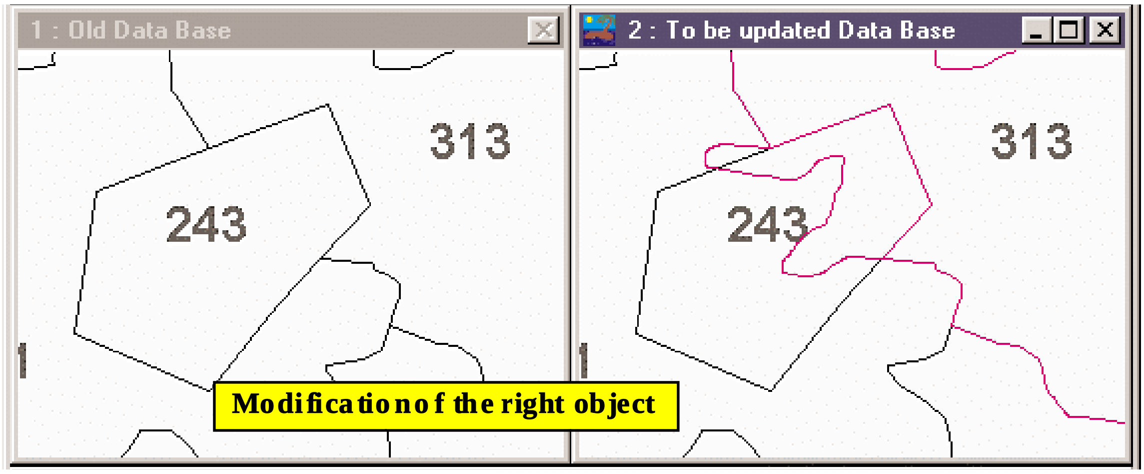


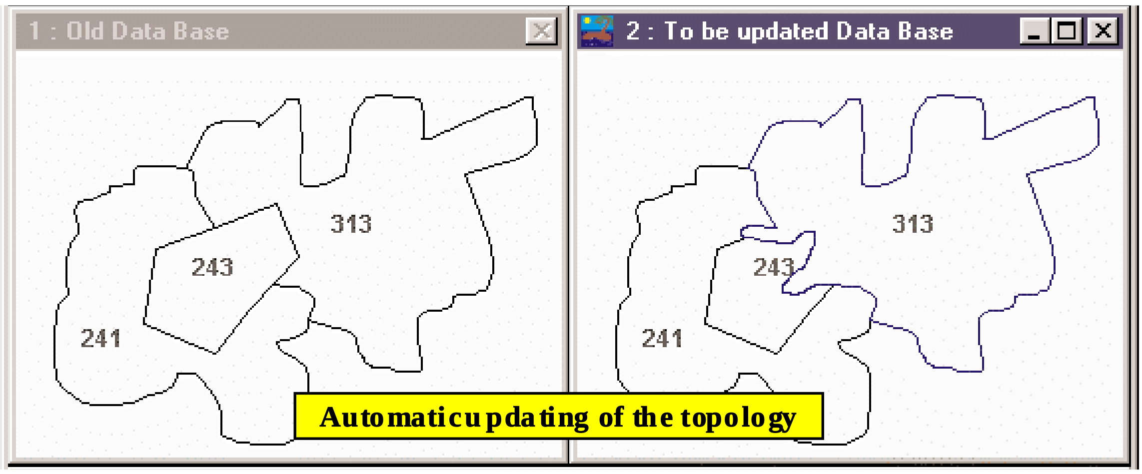


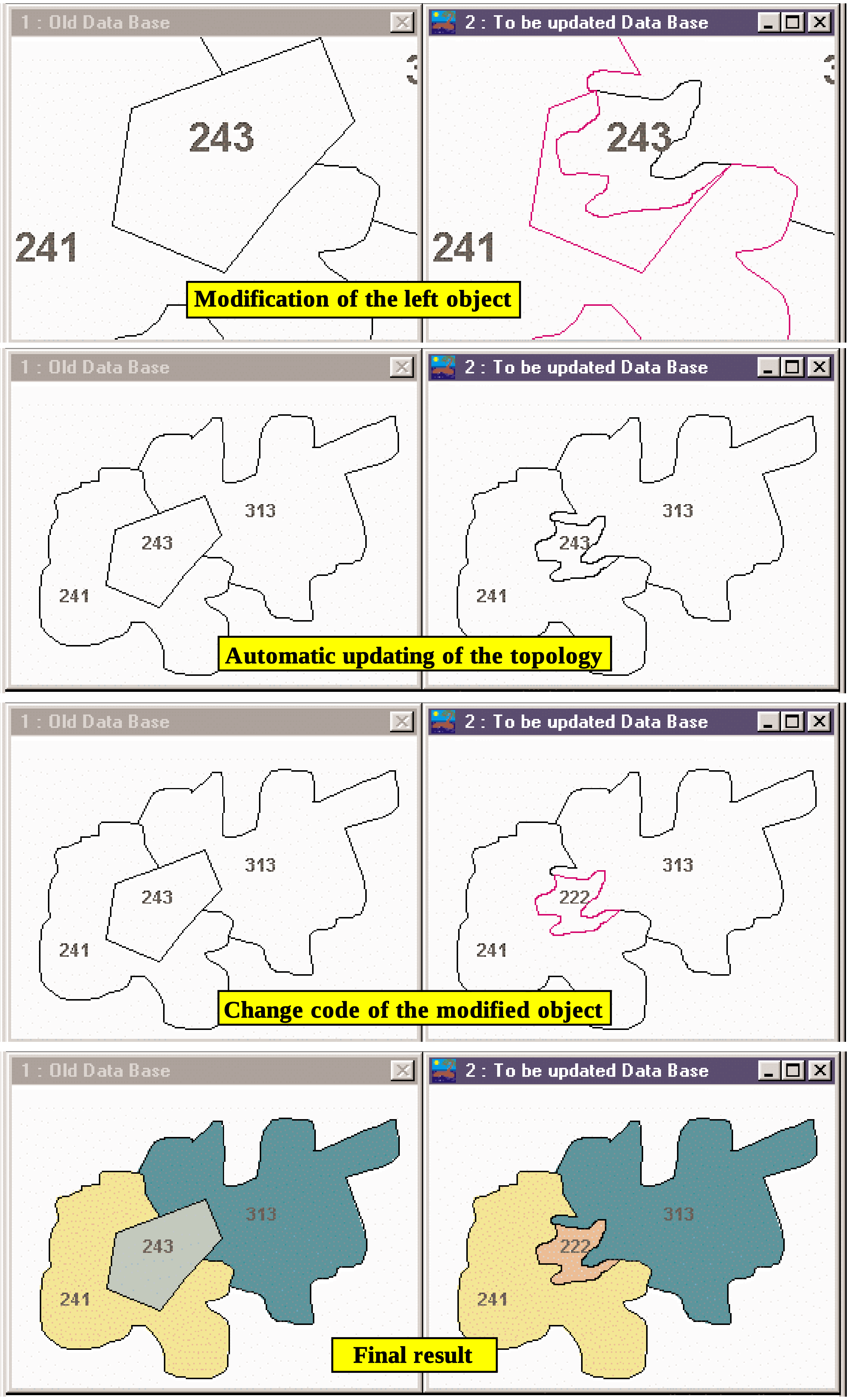


The next pictures show how *Co-Pilot* system manages the deletion of an object in which its area must be partially assigned to the surrounding polygons and part to be classified with a new code.





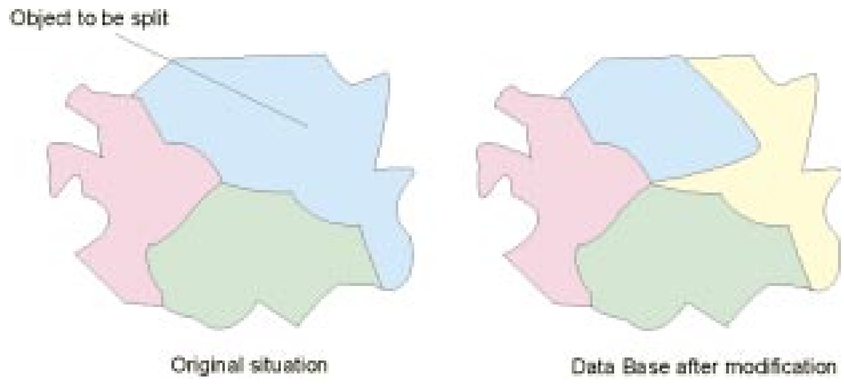




1 : Old Data Base
2 : To be updated Data Base
243
241
Modification of the left object
1 : Old Data Base
2 : To be updated Data Base
313
243
241
Automatic updating of the topology
1 : Old Data Base
2 : To be updated Data Base
313
243
222
241
Change code of the modified object
1 : Old Data Base
2 : To be updated Data Base
313
243
222
241
Final result

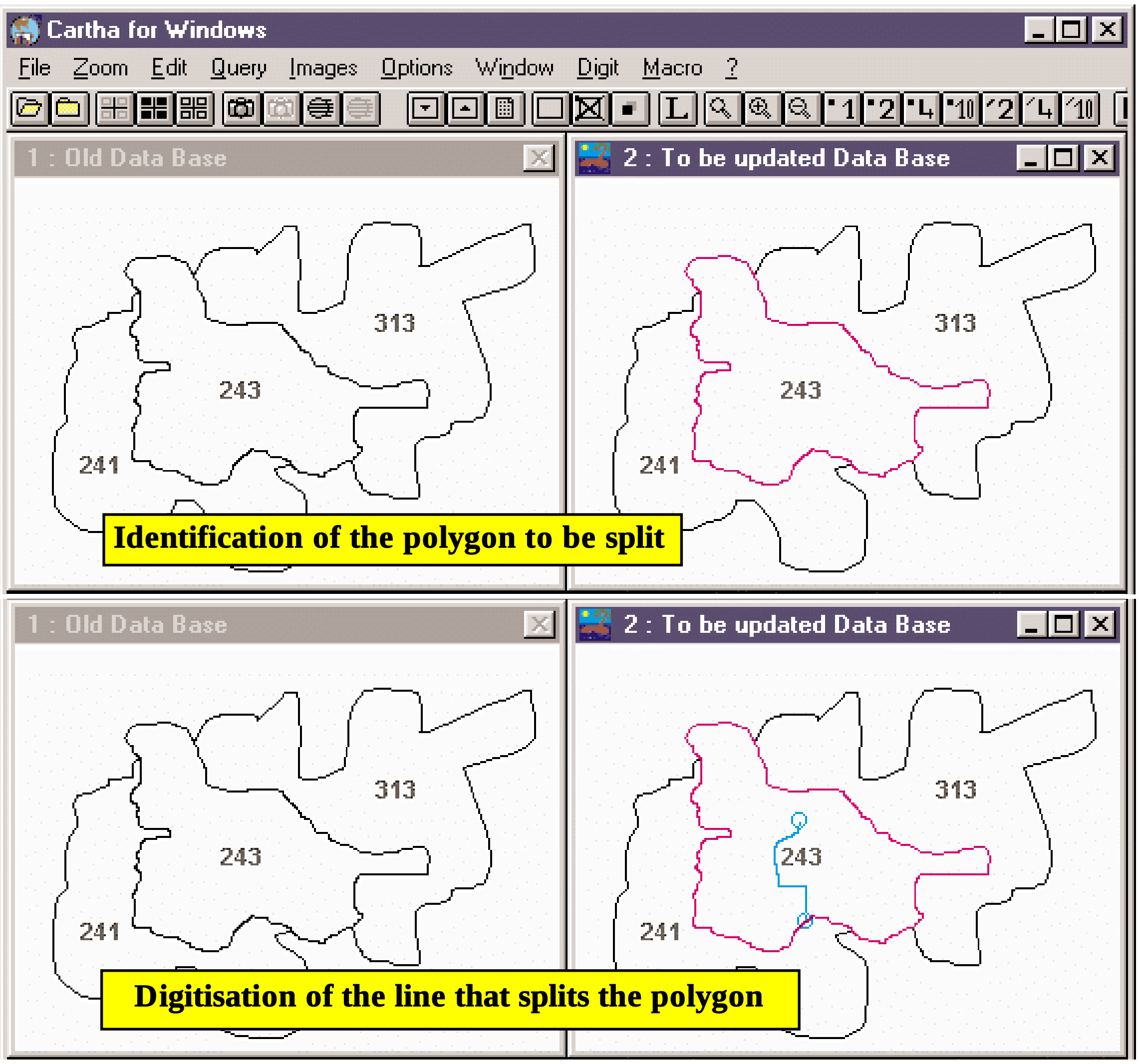
4.4.4.1.4 SPLITTING AN OBJECT

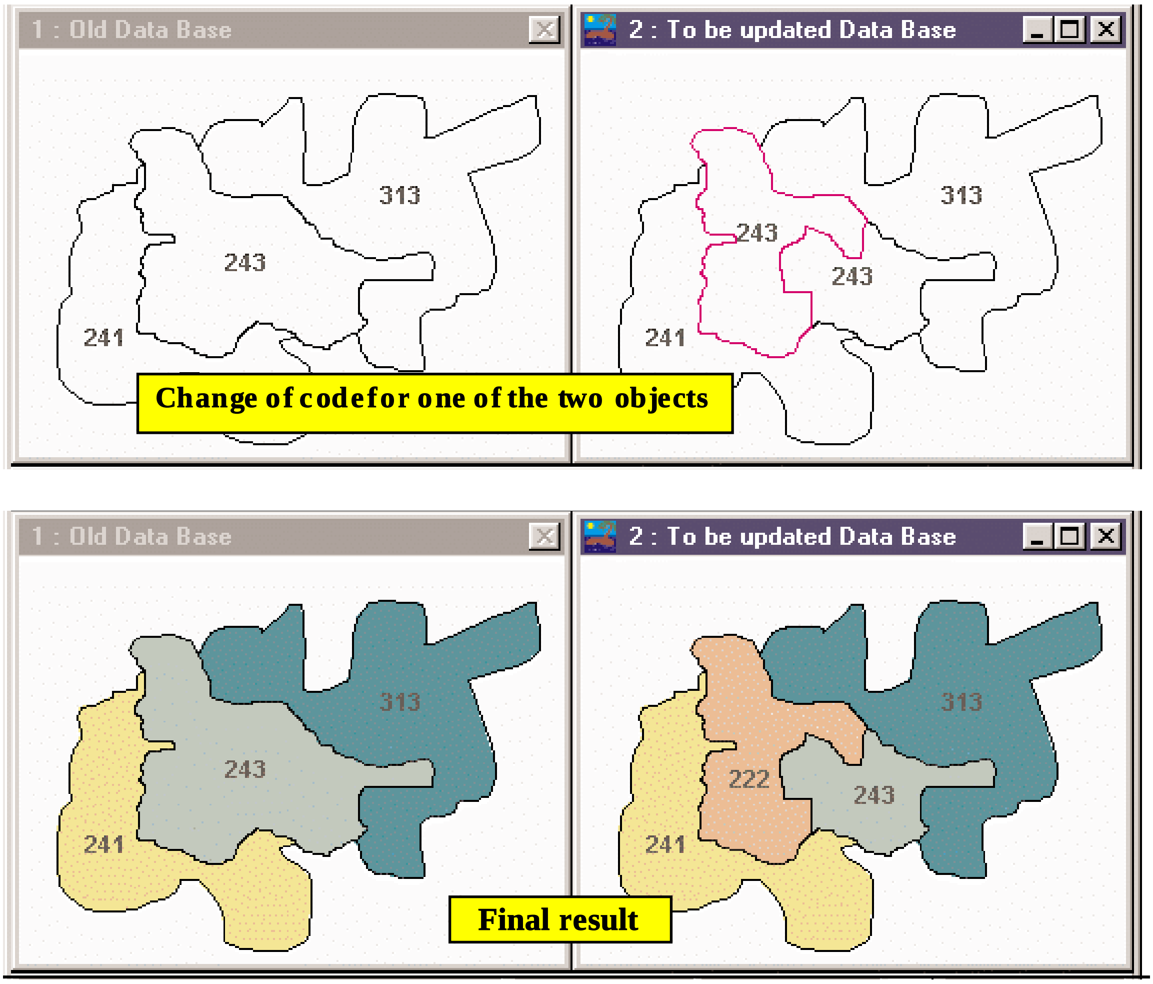
According to specific changes occurred, there is sometimes the need to split a polygon into two or more parts with different codes.



4.4.4.1.4.1 Example of Implementation

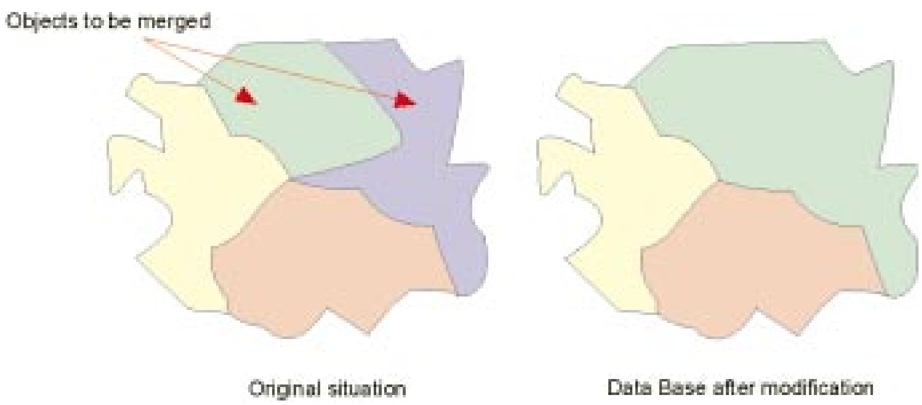
The following pictures show the implementation of the "Split" function under *Co-Pilot* system.





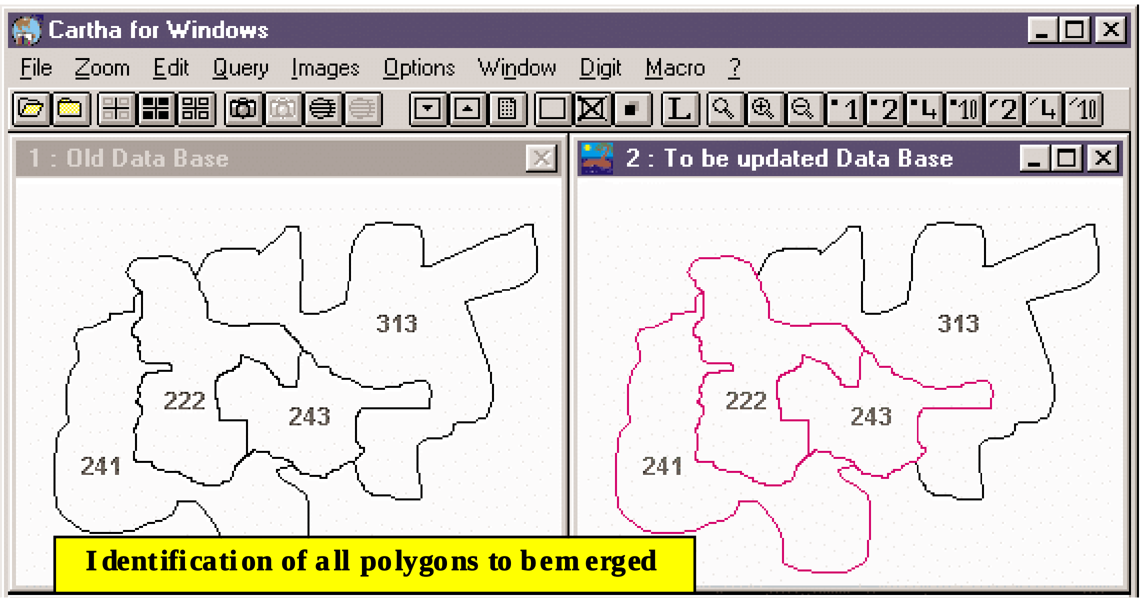
4.4.4.1.5 MERGE A SET OF OBJECTS

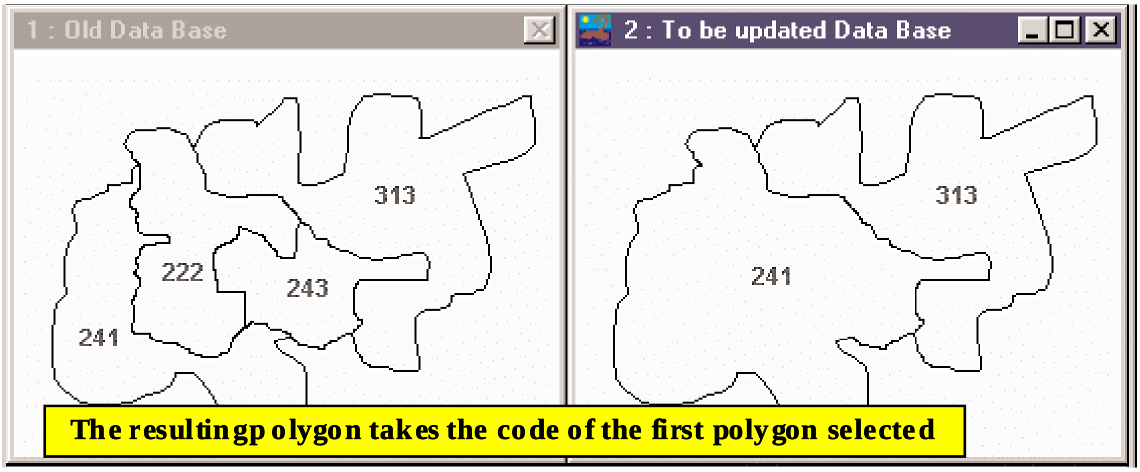
When there are objects smaller than 25 ha or when the nature of a polygon is becoming the same than the nature of its neighbour (because of the land evolution process) the image-interpreter must aggregate them to one of the surrounding polygons. To do this he needs a special function to merge the selected polygons, automatically rebuilding the topology and assigning the correct code.

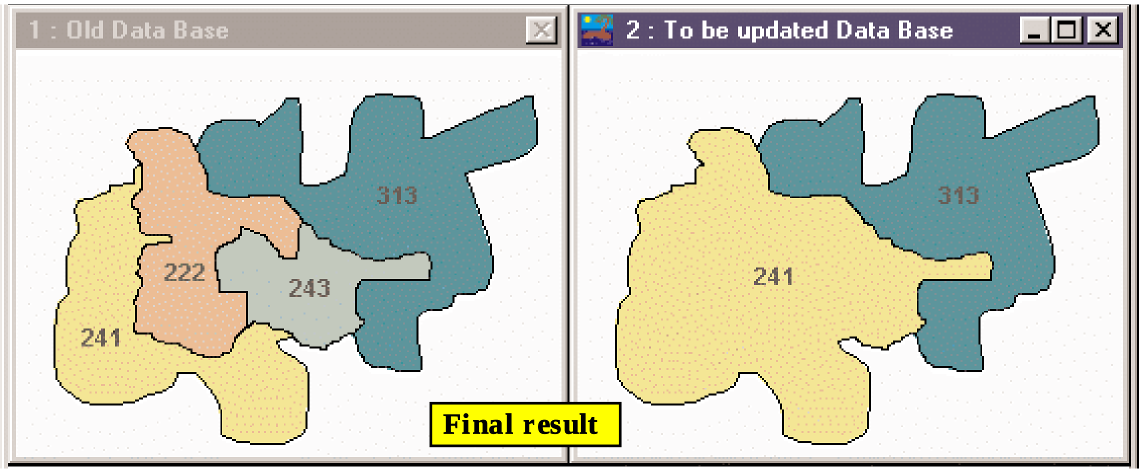


4.4.4.1.5.1 *Example of Implementation*

The following pictures show the implementation of the "Merge" function under *Co-Pilot* system.







4.4.4.2 Spaghetti Oriented Approach

As alternative to the Polygon approach, the "Spaghetti approach", is a very useful method when a lot of geometric changes are required.

In this case the image-interpreter could lose too much time waiting that the system performs topology rebuild at every modification. It may be better to ask the system to perform the work in two separate phases as explained in figure 46 and figure 47.

To decide which type of choice must be made the image-interpreter must quickly evaluate the number of corrections to do and then proceed to the correct choice. The following figure illustrates the two possible situations: in the case illustrated on the left the Polygon oriented method is preferable, in the case shown on the right the spaghetti oriented approach economises the image-interpreter time.

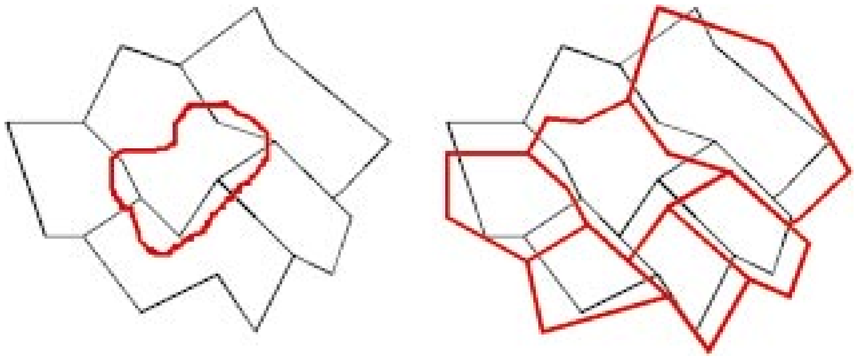


Figure 43 - Polygons (left) or Spaghetti (right) oriented approach ?

In Spaghetti methodology the work flow is composed of at least 3 phases:

- digitisation,
- polygon building,
- polygon correction.

It is important to underline that also in this method, the final part of the process is Polygon oriented. So all the consideration of the GIS requirements made in previous chapters remain valid also for this type of situation.

The main difference is the use of the centroid instead of the Polygon attribute to maintain the status of the operations. In other words, each centroid must be used to mark the related polygon, using the same codes described in the Polygon Oriented approach. The centroid is automatically generated transforming the old polygon in order not to lose the thematic information.

With this methodology (to be used for very bad correspondence between the old base and the new correct image) the image-interpreter normally doesn't move the centroids. Instead he refines the position of the lines only.

Since the time for updating an existing line could be sometimes higher than re-drawing it, the image-interpreter can chose one of the two possible different strategies:

- new digitisation of all lines,
- updating of the old lines.

In the first case the image-interpreter creates a completely new database, using the old one only as help for the image-interpretation.

In the second case, when most of the old lines can be maintained, the image-interpreter must modify the lines that don't correspond to the limits on the image.

The Spaghetti approach, compared to the Arc-Nodes approach, has the advantage that all topology operations are made at the end of the image-interpreter work in a batch session, saving time for the image-interpreter (as illustrated in figure 44).

The image-interpreter can thus leave open lines to be closed in a second panning of the image (becoming a real boundary), and can revise his work in any moment without particular problems of topology. In the Arc-Node approach, each segment must be associated to two nodes, so deletion or displacement of a line interests also possible displacement or creation of nodes and topology consistency checking.

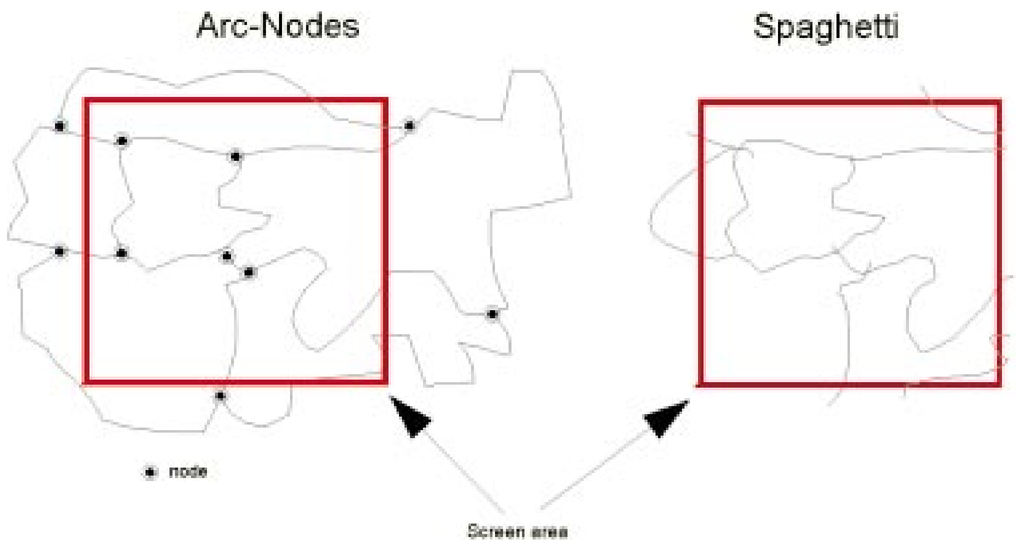


Figure 44 - Arc-Nodes versus Spaghetti approach

The different phases of work in a Spaghetti oriented approach are illustrated in figure 45.

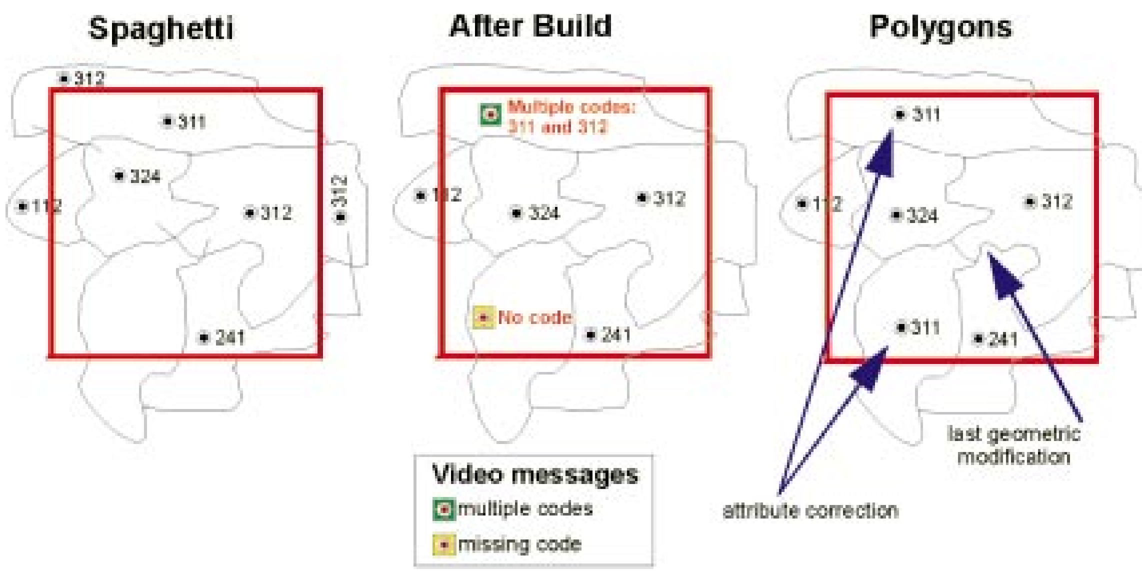


Figure 45 - Different phases of Spaghetti oriented approach

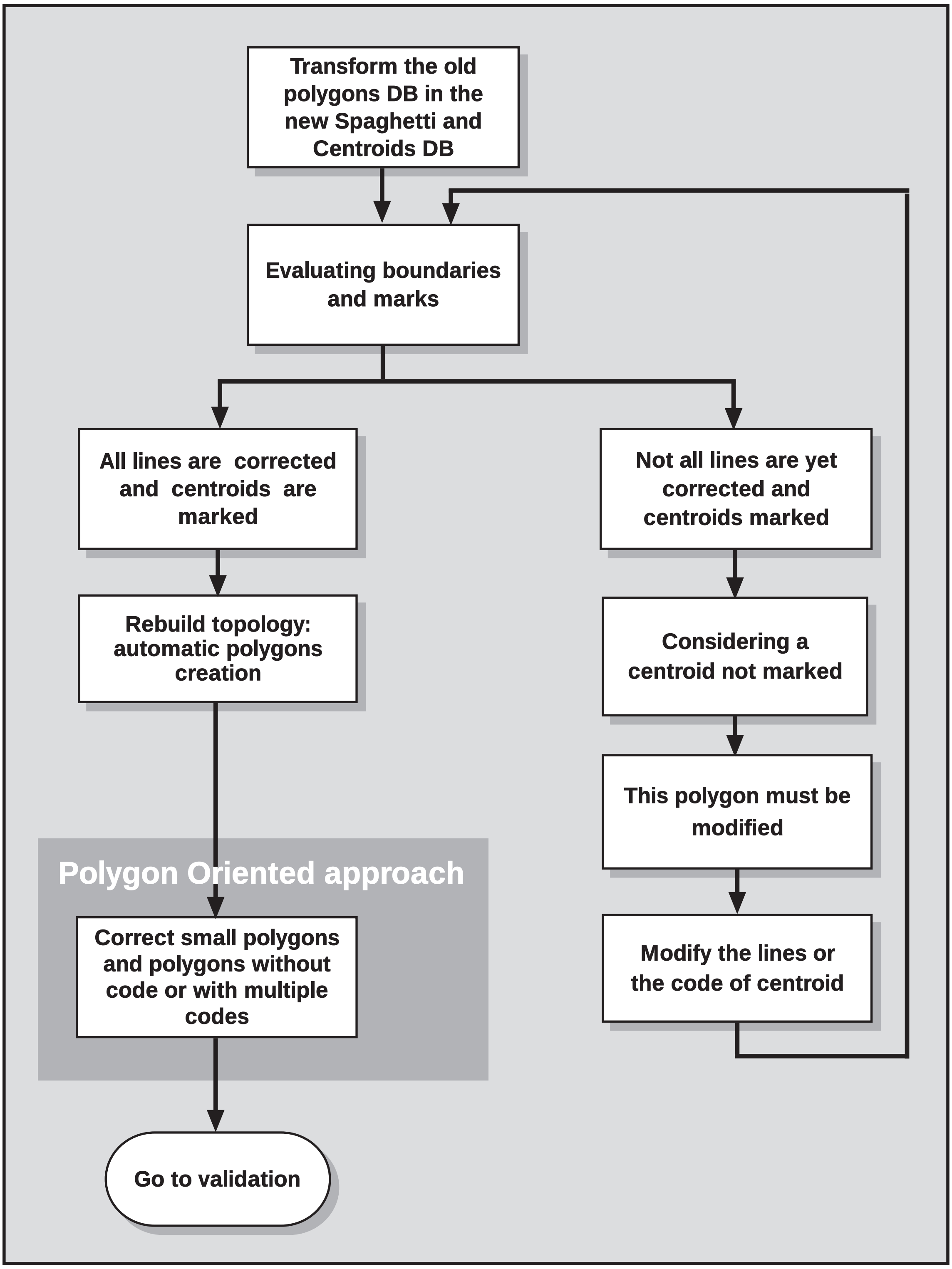


Figure 46 - Spaghetti Oriented approach (lines updating)

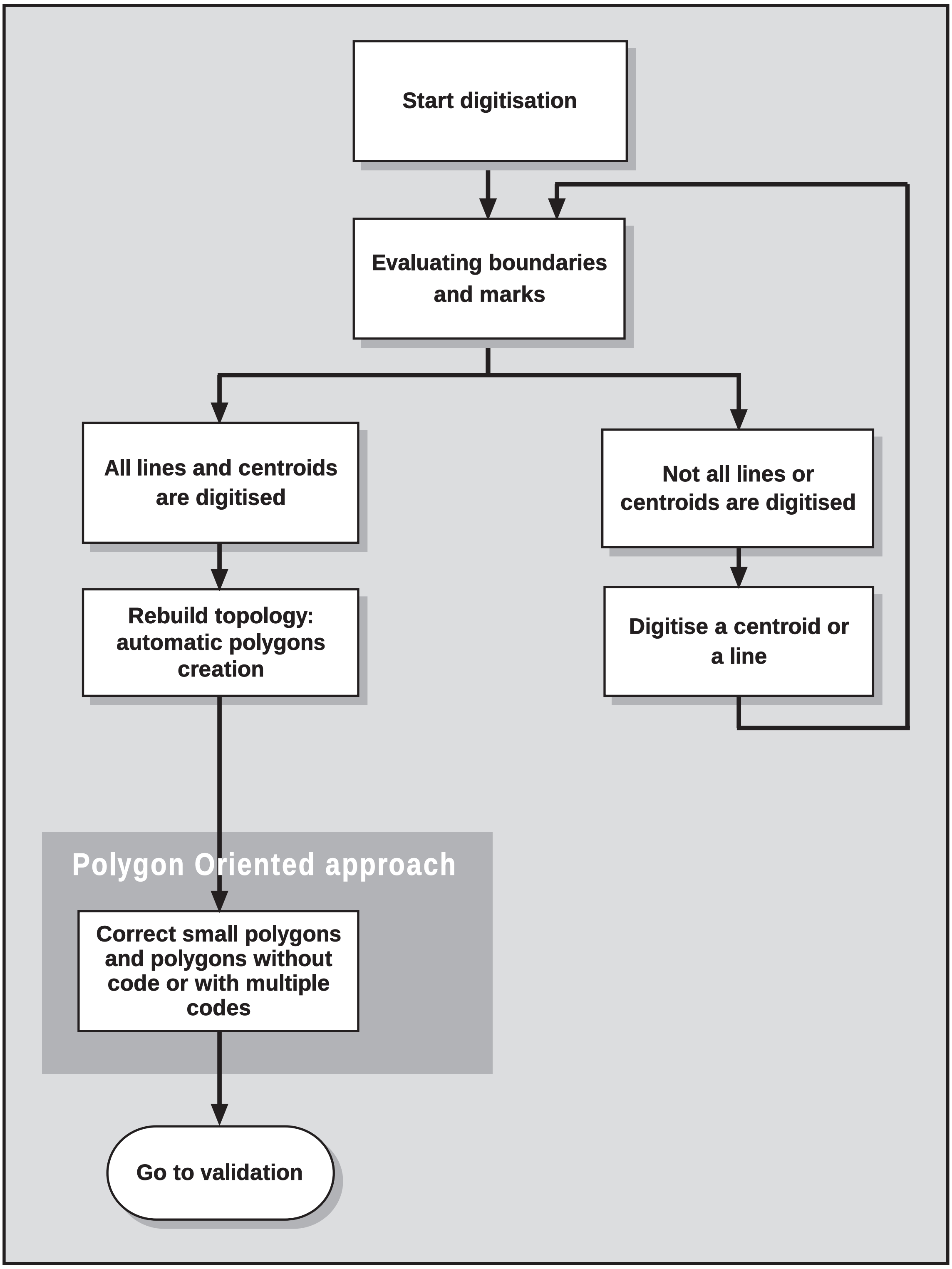


Figure 47 - Spaghetti Oriented approach (lines re-digitisation)

4.4.5 How to update thematic changes

Thematic changes of a whole polygon is a rare process on updating except when there are a lot of bad codes coming from a previous bad classification.

In such cases the image-interpreter needs some tools to easily modify the code associated to a polygon.

The classic interface of a GIS system can be summarised in 3 steps:

- identify the object,
- entry the new attribute,
- confirm and mark the object.

The GIS must check if the introduced code exists in the adopted nomenclature and if not must alert the user to rectify the code.

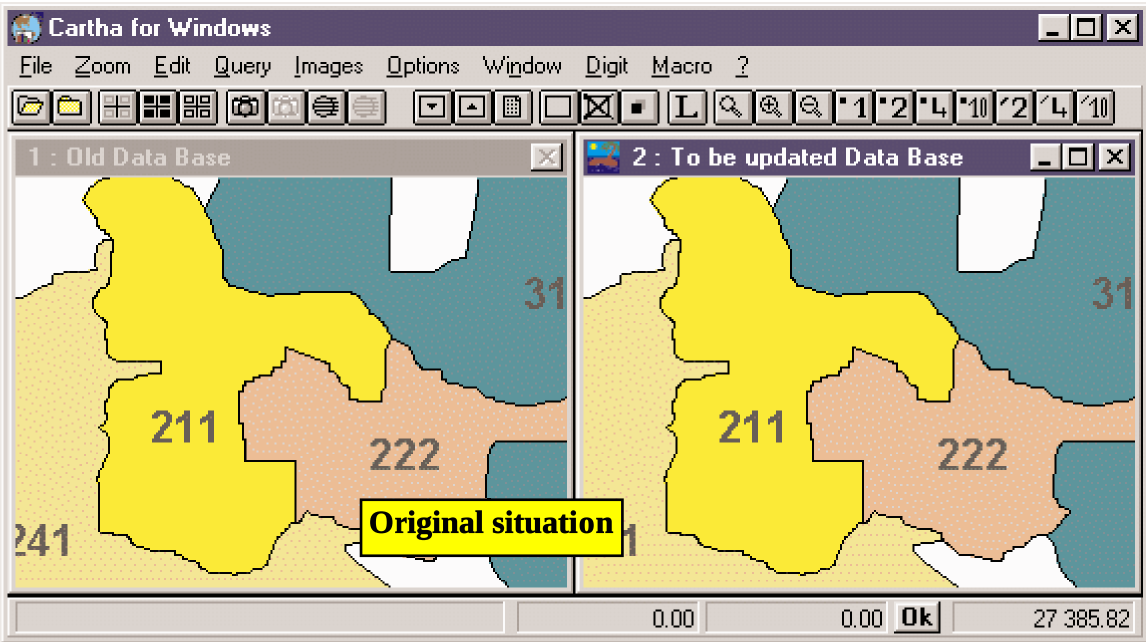
This mechanism is made by means of a Code Look Up Table containing all acceptable codes. This table should be customised in order to permit also its use for 4th or 5th level of the CORINE nomenclature or to exclude some non-possible codes of the 3rd level.

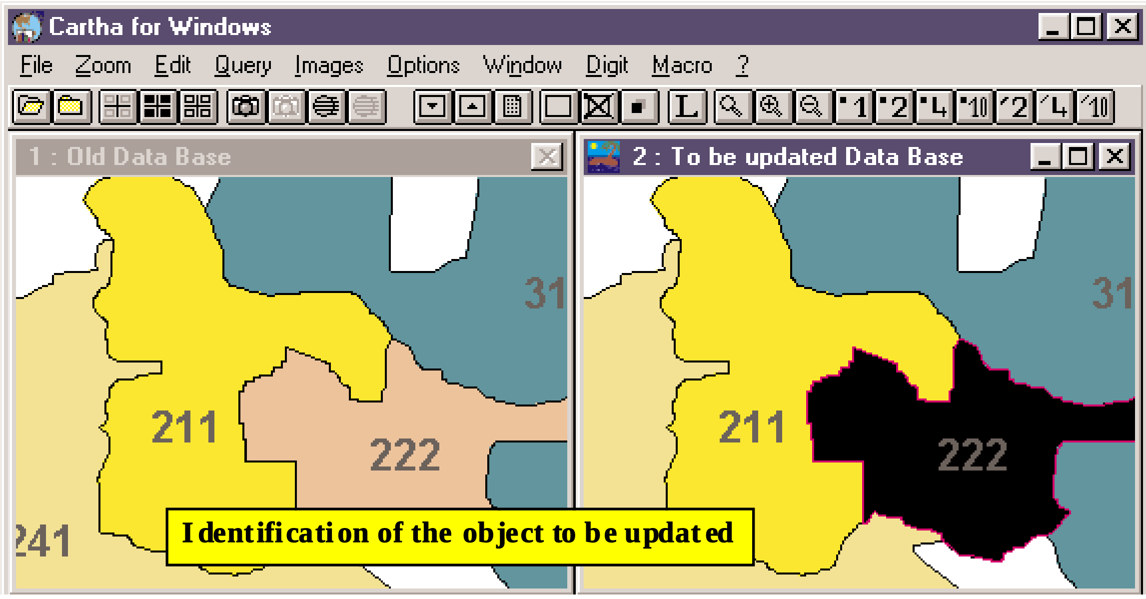
Postulate 17 - Data Entry of CORINE codes

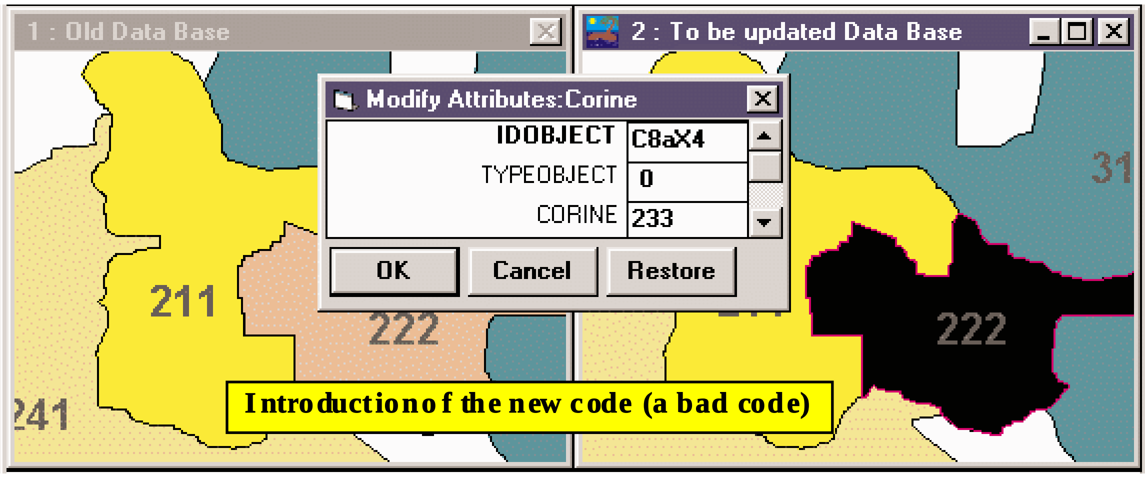
The code check must be done when the image-interpreter enters the code in order to avoid having to return to the polygon on a successive phase (sometimes forgetting the correct code to be attributed).

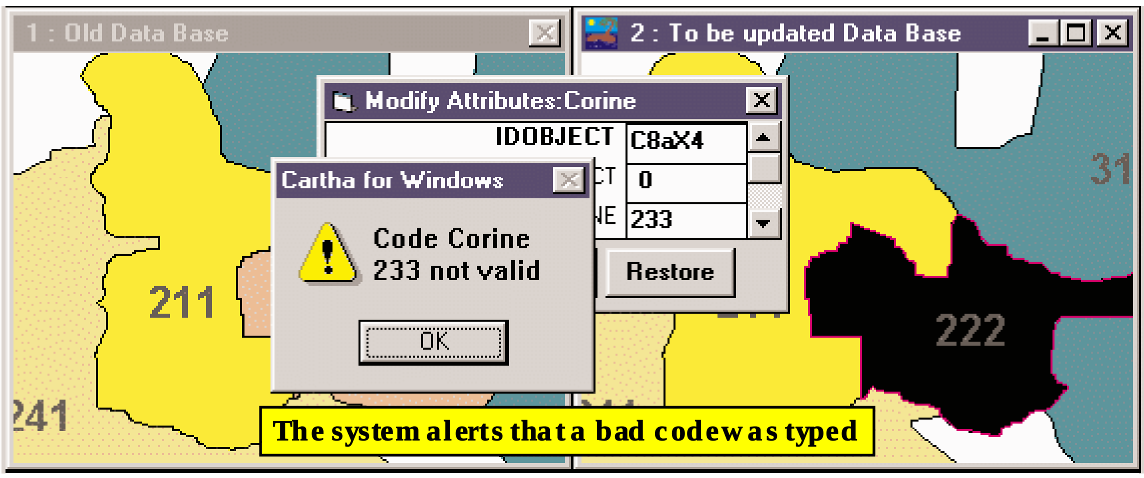
4.4.5.1 Example of Code Checking implementation

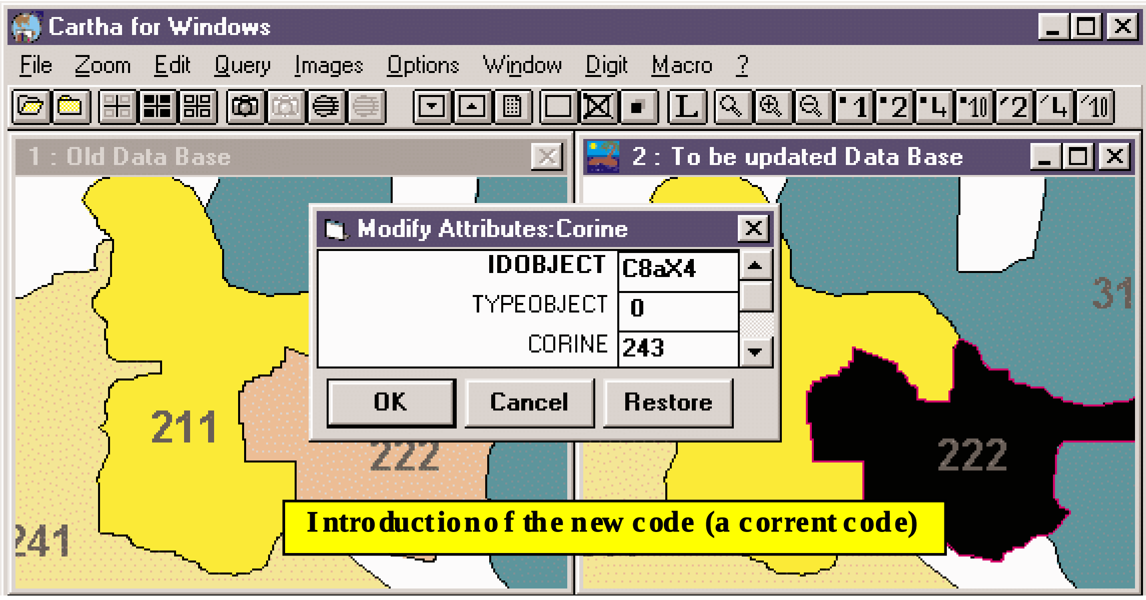
The following pictures show the implementation of direct code checking under *Co-Pilot* system.

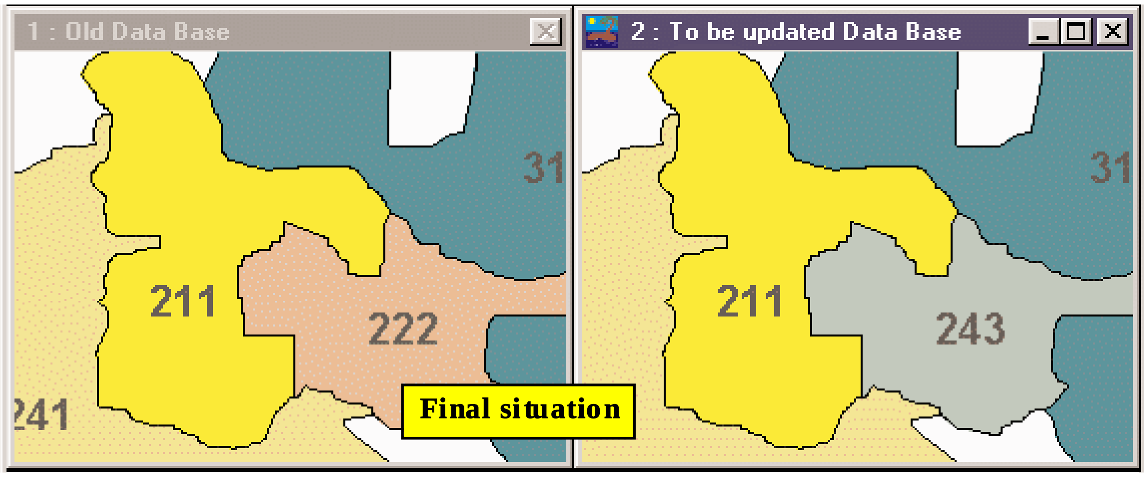



Cartha for Windows
File Zoom Edit Query Images Options Window Digit Macro ?
1 : Old Data Base
2 : To be updated Data Base
31
211
222
241
Identification of the object to be updated


1 : Old Data Base
2 : To be updated Data Base
Modify Attributes:Corine
IDOBJECT C8aX4
TYPEOBJECT 0
CORINE 233
OK Cancel Restore
31
211
222
241
Introduction of the new code (a bad code)


1 : Old Data Base
2 : To be updated Data Base
Modify Attributes:Corine
IDOBJECT C8aX4
0
233
Restore
Cartha for Windows
Code Corine
233 not valid
OK
31
211
222
241
The system alerts that a bad code was typed





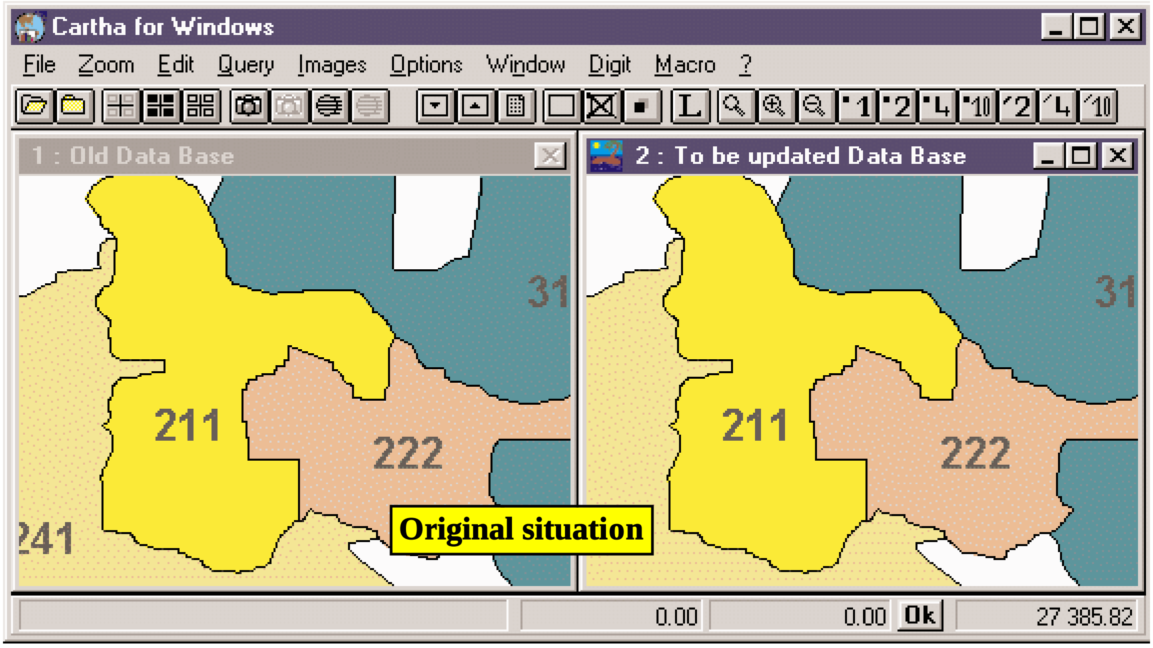
4.4.6 Special Buttons

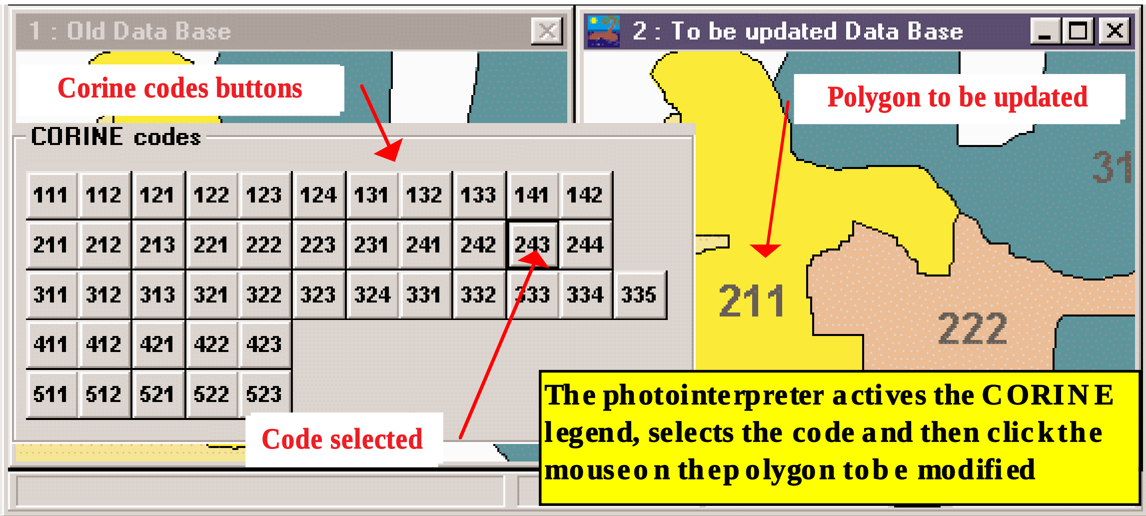
To speed up the image-interpretation process there is another possible mechanism that avoid the image-interpreter having to type the code and that performs the 3 steps of the previous approach in only one step. This method consists of using special buttons; each button is associated to a different code of the nomenclature. The user clicks on the button of the code to be used and afterwards clicks on the object to be automatically updated.

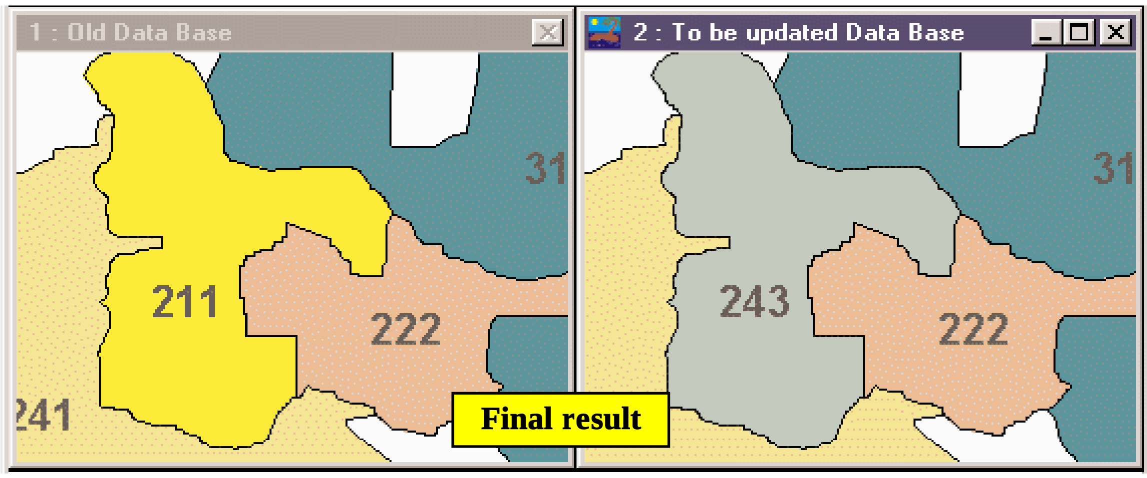
In this way a considerable reduction of the time need to perform updating can be achieved and data entry errors can be eliminated.

4.4.6.1 *Example of Buttons implementation*

The following pictures show the “Buttons” implementation in *Co-Pilot* system.







4.4.7 Polygon's Marking

In order to maintain an updated status of the project, the user must know in every moment which polygons have been verified or modified.

For this reason he must mark each verified polygon with a code to avoid spending time again on the same polygon, or to avoid missing it out in the analysis.

In screen image-interpretation, the user can pan over the scene to complete the interpretation of large polygons and he needs some help to maintain the status of work before panning.

In the new database each polygon has an attribute "INTERPRETATION_FLAG" assuming the values of table 6.

Table 6 - Marking Flag

Value	*Meaning*
0	**Polygon not yet considered.** This is the default value when the old database is copied in the database to be updated.
1	**Polygon confirmed.** This is the value to be used for polygons verified when the old code must be maintained.
2	**Polygon updated.** This is the value to be used for polygons verified when the old code cannot be maintained.
3	**Polygon with residual doubts.** This is the value to be used both for modified polygons and for verified ones (not changed) when there are some doubts in the interpretation.

Postulate 18 - Polygon Marking

During image-interpretation, the image-interpreter must mark polygons to maintain the status of the work. Each polygon must be marked: polygons with code 0 are not accepted and polygons with code 3 must be verified before the end of the work.

4.5 Work management

4.5.1 Use of Marks

As mentioned above the status of the project is maintained by means of the mechanism called "polygon marking". To each polygon an attribute INTERPRETATION_FLAG must be associated. Statistics about the number of verified polygons are automatically performed when necessary as illustrated in the next table.

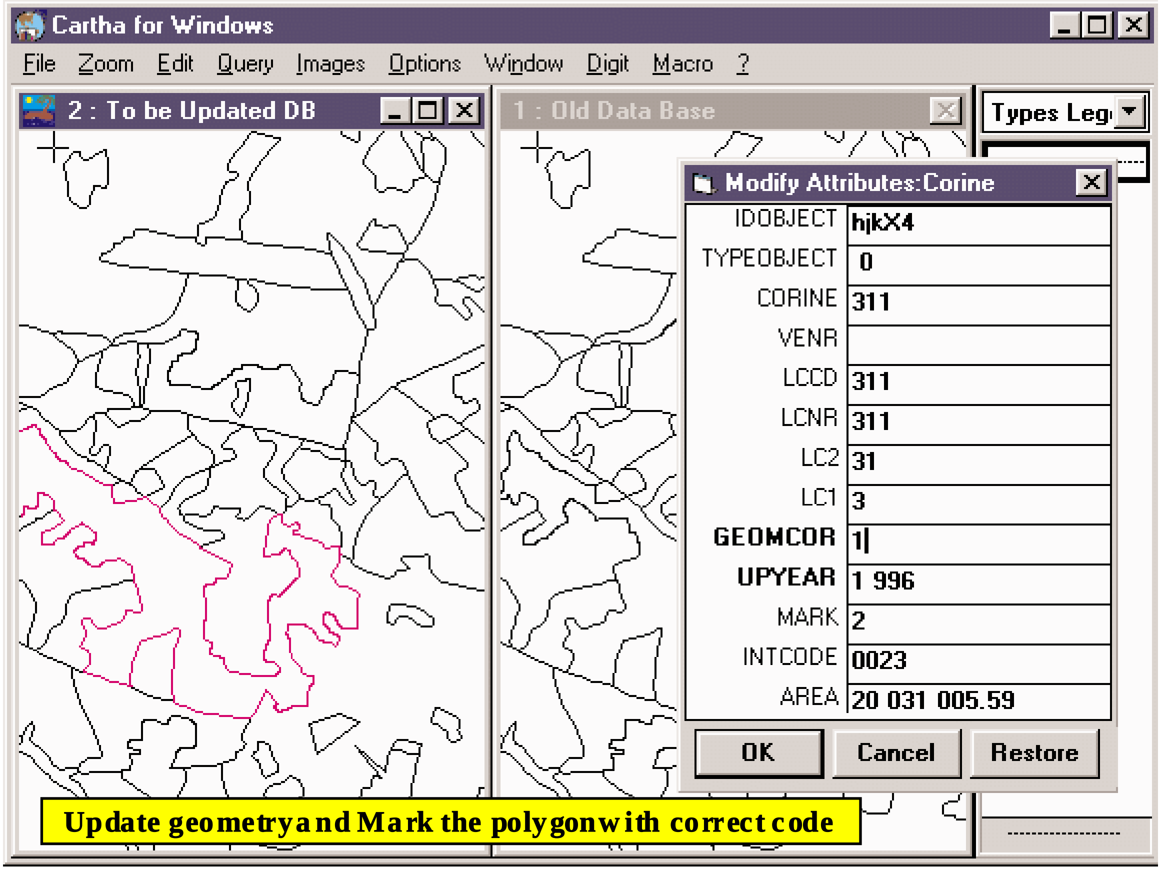
INTERPRETATION FLAG	N. of Polygons	% Polygons	Total area (ha)	% Area
0	2 300	32%	324 300	13%
1	4 500	63%	2 097 000	83%
2	350	5%	90 300	4%
3	50	1%	29 000	1%
Total	7 200		2 540 600	

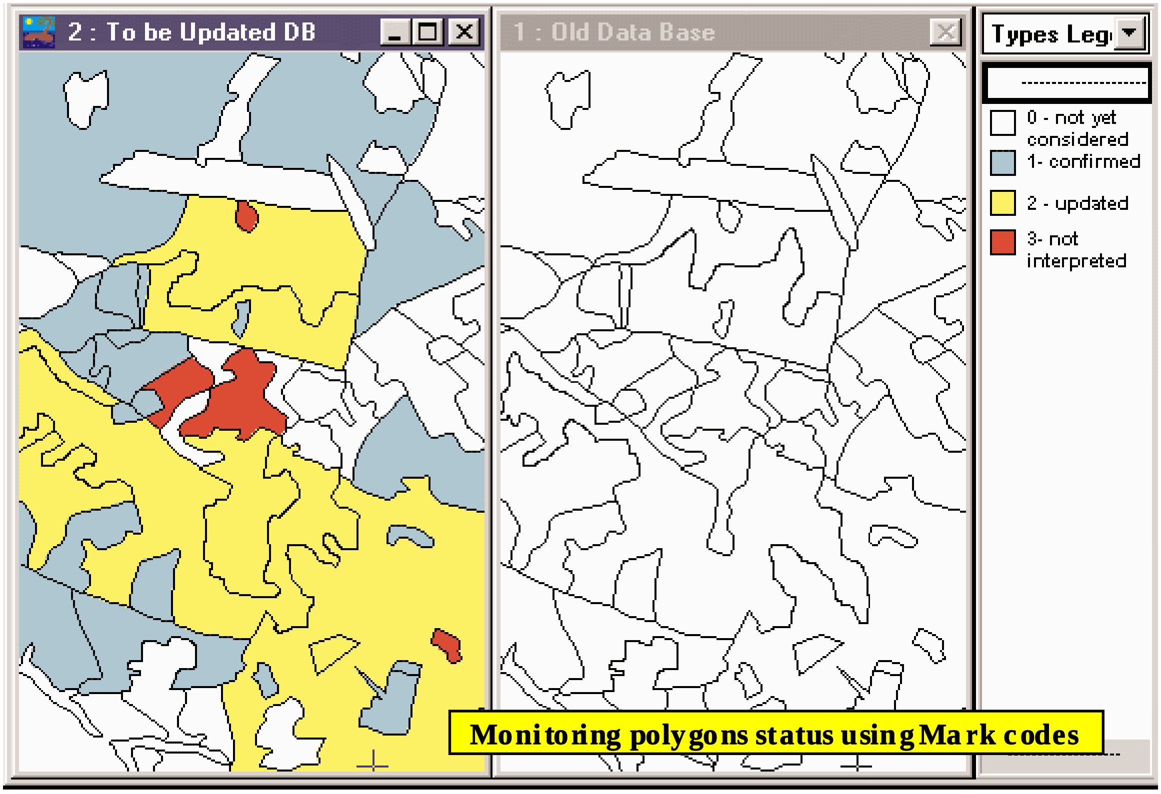
Method 8 -: Check the status of the work at polygons level

The user must utilise in his GIS some automatic procedures that assess the progress of updating the database, calculating the number of polygons completed and the number of polygons to be analysed or revised. The calculation is possible if the image-interpreter marks each polygon during updating.

4.5.1.1 *Example of Mark status monitoring implementation*

The following pictures show the implementation of direct code checking under *Co-Pilot* system.





4.5.2 Storing information about sheets/zones

In addition to the status of the project obtained using the polygon statistics, the work manager must be able to obtain information about the completed sheets/zones.

Considering that the whole methodology is sheets or zones oriented, it can be useful to know when a sheet/zone is completed in order to distribute it or to pass the respective data to the next steps of the processing chain (validation, integration, edition, ...).

To obtain this information, the GIS must provide a simple procedure to count the number and area of polygons contained in each sheet/zone, giving the work manager the same information presented in the previous paragraph but subdivided for each sheet/zone.

Sheet	Status	Interpretation Flag											
		0				1				2			
		n	% n	A	% A	n	% n	A	% A	n	% n	A	% A
A12	to be finished	276	12	20 157	4	180	4	836 506	30	15	30	8 063	12
B21	to be finished	529	23	60 470	12	540	12	55 767	2	1	2	15 454	23
C01	completed with some necessary revision	0	0	100 784	20	900	20	55 767	2	1	2	0	0
A35	to be finished	391	17	60 470	1	540	12	1 115 341	40	20	40	11 422	17
F23	completed	0	0	85 666	17	765	17	0	0	0	0	0	0
C12	at the beginning	1 104	48	176 372	35	1 575	35	724 971	26	13	26	32 251	48
total		2 300		503 919		4 500		2 788 352		50		67 189	

For each sheet/zone a separate form must be compiled to maintain technical information about work. These data should be memorised in the new database as a separate layer. In fact it can result in a very useful information source for the next updating. Standard forms are described in the “Quality assessment/quality control document” of the ETC/LC.

4.5.3 Storing information about the project

By means of the sheet level information, it is also possible to maintain information about the whole project in particular when the work was split between two or more technical teams.

It is important to underline that there are some common activities in data collection and organisation and it may be useful to perform the whole geometric validation (and correction) of the old database before starting the separated process of updating.

Postulate 19 - Maintain information about data

During the whole chain of processing some new data are produced (for example GCPs) or some additional data are utilised (for example aerial photos). The work manager must maintain a reference of all used data and must memorise the new data created for specific purposes. These data will be useful for the next updating.

4.5.4 Integration and co-ordination of work of different teams

According to the subdivision of work between several teams, strong co-ordination effort is necessary to guarantee the correct execution of the whole work and to avoid that the delay of one team can produce delay on the other team.

To do this, all activities are separated at the beginning of the project and only at the end of the work of each team is an integrated process necessary.

The figure 48 shows how co-ordination must be made. Only during the mosaicing activity must two teams work together.

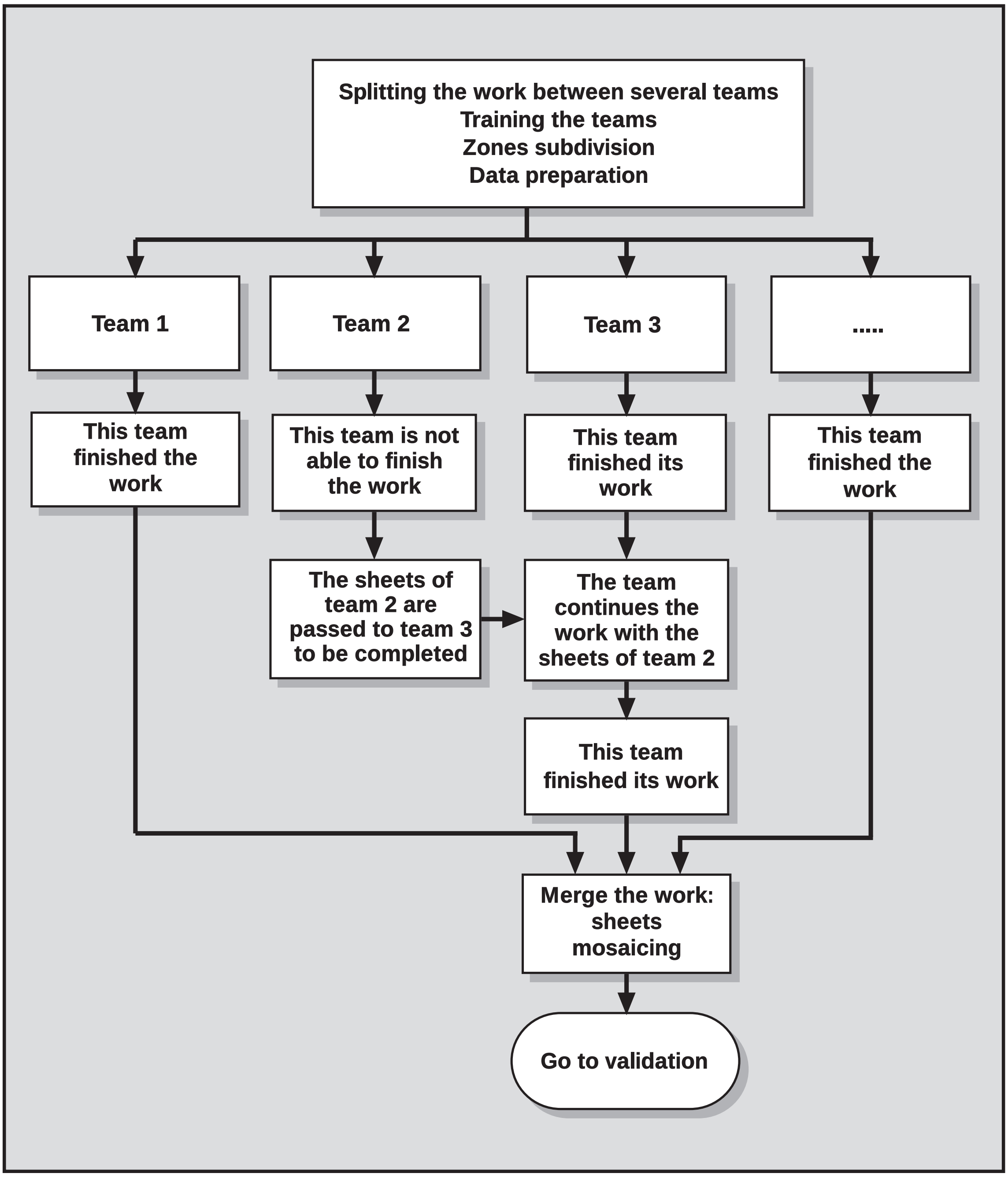


Figure 48 - Management of teams for updating

4.6 Database management

4.6.1 Maintenance of several databases

According to this methodology, the user operates on two databases at the same time (multiwindows environment) but he doesn't necessarily modify both databases.

In fact, if the original database was correctly created, no intervention of the user should be scheduled during updating. Instead, in case of "global errors", a preliminary correction of the original database is highly recommended.

In this case the original database created at time t0 (could be updated (corrected) before starting the real updating process (see figure 49).

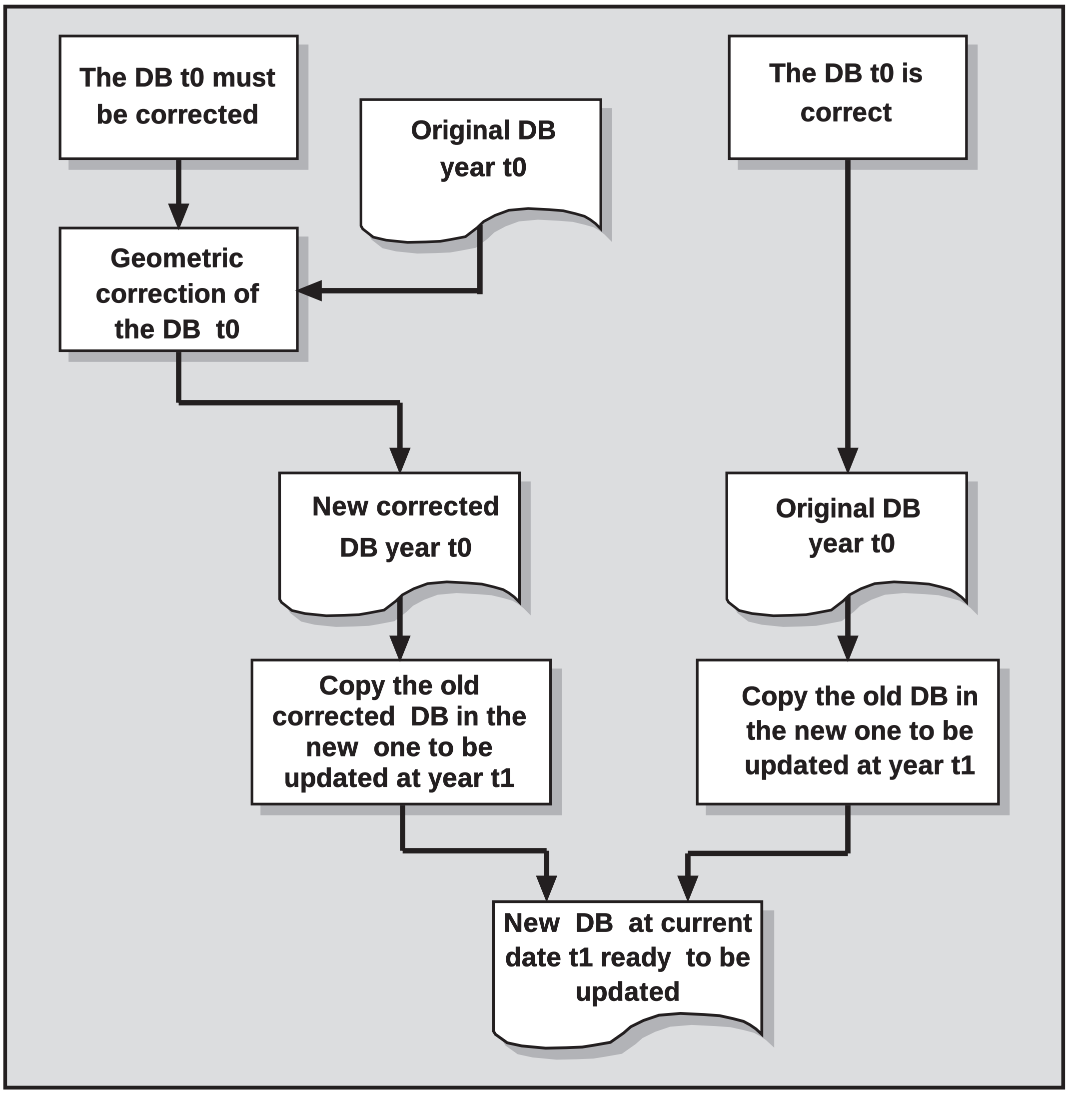


Figure 49 - Database management: suggested approach for the original database

At the end of the first updating process there will be three different databases: original database created at time t0, corrected version of that database, new database updated at current time.

To have the database at time t0 and at time t1 it can be useful to perform analysis concerning the evolution of the territory, so it can not be discharged. Local errors instead can be disregarded because they don't have (normally) a serious impact on statistics concerning changes.

In other terms, only the last database must be fully updated and the previous database can be maintained in their original form or in the last one corrected (see figure 50).

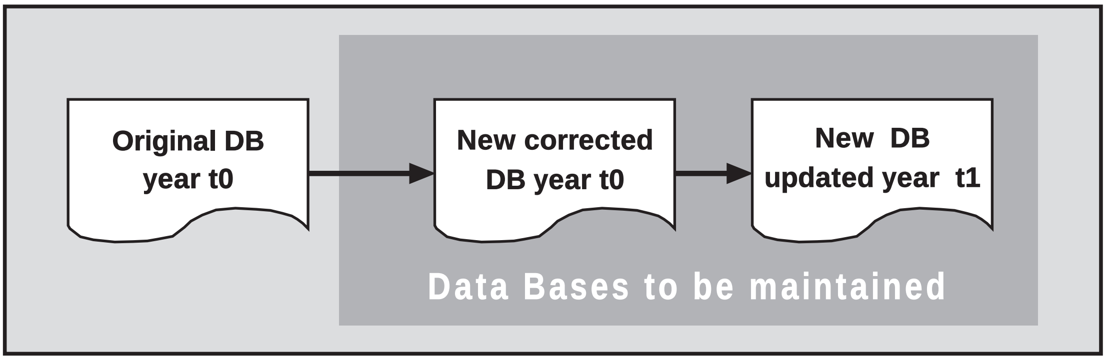


Figure 50 - Database to be maintained for evolution analysis

The situation is more complicated when only partial updates are scheduled. In this case the original database is partially corrected for the areas to be updated and various databases must be maintained (see figure 51).

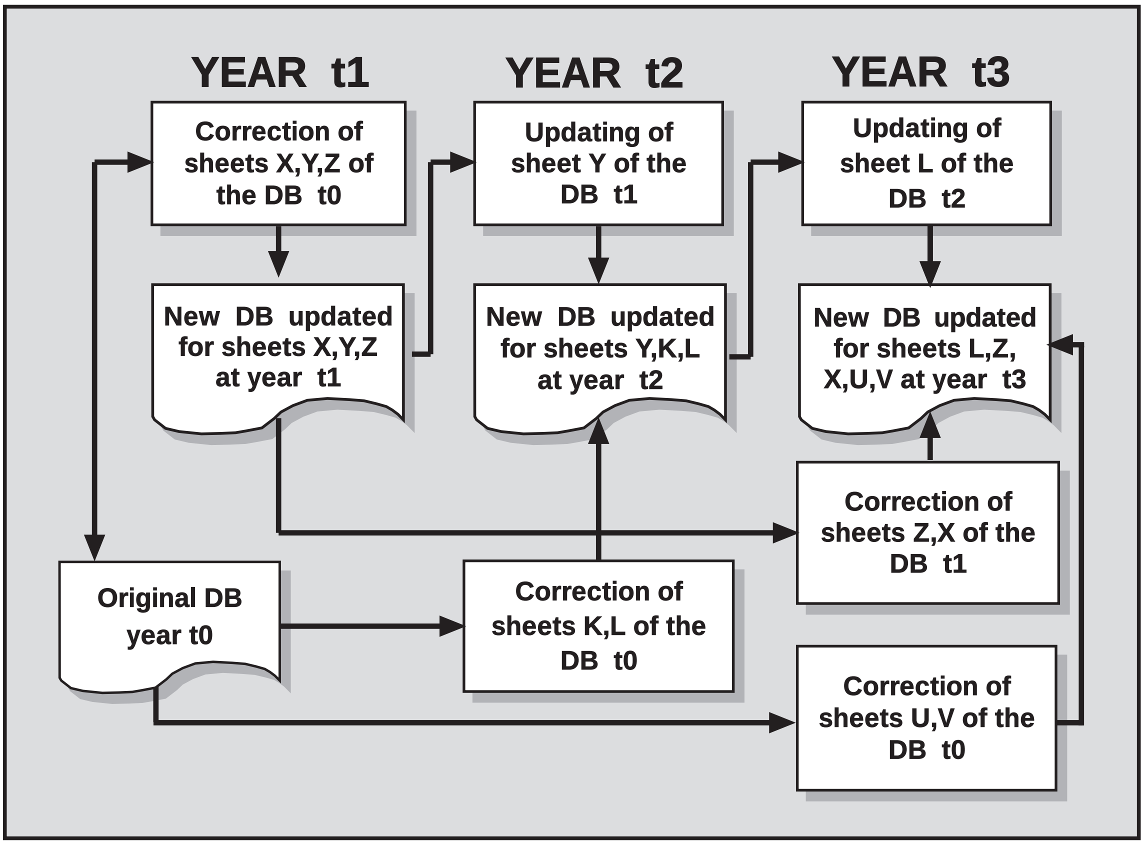


Figure 51 - Maintenance of various databases

Figure 51 shows the complexity of this situation, which is simplified in the case of only one database stored in different sheets.

Figure 52 shows the above situations in the case of sheet oriented memorisation. In this case there is a database at time t3 that contains sheets updated at various dates. To perform analysis concerning evolution the user must perform this analysis separately using the old sheets of the appropriate year.

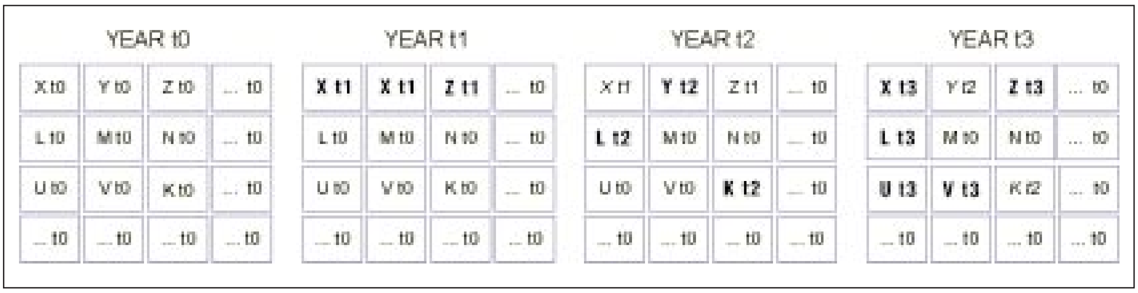


Figure 52 - Database maintenance, sheets oriented

4.6.2 Maintenance of one database

The considerations of the previous chapter are related to the need to perform evolution analysis.

However, if the CORINE Land Cover database is considered as a basic tool for planning and management of the environmental resources, the main need is to maintain a database sufficiently updated to support this type of work.

This is the suggested approach of this methodology: to support the old corrected database and to maintain the latest updated version. If only one database is maintained, one should be aware about the consequences.

To do it every time when updating is done the whole current database must be copied to the new one and updating must be performed (fully or partially).

To take track of the updating history each polygon must be flagged with the date of updating. In this case the situation illustrated in figure 50 must be changed as shown in figure 53.

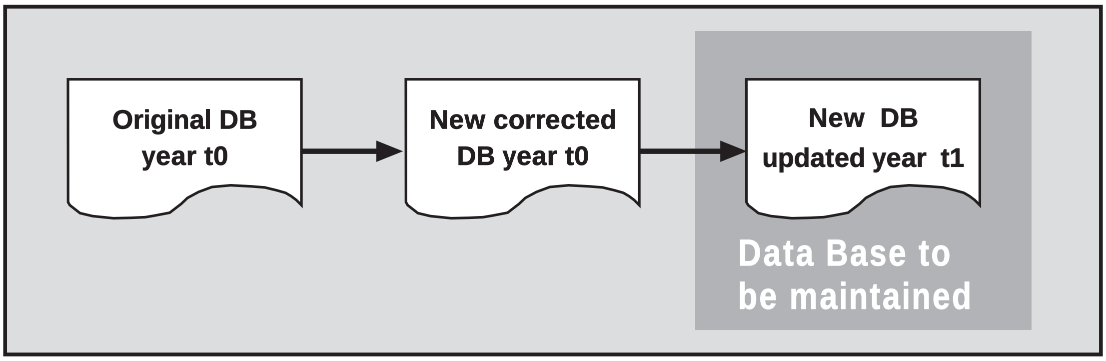


Figure 53 - Database to be maintained for CORINE project

The situation described in figure 51 occurring when partial updating is carried out (on a subset of zones at different dates) is illustrated in figure 54 when the database to be maintained contains items updated in different years.

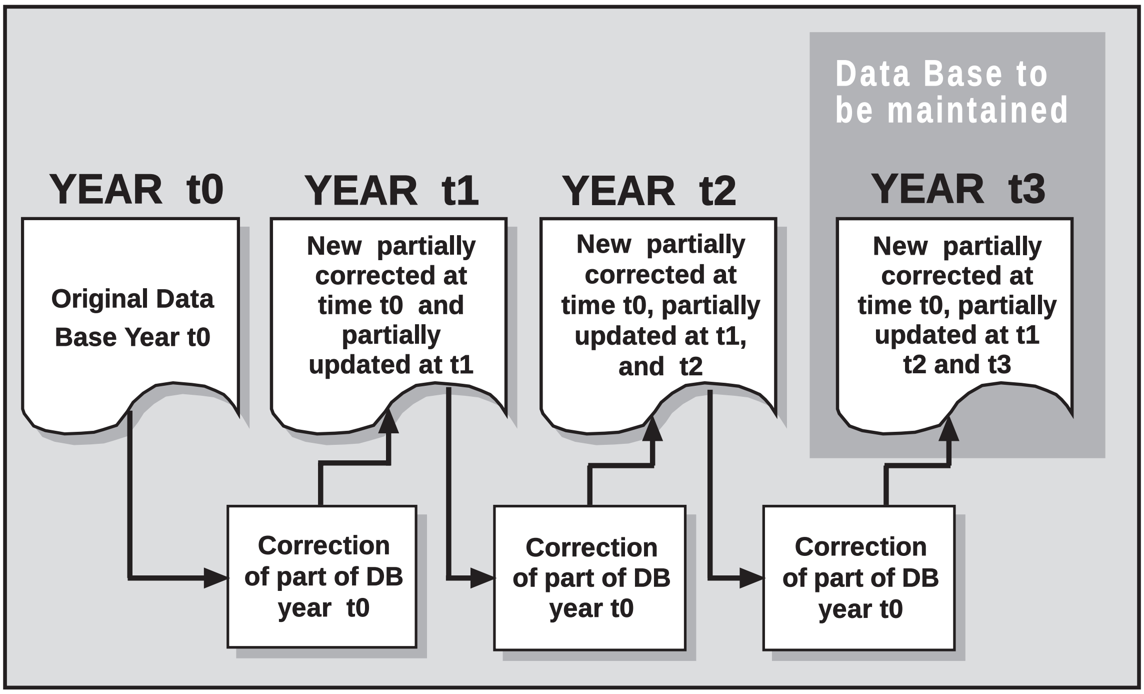


Figure 54 - Database aspect for multiple partial updating processes

As above mentioned, to implement this solution every polygon must be marked when updating is done. At the first updating <u>one attribute of each polygon must be set to the date of creation and the flag relating to the geometry verification must be set to FALSE</u>. If some polygons are geometrically verified before starting the updating phase this flag must be set to TRUE.

When updating is done the flag is automatically set to TRUE and at the same time the date of updating (Year) is set to the current Year. If all polygons are updated every polygon is geometrically verified and the date of all polygons will be the same (corresponding to the Year of updating).

If updating is done partially in different years some polygons will remain geometrically unverified and the associated date could change from one polygon to another.

4.6.3 Database structure

The final structure of CORINE land cover database is the GISCO database structure (see Table 7). Various attributes are stored in the database in addition to the geometric attributes like AREA and PERIMETER.

The Metadata information must be collected in agreement with the existing definition described in the *"Technical Guide Vol.2" of the ETC/LC.*

Table 7 - Current attributes of GISCO CORINE Land Cover database

LCARCD	Land Cover Area Code	Land Cover Class (4th level) (defined as character term)
VENR	Version Number	Actual version of the land cover data
LCCD	Land Cover Code	Land Cover Class (3rd level) (defined as character term)
LCNR	Land Cover Number	Land Cover Class (3rd level) (defined as numeric term)
LC2	Land Cover 2	Land Cover Class (2nd level) (defined as numeric term)
LC1	Land Cover 1	Land Cover Class (1st level) (defined as numeric term)

(*) source EUROSTAT GISCO

For the specific needs of updating the suggested structure is a collection of temporary attributes (to be used during updating) and permanent attributes (to be exported to GISCO database).

Table 8 - Attributes to be used in the CORINE Land Cover database, during updating

Item		**description**	**type(*)**
LCCD	Land Cover Code	Land Cover Class (3rd level) (defined as character term)	
LC3	Land Cover 3	Land Cover Class (3rd level) (defined as numeric term)	P
LC2	Land Cover 2	Land Cover Class (2nd level) (defined as numeric term)	P
LC1	Land Cover 1	Land Cover Class (1st level) (defined as numeric term)	P
GEOMCOR	Geometric Correction	Flag to be used to remind that the preliminary geometry verification and correction has been done.	T
UPYEAR	Updating Year	Year of updating (defined as numeric term)	P
MARK	Mark Polygon Status	Polygon status (defined as numeric term): • value =0, polygon not yet considered • value =1, polygon verified (interpretation confirmed) • value =2, polygon updated (new interpretation) • value =3, polygon to be verified (using other data)	T
INTCODE	Interpreter Code	Code identifying the image-interpreter charged of updating (defined as character term)	P
REMARKS	Interpreter remarks	Remarks to be associated to a polygon (defined as numeric term)	P/T
ERRORS	Polygon errors	Free description of encountered errors associated to the previous version of the DB when not corrected (defined as character term)	P/T
PERIMETER	Polygon perimeter	defined as numeric term	P
AREA	Polygon area	defined as numeric term	P
LC4 (**)	Land Cover 4	Land Cover Class (4th level) (defined as numeric term)	P
LC5 (**)	Land Cover 5	Land Cover Class (5th level) (defined as numeric term)	P

(*) T = Temporary, P = Permanent
(**) optional attributes

If the Sheet oriented approach is chosen, during the work it is useful to associate to each polygon an attribute containing the related sheet number. Practically this link can be obtained by GIS queries, intersecting the sheet object and the polygons. As a consequence this attribute is not necessary.

5. VALIDATION AND QUALITY ASSURANCE

Validation and quality assurance should be the same defined for creation (for further information see *"quality assessment/quality control"* of ETC/LC).

The main difference in validation for updating concerns the numbers of points/polygons to be checked to validate the database. In fact, for creation the whole territory is interpreted and theoretically errors can be found anywhere.

In updating process, errors of the image-interpreter are concentrated in the modified zones and some errors can be found in areas changed but not discovered by the image-interpreter. This means that the distribution of errors is not uniform. As a consequence, the random selection plan must take into account this difference. In other words, most of points to be checked for validation must be taken inside changed areas and only the remaining number of points must be taken in not changed areas. The criteria to select points must be the same as used for creation but two different strata must be considered: changed and not changed areas (as illustrated in Figure 55).

The approach described above is correct for a real updating. When the original database has not been validated before or when it is known that it contains several errors, all the previous considerations do not remain valid. In that case the simplest way to act is to perform a standard validation. The result of the validation will have the effect to detect both new and old errors.

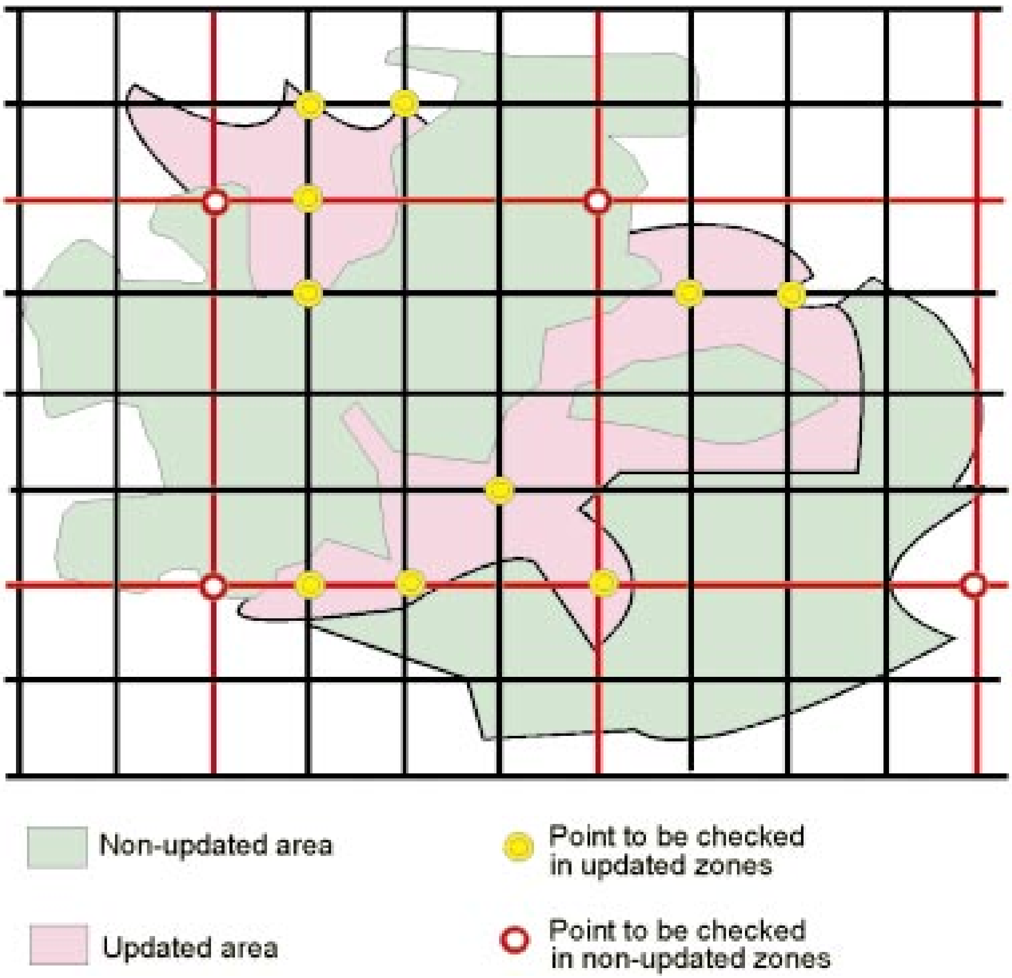


Figure 55 - Validation plan

6. UPDATING FREQUENCY

The frequency of updating is a very delicate point of discussion.

In an analytical form, the frequency can be expressed as a function dependent on several independent variables:

$$F_{upd} = f\ (B, U, C, D, Q, Ri, \ldots)$$

where

B =	Budget	Total of money to be spent to maintain up to date the database. According to the budget at disposal several solutions can be adopted (for example collection of specific ancillary data, scale of work, ...).
U =	User needs	According to the specific user's requests and needs, some classes or some areas (i.e. sea coastlines) can be considered more relevant and the frequency of updating can decrease or increase in direct proportion to the verified interest.
C =	Changes rate	According to the evolution rate of certain areas the frequency can be dynamically adapted, increasing updating frequency when territories quickly change and vice versa, decreasing it when changes hardly occur.
D =	available Data	In correspondence with other inventories or census, some information (useful also for CORINE updating) are collected. A link with these projects permits economies in the updating costs and improvements in the quality of the final results. Frequency can be re-defined to take into account these events.
Q =	Quality	As later illustrated the global quality of the database generally increases at every updating. In case of an initial bad quality of the database the updating should be scheduled earlier than expected.
Ri =	Recognition Interval	This parameter represents the maximum time interval in which a change can be detected. For example a new road under construction (133) and the relative dump sites (132) can be recognised if images are acquired before (t0), during (t1) and after (t2) the period of work until the road is finished. Vice versa, if images are acquired only before (t0) and after (t2) the period of work, these changes can be difficult to recognise (as illustrated in figure 56 and figure 57).

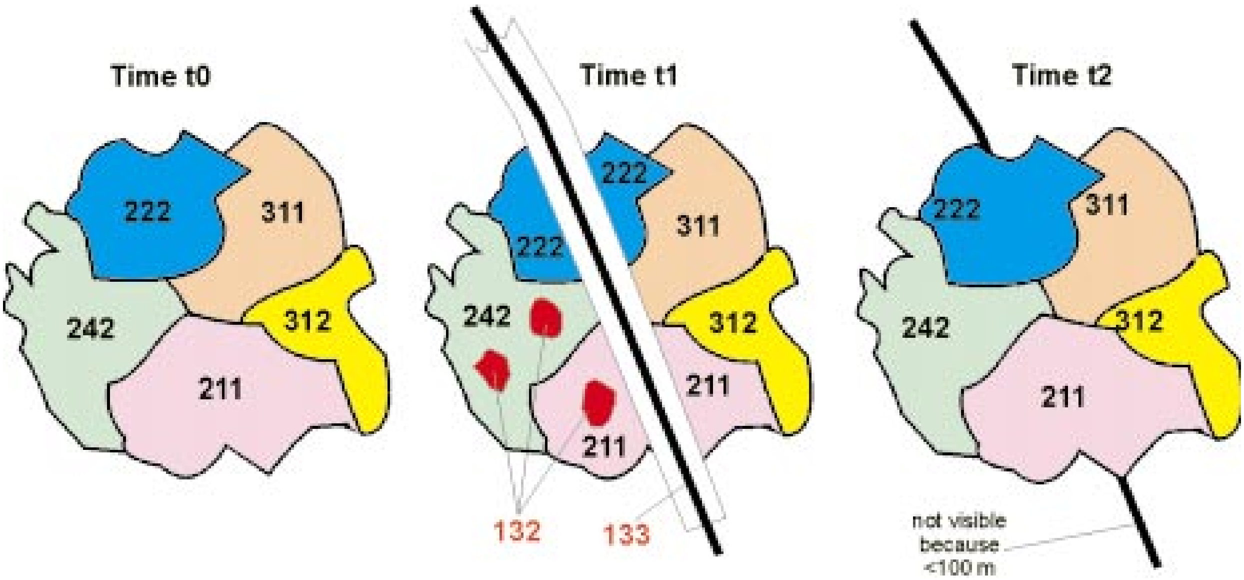


Figure 56 - Frequency of updating and observable changes

Figure 57 - Difficulty of interpretation related to updating period

Taking into account the above mentioned variables, to decide when updating is necessary there is a need for some external information or "Land cover change indicators".

Definition 7 - Land Cover Change Indicator

The term Land Cover Change Indicator is referred to every data and model that can be used to estimate if relevant changes have occurred since the last updating date.

> *Definition 8 - Relevant changes*
>
> A specific change is considered relevant if it is assessed as important for the planned use of the database. The importance can be appreciated both in terms of percentage (i.e. a total surface change greater than 5% of the whole area, than in terms of hierarchic importance of the class i.e. an increase of 10% of the water class) or if the land cover change is an indicator for another important phenomenon.

It is important to find some indicators using all available sources of information like:

- national annual statistics,
- ground surveys,
- environmental observatories,
- forecasting models,
- ....

If no data is available some automatic approaches using satellite imagery can be implemented. These methods of "Land Cover change detection" are not sufficiently accurate to directly update the database but can be used to provide a raw objective estimation of rate of changes in some classes (forest, urban, water).

An alternative approach is based on a random selection of a certain number of points to be investigated applying the computer aided image-interpretation methodology for updating. At the end of the checking work it will be possible to perform statistics regarding how many changes (in percentage) have been found and which important classes are significantly changed.

The main disadvantage of the last two mentioned methods is that satellite images are necessary and so the cost of the data must be taken into account.

These methods permit a rough evaluation of the rate of changes. When no important variations can be estimated, the updating could be postponed.

It is important to underline that the rate of change is not the sole factor influencing the frequency of updating. Updating frequency depends of many other factors, mainly:

- some classes need more frequent monitoring,
- the satellite data enable the evolution of a change to be followed well (in fact the understanding of some phenomena by using of remotely sensed data is strongly related to the survey frequency as illustrated in figure 57).

6.1 Updating cost

The updating cost depends of several parameters and it may be considered a complicated function of the Updating frequency.

The cost of the satellite data depends on the particular satellite currently used: Landsat TM, SPOT XS, SPOT Pancro, IRS, ... (or the future scheduled new satellite missions). It is difficult to correctly quantify the cost of the whole Updating.

The cost evaluation contained in the document "CORINE Land Cover: l'apport de Spot" estimated that, in the case of database creation, the total cost of the data (including pre-processing operations) is about 75% of the total cost, and 0.71 times the cost of the image-interpretation (including supplemental processing of the data).

Our experiences in creation are little different: for example, using Landsat TM the cost of satellite data may range between 30-50% of the total cost for CORINE Land cover creation.

In any case, considering that the image-interpretation cost decreases in updating it is evident that the cost of satellite data becomes more important than the cost of the image-interpretation. The proportion of the total related to image acquisition costs varies according to the updating frequency. By comparison, the cost of image-interpretation decreases when updating frequency increases.

The time and consequently the cost spent by the image-interpreter can vary according to the rate and nature of changes.

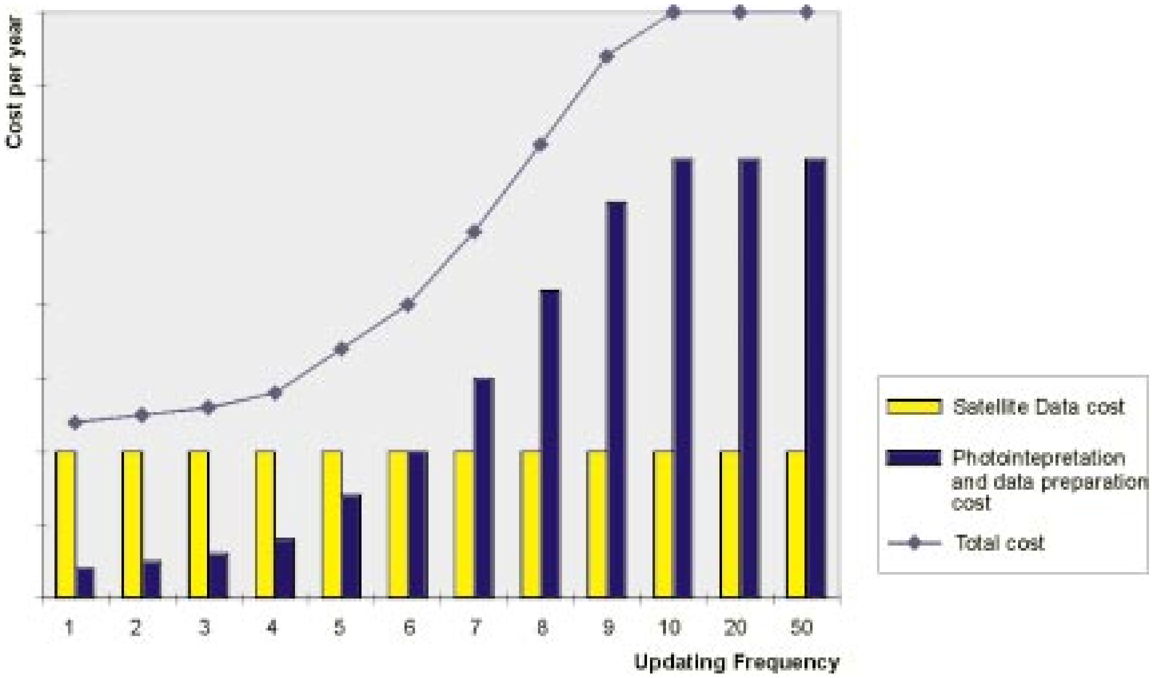


Figure 58 - Cost depends on the updating frequency

7. QUICK GUIDE FOR UPDATING

1. Data collection	• satellite images (previous and new ones) • ancillary data • previous database
2. Data preparation	• image geo-referencing • image preparation (contrast enhancement - LUTs set-up, filtering, NDVI, PC, ….) • database design (attribute table, standard to be used, relationships, definition of sheets if relevant, …) • data import • work environment (graphic look, LUTs, windows, scales,…) • copy of the old database in the new one (to be updated)
3. Data checking ([1])	• codes checking ([2]) • topology checking • geometry checking of the database
4. Database updating	• detect changes (overview) to be done ◊ at 1:100,000 scale ◊ using ancillary data ◊ by means of image comparison in a multiwindows environment • identify and correct changes ◊ at 1:50,000 scale ◊ polygon editing ◊ polygon marking • check and survey status work ◊ follow status using polygons and sheets flags ◊ complete missing polygons ◊ interpret doubtful areas using any kind of additional information ◊ update metadata information
5. Database validation	• define a sample of polygons ◊ where changes occurred (high rate) ◊ where no changes occurred (low rate) • re-interpret the sample of polygons
6. Database integration ([3])	• checking and re-interpretation of overlapped zone (when different codes are found) • data merging
7. Database delivery	• data export • data report (collection of remarks, statistic data, ..) • data delivery

[1] To be done only in the first updating or if a previous validation has not been carried out
[2] This check concerns only missing codes or non-existing codes (no check of interpretation)
[3] To be done if several teams work in independent manner

7.1 Standards to be used

1. Precision in location	• 100 m
2. Precision in digitising vertices	• 5 m
3. Precision in digitising nodes	• 20 m
4. Dangle and fuzzy tolerance	• 0.1 m
5. Scale of work (for digitising)	• 1:50,000
6. Image geo-reference precision	• RSM < 2 pixels
7. Minimum cartographic unit	• 25 ha

8. IMPROVING THE METHODOLOGY

The proposed methodology as previously explained is strictly Computer Aided Image-Interpretation oriented although the use of intermediate products coming from various classifiers is accepted and in some cases suggested.

Evaluating the European experiences on updating described in the "assessment of the existing experiences on the updating process" (ETC/LC work package 3.2) it is evident that, to cover all the CORINE Land cover classes, only the computer aided interpretation methodology can be currently considered as operational.

This means that updating work starting now cannot use as automatic approach and also in any use of a semi-automatic approach a final manual revision must be planned by the image interpreter.

Looking to the future and roughly simplifying the matter we can identify two possible strategies to reduce the manual work of updating:

- CORINE nomenclature characterisation, according to an European "ecozoning"
- development of tools for Object oriented classification (or more correctly monitoring).

Heterogeneous classes are very complicated to be detected with traditional classifiers (also using additional parameters like texture). In addition due to the subjectivity of their delineation the classifiers must use all the ancillary data considered by the image-interpreter and as a consequence the costs to digitise them often surpass the cost of traditional updating.

In the CORINE Land Cover Technical Guide vol.2 a considerable effort has been done to normalise the definition and to describe the rules to be followed both for manual or automatic identification. Only having clear and not subjective rules the use of decision systems could be planned.

The second proposed strategy concerns the development of tools specially designed for updating. In fact, the current tendency for automatic updating is (as underlined in above mentioned study) to make two different classifications of the same area and to define changes as main differences between the two classifications. The first criticism that can be made is that in this way the problems of bad classifications of some classes can not be solved; the second criticism is that, as fully illustrated in this guide, a CORINE change does not always correspond to a land cover change !

We think that more consistent and reliable results could be obtained by introducing a new set of classifiers that can be defined as "object oriented agents".

In this new approach the automatic process does not start to classify images to detect changes but it start from each object to follow its evolution. To each object a different "agent" must be associated. An agent can be defined as the guardian of a set of properties specific to the object that must be maintained. When one or more of these properties change, the object itself is changed and updating must be done.

This approach is very innovative since it means that for each class of the CORINE nomenclature a different agent must be defined, and also it is likely that some sub-agents can be used inside a class.

The agent consists of tools to evaluate the properties of the objects. Some tools are already available (for example texture classifiers, per field classifiers, anomalies detectors, …), others must be developed.

If the agents work correctly the manual inspection time will be reduced, requiring to interpret the changed areas only. In fact, the image-interpreter will be charged to only solve problems in modified areas not directly soluble by the agents. If the agents will be able to <u>classify</u> all changes, no manual inspection will be required (too optimistic for us) ! In other words, the very important work of the agents is to <u>identify</u> all changes and not to classify them.

An example of a very simple agent clarifies our concepts.

Updating of homogenous forest can be done with an agent evaluating the following properties:

- non existence of a sub-unit greater than 25ha and with spectral values far from the mean value of the unit itself. When these sub-units exist the cause could be attributed both to forest fires, rotational cuts, or other antropic or natural events. The new parcel must be created and the image-interpreter must be used to classify it (or in some case to subdivide more or delete).

- the spectral distances of the border pixels to the main spectral value of the unit must be respected both for inner and outer pixels. When the pixels distance is too high, a need to merge or split would be suggested or directly made. The spectral distance must be considered contextually to the spectral distance of the surrounding units.

In conclusion, to apply this kind of approach the image processing must be GIS oriented due to needs of contextual analysis and of the storing of the properties of the original units.

The evolution of GIS technology towards OpenGIS systems seems to facilitate the development of a set of new agents solving the current limitations due to a lack of Interoperability. As a consequence the research in this area could provide operational solutions in the near future.

9. REFERENCES

1. ETC/LC (1996), "Technical guide vol.2". First draft
2. ETC/LC (1996), "Technical guidelines on Quality assurance / Quality Control". Final draft
3. ETC/LC (1996), "Report on Prototype for LC Metadata information". Final draft
4. ETC/LC (1996), "GISCO Database manual Chapter 11.4 - Land Cover". Final draft
5. Y.Heymann (1993), "CORINE Land Cover: l'apport de Spot"
6. V. Perdigão, A. Annoni - "Integration of Remote Sensing and GIS to Update a multisources Land Cover database". Proceedings International Symposium Operationalisation of Remote Sensing- Vol.6. Apr.1993, Enschede, the Netherlands
7. Annoni, Cumer. "Il progetto Corine Land Cover: le mappe delle regioni italiane". Atti del 7 convegno AIT (Associazione Italiana per il Telerilevamento) Telerilevamento GIS e Cartografia al servizio dell'informazione territoriale . Chieri,1995.
8. Annoni, et all. "Prova sperimentale per la realizzazione della carta dell'uso del suolo con immagini telerilevate". Documenti del Territorio. Anno VIII n.28/29 giugno-dicembre 1994

10. ANNEX 1: EXAMPLES OF UPDATING

The following pages show some examples of updating to be done comparing the old database of Lisbon region produced on 1985 with a new satellite image acquired in 1991.

Both the images were acquired in the same season (January), so the vegetation condition and the agricultural practices can be compared.

Some changes can be observed: these changes describe two different situations: changes caused by increasing of urban (new buildings, new roads, new industrial settlement,...) and by agricultural innovation (for example use of Pivot for irrigation).

In the last case a distinction must be made between changes in the landscape (without an effective CORINE class migration) and changes that correspond to a re-classification of the territory (for example changes from forest to agricultural or from rice fields to arable lands).

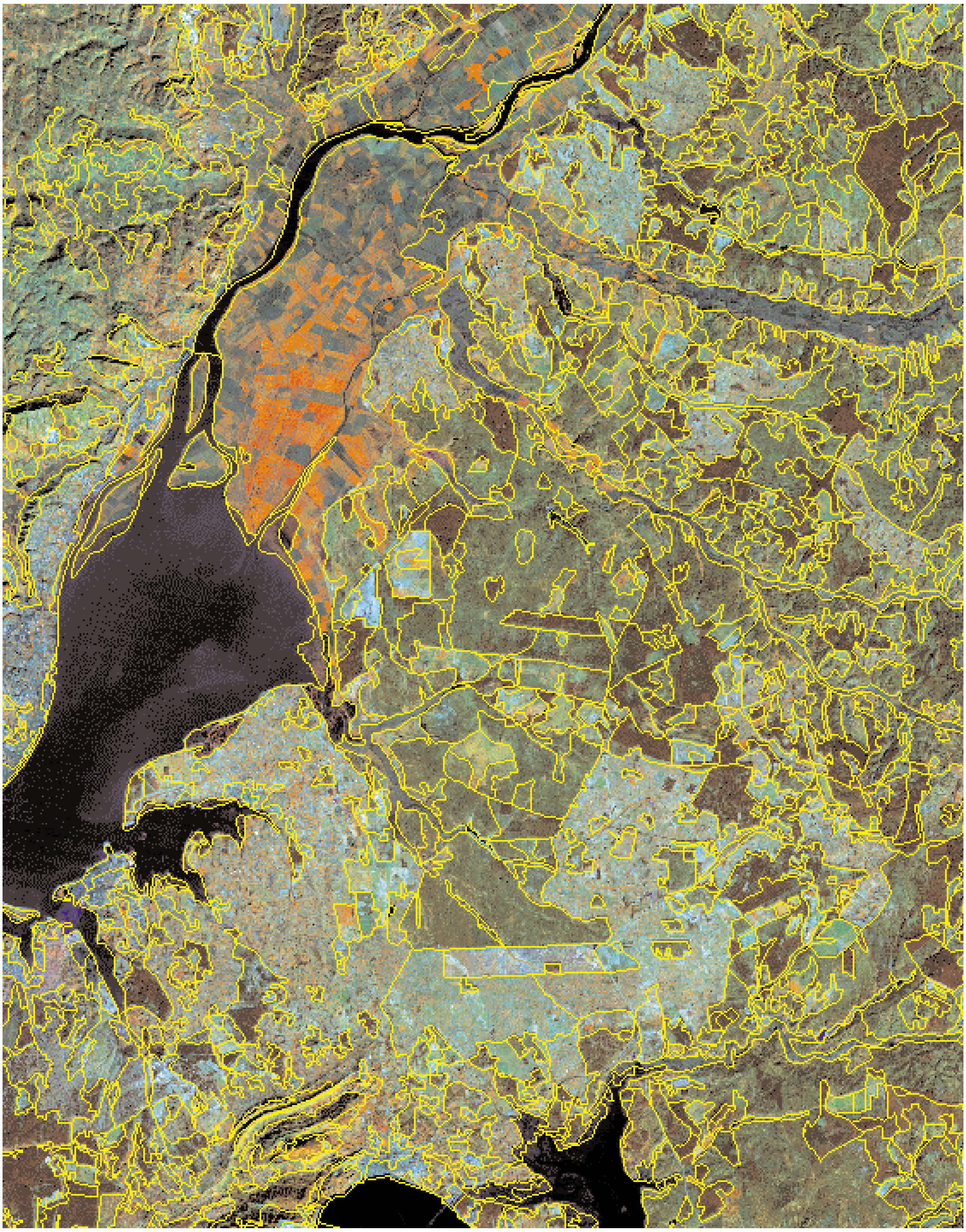
In the following examples some discrepancies between images and database can be observed. This lack of precision is sometimes related to the error propagation of the several geometric transforms of the data but also to the original use of satellite data with less resolution. In fact Portugal was initially interpreted using MSS data instead of TM or SPOT. As a consequence the boundaries could be in some cases less precise than in different countries.

These discrepancies are specially evident at 1:50,000 scale. It is important to underline that original image-interpreters are rarely responsible of the lack of geometric precision. In fact they worked on satellite printouts at 1:100,000 scale. It is so obvious that the derived database cannot be precise if observed at higher scales.

The following examples are for demonstration purposes only:

- the geometric correction of the original database has not been done before starting updating,
- updating is not complete, only some polygons are updated to show different situations.

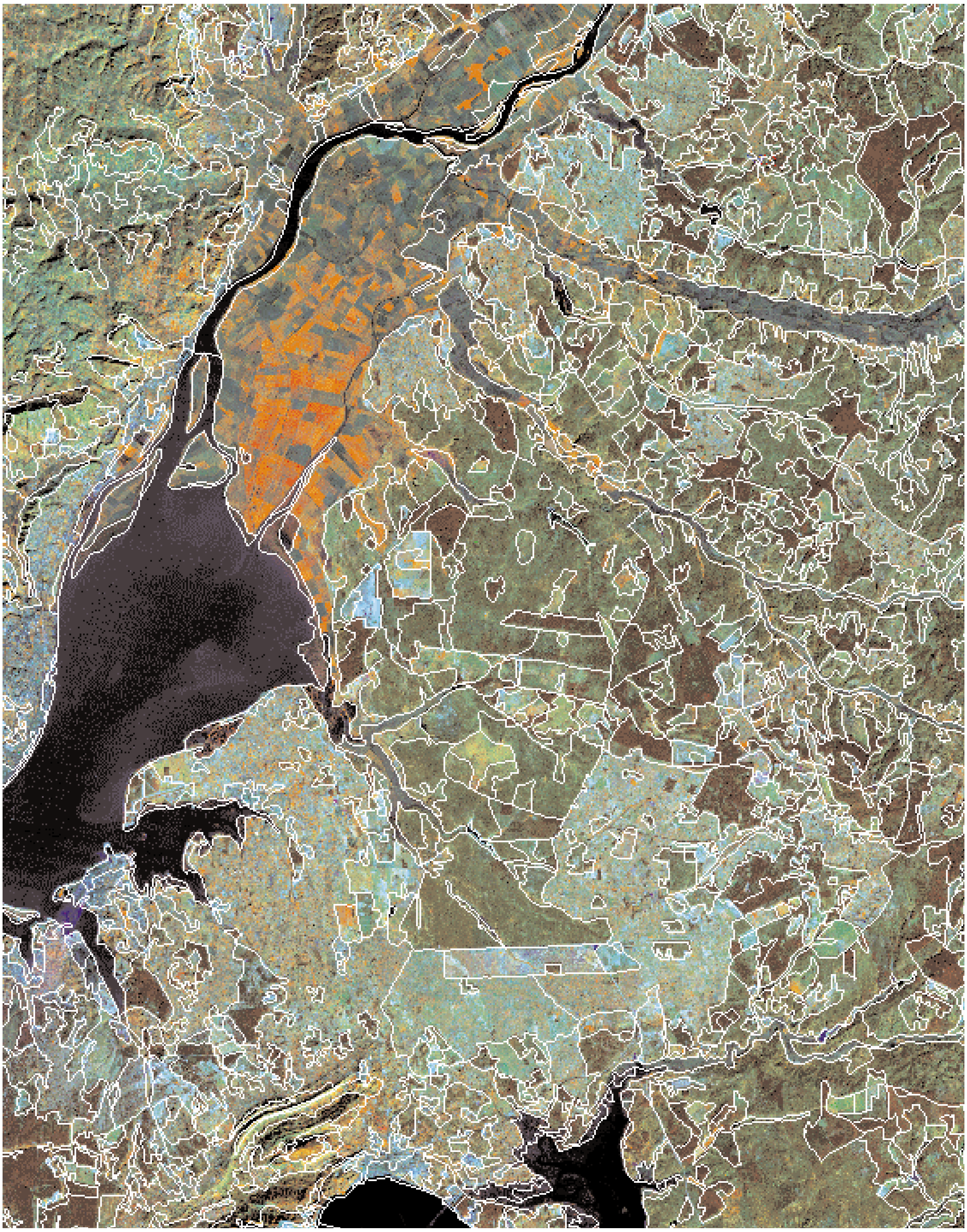
1985 CORINE Land Cover database and LANDSAT TM image(4,5,3) - January 1985 - scale 1:350,000



The left and right pictures show the same area in two different years with the overlay of the 1985 CORINE Land Cover database. The left image of 1985 corresponds to the date of database creation, the right image was acquired six years later.

According to the selected period (January) for both images, the two scenes can be easily compared after performing histogram matching (in that case the pixel values of the second image are recalculated in order that their histogram can be compared with the previous one).

1985 CORINE Land Cover database and LANDSAT TM image(4,5,3) - January 1991 - scale 1:350,000



With the selected color composition (bands 4,5,3 on red, green and blue respectively) water is black, forest is brown, natural grassland and mixed forest are dark green, agricultural areas are red or light green, urban areas are cyan.

Because of the low rate of changes, at this scale, for this area, not very important changes can be seen.

A more detailed scale is so necessary to start the updating work.

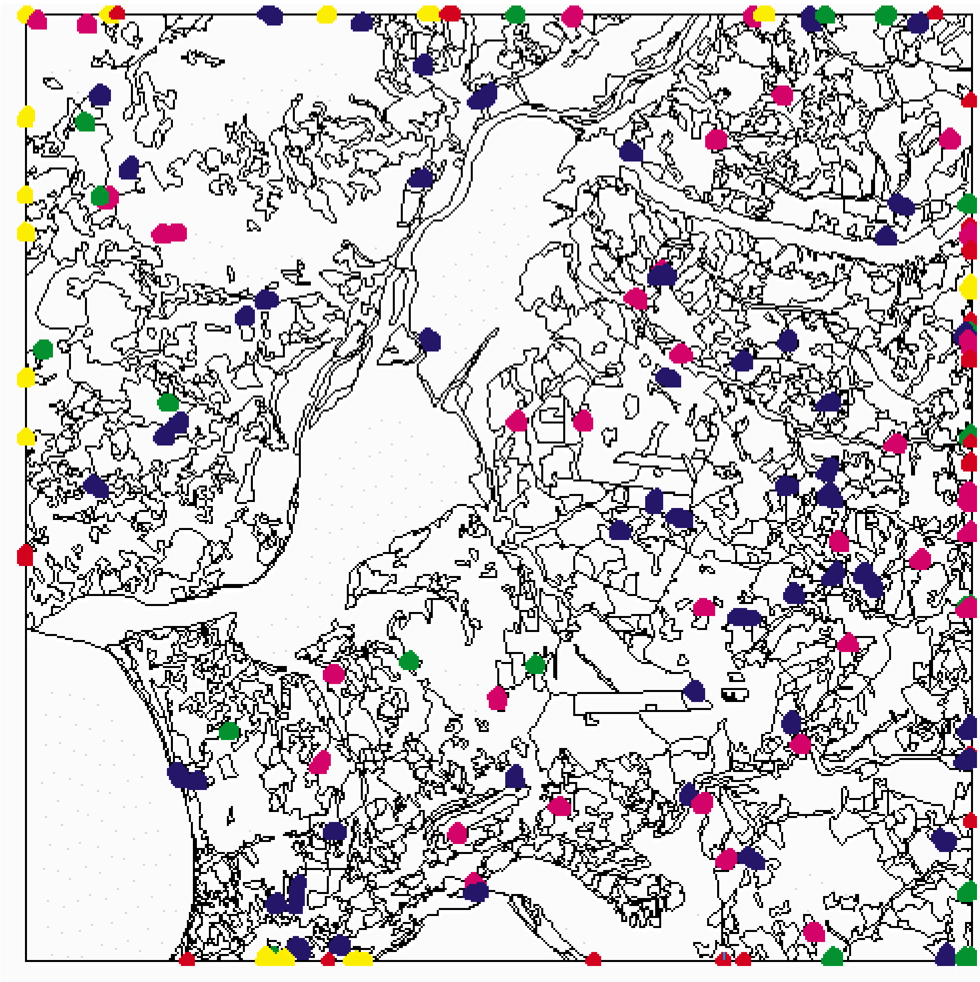
CORINE Land Cover database 1985 version - scale 1:350,000

Before starting the updating process, a quick look of the existing database can be necessary (in particular when validation has not been done).

On the left picture each unit of the CORINE Land Cover database is filled with a different color corresponding to a different class.

This type of representation is very useful at this scale when code numbers cannot be read. Together with the type or representation of the previous page it permits to detect important errors on code attribution or problems in contiguous regions interpreted by different teams.

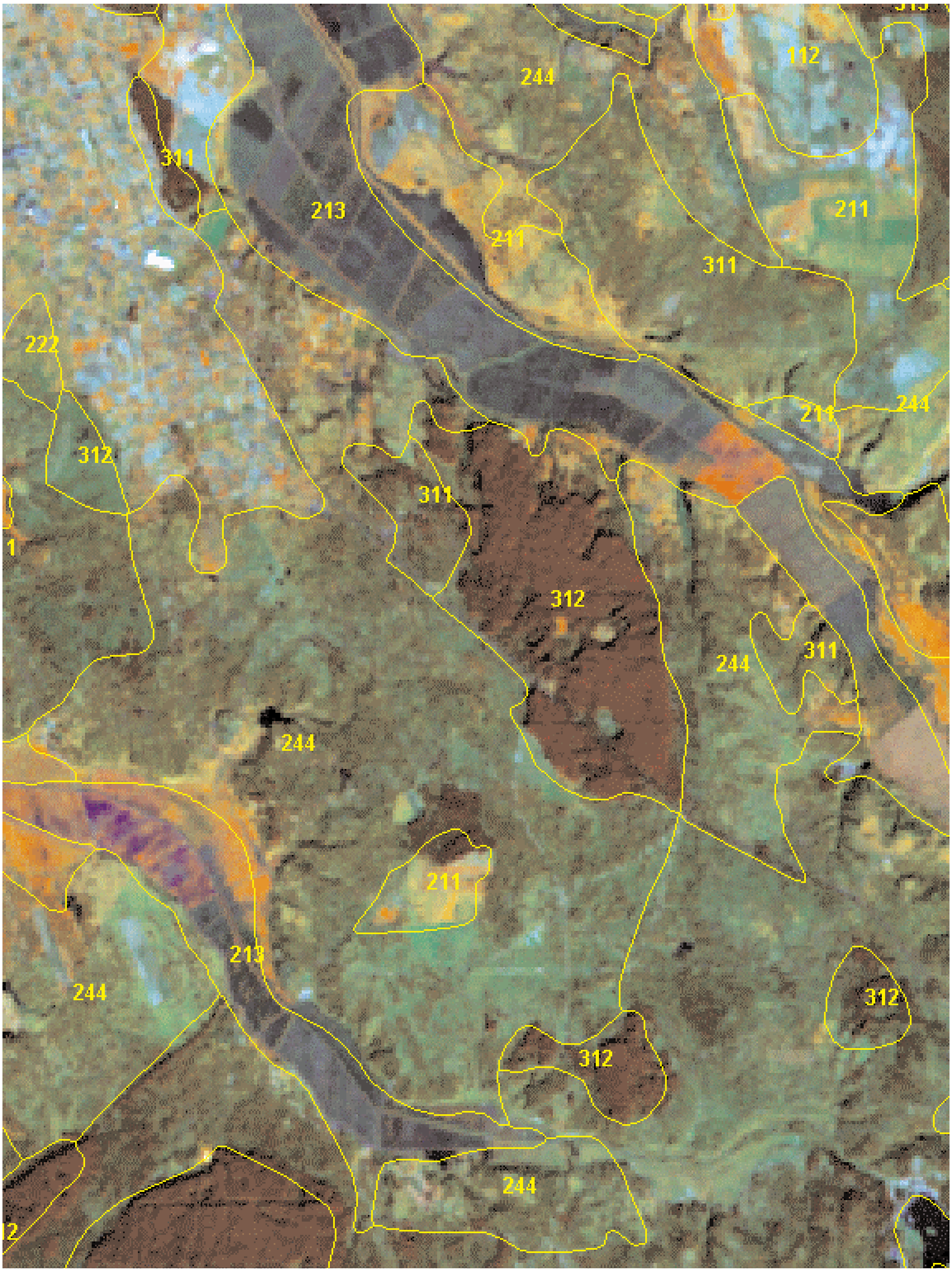
Units smaller than the Minimum Cartographic Unit (25 ha)



In this picture a preliminary check of areas smaller than the minimum cartographic until has been performed.

The different colours correspond to different thresholds (**red** = < 5 ha, **yellow** = 5-10 ha, **green** = 10-15 ha, **magenta** = 15-20 ha, **blue** = 20-25 ha). Small areas on the border are caused by the sheet subdivision, instead areas inside the picture could be considered as geometric errors (in sense of not respect of the defined tolerance).

1985 CORINE Land Cover database and LANDSAT TM image(4,5,3) - January 1985 - scale 1:50,000

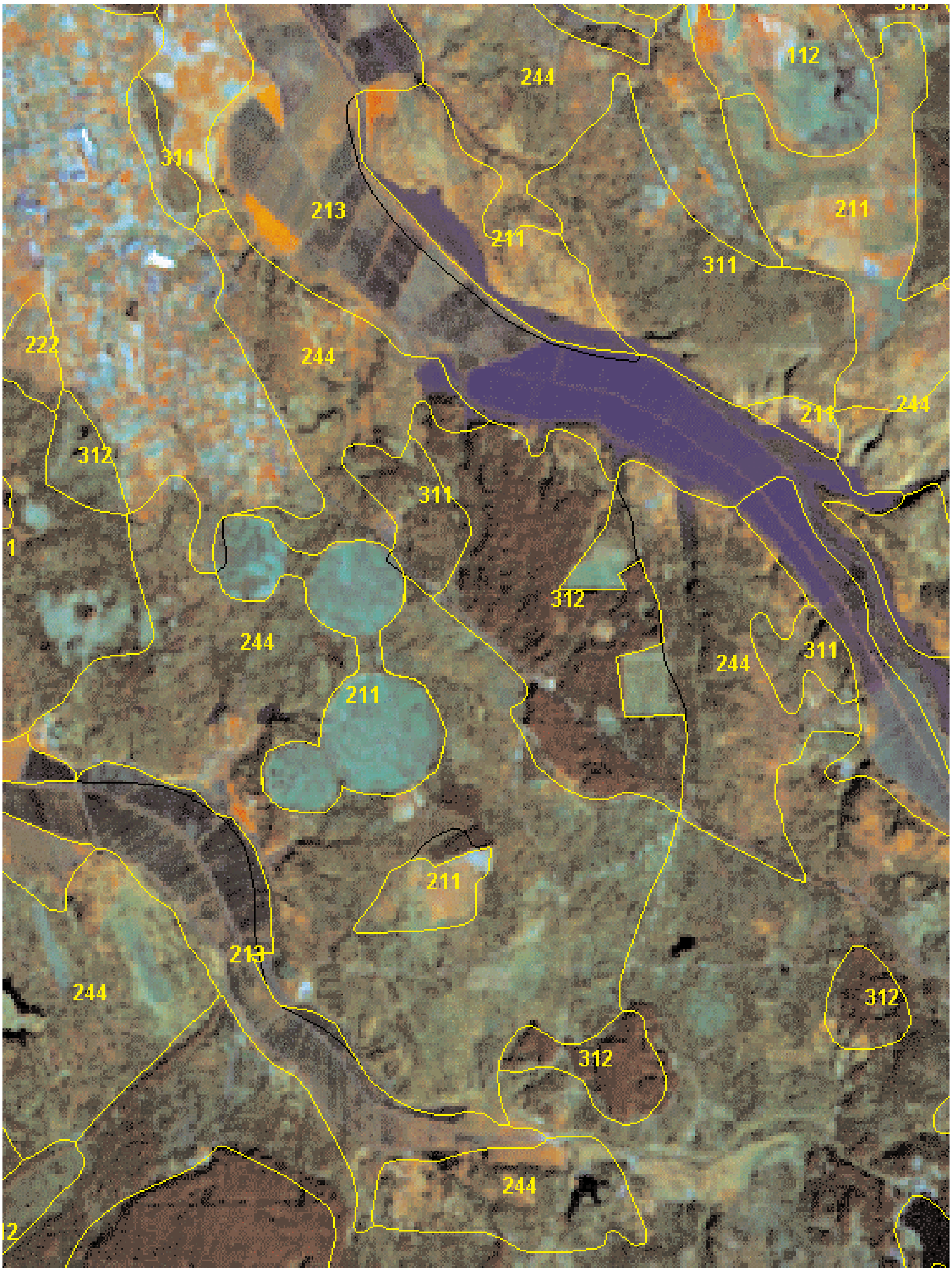


These two pictures contain several real changes or possible misunderstandings.

In particular in the big polygon coded in 1985 as **244** “Agro-forestry areas” are now evident patterns of intensive crops (the typical pivot shape is evident on 1991 image), so these area must be separated from the existing unit and must be coded as **211** “arable lands”.

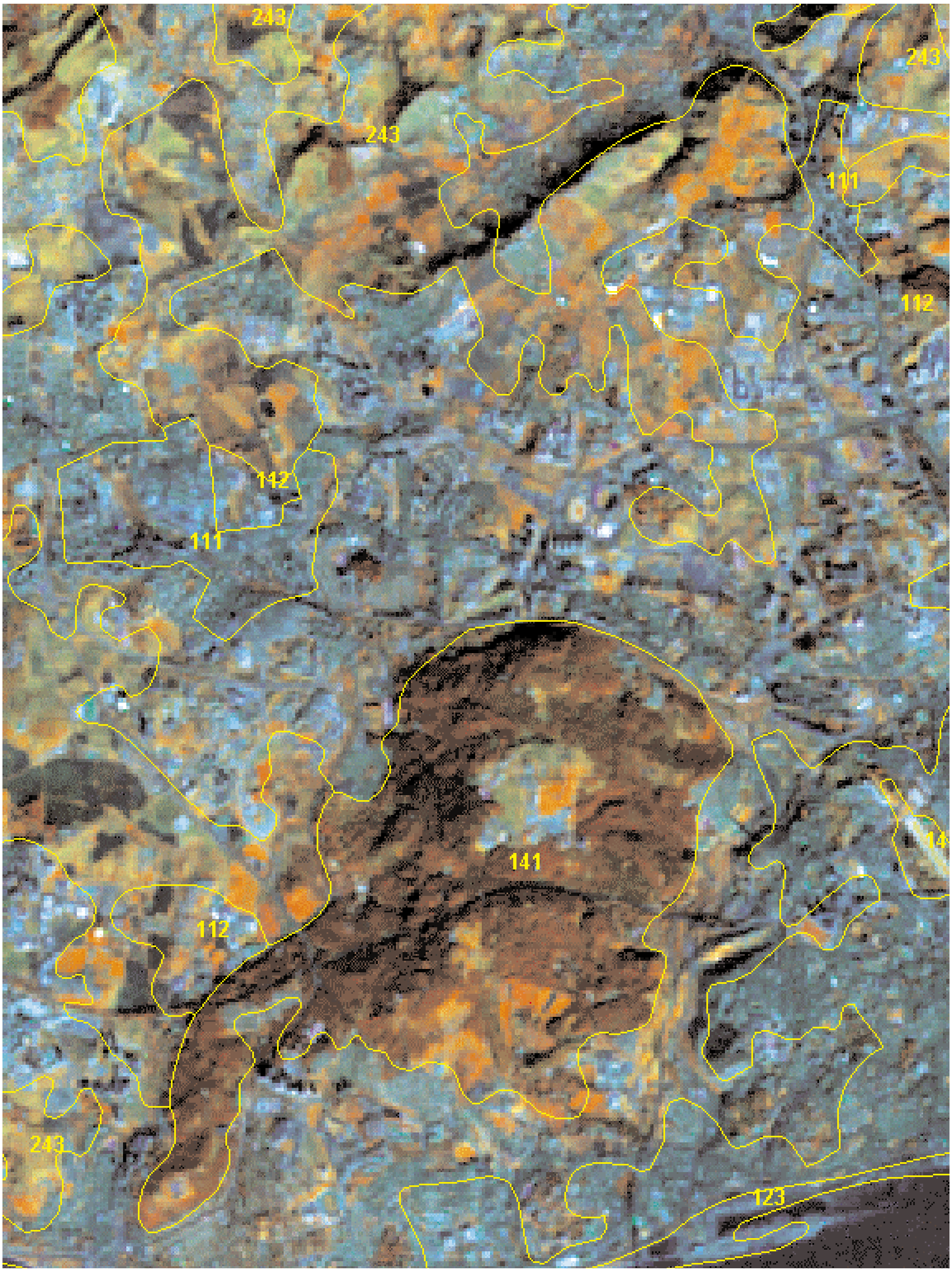
The big rice area coded as **213** seems now not homogeneous for the presence of water. This is not a real change but corresponds to a different status on the agricultural practices.

Updated CORINE Land Cover database and LANDSAT TM image(4,5,3) - January 1991 - scale 1:50,000



Finally the unit coded as **312** “Coniferous forest” in 1985 in the center of the picture could be reclassified according to the observed cuts. This change needs additional information. In fact if the cut areas were replanted with coniferous forest (not clearly distinguishable on the image) it cannot be considered a change and the unit shape doesn’t change. Instead if replantation has not been done, these areas (less than 25 ha) must be aggregated to the surrounding unit coded as **244** “Agro-forestry areas”.

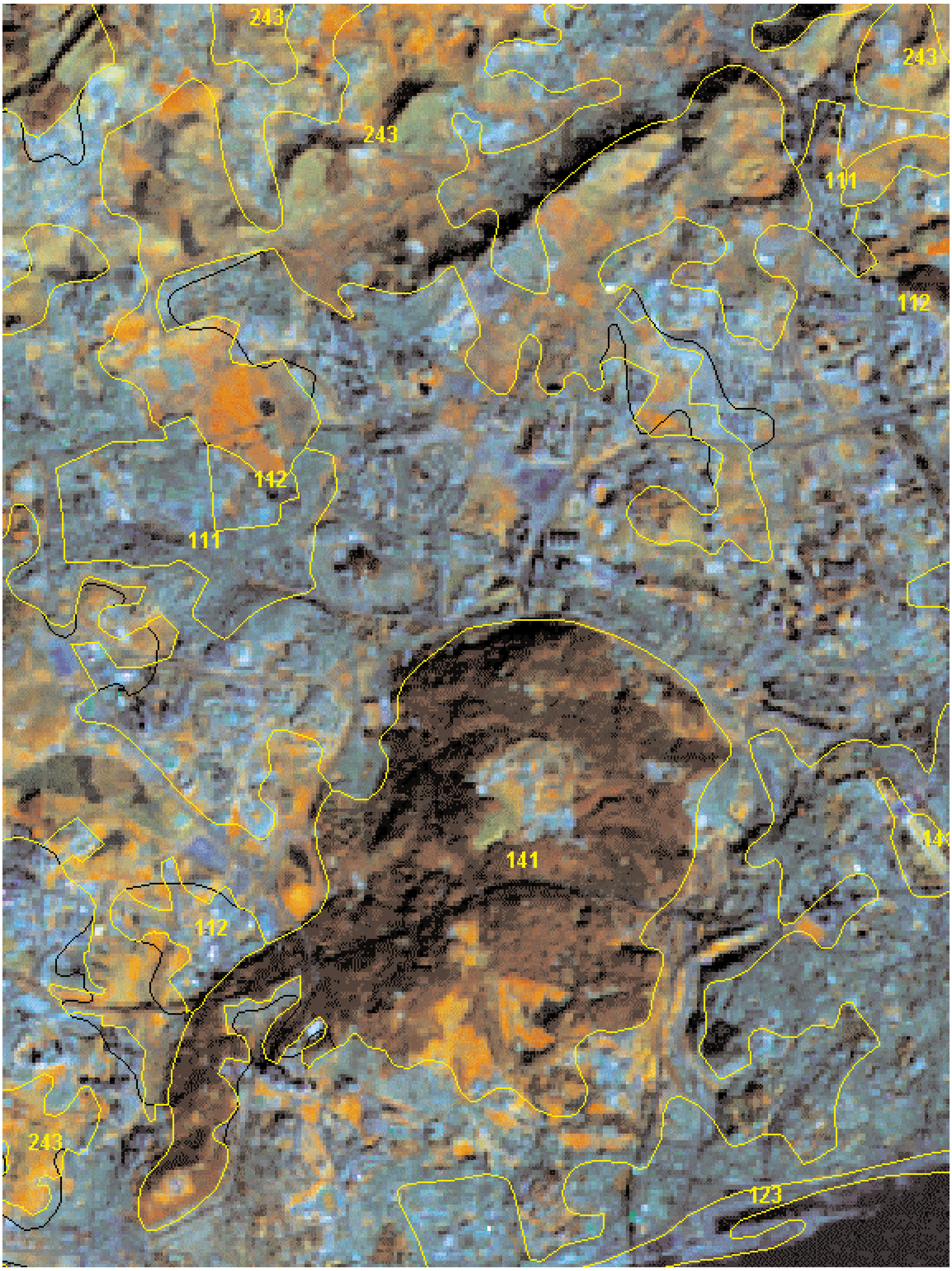
1985 CORINE Land Cover database and LANDSAT TM image(4,5,3) - January 1985 - scale 1:50,000



These pictures show the ambiguity in the interpretation of boundaries for some classes and also illustrate the difficulty to discriminate between real change and error (or more precisely: inaccuracy) on the original database.

In the left picture it easy to see that sometimes the database boundaries don’t fit with the satellite image.

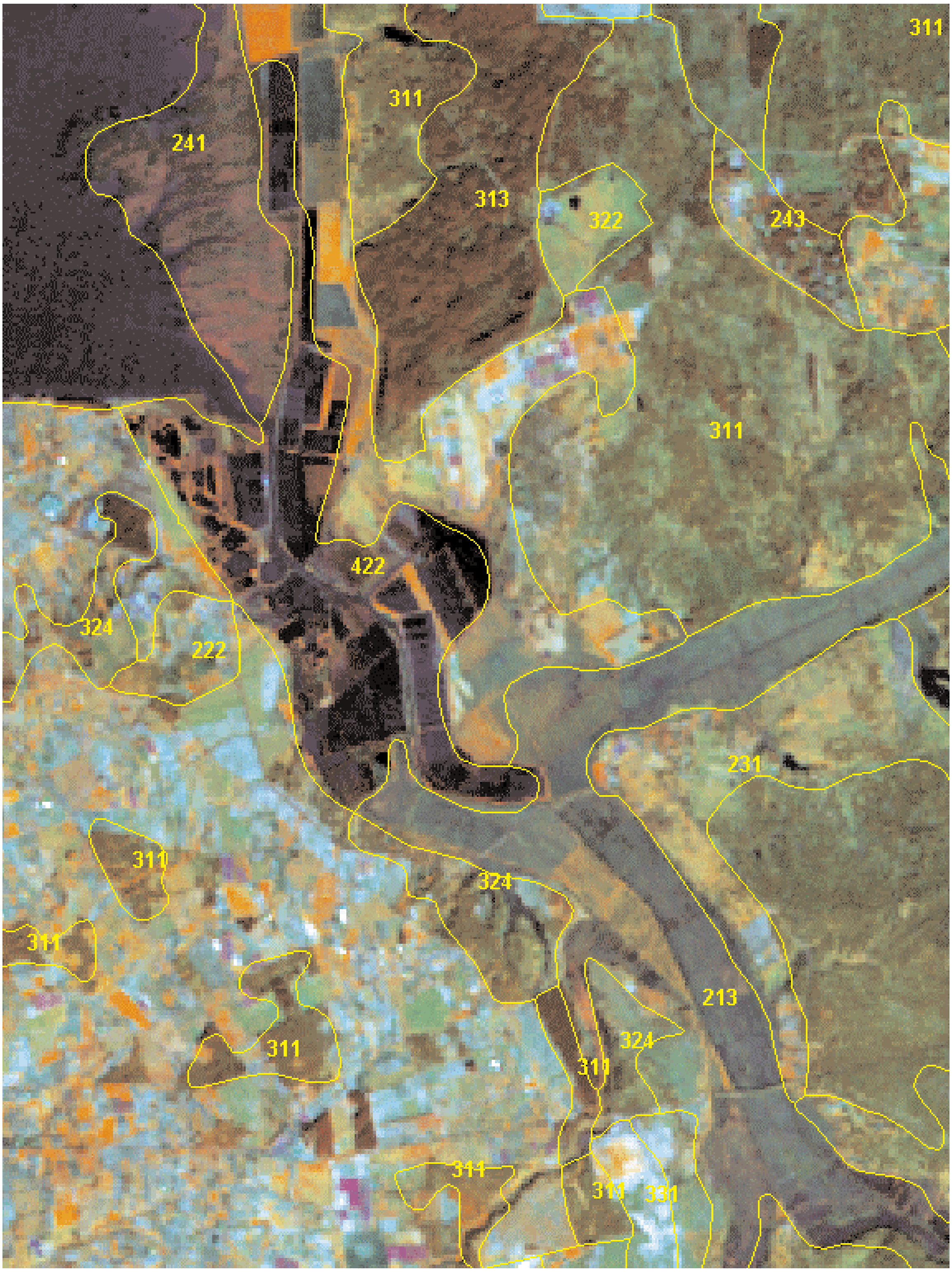
Updated CORINE Land Cover database and LANDSAT TM image(4,5,3) - January 1991 - scale 1:50,000



With direct screen digitisation a better unit's delineation is easier. In fact the problems of saturated areas on the printouts can be solved using appropriate local contrast stretching. As the consequence the urban areas that according to their brightness are often over-evaluated can be now better interpreted.

During updating it is possible to encounter cases of bad delineation on the original database mixed together with real changes (in the right picture the dark lines show the old interpretation before updating).

1985 CORINE Land Cover database and LANDSAT TM image(4,5,3) - January 1985 - scale 1:50,000



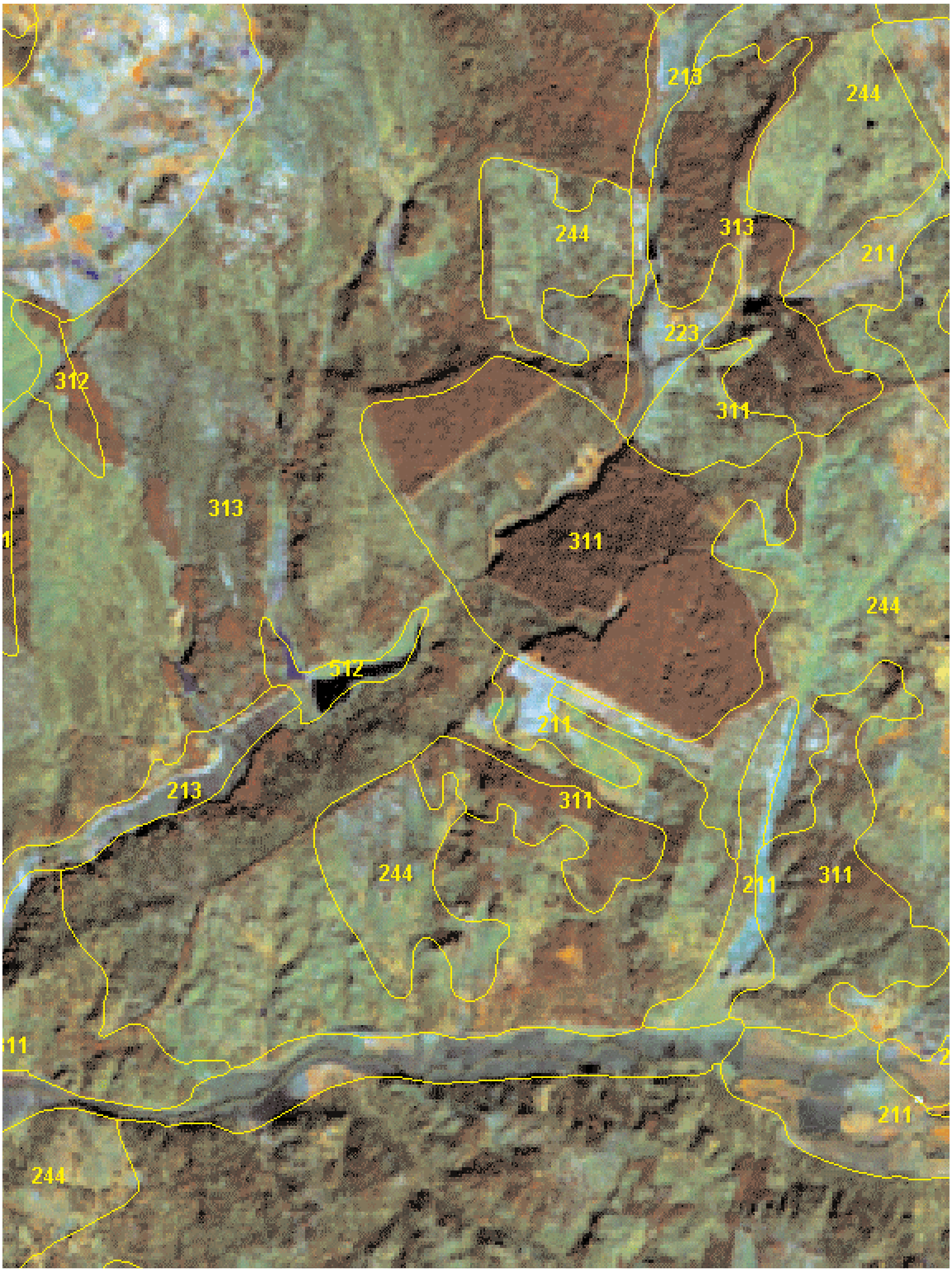
These two pictures show a change that often happens.

The area in the center of the image coded in 1985 as **213** "Rice area" is now cultivated with winter cereals.

This rotation is well diffused in some regions. This type of updating can be meaningless because, depending upon the year of updating the class can change but it is still the same rotation. Although it is not a real "environmental" change it is important to check if there is a significant modification on the total surface of rice for that region. In fact in this case the water needs could change.

Updated CORINE Land Cover database and LANDSAT TM image(4,5,3) - January 1991 - scale 1:50,000

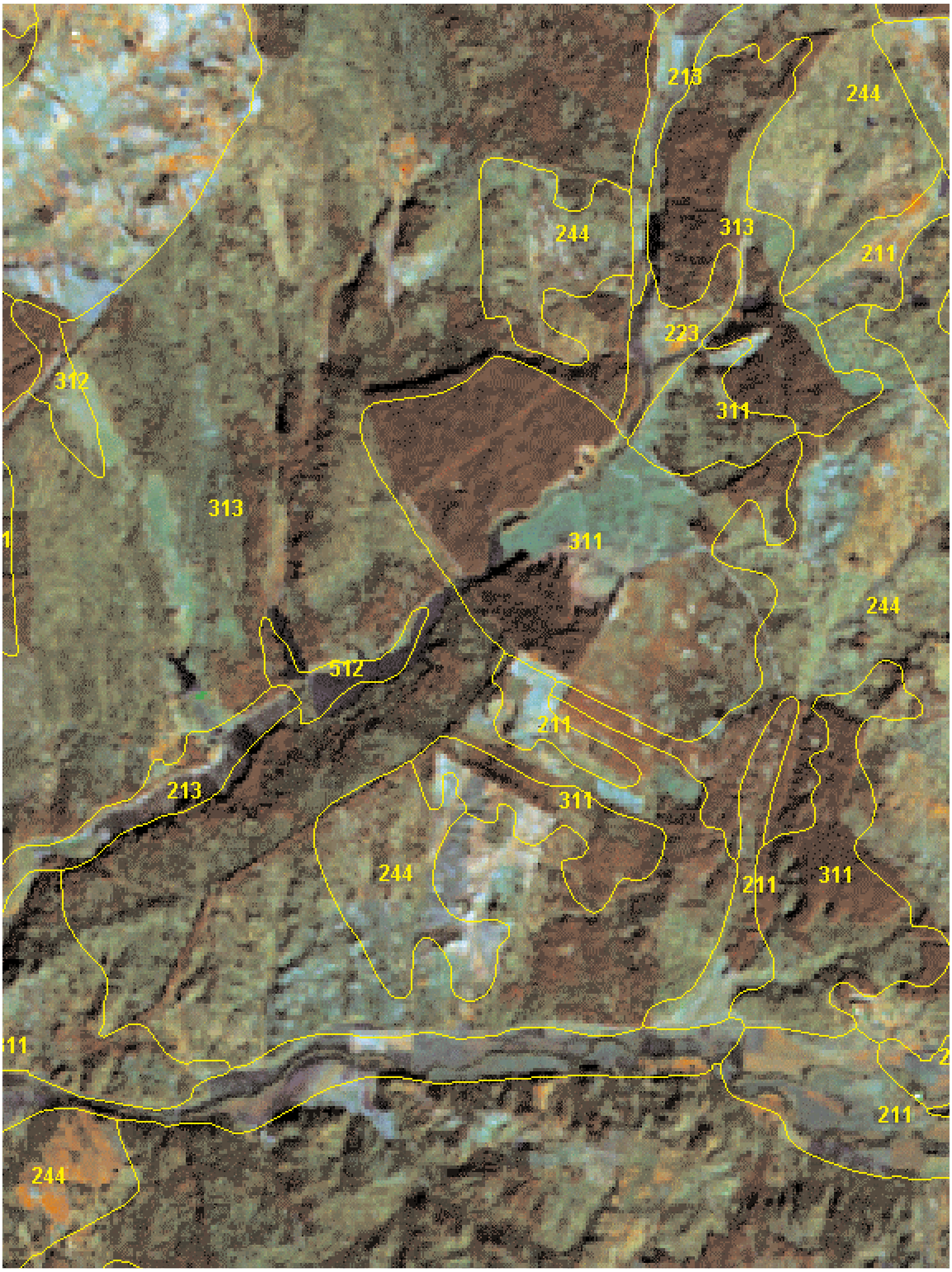
1985 CORINE Land Cover database and LANDSAT TM image(4,5,3) - January 1985 - scale 1:50,000



These two pictures show why automatic classification must be carefully used.

In fact, in 1985, in the big area in the center of the picture classified as **311** “Broad-leaved forest”, there is a lack of homogeneity due to cut and re-plantation practices. Inside this unit the brown areas correspond to old trees instead the green-brown zones are younger trees. Without additional data it seems very difficult to distinguish these areas from the contiguous unit classed as **313** “Mixed forest”.

1985 CORINE Land Cover database and LANDSAT TM image(4,5,3) - January 1991 - scale 1:50,000



Comparing the new image (1991) to the old database (left picture) some changes in this unit are evident. In the bottom-left part of the unit the forest is in 1991 not homogeneous and in the center a green area appears instead of the previous brown.

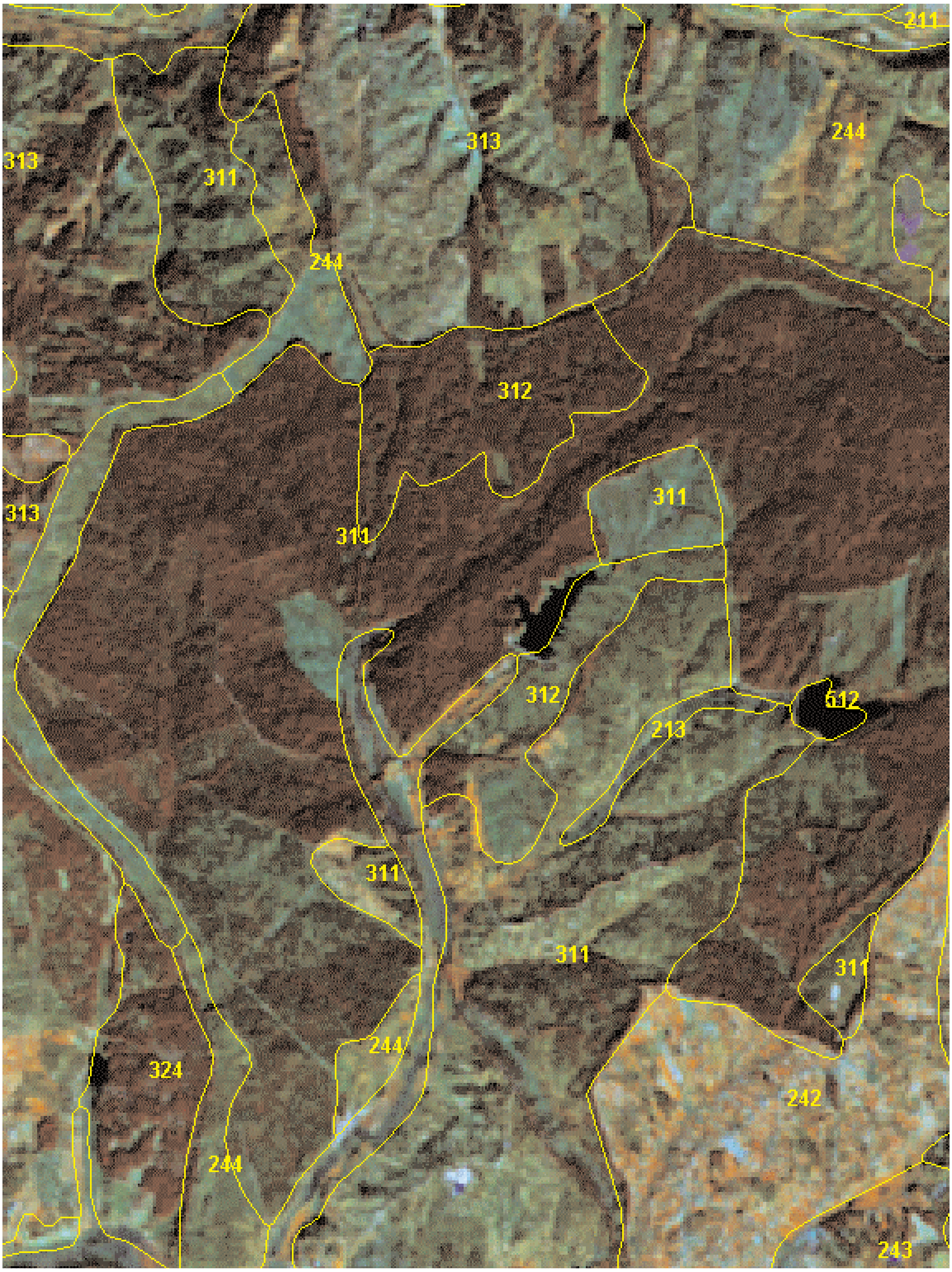
For CORINE nomenclature these are not really changes because inside the unit there is the same type of forest (Eucalyptus) everywhere and the different colors simply correspond to different ages of the trees.

1985 CORINE Land Cover database and LANDSAT TM image(4,5,3) - January 1985 - scale 1:50,000

These two pictures illustrate how can be sometimes difficult to define specific classes of CORINE using satellite images only. These examples are also useful to understand that, when updating is carried out, the image-interpreter can validate the previous interpretation or re-discuss it.

In fact looking to 1985 image it can observed the spectral difference between units coded as **311** (because of different age, type or structure ?) and how is difficult, sometimes, to distinguish the class **311** from **312** (without a multi-temporal approach). In this case the interpretation of 1985 seems correct.

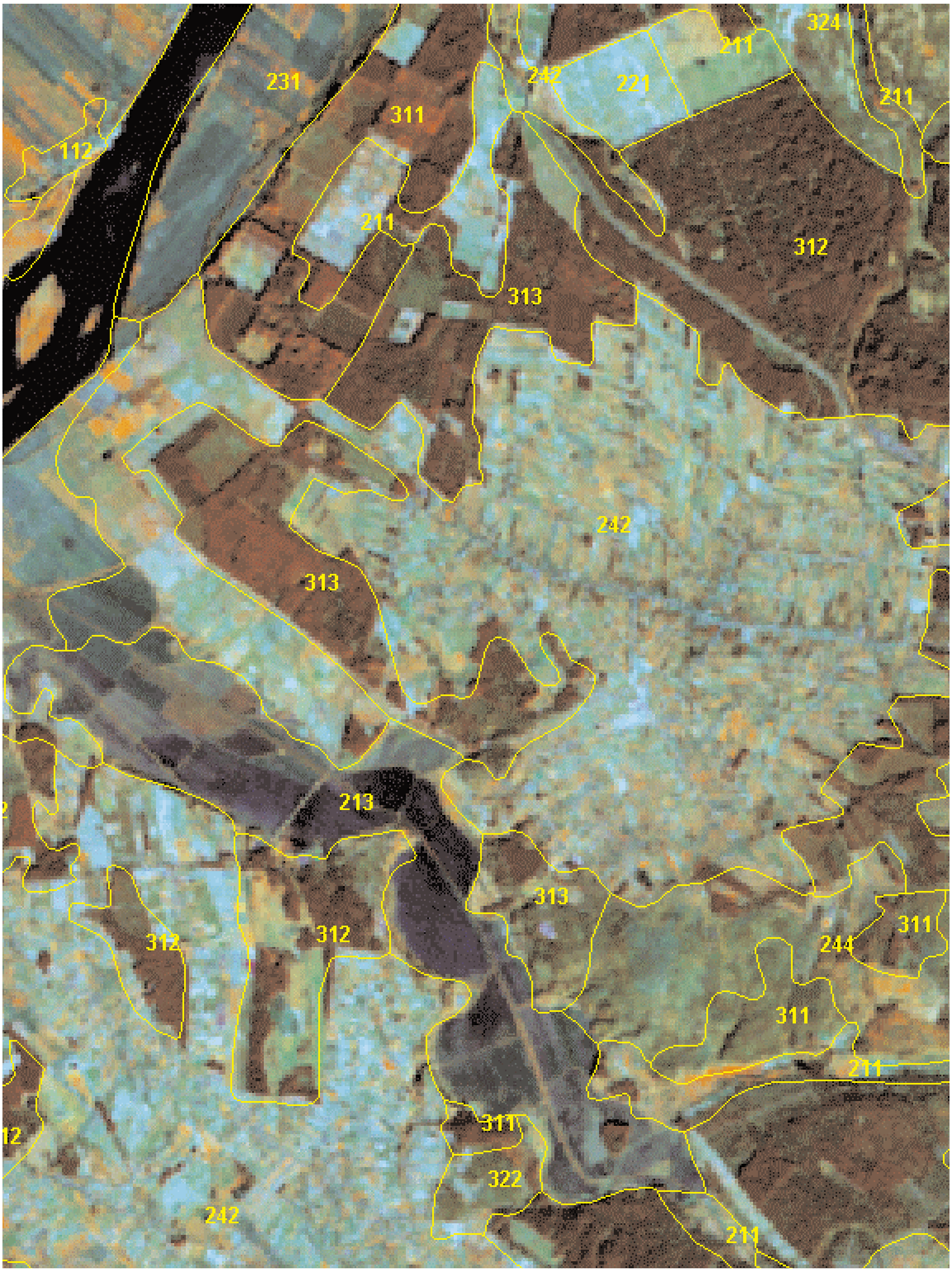
1985 CORINE Land Cover database and LANDSAT TM image(4,5,3) - January 1991 - scale 1:50,000



Looking to 1991 image, when updating is performed it can be seen that some doubtful interpretations of 1985 have found in 1991 their confirmation. For example the green narrow area in the biggest **311** unit is now forested (brown).

On the other hand the unit (located at the bottom right of the picture) classed in 1985 as **324** "Transitional woodland/shrub" could maybe classified as **311**. The possible **512** unit inside the biggest **311** was not identified because its area looked too small (instead in 1991 image the real area is greater than 25 ha).

1985 CORINE Land Cover database and LANDSAT TM image(4,5,3) - January 1985 - scale 1:50,000



These pictures are very interesting as case study.

In fact, the same change from Forest to Non Forest that in previous example was not interpreted as a real change (simply Cut and Re-plantation) must be now interpreted in a different manner.

Looking to the unit coded as **313** on the top of the picture, it can be observed that in 1985-91 period some cuts were done. Analysing the shape of the cuts the typical “pivot” pattern can be recognised (caused by new the irrigation practices). More precisely four pivots on 1991 image can be detected.

Updated CORINE Land Cover database and LANDSAT TM image(4,5,3) - January 1991 - scale 1:50,000

For this reason, it is probable that there is now a real crop cultivation instead of the previous forest.

For similarity, it can be justified the attribution of part of the unit below (also coded **313** in 1995) to the surrounding unit coded as **242**.

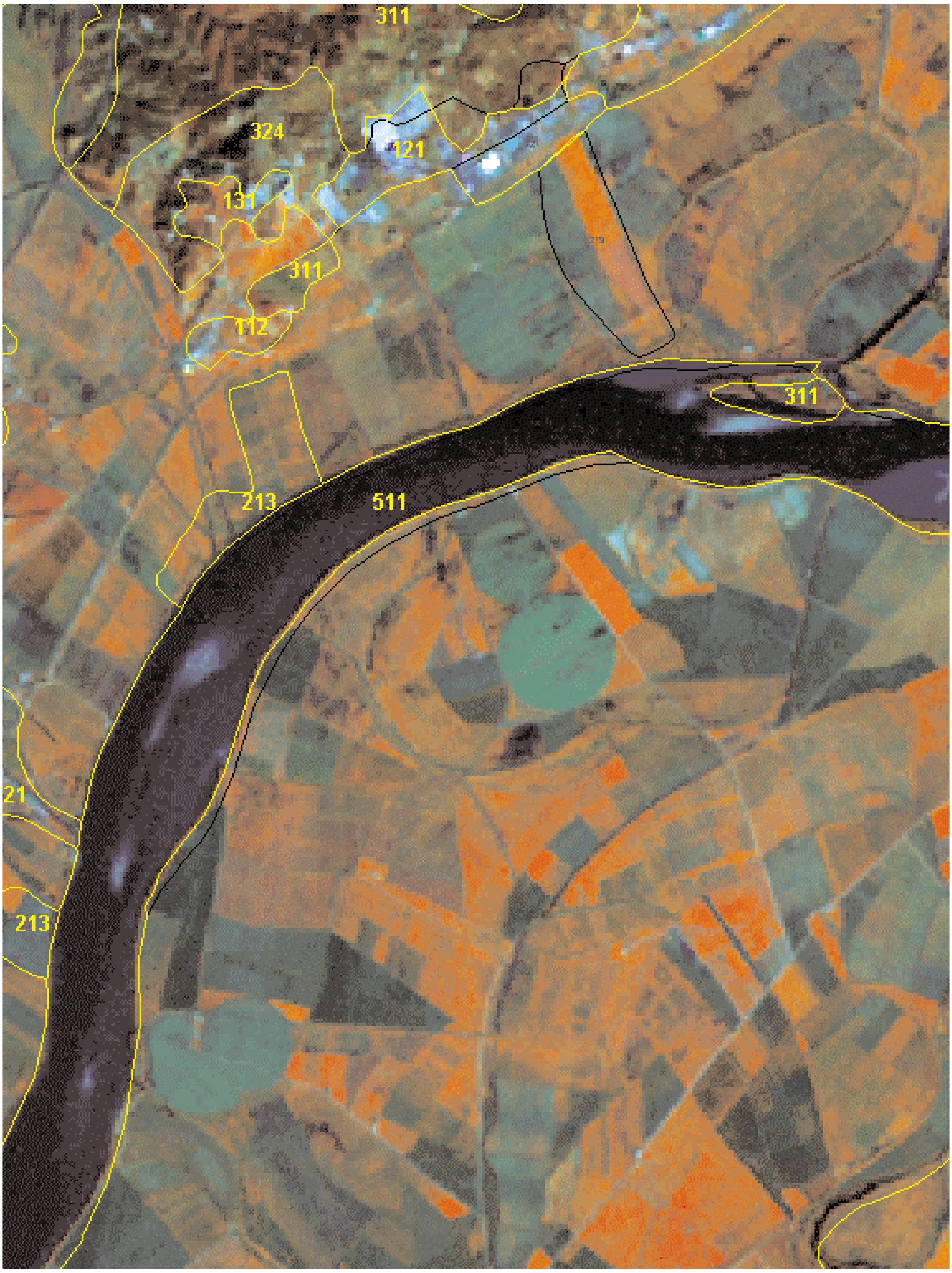
The use of ancillary data could be useful for the image-interpreter to confirm these new interpretations.

1985 CORINE Land Cover database and LANDSAT TM image(4,5,3) - January 1985 - scale 1:50,000

These two pictures contain several interesting factors:

- the expansion of the industrial area (121) eroding natural areas,
- a confirmation for a doubtful sub-area in the unit coded as 324 (in 1985),
- the possible ambiguity on 213 classification without additional ancillary data.

Updated CORINE Land Cover database and LANDSAT TM image(4,5,3) - January 1991 - scale 1:50,000



- the changes on agricultural practices that provoke a change on the agricultural pattern (presence of circles instead of rectangular areas) without changing the CORINE class,
- morphological units of the landscape often don't correspond to land cover boundaries of different units (in this case the presence of the paleo-alveo isn't linked to differences in Land Cover classes),
- the modification of the river boundary, must be considered as an error of the old database and not as a new change. In this case, it is necessary to correct also the old database.

11. ANNEX 2: SOFTWARE NEEDS FOR UPDATING

As clearly illustrated in this guide the proposed methodology comports a considerable use of Computer Aided Image Interpretation to update the existing database.

JRC has developed a sw prototype “Co-Pilot” (described in Annex 3) with all the functions required for a better execution of the job.

Other GIS systems available on the market can be obviously used. In that case the same parameters defined in this guide (precision, tolerance, ..) must be used. The following paragraphs describe the system (minimum requirements for this updating methodology.

General

The following general features are required:

- Raster and Vector data management at the same time,
- topology of Vector data must be managed during image interpretation. Graphic (without topology) management for successive import to additional GIS systems is not recommended,
- management of geometric and alphanumeric data for each polygon,
- database design and maintenance,
- support for different geometric features (polygon, point, line, ….),
- import/export capability,
- query language,
- image georeferencing,
- image processing,
- printing tools for cartographic purposes.

Land Cover Map Display

- Visual display of land cover map at actual on-screen scales ranging from 1:10,000 to 1:1,000,000.
- changing between display scales may be made either continuously or in discrete steps via a "zoom-in"/"zoom-out" facility,
- possibility to interactive select a precise display scale,
- full display “pan” facility for roaming in a continuous manner around the land cover map,
- selection of the displayed area by direct introduction of the co-ordinates,
- view’s editing and interactive choice of different display views according to various scales,
- the database polygons can be displayed with or without Polygon hatching (with specific fill pattern) and with or without Land cover code drawing.

Image Display

- Visual display of satellite images (Landsat Thematic Mapper, SPOT, other ..) and derived images“classification products”) both separately from and in combination with the land cover data base,
- the image display must permit zooming within the display scales above described and panning within one full image “scene”,
- for classification products the display must be able to differentiate between separate image classes,
- at least a <u>full</u> scene must be displayed in each window (capability to manage images until 65,536 rows x 65,536 columns is recommended),
- colour composition of different images. The system should possibly display a combination of images with different pixel size using real-time resampling for any the requested scale.
- different types of contrast stretch must be supported,
- fixed Look Up Tables (LUTs) must be managed (in addition editing of LUTs must be provided).

Multiwindowing

- Images and database are displayed on windows. The system must be able to open and display simultaneously at least 4 windows,
- in each window the system can display a specific image with a particular band combination and with or without overlapped vector data,
- different combinations of views and LUTs can be used for different windows.

Image Georeferencing

- Interactive selection of Ground Control Points (GCPs),
- GCPs database editing and management,
- polynomial transforms with different degrees,
- orthoprojection capability must be provided if necessary for some Countries,
- evaluation of Transform Accuracy (RMS),
- evaluation deviations of each GCP.

Comparative Display

- Comparative display of old and new versions of the land cover data bases both separately from and in association with old and new satellite images,
- integrated display of land cover map and images in a window,
- display of different views of the same data bases in various windows,
- geographic link among windows (geographic link is a mechanism allowing to synchronise the display of data bases and images placed in different windows; when geographic link is set between two windows, any change of the displayed area in a window operated by the user by means of pan and zoom functions is reflected on the other window),
- geographic link between two or more windows can be set at different levels:
    - at first level, windows are constrained to have same centre but may have different scales,
    - at second level, windows are constrained to have same centre and same scale.

Quality validation and error detection

- Quality validation and error detection for the original version of the land cover database (check for internally consistency of the database topology and valid land cover attributes codes for all polygons),
- appropriate handling of any detected error for user correction,
- geometrical quality control of the original version of the database to detect mismatches between digitised polygons and original image information,
- tools for geometric validation of the original database and for correction of topology's errors like:
    - missing areas (holes in the database),
    - overlapping of polygons,
- build and clean possibility,
- tools to thematic validation the original database and for correction of coding errors like:
    - missing codes,
    - bad codes (non existing in the nomenclature),
- automatic search, display and identification of bad codes and units with area less than the minimum cartographic unit.

Overall management of the updating process

- Overall management of the updating process by maintaining checks on the status of individual areas e.g. corresponding to separate physical map sheets using polygon marking or similar,
- management of additional data used in interpretation phase.

On-screen display information

- Single or multiple objects selection and attribute consultation,
- on-screen display information from the digital database in tabular form.

Interactive selection of one or more polygons for updating

- attribute's updating.
  - updating of an attribute common to a whole set of objects selected according to some criteria (for example change all codes 211 in 212),
  - interactive assignment of land cover attribute codes to map polygons (with automatic control on the new assigned value),
- interactive modification of polygon topology, i.e. interactive digitalisation of modified/new polygon boundaries and modification of the database in a consistent way (e.g. without creating holes, spurious polygons, … and maintaining the consistence with the minimum cartographic unit),
- basic tools to speed-up the geometric updating process:
  - deleting an object (without leaving holes),
  - create a new object,
  - modifying part of the boundaries of an object,
  - split an object,
  - merge a set of objects.

Query language

- Query language for database interrogation and for production of specific statistics (e.g. number of polygons with area < 25ha),
- user friendly interface for use of the query language.

Non-digital Information Referencing

- Use of Metadata,
- effective referencing in the updated database to any non-digital information used in the updating procedure (e.g. aerial photographs):
  - point information. Point information may be represented in the database by a graphic symbol and a set of alphanumeric attributes with a short description and the reference to the ancillary documents,
  - polygon information (Aerial photographs and thematic maps have rectangular or near trapezoidal shape, as projected on the cartographic frame of reference. To each rectangular areas alphanumeric attributes may be associated,
  - tabular information. The system must be able to manage this information (related to some statistics of the observed region). This information must be managed using database tables geo-addressed by means of polygons corresponding to the involved administrative or geographical regions,
- storing and database management of documentary images (a documentary image is a non geo-corrected image to be used as ancillary information during photo-interpretation or updating),
- effective referencing of documentary images (trough attributes of specific objects).

Print

- Print of images and vector at precise cartographic scale,
- screen hard copy,
- editing of ancillary cartographic symbology (legend, grid, ticks, ..).

12. ANNEX 3: CO-PILOT SYSTEM

The *Co-Pilot* system (CORINE Photo-Interpretation Land cover Oriented Tool) is a specific product based on a customized version of the GIS engine sw “Cartha for Windows” produced by RSDE company. Co-Pilot has been developed by RSDE exclusively for the JRC (who financed the prototype version and its final re-engineering).

Co-Pilot has been designed according to the specifications of two studies: “System definition for updating CORINE Land Cover database” (JRC 1992) and “Provision of a prototype demonstration system for updating the CORINE Land Cover database (JRC 1993). A list of these specifications is given in annex 2.

Co-Pilot was tested in 1994 by 4 different technical CORINE Land Cover national teams (G2ERE for Luxembourg, CNIG for Portugal, SC-DLO for the Netherlands, and the Agencia de Medio Ambiente - Junta de Andalucia for Spain).

These pages briefly describe the main features of the system.

Overview of Co-Pilot

Co-Pilot is an Integrated Geographic Information System running under MS-Windows 3.1x or Windows 95. It was developed by RSDE under JRC specifications to allow the integrated processing of satellite images, cartographic data, digital elevation models and so on.
The basic concept of *Co-Pilot* is to facilitate the image-interpreter work with a specific user interface adapted to his philosophy and giving him suitable functions to speed-up the GIS tasks.

The GIS

Co-Pilot is provided by a vector data base manager designed by RSDE to work together with raster data. A proper design of a GIS engine is required to reach high performances in those operating modes typical of an integrated system, such as the computer-assisted photo interpretation, the updating of an existing raster cartography, the use of scanned maps as a geometric base for planning and management (using vector objects), ...

Geographic data in *Co-Pilot*, are managed “in continuum”. It means that data acquired from different maps on different times are managed only in a geographic database without breaks.

The minimum information unit on *Co-Pilot* is the *geographic object*. From the geometric structure viewpoint, a *geographic object* may belong to three different classes: point, line or surface. Any *geographic object* is characterised by a *type*, i.e. building, railway, forest parcel, etc. *Types* are defined, for each geographic data base, by the user in an information structure called *Catalogue*. The object type specification contains information about geometric class, alphanumeric attributes, logic and topologic relations with other objects, auxiliary display attributes (i.e. location, size, angle, font of a toponym). The graphic display mode is defined in another information structure named *TypeLook*. This describes for each *type* what colour, line-style and fill-pattern must be used. These primitive graphic elements are defined in another structure called *GraphicSet*. All main information structures of the system such as *Catalogue*, *TypeLook*, *GraphicSet*, are stored on ASCII files, which are self-documented and easy to edit.

The alphanumeric attributes related to geographic objects are managed by a relational data base (available on the market) integrated to *Co-Pilot*. The current default data base engine is Paradox of Borland; several other data bases are supported. The *Catalogue* information structure contains the attribute specifications for each *type* and the reference to the external data base. *Co-Pilot* is equipped with an attributes display and editing form which is independent from the external data base engines.

A special type of information called “relation between objects” allows the setting up of a logical link amongst the different objects of the database: this relationship can be used in the data analysis phase, i.e. in a network analysis (arc-node with weight) the relationships are useful to find out the shortest path. The weight can be either defined as an arc attribute or computed by formulae.

The query operations on a geographic data base may deal with geometry, attributes, logic and topologic relations. A query operation, running in interactive or batch mode, produces a list of references to the objects of geographic data base: on this latter list act the verbs defined in the query procedure.

Some verbs change the display mode of the selected objects, others send the results either directly to a printer or to a spreadsheet: this spreadsheet can be directly edited or imported into Microsoft Window products such as EXCEL.

In order to speed up the process of searching an object in the geographic data base, a proper geographic index, completely invisible to the user, based on quad-tree logic, is implemented.

There are several data import/export procedures from/to different systems; APIC, ARCINFO (EXPORT and UNGENERATED), MOSS, DXF formats, ….

Co-Pilot supplies a tool to edit and print at a user defined scale accurate raster + vector maps on any black and white or colour printers (supported by MS-Windows).

Multiple management of geographic data bases

One of the most innovating aspects of *Co-Pilot* is the capability to manage many contemporary geographic data bases (up to 8 data bases) in different windows or in the same window, if they have the same frame of reference, and to link each window to a different set of colour or B&W images (up to 32 layers).

The layers

A *Layer* in *Co-Pilot* is any data in raster format, for instance, a Landsat TM image, an aerial photo digitised by a scanner, an image grabbed from a video camera, a geographic map acquired by a flat scanner, a runoff map computed by a simulation model. Any *Layer* is a matrix of size up to 65,536 x 65,536 pixels.

In order to manage a wide applications range, *Co-Pilot* supports different layer data types: bit, byte, short integer, long integer and double precision. Import/Export procedures for common raster formats, such as BSQ, PIL, LIL, TIFF, BMP, ERDAS, are supported.

The image and text documents

Many different pieces of information may be connected to a geographic object, consisting not only of alphanumeric attributes, logic and topologic relations with other objects, but also of image documents, icons and texts.

Image documents and icons are very different from layers because they are not georeferenced. Image documents may be pictures or drawings showing the features of a geographic object and its neighbours. The formats recognised by *Co-Pilot* are BMP and WMF. For instance, a set of photos of the front face of the object 3Ancient Building", or the illustration of vegetation and animal species existing in a particular area of a natural park.

A set of images and texts may be linked to each object. Single images or text may be interactively selected and displayed at full resolution from a quick-look catalogue. The text related to objects can be edited using standard Windows products such as "WORD", "WRITE" and "NOTEPAD". The same product used to generate the document should be used in the consultation phase. Text can for instance be legal documents related to the application, description of flora and fauna of the surrounding area, ...

To each object more than one document can be related in a logical folder. Obviously, it is possible to select a single document to read.

The Virtual Graphic Board

Co-Pilot operates with a single screen on which images can be displayed on different modes: RGB, monochrome, pseudo colour and overlay. Thanks to a software device called *Virtual Graphic Board*, the internal representation of images is completely independent from the physical graphic board. For instance, the colour synthesis of bands 4,5,3 of Landsat TM is internally managed by the *Virtual Graphic Board* in true colour (24 bits) without regard to the colour resolution of the physical graphic board. In this way it is possible to work with a very cheap hardware configuration based on VGA, and later upgrading the system with a 32,000 colour SuperVGA or a true colour (16 million colours) graphic board.

The Virtual Graphic Board is provided with six independent frames. five frames are devoted to image display: red, blue, green, overlay1 and overlay2. One frame is devoted to vector data display. A user can select a proper display mode separately for each window.

Customisation

The *Co-Pilot* system is composed of a kernel of DLL functions (Dynamic Link Library), written in C Language, and an interface, written in Visual Basic. Visual Basic permits easy development of very advanced graphic user interfaces following the MS-Windows standard in addition to the development of complete applications.

Such a separation between kernel and interface, and the choice of Visual Basic allows the user to develop system customisations at different levels depending on his needs and programming experience. The first level is the development of a customised interface. The second level is the development of simple applications in Visual Basic using DLL function calls. The third level consists of the development of advanced applications in C Language.

The MS-Windows environment offers very powerful and standard technologies to create links among different applications. For instance, DDE (Dynamic Data Exchange) technology permits automatic data sharing among applications.

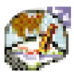
Software specifications

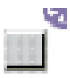
Co-Pilot Modules

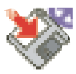
Basic Module
The Basic module allows the user to display, insert, modify and analyse vector data, alphanumeric data and raster data (including images).


Basic tools

- ⇒ Geographic database management functions.
- ⇒ Image management functions.
- ⇒ Query functions
- ⇒ Specific macros for CORINE updating.


Plot Utility for Thematic cartography production..


Toolbar Utility for Toolbar customisation..


Various Import/Export programs.


Header Image (creation of headers for image files).


Image Legend editor


Georeferencing

 Fast Image (fast format image conversion).

 Polygon Builder (Creating and Intersecting polygons to produce derivative geographic data)

Module
The custom module allows the user to create and customise a data base.

 DB Maintenance Utility (allows the user to structure the geographic data base).

 Custom Utility (allows the user to define all graphical aspects of data bases).

Raster Operations Module
This module provides a set of raster functions: convolution (filters), logical arithmetic operations, vegetation indexes, linear combination among spectral bands, ...

 Raster Operations

European Commission

EUR 17288 – Technical and methodological guide for updating CORINE land cover data base

Vanda Perdigão and Alessandro Annoni

1997 – 140 pp. – 21.0 x 29.7 cm

This guide has mainly been designed as a working tool for people involved in Updating the CORINE land cover Data Base, but it also interesting for all people generally involved in the Updating of thematic maps by means of satellite data. The whole CORINE project is re-analysed and its basic principles and standards concerning creation methodology are discussed in detail. Particular attention is done to their consequences on the Updating process.

A specific Updating methodology has been defined by JRC and all the aspects concerning landscape modification are illustrated here.

This document contains rules (to be strictly followed), suggestions (to optimise the work) and methods (how do the work) very usefull for people involved in this activity. Conclusions and suggestions concerning Updating frequency costs, staff are finally described.