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Land cover and land use information systems for European Union policy needs

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LAND COVER AND LAND USE INFORMATION SYSTEMS FOR EUROPEAN UNION POLICY NEEDS

Proceedings of the seminar
Luxembourg, 21 – 23 January 1998

Seminar organised by:

- Eurostat, Statistical Office of the European Communities, Luxembourg
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- CESD-Communautaire, Land Use Programme, Luxembourg

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OPENING SPEECH

Y. Franchet
Director-General
Eurostat
Luxembourg

Some ten years ago, in this very place, the Statistical Office of the European Communities, Eurostat, organised a seminar entitled Statistics of land use, the impact of remote sensing and other recent methodological developments. On this occasion, the president of the seminar, Sir John Boreham, quite rightly stressed that statistics on land cover/land use should not only be produced, but be used as well. He highlighted the dangers of an over-technological approach, centred on the increasing development of new information sources, such as remote sensing, emphasised the fundamental role of statisticians on concepts and methods and stressed the role of users "Actions by customers must be the start and the finish of specifying the best technology, methodology and medium for the statistics." Obviously, these remarks could still be used as the leading thread for our discussions over the next three days.

For my part, I wish to stress a number of aspects, to be drawn up in the form of questions, which, I hope, will enable us to advance in the development of information systems on land cover/land use meeting the needs of Community policies.

The first question which I consider fundamental is the problem of the wide range of existing needs and the solutions they are given. Without going into detail on these needs, which will be the subject of future presentations, it should be remembered that the implementation of Community policies has some impact on land cover and land use at all geographical levels and, as in the case of the Common Agricultural Policy, leaves a mark on the landscape. It must be possible to measure and assess this impact. Information and indicators are necessary for their management. The increasing multiplicity of these needs poses the problem of the development of new tools for methodological and technical reasons and reasons of cost alike and highlights the difficulty of offering a single solution.

The second question which I consider important is that of development. Development can mean using the tools we have been provided with over recent years: Earth-observation satellites as an information source, geographical information systems as an analysis tool. It can also mean developing both existing tools (the traditional tools of statisticians that have proved their worth) and existing information sources in the Member States. Over the past decade, the issue of the interface between statistical data and geographical data has also arisen.

The third question of interest to me as Director-General of Eurostat is the role of the statistician in the field of land cover/land use. In my view, it is a multiple one: firstly, from a conceptual and methodological point of view where the statistician is accustomed to integrating different information sources, standardising and harmonising by proposing nomenclatures, sampling designs or quality assurance methods. Secondly, he/she can to some extent act as an interface between data and the user, by "decoding" the user's needs and providing value added to the various layers of existing data. Lastly, in view of the increase in needs and the inclusion of the spatial dimension of information, there has been an increasing level of cooperation with other disciplines: geographers, cartographers, planners, regional and local authorities, to enhance the knowledge of other approaches and fields.

I will close this speech by setting out the reasons that led to Eurostat's interest in the field of land cover/land use over recent years and to its proposing this seminar.

Land cover/land use are horizontal themes par excellence, covering numerous application domains. Eurostat, as a "horizontal" Directorate-General within the Commission, is responsible for providing harmonised statistical information at European level on topics which may be related to land cover/land use: agricultural, forestry, environmental and regional statistics. This position at Commission level has led us to propose the creation of an interservice group at Commission level on land cover/land use. It was at the initiative of this interservice group that this seminar was organised.

I hope that these three working days will enable us to take major steps towards building information systems on land cover/land use meeting the needs of Community policies.

OPENING

J. VIGNON
Representative of the European Commission
Brussels - Belgium

Ladies and Gentlemen,

Minister, Mr Franchet,

It falls to me, on behalf of the European Commission's Forward Studies Unit, to try to place your seminar in relation to long-term stakes and, if I may go so far, within the very strategy for European integration. Very appropriately, your seminar goes under the significant title: "Information systems on land cover and use". So what has this to do with the major trends and challenges of European integration in this day and age?

We are meeting here a few days after a historic summit was held in Luxembourg, with Jean Claude Juncker in the chair, a summit which may well have marked the start of a thoroughgoing geographical and territorial upheaval which we can call "the birth of Greater Europe". Five groups have been identified as concentric circles, and several of these are fully represented here:

- the conference group: those countries which aspire to join the European Union, including Turkey,
- the enlargement group: all those countries which are committed to negotiating their accession to the European Union in the relatively short term,
- the accession group: the six countries with which accession negotiations are due to begin in the coming weeks, as of March 1998,
- the European Union and a fifth group within it, sometimes called EuroX, because the number of countries has not yet been quite settled or soon will be, those committed as of now to united monetary policies, which will adopt the euro and forge infinitely stronger economic and, no doubt, political co-operation.

Why choose this image? Because, beyond any doubt, never before this historic summit have there been stronger grounds for a vision of concentric circles, of territories and a geographic vision of Europe as a political force.

We therefore share your concerns, we can identify with your mission of giving substance, in information and statistics, to territories within a greater Europe.

Take another image from physics - the atom: as the European Union of today acquires the dimensions of greater Europe, it resembles an atom, with its layers of electrons and a dense core. Both levels are driven towards integration, the electrons in concentric circles moving ever closer to the centre, and the centre itself becoming ever denser as European Union takes on greater substance.

The question raised in the centre, i.e. in some of the Member States of the current European Union, is whether the transformation of these policies and institutions will be able to support (in every sense of the word) this dual process of spatial and institutional integration.

For three years now, this question has occupied all our diplomats and national politicians concerned with European integration, in the intergovernmental conference in Amsterdam some months ago, in what we call Agenda 2000, i.e. the renewal of European policies for the period 2000-2006, and right across the circle which I cited in attempting to answer the question of adapting structures, institutions and policies to the very real movement towards political and territorial integration in Europe. But neither of these responses, the intergovernmental conference or Agenda 2000 and its array of important policies, can any longer be seen as purely rational processes. No group of experts got together around a table saying: "Our objective is enlargement, is the euro; and we are going to look carefully and rationally at how to make these objectives workable, at how to transform our policies, increase our resources and strengthen the decision-making powers of our procedures". No, these responses were not dictated by intellectual reasoning. They were policy-led, and conditioned not only by the objectives, but also the constraints dictated by the vitality of our societies and not merely rational, budgetary constraints. We cannot do everything at the same time. The Member States, and the largest contributors in particular, have their own burdens, and the credibility and the acceptability of politically strengthening the European Union depends from the very outset on the will of the citizens of Europe to pool sovereignty and in so doing to change it to some extent. It was therefore not the time for a strictly rational response. It was a strategic response, postulated on the possibility of looking in the future to other courses, other dynamics and other responses.

This being so, and granted that the response is less than perfect, in that the intergovernmental conference has not met all the strictly institutional requirements for enlargement, and that Agenda 2000 itself also has to heed budgetary constraints, and not only whether the requirements are proportional to the objectives, there are good grounds for wondering whether - as regards the cohesion of the current Member States of the European Union - the prospects up to the year 2006 are such that they will be able to last the course, or whether we should not rather fear a reduction in their cohesion, their unity, at the very time when it needs to be affirmed in ever clearer terms if we are to be able to welcome the new members. More specifically, while there is an inevitable deceleration and in certain cases a reduction in the resources available for the European Union's budgetary policies, these policies are of growing importance in terms of economic and social cohesion. The euro itself will increase the dynamism and growth of the European Union and will be to the benefit of greater Europe. However, it will also accentuate tensions and disparities between all economic, social and - especially - territorial operators, as differences in the comparative advantages of regions and cities become more directly evident.

Similarly, the need to combat unemployment will inevitably underline the need for structural policies on training and for developing certain areas. At the same time, however, relatively fewer resources will be available; i.e. they will continue to grow, but much less quickly than they have since 1987. There is, therefore, something of a contradiction between asking more of these policies while at the same time not being able to lend them the dynamism they once embodied.

This is the strategic dilemma - and you have to read between the lines of Agenda 2000 to appreciate it - created by a profound change in the nature of the policies of the European Union, and one which concerns you.

We are witnessing what political scientists call a change of governance, a change in how the European Union is governed and in the very way in which Community policies themselves are implemented. Very briefly: there are three features of this change: the integration of policies, the comparability of national and local policies and the transparency, visibility, openness, the public character of the grounds for these policies and their results.

Sustainable development is one of the best examples of integration. It is the process whereby environmental policy is no longer isolated from other policies, but is located at the very heart of all other Community policies, including agricultural policy and local development policy.

Comparability: last year the principal result of an extraordinary Council on employment in Luxembourg was the commitment to making the comparability and convergence of national employment policies, based on common, comparable indicators, the touchstone for dealing with employment within the European Union's general economic strategy. Transparency and openness: In Europe, national authorities no longer act alone, but with partners, and the essence of partnership is that it is based on common indicators which can prove that the contract is being fulfilled.

This means that the strategic shift in the nature and premises of Community policies will demand an enormous increase in the resources allocated to statistics. Since, at the same time, the budgetary resources and the statistical demands made on taxpayers, enterprises and households cannot really increase so much, it is logical to speak in terms of an information system, i.e. of enriching the statistical foundations by incorporating many additional elements which will be cast in key roles by the techniques which you have developed over the years.

This is one of the essential incentives for the success of your seminar. But to get back to something which we have already referred to for those who tackled a comparable subject in Lille a few months ago, statisticians, in close co-operation with other professionals, such as engineers, sociologists and geographers, have - as a result of this strategic shift - become a core of scientists with a direct role to play in renewing the methods of democracy in our countries. This requirement of transparency, and of more flexible, prompter and more finely-tuned statistical and economic information, obliges you to contribute to a broader public discussion, one which engages and involves all levels of society, and I am convinced that this is especially pertinent in this country, in Luxembourg.

Thank you.

WELCOME ADDRESS

A. BODRY
Minister for Regional Planning
Grand Duchy of Luxembourg

Ladies and Gentlemen,

It is a great honour and pleasure for me to welcome you all to Luxembourg on behalf of the Luxembourg government. As Minister for Regional Planning, I would like to congratulate the organisers of this event, and obviously extend my particular thanks to Eurostat for setting the ball rolling. It cannot have been easy to bring together experts and users not just from different professional circles, but also from across the EU and, indeed, Europe, all actively involved in investigating an area as complex and vast as land cover and land use.

One of the reasons that prompted you to organise this event was, no doubt, the ever-growing demand in the field for information on the state of the natural and man-made environment and on geographical development patterns. Decision-making processes are becoming increasingly complex, lengthy and difficult to manage.

The same applies to the two policy fields that are particularly close to me - regional planning and regional development. The ability to draw on statistical and cartographic data that are reliable, up to date, exhaustive, readily accessible and, as has already been pointed out, transnationally comparable, considerably facilitates the work of decision-makers in the political and economic fields. The objectives of this seminar thus seem to me to be of fundamental importance - to try to determine the Commission's needs whilst compiling a qualitative and quantitative inventory of what exists at Member State level, to compare national approaches to the production and management of data on land cover and use and to agree on a common action plan to improve our knowledge of this field, at European, transborder and even regional level.

The main ideas that came to mind when I looked at this programme, which will keep you busy for the next three days, were as follows:

Firstly, I think it extremely important at events such as this to bring together both producers and users of statistical and cartographic data. I sometimes think that statistics have too long been produced in isolation by experts who are sometimes a little out of touch with what is going on in the field, which may explain why some people are less than enthusiastic when it comes to "official" statistics. But this is a thing of the past. And Eurostat is proof of this. Over the years, the Statistical Office of the European Communities has been endeavouring to systematise the collection of relevant data for regional analyses and has recently published a collection of indicators on sustainable development. In doing so, it has shown us the way forward and has doubtless beaten more than one national statistical institute to the mark.

Secondly, I am addressing you not just as a representative of the Luxembourg government, but also - as I have already pointed out - as Minister for Regional Planning, thus testifying to the interest which planners and all those concerned with regional management policy show in the problems of land cover and use. Like regional planning, the collection of statistics is a complex exercise with both horizontal and vertical components. When the sectoral approach leads to a dead end, we need to broaden the debate. I hope the participants in this seminar will remember that we need to come up with approaches that are general but can be adapted to suit the wide range of users' needs.

Thirdly, the collection and management of statistical and geographical data are obviously no substitute for the policy measures we must opt for in the field of land management. However, they may form a corollary to, and foundation for, such policies. Hence the need to find suitable instruments at European level too, instruments that will accompany and guide decision-makers in the field of land use and land management in the choices they make.

I am convinced that an instrument such as ESDP, the European Spatial Development Perspective - which is currently in its infancy - might prove one such component, one of the instruments that will accompany and guide Community policy.

Fourthly and lastly, this ties in with the work being done in the field of regional planning at European level, as there is a direct link between this work and your discussions at this international seminar. At the informal meeting of the Ministers of Regional Planning of the European Union in September 1994 in Leipzig, it was decided to draw up a European spatial development plan. At the same time, after note had been taken of the serious gaps in, and major disparities between, the contextual data that are so important to planners if we are to carry out our work properly, it was decided to set up a permanent territorial monitoring system in Europe and systematise co-operation and mutual assistance between the Member States, the Commission and the research institutes affected by this problem. The national experts from the Committee on Spatial Development have been trying to define a model that meets the needs described above. The question is whether it will prove possible to create a new monitoring unit and make it part of the Commission, or whether it will suffice to network national monitoring centres. The ministers and Member State representatives that met in early December in Echternach (Luxembourg) basically decided to go ahead with the creation of the European Spatial Planning Observatory Network, or ESPON for short, the actual start-up of which will be preceded by a test period of two years. 1998 and 1999 must therefore be turned to account to implement a programme of studies which will be carried out on a network basis by institutes specialising in regional planning and which will, in a sense, provide a foretaste of the future monitoring system. After 2000, caution will be required. The budgetary authority of the European Union will create a specific budget heading to fund the observatory network in the long term. In the meantime, it might be advisable to see what role Eurostat could play in the observatory's test phase. I am certain that, if approached, the Luxembourg government would be willing to provide political and logistical support for the implementation of this test phase in close collaboration with Eurostat.

Ladies and Gentlemen, the international seminar you are attending is being held here in the European quarter of Kirchberg. If you look around, you will find major European institutions - the Court of Justice, the European Investment Bank, the Court of Auditors, the Secretariat of the European Parliament, departments of the Commission and other institutions. Luxembourg is also one of the places where the Council of Minister meets and, during the last six months of 1997, again saw a number of major decisions taken, decisions that I would say are of historic importance for the European Union. I hope you make the most of this European environment and draw inspiration from it, and I am sure your work will prove highly fruitful.

Thank you.

SESSION 1

INFORMATION REQUIREMENTS OF THE EUROPEAN COMMISSION

INFORMATION REQUIREMENTS OF THE EUROPEAN COMMISSION: SYNTHESIS OF THE REQUIREMENTS

D. W. HEATH
Eurostat
Luxembourg

1. Summary

A synthesis of requirements goes beyond a simple list of information demands indicated by different services in relation to the policies they serve. But our starting point is that increasingly EU policies have a direct or indirect geographical component that has to be consciously considered: agriculture, forestry, transport and tourism all have important, spatially-specific impacts including environmental considerations. These have to be integrated in specifically spatial policies, as in the recently-issued, first official draft "European spatial development perspective". Official statistics have to develop their information systems to provide information on the intersection of the world of geography and of socio-economics. Very many of the new information needs involve measures of land cover or land use and of changes in them. A comprehensive land cover/land use information system, flanked by and based on specific, specialised (existing) systems could constitute the integrated, multi-purpose system which is necessary to provide, at reasonable cost, the extensive information which is becoming increasingly necessary.

2. Introduction

This seminar is but one of numerous activities related to land cover/land use in recent years by numerous organisations. A number of these are indeed presented or represented here. In this paper I try to show why we are working in this area. An underlying issue for Eurostat is how can the European Statistical System, that is Eurostat plus the official statistical services of the Member States, best meet the new information needs of Union policies which directly target local situations or which in their formulation at Union level need to take account of their impact on local situations. Many of the specific requests for information involving local data depend directly or closely on land cover/land use. Successful development of a general system of land cover/land use data would thus go far towards meeting new needs. It would also be the basis for developments to meet efficiently further needs.

3. Background

Elucidating user needs is notoriously difficult. Designing and implementing an appropriate statistical response can be equally so. Users are often not able to explain what information they really need. It is difficult to assess in advance the actual importance and relative priorities of the different information needs expressed. The practical restrictions limiting the response of the statistician (data that are measurable, cheap, repeatable etc.) are of course not part of the users' criteria. So a discussion on different possibilities and trade-offs is not normally possible. The newer the area the greater these difficulties. For land cover/land use data needs there are additional complications stemming from:

- the interplay between the local and the national dimension;
- the dual approach, mapping and statistics.

The characteristic official statistics (and one remembers the semantics of "state-istics") give data reliable at the national level and useful at that level. Although population censuses are built up from detailed, local figures many official statistics are not able to give comprehensive, local detail especially after recent pressures to reduce sample sizes to the bare minimum necessary to achieve representative results at the national level only. The new information need however is for information with a local spatial dimension but set in a national or international context. It is for information of the type provided by official statistics at the national or the European Union level and largely serves policy formulation at that level. This need to take account of the detail of specific local situations brings the official statistician close to the world of the geographer and the map-maker.

One reason for considering the local dimension is that one needs to take account of the local impacts of a national or Community policy primarily driven by other considerations. A change in the Common Agricultural Policy can influence the local situation all over the Community. The need to integrate environmental protection requirements into the definition and implementation of all Community activities and policies in most cases requires considerations of local situations. Environmental consequences are often found in environmental "hot spots" rather than evenly spread. The other main reason for considering the local dimension is that there are also ever more policy areas specifically targeting local situations: the structural funds; the embryonic rural development policy, the European Spatial Development Perspective (of which the first official draft has recently been issued, in which there is highlighted "the lack of reliable, comparable and geo-referenced data to underpin the ESDP" and which proposes close co-ordination with Eurostat) with interests which include urban problems, and also the Trans-European Networks. There is formal recognition in the Committee of the Regions created by the Treaty on the European Union, a Committee consisting of representatives of regional and local bodies. To support policy work related to all of these, statisticians need to provide comparable data covering the various local situations. This is necessary firstly to permit accurate aggregation to give averages and totals for an overall assessment of the local effects of policies and secondly to ensure equable treatment of areas of interest over the whole territory.

There is also interest in wide comparability of local data by those responsible for a certain locality, and by market operators. Locally determined figures may in some sense be adequate for local management but there is often an interest in comparing notes with those in a similar situation or in being able to situate oneself in a broader context. The data available to the local operator are of two kinds: those received from some general system where comparability is ensured and secondly those produced locally, geared towards local needs and where special efforts are necessary if wide comparability is to be achieved. There is of course a profound difference of view point between the local operator or manager and the national or community policy maker. The first considers the sum of impacts on a local situation of many national policies. The second considers the sum of many local consequences of a specific policy.

The challenge for the statistical services in meeting these new needs is considerable. With their limited resources it is not the statistical services which can develop new systems tailored to cover each of the new needs. When dealing with economic phenomena arbitrage over space prevents great regional differences and these differences are not of such great importance where goods and currencies are really mobile. National and Community totals and averages can be obtained from a restricted set of sources where data are already concentrated and synthesised. The local phenomena which are now having to be measured do not spontaneously form regional averages like prices in an auction market. The requirement to consider the variety of local situations implies a level of detail and so volume of data far greater than that of most national statistics. A systematic approach capitalising on existing data sources is essential.

4. User Needs

What could be a starting point? Land cover/land use is not only a common element in many user needs. It is a topic where there are numerous specialised information sources. It also has advantages as a basis for further statistical work. Examples of the strong interest of certain services in land cover/land use data are topics in later sessions. In addition, it is also striking how broad and how varied are the interests. These are summarised in the following paragraphs.

Eleven separate directorates general of the Commission have been identified as having information needs related to land cover/land use. They range from external relations through agriculture, environment, regional and research to transport and energy. There is a considerable measure of overlap in the areas of interest identified by the representatives of the different policy complexes. The types of information of interest to the wider agricultural policy complex include

- the traditional, detailed agricultural statistics: annual data on crops and at less frequent intervals on perennial crops, on pasture and on fallow and abandoned land where greater geographical detail (also necessary for yield modelling) and better information on the movements between the different classes (land use dynamics) are required;
- a substantial development of forestry statistics including the interactions between agriculture and forestry, mixed agriculture and forestry areas and the environmental dimension of forestry;
- environmentally relevant breakdowns including landscape aspects - hedges, walls, trees, environmentally sensitive areas, buffer zones to water, intensity of use
- grazing patterns, irrigation
- diversity and structure (corridors, fragmentation)
- rural infrastructures
- vulnerability (landscapes, abandonment, erosion ...)
- urbanisation and agriculture.

Relevant environmental[1] policy considerations include

- land use accounting
- small, special interest areas
- coastal zones
- local impact assessments
- generalised environmental impact of other polices
- urban structures
- biodiversity
- climate change
- landscapes
- water (demand and supply, wetlands, pollution ...).

Relevant transport/network considerations include

- areas occupied
- impacts on other activities
- fragmentation
- population served
- network structure
- environmental consequences (noise, biodiversity, special interest zones, water surfaces)
- consequences for secondary development.

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1 The importance of land cover as a part of environmental information is exemplified by the CORINE Land Cover programme and the European Environment Agency's Topic Centre on Land Cover.

Regional requirements include

- classification of regions (urban, rural, coastal, transfrontier ...) and provision of a variety of statistics for each
- urban structure and infrastructure
- industrial areas
- abandoned land.

The information needs which have been formulated involve not only aspects directly or closely linked to land cover/land use data. They also include certain common requirements which the statistician's response needs to take account of. One is the need to link the land cover/land use data to other statistical data concerning the zone of interest. This is of course essential to making the link between the local situation and general policy and to assessing the local situation in its entirety. Another general need is that for many of these features useful information will require modelling work. This needs as input spatially differentiated data involving classification by common land cover/land use. Finally visualisation of results and the possibility of spatial analysis are very often requested, indicating that the full range of GIS facilities is necessary, not merely the efficient handling, storage and restitution of geo-referenced data.

5. A Land Cover/Land Use Statistical System

The solution in view thus involves the following components

1. using land use/land cover data as the centre of the system:

- land use/land cover information is a main component in much of the new information sought
- it overlaps with the function of the territory acting as a register for layers of geo-referenced data which can be superimposed for extraction of statistics and analysis
- it overlaps with mapping information in providing the frame for area frame sampling.

2. multi-source and capitalising on existing data:

- generalised nomenclatures facilitating re-use for other purposes of specialised, localised data
- geo-codification of general official data
- use of geographical information systems for storage, analysis and presentation
- use of remote sensing data where cost efficient for
    - ◊ calibration of data from varied sources covering a wide area
    - ◊ "zooms" on areas of particular interest (urban, environmentally sensitive, coastal, cross-frontier ...)
    - ◊ samples.

The concept of a general system does not of course imply that official statistics aims to provide all possible results. It is necessary to clarify where the official statistical services are the most efficient operators e.g. providing very rapid information on emergency situations such as floods, fires or oil spills is not part of the statistician's role even if he can usefully try to provide summary information afterwards so that links between policy and the incidence of such events can be examined. Similarly statisticians do not aim to take over the work of cartographers even if we have to learn some of their skills. The main outputs will be statistics on changes which can be measured on an annual or 5 yearly basis. The focus will be on establishing a limited number of key results with maximum reliability. These can then be used as the framework within which other, more specific local or sectoral work can be situated.

The broad aim of the current work on land use/land cover is thus to create an open-ended system which meets directly many of the new needs expressed and which provides a framework for extension to meet others. By maximum use of existing data (from a variety of sources) the need for any new data collection can be more accurately assessed and any action limited to cases where the cost benefit ratio is clearly favourable. Covering a multiplicity of needs by a single integrated system is a characteristic response of official statistics to meet complex, continuing statistical needs. This allows answers to be given to numerous requests each of which, taken in isolation, could not justify the costs of providing the information it needs or at least not on the regular basis needed for assessing trends. The general system approach ensures the necessary consistency in the data used to support the different policies impacting on a given geographical area.

It is of course easier to describe and justify this target of a general system than to achieve it. The way forward will be by specific actions, each aiming at meeting a particular set of demands. It is the sum of such actions, not necessarily all by the same organisation, which will step-by-step lead to a general system with all the advantages set out above. This work will require efficient co-ordination between the various information-producing bodies involved at the European Community level.

FULFILMENT LEVEL OF INFORMATION REQUIREMENT

R. MUTHMANN
Eurostat
Luxembourg

Dear Mr Chairman, Ladies and Gentlemen, Dear Colleagues,

Having just heard some general remarks concerning the data requirement in the fields of land cover and land use, I would now like to try and formulate a few thoughts, together with you, on the information systems existing in this area, on answers already available.

We have heard that the data requirement is very heterogeneous. It refers to very different subjects and therefore an appropriate analysis of the existing systems is difficult.

I would like to make another remark at this point. Our priority here is to make better basic data available and to work on improving the existing basic data. We should not forget this, as only if the basic data are correct we can formulate aggregates and indicators. We could make a comparison with a good cook: he can only work well if the basis products are right. We have the same problem here. We can only have good indicators and aggregates if the basic data are of sufficient quality.

As already mentioned by Mr Heath, we have observed by surveys and discussions within the Commission that colleagues in the Directorates-General can give only very general answers regarding their data requirement. This means that we face the problem of creating a close, direct link between the generally formulated requirement for information on land use and land cover and the concrete basic data arising from it. We can only achieve this, and this point really should be underlined, through dialogue. This seminar is one of the means available to us.

We need, it was already mentioned, reliable links, nowadays we would surely say "interfaces", between data suppliers and the people I would call decision preparers. Think of our colleagues in the Directorates-General who have to prepare specific programmes; we usually speak of the relationship between data suppliers and decision makers, but our direct opposite partners are those who prepare decisions for the decision makers.

We can promote this link between data suppliers and decision preparers, or decision makers, by devising a common language for basic concepts, nomenclatures, etc.

We can promote it by attempting to create bridges between the existing information systems, transitions and links with which the results of one system can be converted to another system, and obviously we can attempt to get ahead by devising common, approved standards. All these form the basic tasks of statisticians.

An analysis of the data needs and requirements, as Mr Heath has shown, is already difficult; an analysis of the existing information systems is just as problematic. I want to try, nevertheless.

I wish to concentrate here on the systems at European level and to make a number of observations. We should keep a mental eye on the differences between the systems at European level and at national level, since there is a much greater need for harmonisation and standardisation at European level.

If you consider the few existing systems at European level focusing on information on land cover and land use, you will see that these were initiated and financed by the Commission in the late 1980s. CORINE Land Cover and the MARS programme in the field of the common agricultural policy were named as the most important examples. I do not wish to present these programmes in detail, but to discuss with you just some important general points concerning these systems. For those interested in more details, there are a great number of experts of both these systems here in this room.

These systems were developed for quite a precisely outlined, specific sectoral data requirement: CORINE Land Cover in the field of the environment, an application focusing on cartographic data requirements, and the MARS programme in the field of the common agricultural policy, focusing on statistical data requirements.

Both programmes have achieved good results for the field for which they were developed. Sometimes they have been used beyond the specific requirements originally provided for. I could cite as an example the application of CORINE Land Cover in the field of coastal areas.

If we perhaps consider briefly here how an ideal information system for land cover and land use could be devised at European level, then the following words would most certainly come to mind: the system should be polyvalent; it should be sufficiently flexible; it should be relatively quick to convert or relatively quick to construct within a particular framework, in a Member State or at European level, and it should not cost too much.

In practice, the situation or the analysis of the activities currently being carried out by the Member States obviously looks considerably different when it comes to the four general characteristics summarised above.

In practice, the main activity in the field of information systems is compilation, i.e. the sighting and combining of existing information at the level of the Member States.

Now, you can say that Eurostat has much experience in the field of the harmonisation and standardisation of information at European level. This is certainly an advantage and this knowledge is also very much in demand in this field. However, as one of those responsible for one of the departments in the field of agricultural statistics, I can assure you that this harmonisation work in what are now 15 Member States, and we forecast some 25 or more within five to ten years, is arduous, lengthy and is outwardly underestimated.

The work involves the development of nomenclatures, standardised questionnaires and, something that should not be underestimated in terms of workload, the necessary adjustments to the political changes of certain policies. Think of the example of the common agricultural policy and key words will spring to mind that are associated with data on land cover and use: rural areas, development of rural areas - we will return to this point later - the relationships between agriculture and the environment, and how these are to be quantified; how can they, as regards land use, be captured and, something that also shows the considerable participation of central and eastern European countries in this seminar, which land use and land cover data we can compile for the countries of central and eastern Europe over the next five to ten years, and how we can ensure comparability, which, we must admit, has not been achieved so far between the countries of the European Union.

With these considerations in mind, we have intensified our work on land use statistics; two years ago, we firstly furthered coordination within Eurostat, then initiated a working group with the Member States and, as already explained above, held regular meetings with our users in the Directorates-General in Brussels, on whose suggestion this seminar begins today.

Given the many partial approaches of the existing information systems at national level, the considerable number of approaches with cartographic and/or statistical aims, a uniform approach is very difficult.

In this context, I would like to once again address three fundamental ideas:

1. The valorisation of data, as already mentioned in the lecture by Mr Franchet:

   We have a situation in Europe in which we have the privilege of having access to qualitatively good information. While this information is obviously partial and heterogeneous, there is a lot of it, sometimes even too much, which can also be a disadvantage. We must valorise this data, giving it "value added" with four possibilities:

- we can achieve this valorisation, this value added, by using methodological instruments;
- we can try to produce reliable transitions, links and conventions between existing information systems, allowing us to move from one system to another system;
- we can take additional information, for example from satellite remote sensing, enabling us to increase comparability;

  and perhaps most importantly, and something that should never be forgotten:

- we can and must use the "know-how" of those working on the analysis of this data as an important factor for the valorisation of this data.

2. Both the Statistics services, formulated in the comprehensive sense, and the cartographic institutes must strengthen their cooperation, promote the exchange of "know-how" and significantly increase their mutual comprehension.

   We held the first meeting between these two groups here in Eurostat well over a year ago. It became apparent that there was much left to be done on the complementarity between cartography and statistics.

3. The coordination between different organisations working within the Commission in these fields at European level, as well as with other international organisations, for example the FAO, must be strongly promoted.

We will return to these ideas in a concrete manner, regarding coordination.

Allow me to complete these thoughts on the existing information systems with three examples, which perhaps demonstrate the insufficiency of these systems at present.

<u>Example one:</u> keyword: multifunctional agriculture

We can assume that we will in future have two sectors under the agricultural policy of the Community: on the one hand, the major units focusing productively and efficiently on the production of agricultural products; and on the other hand a second group of ecological agriculture, active in problem areas, for example mountains, a form of agriculture we do promote with public funds, but not as a priority from the production aspect. In the future, the promotion of so-called multifunctional agriculture will require a considerable amount of data on land use.

If we now return to the three criteria I have cited, we could say: in this field, we have access to very little, very heterogeneous and sometimes very partial basic data; it is methodically very difficulty to devise indicators for this sector – think of the effects of agriculture in mountainous regions – but we must work in this field, because this is an issue facing us politically.

<u>Example two</u>: land use data in urban areas

We have access to a considerable amount of data. Unfortunately, however, this data is very heterogeneous and not very comparable. And the task of valorising this data, or making it comparable, is challenging. In addition, we still have a generally unsolved problem in this field: we have up to now dealt with city regions comparable at European level in pilot projects, but we have no approach for comparable city regions or for the most important comparable city regions in Europe. This is still to be carried out.

<u>Example three</u>: basic data

A major project is currently being prepared in Italy, involving the renewal and compilation of a land cover map covering the whole national territory at a scale of 1:25,000. It therefore fundamentally involves a cartographic approach and, within the scope of this project, we are attempting to find out

- what is needed,
- what additional steps are required if this approach is to enable reliable statistical data to be derived and prepared intelligently and efficiently.

After these remarks, Ladies and Gentlemen, one thing is certain: there is enough work to be done.

I would ask you to consider with us over the next three days better solutions for the future in this field and thank you for your attention and patience.

THE NEED FOR INFORMATION ON LAND USE FOR THE REQUIREMENTS OF THE COMMON AGRICULTURAL POLICY

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The Common Agricultural Policy (CAP) is one of the key policies of the European Union (EU). It is also the oldest policy and absorbs the largest share of the Community budget (some 50% of EU expenditure).

The need to have a sufficiently precise level of information on agricultural land use has led to the establishment of an information system based on Community legislation specifically designed to meet the needs of the CAP and on land use information developed to meet the needs of other policies (e.g. forestry, regional and environmental policies).

The CAP needs specific data on land use:

1. for day-to-day management: information on annual crops, area used for fodder production and permanent crops
2. owing to the increased importance, since the 1992 reform, of data on the use of agricultural areas not used for arable crops: multi-annual and/or permanent uses of agricultural land (fallow land, permanent grasslands)
3. for medium- and long-term CAP analyses: the impact of policy changes on agricultural land and the location of production (crop and livestock).

Apart from these specific needs which require a regular flow of harmonised data, there has always been a high level of interest in having sufficient information on land use in general because of the numerous forms of interaction between agricultural and non-agricultural land (e.g. forests, urban areas, protected natural areas).

The new proposals which are being developed for the CAP as part of Agenda 2000 only reinforce these requirements and increase the importance of certain aspects such as the links between agriculture, the environment and the countryside, which will probably require a strengthening of the system for collecting information on land use in order to have a more harmonised system able to meet the needs of both a changing CAP and other policy requirements.

Land constitutes an essential agricultural resource, the true value of which needs to be recognised on account of its essential and, more importantly, non-renewable nature. If agricultural activity is carried out in an insensitive or inappropriate way, it may in the long term render the land unusable, not only for agricultural purposes, but for other uses as well. However, this propensity to swallow up land is not the sole preserve of agriculture: all economic activities put pressure on the available land, and as they expand, they too swallow up land.

The Common Agricultural Policy (CAP) has been a key policy since the creation of the European Community. Utilised agricultural area accounts for some 45% of the total area of the European Union (EU), The CAP is the oldest policy and absorbs the largest share of the Community budget (some 50% of EU expenditure).

The need to have a sufficiently precise level of information on agricultural land use, allowing comparability, has led to the establishment of a Community information system based on Community legislation specifically designed to meet the needs of the CAP and on land use information developed to meet the needs of other policies (e.g. forestry, regional and environmental policies).

The CAP basically uses statistical information obtained from the following legislative framework:

- Council Regulation No. 837/90 concerning statistical information to be supplied by the Member States on cereals production
- Council Regulation No. 959/93 concerning statistical information to be supplied by the Member States on crop products other than cereals
- Council Regulation No. 571/88 on the organisation of Community surveys on the structure of agricultural holdings.

The data received from this system as a whole provide information on land use according to the following classification:

Arable land (including fallow land)	Permanent crops (including crops under glass)	Permanent grassland	Utilised agricultural area	Wooded area	Other area N.E.S. (including inland waters)	Total area
1	2	3	4 = 1 + 2 + 3	5	6	7 = 4 + 5 + 6

The definitions and subdivisions of each of these categories are appended.

At present the system is merely the result of a harmonisation of the various systems applied in each Member State within a very mixed European Community subject to ongoing expansion. It is common knowledge that this process of geographical expansion of the EU is far from over and will require once again a review and adaptation to the new requirements resulting from future enlargements.

The need for a more uniform and harmonised Community information system originates from the present limitations in the Community statistics available, which have created a lot of problems in and placed great restrictions on the use of the statistics for the requirements of a multinational community operating a common agriculture policy.

These problems are of different nature. On the one hand, they were purely methodological: definitions used by the Member States were not identical and even varied a great deal from one country to another. The time series established from existing data could not be used easily for analysis owing to changes to definitions introduced by Member States either for independent reasons or because of the need to adapt to Community definitions. On the other hand, a good deal of the problems were linked to errors or gaps due to the lack of resources to carry out censuses. This situation has improved slightly over the years, but some of these problems still exist and those which have not been solved still have their effects on the statistical series currently available. Given all these limitations, these statistics must be used with the greatest care and the utmost caution must be exercised in comparisons between Member States and in carrying out analyses.

Information on agricultural land use is used in preparatory work in the following areas:

- for day-to-day management of farming sectors for which there is a common organisation of the market: information on annual crops, area used for fodder production and permanent crops
- owing to the increased importance, since the 1992 reform, of data on the use of agricultural areas not used for arable crops: multi-annual and/or permanent uses of agricultural land (fallow land, permanent grasslands
- for medium- and long-term CAP analyses: the impact of policy changes on agricultural land and the location of production (crop and livestock)

This concern stems from the need to be constantly aware of the factors governing the trend in land use and in particular to be at least in a position to assess, even in very rough terms, the impact of the factors located within the agricultural sector itself. It should not be forgotten that some of these factors relate to changes in the socio-economic conditions of agricultural activity but others are much more specifically linked to agricultural policy measures. This implies that any change in each of these factors changes the importance of agriculture in terms of land use, which results either in changes in the breakdown of agricultural land amongst the various types of production or in making agricultural land more or less attractive for other non-agricultural uses.

Factors such as the situation of agricultural markets (prices of agricultural products, trade etc.), changes in production conditions (technical progress, mechanisation, means of transport etc.), structural factors (types of farm, age of farmers, types of farming, less-favoured areas etc.) and agricultural policies themselves (price support measures, production aid, area aid, livestock premiums etc.) are all elements within the agricultural sector which influence the trend in land use.

However, other factors, which are essentially controlled by non-agricultural sectors, exert an even greater influence on the demand for land, on account of the greater income which the sectors derive from agricultural or non-agricultural land. Requirements relating to urbanisation, industry, commerce, communications infrastructure and, more recently, leisure activities therefore make increasing demands not only on areas on the edge of towns but also on rural areas themselves, which are sometimes impossible to deal with by applying agricultural policy measures.

All these complex elements, which combine to form a source of background pressure on agricultural land, are of interest to policy makers - not only those concerned with agriculture, but no doubt also those responsible for other sectors needing land in order to develop.

The Commission recently published Agenda 2000, which presents an overall analysis of the two main challenges facing the European Union: developing Community policies and enlarging to include the countries of Central and Eastern Europe.

In this context, the new reforms of the structural policies and the CAP must further elaborate the measures taken in favour of economic and social cohesion, agriculture and rural development. In terms of agricultural policy, the policy of continuing to move towards world market prices, together with direct income aid, will continue to follow the guidelines initiated with the 1992 reform but with the aim of achieving an agricultural sector with greater respect for the environment by integrating environmental objectives in the CAP (for example, better management of natural resources or protecting the landscape).

The CAP which is taking shape aims to safeguard the ecological and recreational functions which potentially exist in rural areas and which are to offer new development opportunities for farmers and their families. Highly valuable natural areas will be able to count on a support system which recognises the importance of preserving these sites. Moreover, work on initiatives concerned with, for example, the application of organic farming, the preservation of semi-natural habitats, the maintenance of traditional orchards and hedgerows or the continuation of hill farming will be reinforced and encouraged through increased budgetary resources.

All these new trends are merely aimed at protecting agriculture and the landscape, which are the results of the interaction between climate, type of soil, tradition, culture and technical progress, and a capacity acquired over time to overcome the constraints of nature.

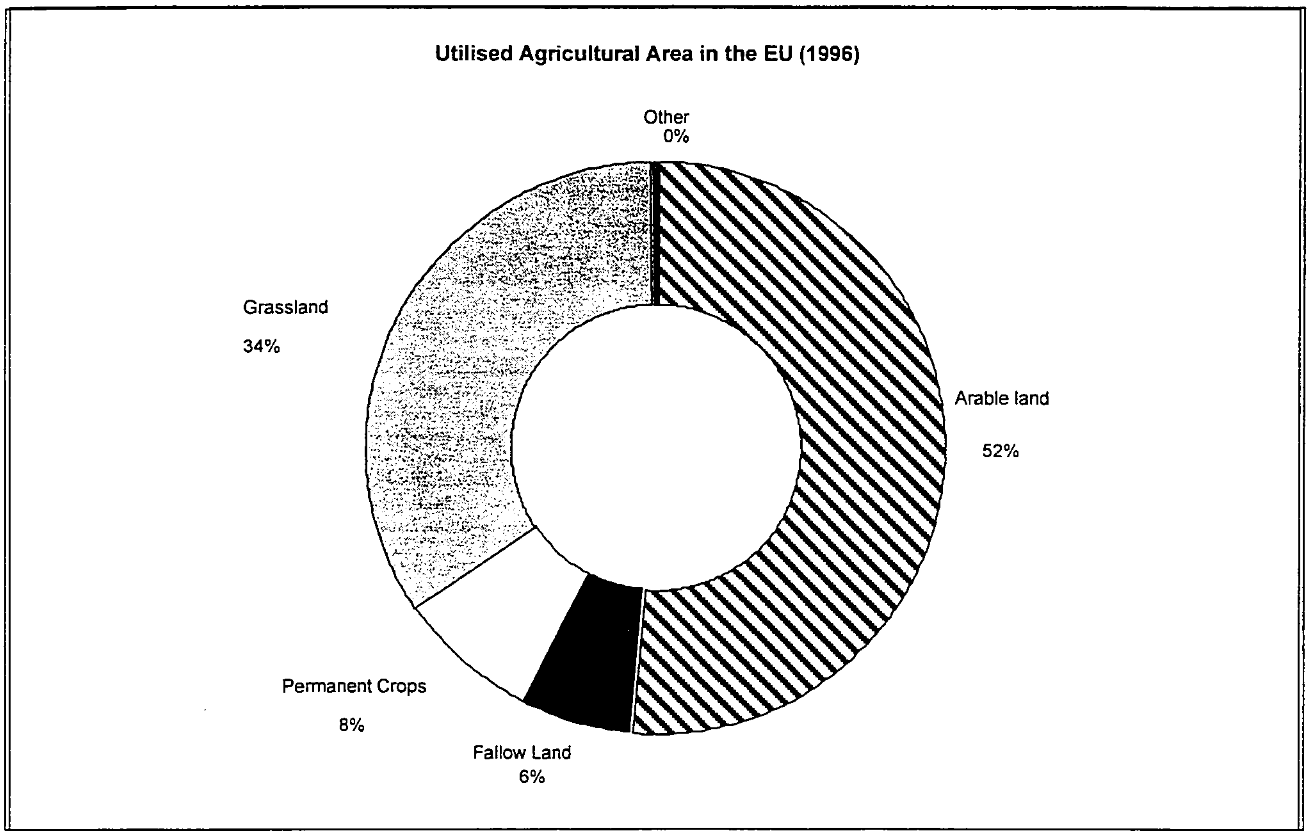
As far as the needs of information on land use are concerned, these new requirements will call for the creation of new classification sub-classes in order to improve the level of accuracy of the information on certain types of land use about which little is known at present, and they will probably make it necessary to create classification systems which can cross-reference existing classifications with uses considered more in line with the new agri-environmental objectives such as organically produced crops or less intensive crop or livestock systems.

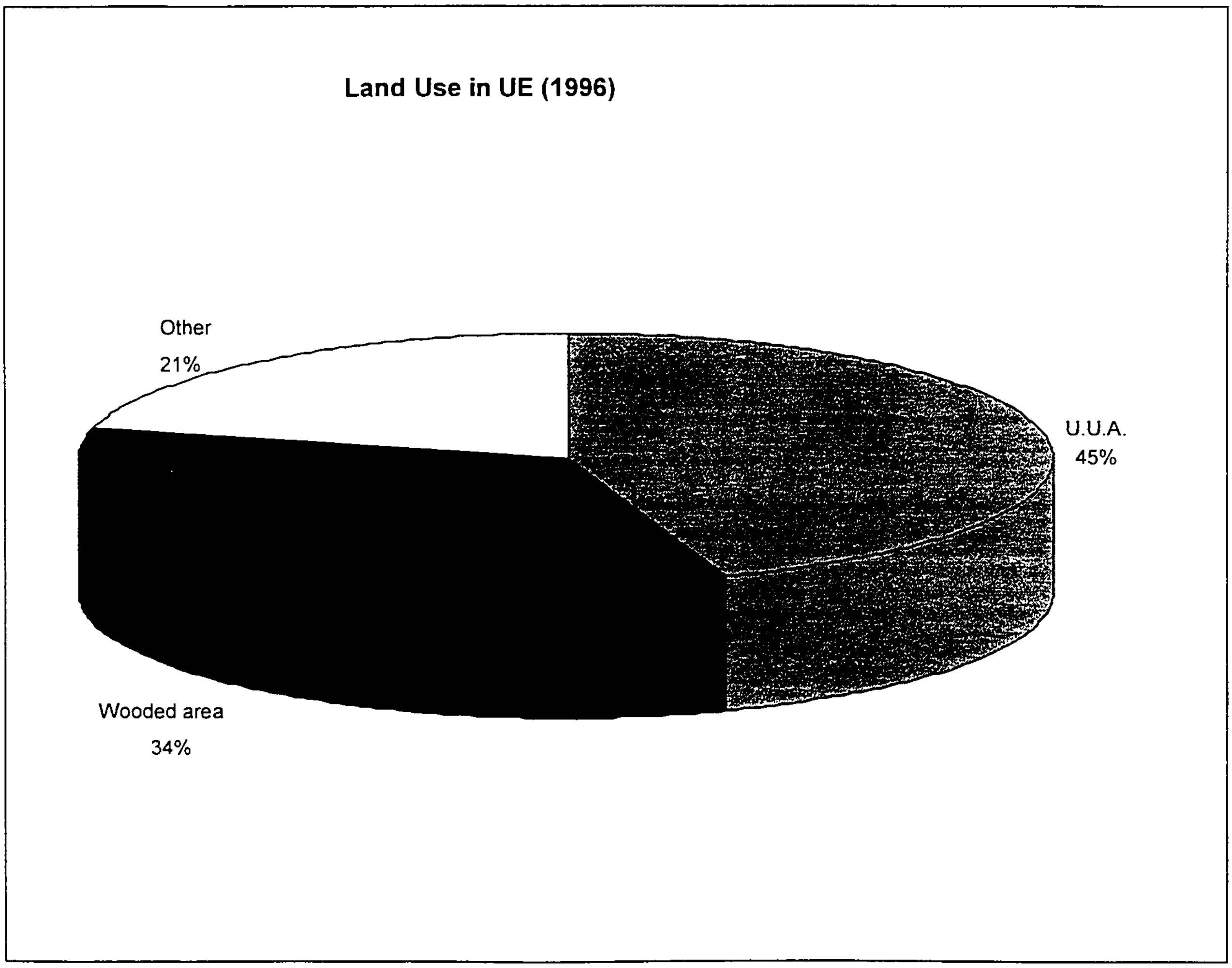
The Commission is busy working on concrete proposals for presentation in the course of this year. The new proposals will shed more light on the direction to be taken and will define the new requirements more precisely.

However, whatever new proposals are presented, it is of fundamental importance that the current system should remain a quality system which can be readily used by all the EU, national or international bodies concerned, and which has responsibilities in the political decision-making process or the assessment of the effects of these decisions. It is up to the departments responsible for data collection to determine the way to optimise all the possibilities currently offered by the various existing information systems, and it is up to decision-makers who use this information to maintain a continuous open dialogue with them in order to become aware of their scope and limitations.

Table 1 Main categories of land uses

<table>
<tr><th colspan="5">CATEGORIES</th></tr>
<tr><td rowspan="22">AREA TOTAL</td><td rowspan="21">LAND AREA - TOTAL</td><td rowspan="19">UTILISED AGRICULTURAL AREA (UAA)</td><td rowspan="11">ARABLE LAND</td><td>CEREALS</td></tr>
<tr><td>RICE</td></tr>
<tr><td>DRIED PULSES</td></tr>
<tr><td>ROOT CROPS</td></tr>
<tr><td>INDUSTRIAL CROPS</td></tr>
<tr><td>VEGETABLES</td></tr>
<tr><td>GREEN FODDER FROM ARABLE LAND</td></tr>
<tr><td>OTHER ARABLE CROPS N.E.S</td></tr>
<tr><td>FALLOW LAND AND GREEN MANURES</td></tr>
<tr><td>FLOWERS AND ORNMENTAL PLANTS</td></tr>
<tr><td>SEEDS AND SEEDLINGS</td></tr>
<tr><td rowspan="5">PERMANENT CROPS</td><td>FRUIT AND BERRY PLANTATION</td></tr>
<tr><td>VINEYARDS</td></tr>
<tr><td>OLIVE PLANTATIONS</td></tr>
<tr><td>NURSERIES</td></tr>
<tr><td>OTHER PERMANENT CROPS N.E.S</td></tr>
<tr><td>PERMANENT GRASSLAND</td><td></td></tr>
<tr><td>KITCHEN GARDENS</td><td></td></tr>
<tr><td>CROPS UNDER GLASS</td><td></td></tr>
<tr><td>WOODED AREA</td><td></td><td></td></tr>
<tr><td>OTHER AREA N.E.S.</td><td></td><td></td></tr>
<tr><td colspan="2">INLAND WATERS</td><td></td><td></td></tr>
</table>


Utilised Agricultural Area in the EU (1996)
Other
0%
Grassland
34%
Arable land
52%
Permanent Crops
8%
Fallow Land
6%


Land Use in UE (1996)
Other
21%
U.U.A.
45%
Wooded area
34%

SESSION 2

SOME ANSWERS FROM EUROPEAN NETWORKS

STATE OF PLAY OF THE EEA EUROPEAN TOPIC CENTRE ON LAND COVER

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1. Background

The European Environment Agency (EEA), which mission is to provide the Community and the Member states with objective, reliable and comparable information at European level, has contracted different institutions and organisations to form expert consortiums on specific topics, named European Topic Centres (ETC). These Topic Centres executes particular projects identified in the Agency's multi-annual work-programme. For the European Topic Centre on Land Cover (ETC/LC) the project is "Land Cover – Ecological Monitoring" (MN4).

The task for ETC/LC is to make full use of and further develop the results obtained so far through the implementation of the CORINE Land Cover (CLC) programme. The CLC-programme was initiated by the European Commission in 1985 and is now under the auspices of EEA. The arrangement is significant for the integration of environmental aspects, in particular those regarding the 5th European Environmental Action Programme, Regional Planning Strategies, Integrated Statistical and Geographical Information Systems.

2. Organisation of the ETC/LC

In 1995, the Environmental Satellite Data Centre (MDC) was appointed lead organisation for the Topic Centre on Land Cover (ETC/LC). The Topic Centre is organised as a consortium of 16 partners. Centro Nacional de Informação Geográfica (CNIG) and the Joint Research Centre (JRC) are co-leaders.

3. Work programme

The main objectives of the ETC/LC are:

- to develop the CORINE Land Cover database by continuing the technical co-ordination of national land cover inventories.
- to distribute land cover data, reports and other information, produced within the Topic Centre.
- to apply and use land cover inventory data for environmental and integrated applications.
- to identify needs of and pursue applied research on land cover.

The various tasks has also been co-ordinated with several other projects in the EEA work-programme, particularly projects where land cover data for GIS applications is a basic requirement.

ETC/LC has also worked for or co-operated with other European Commission Institutions, for instance DGVII, DGXI, DGXII, DGXVI, Eurostat/GISCO as well as other international organisations with an interest in land cover related topics or with contractors working on other projects with mutual relevance.

4. Progress of work

4.1. CORINE Land Cover database

The CORINE Land Cover database is compiled of individual national land cover inventories, according to the defined methodology. It is based on computer-aided interpretation of Landsat TM satellite imagery and a simultaneous use of ancillary data. Land units or areas have been classified by vegetation type, type of habitation (built-up areas, urban, industrial, transport areas), or wetland and water bodies. 44 different classes have been defined, covering all types of land cover. They are grouped in a 3-level hierarchy, and this 3 level 44 classes nomenclature is identical for all countries. The smallest mapping unit is 25 hectares and the standard mapping scale is 1:100 000.

During 1997 the CORINE Land Cover database was completed for 12 Member States. Together with the CORINE land cover data sets from 6 Phare countries (Bulgaria, Poland, Hungary, Romania, the Czech Republic and the Slovak Republic), the CORINE Land Cover database is currently composed of data sets covering 3.6 million km² of Europe. The volume of this database is 1.2 Gigabytes.

Table 1: CORINE Land Cover inventory, data on completed national inventories

EU members					
Country	**Satellite data acquisition years**	**Mapping Completed**	**Country**	**Satellite data acquisition years**	**Mapping Completed**
Austria	1985-1989	1996	Ireland	1989-1990	1993
Belgium	1989	1995	Italy	1989-1990	1997
Denmark	1989-1992	1994	Luxembourg	1989	1990
France	1987-1990	1996	The Netherlands	1986-1987	1992
Germany	1989-1992	1996	Portugal	1985-1986	1990
Greece	1987	1995	Spain	1985-1988	1991

Phare countries		
Country	**Satellite data acquisition years**	**Mapping Completed**
Bulgaria	1989-1992	1996
Poland	1987-1988	1996
Hungary	1990-1992	1996
Romania	1989-1992	1996
Czech Republic	1990-1992	1996
Slovak Republic	1990-1992	1996

In Finland, Norway, Sweden and UK CORINE Mapping projects are under way. They are carried out as high resolution land cover mappings, to a large extent utilising existing national databases. The data are generalised and aggregated to the CORINE 3 level, 44 class nomenclature. The inventories are planned to be completed between 1999 and 2002. The CORINE Land Cover project has also been extended to Albania, Estonia, Latvia, Lithuania, Slovenia and Former Yugoslavian Republic of Macedonia.

4.2. CLC Meta information

For management and use of the CORINE Land Cover data, information on the data sources, organisation of the work for the mapping are necessary. This information is organised in a CORINE Land Cover meta-information database. This database contains information for each country on the national teams, satellite data and topographic maps used, ancillary data such as airphotos and other thematic data (i.a. statistics), the field logs of interpreters with dates of field work, border matching names, verification and acceptance data and also information on the digital data, such as formats and name of host organisation. Information about the National Teams, statistics on areas, maps sheets, interpretation teams are also collected and included in the CORINE Land Cover Directory.

4.3. A data storage and distribution system

The distribution system, which started to be developed under 1997 meets the EEA requirement of distributing to the member states objective, reliable and comparable environmental data, but is also intended to promote the use of CLC data.

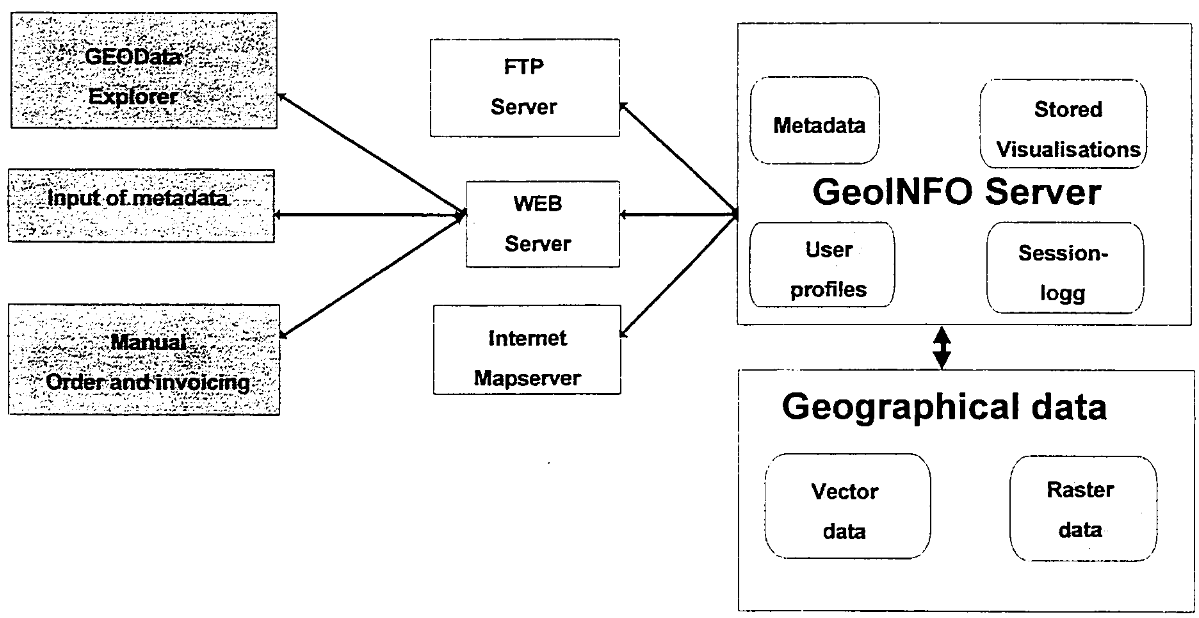
The strategy for a data storage and distribution system is based on the idea to enable the user to find the meta-information on the CLC data, to browse, select, clip and download actual parts of available CORINE Land Cover database and other data sets via the Internet. The system developed is designed as an interactive Helpdesk function based on ArcView software and Oracle Relational Data Base Management System.

4.4. The storage system

A data storage system and a distribution function enables the user to browse the databases, clip data of interest from the data sets and download the desired sets or information, all operations performed via the Internet.

The data storage system is based on a GeoINFO-server containing five categories of information or data: Metadata, describing all characteristics of available data sets; Geographical data, which is the CLC data and other data sets needed for the user to produce the requested maps and data sets; stored visualisations, which contain pre-organised data sets or base maps, allowing less advanced users (not running desk-top GIS) to produce maps by combining real CLC data and the base maps; user profiles, which is a compulsory user registration function without which the potential user cannot get access to the helpdesk data; and also a Session log, to automatically register all helpdesk operations .

Figure 1: The GeoINFOserver



The user profile and session log functions will build up an information database on the various applications for which CLC data are requested with CLC and also a register of the users. The aim is to create a database of applications and users, from which other users can obtain information on how to use CLC data and find where to find expertise for different application domains.

The distribution function contains output functions for distributing data by off-line and on-line methods. At present, all users have CD-ROM drives, and most deliveries of CLC data to day is made on Cds. However, on-line distribution technology is regarded to be the predominating method for the foreseeable future.

4.5. Workshop on Land Cover Applications – needs and use

The ETC/LC organised in May 1997 a workshop on Land Cover applications – needs and use. Invited participants were potential users of land cover data and information. The aim was primarily to demonstrate and assess the importance of land cover data in environmental and integrated applications and especially as support to EU policies.

28 applications, in support to different European environmental policies, results from current studies or assessment projects from all parts of Europe (EU15 and Phare countries areas) were presented to exemplify specific domains or application fields. Table 2 gives a survey of the main environmental domains illustrated by the 28 examples, the regional coverage of the examples, and of the authors.

Table 2: Application domains

Application domain	Coverage/scale of the examples
Nature conservation	European
Water management	Regional
Forest fragmentation	European-Regional
Coastal management	European
Transport (SEA/TEN)	European
Agriculture	Regional
Urbanisation	Local comparison of European cities
Structural funds/Land planning	Regional
Soil degradation – desertification	Local-Regional
Hazards (forest fires, flooding)	Regional

The full account of the Workshop is available as plotted dossier for the Workshop and in the Proceedings of the Workshop, on the ETC Homepage under the heading "Workshop on Land Cover applications". http://www.mdc.kiruna. se/etc/ Workshop /-contents.htm).

4.6. Support of the ETC/LC to the pilot SEA of TEN

In 1996 The European Parliament and the Council adopted the Community guidelines for the Trans-European transport Network, TEN. The objective of the TEN is the development of a transport network to strengthen the economic and social cohesion in the Union, by bringing about a sustainable mobility of persons and goods within a Europe without internal frontiers. The guidelines for the TEN should also help to achieve the environmental objectives of the Community.

To achieve the environmental objectives, the Commission realised the necessity of developing a process of strategic environmental assessment, SEA. It was stated in the guidelines that the Commission "will develop appropriate methods of analysis for a strategical evaluation of environmental impact on the whole network" and "appropriate methods of corridor analysis covering all relevant transport modes".

The Commission, through DGVII and DGXI, requested the EEA to co-operate on the Pilot SEA of TEN. A working group between DGVII, DGXI, Eurostat/GISCO and EEA has been established. The EEA has on hand extensive environmental georeferenced databases, which can be used for this assessment. Land cover data plays a key role in the integration of the various geographical data sets, available through different Topic Centres, which will be used in the SEA of TEN.

The contribution of the ETC/LC so far has been a methodological study containing spatial-ecological assessments of a number of TEN variants or alternatives. The objectives of this work includes:

- the development of an integrated GIS database on the TEN, including thematic data and maps of infrastructure, land cover, demography, geography, environment and nature.
- a selection and a review of indicators for assessments of the spatial and ecological impacts of the TEN.
- development and testing of a number of GIS assessment techniques.
- compilation of the results in the form of a GIS demonstration package, allowing an interactive demonstration of indicators and methods.

A range of assessment techniques were tested, for instance:

- analysis of the proximity of the planned TEN infrastructures to legally or scientifically designated sites.
- calculations of indicators, such as land take, waterway crossings, noise disturbance
- a vulnerability mapping analysis, in which the TEN alternatives are matched against sensitive zones, defined on the basis of a combination of indicators, whose sensitivity is evaluated by indices of significance.

To assess the potential impact and conflicts of the TEN alternatives on environmental issues, thematic GIS-based analyses have been carried out regarding biodiversity, water resources, noise and land resources and various indicators have been tested.

The study also identified issues which require additional research and consultations. The proposed work programme for 1998 includes for instance, optimisation of indicators and methods of analysis, a filling of the major data gaps on TEN and the environment, a full spatial and ecological assessment of TEN.

4.7. Integration of CLC data with other data

The CLC inventory, when combined with other data sets, constitutes a very important input to environmental integrated analysis. It must thus be possible to combine the data with other thematic data sets, describing environmental driving forces (e.g. demographic and socio-economic data, data on emissions), environmental status (e.g. air and water quality) and impacts (e.g. human health, condition of biotopes).

In most of these different data sets, there is a lack of consistency in how they are recorded or in the nomenclature or terminology that exists. A greater consistency is most needed in the recording of data on land cover and land use.

This need was identified by the ETC/LC, which led to the initiation of a task to create an engine to harmonise otherwise incompatible data. The objective was to establish and promote a common framework to record land units. The way to achieve this is to develop a common structure and a common nomenclature to which other systems can be related. This procedure should be applied in computer programmes designed to facilitate intercomparisons between existing classifications.

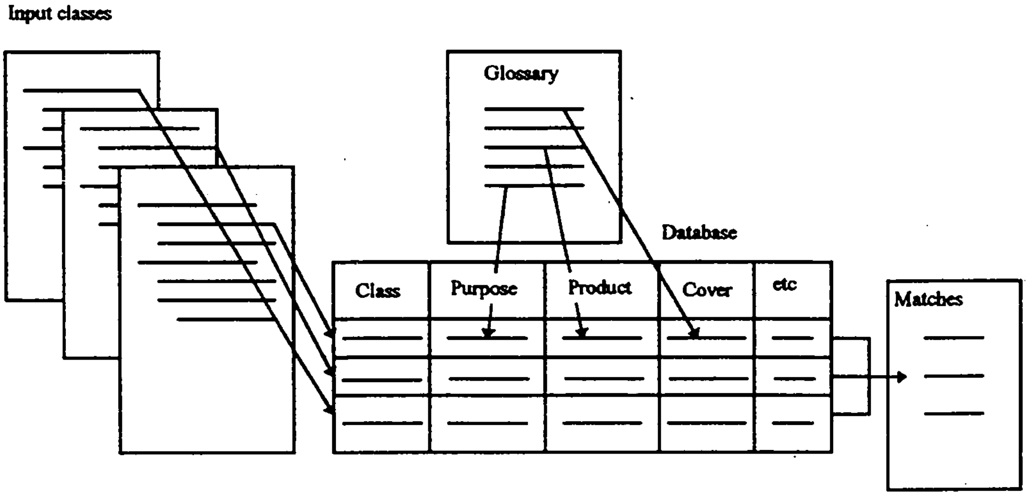
In this method, land units are described in terms of functional attributes, used to define the key characteristics of the particular land unit. To exemplify, land use attributes describe the land management operations, the products and benefits, while land cover attributes of the same land unit describe the vegetation types.

The major work in creating this system has been to design and populate the glossaries that are needed to record the attributes of land use and land cover. The main sources for this work have been:

- literature on plant physiognomy,
- systematic analysis of representative classifications and
- existing land use databases.

In the glossary the land attributes are described in terms chosen from a controlled nomenclature, also held in the glossaries.

The procedure of intercomparisons between land cover classes/units is carried out within the database by matching attributes and logical combinations of attributes. This matching procedure is supported by a computer programme to manage the database and to facilitate these intercomparisons, see fig 2.



In relation to the activities of the European Environmental Agency, this system describes correspondence between the CORINE Land Cover nomenclature and a number of other important European Land Classifications. This characteristic property of the system for Correspondence with other themes including the supporting software, is further enhanced by the CORINE Land Cover database, one of whose characteristics is to provide geographically localised land unit data.

4.8. Research and development of new applications

The main R&D activities, co-ordinated by JRC, concerned implementation of updating methods for CLC data, through the CoPilot software, development of new applications on Indicators, an assessment of the use of more detailed CLC inventories and the LACOAST Project.

A final assessment of the methodology developed by the JRC for updating the CORINE Land Cover database resulted in a software, the COPILOT, on updating and change detection. It was distributed to the national CLC teams involved in the Lacoast Project and the necessary training was organised. More information about Lacoast can be found on the Internet: http://aisws6.jrc.it:2001/lacoast.

The methodology is also described in "Technical and Methodological Guide to Update CORINE Land Cover data base", a co-publication of the JRC and the EEA. The dedicated software will be made available for national teams that wish to use it for updating the database.

During 1997, a study was carried out, targeted to short term operational use of CLC database for indicators linked to issues that can be produced on a European level such as: land cover of protected areas, impact of major urban areas and transport networks on the natural and semi-natural countryside, natural and semi-natural countryside remote from artificial features, potential connectivity of habitats, pressure on protected areas from land use, fragmentation of forests by road networks, forests and nature conservation and pressure on water systems from non-point emissions of nutrients. Future developments were identified for development during 1998.

5. Plans for 1998

1998 is the 3rd and last year of activity under the current agreement. In the first part of the period, emphasis was on developing the CORINE Land Cover database. This database is now completed for most of continental Europe and a unique consistent land cover database is available.

The emphasis of the Topic Centre work has therefore gradually been shifted towards information and demonstration of the usefulness of the database by carrying out GIS applications with CLC data as basic input and integrated with other environmental data.

This trend is further emphasised in the plans for 1998. The main objectives of the work is focused on three issues:

- policy relevant European environmental applications and indicators for land cover;
- update of the European Land Cover database;
- research and development of applications on land cover/land use changes and landscape analysis.

LAND USE / COVER CHANGE

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1. The LUCC IGBP-IHDP project: a general overview

The LUCC project co-sponsored by IGBP (International Geosphere-Biosphere Programme) and IHDP (International Human Dimensions Programme), aims to improve the understanding of the dynamics of land-use/land-cover at regional and global level. The relevance of LUCC is that the studied processes constitute a major proximate, unequivocal and tangible cause of the global environmental change. These perspective opens a number of scientific questions that broaden the concept of global change as particularly associated to climate change. LUCC research is meant to advance towards a emerging science for sustainability, since it is directly related to important environmental themes with socioeconomical and policy implications like land and water management, sustainable development, food security, human health and biological resources conservation among others. Facing these interdisciplinary key issues, the LUCC research agenda has generated a high interest and expectation to the international and national research programmes, which makes its implementation an exciting challenge.

LUCC is organised in three focus areas and two integrating activities:

- Focus 1: Land-use dynamics - comparative case study analysis. Land-use dynamics is a comparative case study approach aimed at improving our understanding of the variation of the nature-society dynamics of land management, thereby facilitating regional and global modelling. It aims to identify and analyse a series of regional situations that represent the major clusters of LUCC dynamics world-wide, thus permitting spatial and temporal fine-tuning of the overall modelling effort as well as providing the local, and, with Focus 2, regional understanding that is vital for climate impact and sustainability research.
- Focus 2: Land-cover dynamics - empirical observations and diagnostic models. Land-cover dynamics involves regional assessment of land-cover change as determined from direct observation (e.g. satellite imagery and field studies) and models built from these observations. It seeks to provide spatial specificity in the land-cover outcomes associated with the management of particular land uses.
- Focus 3: Regional and global integrated models. Regional and global models aim to improve upon existing models and build new ones that provide a basis for projecting land-use changes in the underlying causes or driving forces. These models will incorporate the regional and sensitivity provided from Foci 1 and 2 to generate more spatially explicit outcomes from regional and global models.
- Framework activity 1: Data and classification: analyses data availability and quality and devises a classification structure suitable for the various needs of the three research foci. It also identifies and develops the major datasets and measures important for LUCC studies.
- Framework activity 2: Scalar dynamics: recognises that the different scales at which LUCC processes operate, and the different scales at which they are analysed, pose major impediments to developing a comprehensive understanding of LUCC. This activity seeks to identify the major rules and lessons that should guide LUCC efforts in this regard, thus improving the integration of the three foci.

The project is engaged in the co-ordination and promotion of emerging and existing LUCC projects. These initiatives are mainly supported by Asia-Pacific, European and North American funding agencies. At regional level, most of them are being developed in collaboration with START (Global Change System for Analysis Research and Training) and other IGBP and IHDP programme elements. Some examples of these are:

- The Southeast Asia LUCC Project consisting of four country case studies analysing sequences of satellite data combined with socio-economic variables.
- The Amazon regional inter-project developed under the LBA (Large- Scale Amazon Basin Experiment) programme, where LUCC constitutes the major driving force of change in this region.
- The pilot study on modelling LUCC in Amazonia ("Human Dimensions of Deforestation and Re-growth in the Brazilian Amazon"); this project is a two-year pilot study to build up a model of deforestation, secondary growth and fragmentation.
- The Miombo network ("Miombo, Causes and consequences of land-use/land-cover change in the Central African Miombo Ecosystems"); a research agenda for this area has been developed, in collaboration with START and GCTE, aiming at how LUCC is affecting land cover and associated ecosystem processes.
- The regional project in Central America which aims at understanding and monitoring deforestation and land use intensification and modelling and projecting land-use/land-cover changes in general.
- The regional project in Temperate Asia; an initial effort has been made, in collaboration with START-TEACOM, to identify key research priorities for land-use/land-cover research in the area, with a major emphasis in China.
- The regional project in the Hindu-Kush Himalaya; this initiative is just getting started with the main objective of defining a regional implementation strategy for LUCC.

2. LUCC research framework at European level

The Electronic Conference on land-use/land-cover change in Europe produced the basic scientific framework for the development of a specific European LUCC research agenda.

The electronic Conference brought together a wealth of LUCC information and of expertise on both the policy needs for information and research activities in Europe. It has further raised awareness on complex multifaceted issues.

These issues are of potential relevance to a large number of users, including those concerned with the Common Agricultural Policy, EU enlargement process, EU Transport policy, merging policies on European Spatial Development, Regional Policies and Cohesion Commission, State of the Environment Report, nature conservation, water management, and activities of the EEA Topic Centre on Land Cover.

The exercise constitute a first step in the process of better adjusting the research response to policy needs which should generate direction and ideas to be taken into consideration when addressing LUCC issue, for example in the implementation of the EU Fifth Framework Programme.

The Electronic Conference on LUCC in Europe took 'virtual' place from 21^{st} November to 19^{th} December 1997, organised by the LUCC International Project Office and the Environment and Climate RTD Programme from the European Commission, Directorate General XII/D. 174 participants from 28 countries were connected by means of an electronic distribution list hosted at the LUCC-IPO, so that an e-mail message sent by a participant to the defined e-mail address was received by the entire group. Moreover, it was possible also to participate in an 'off-line' mode, by sending comments to the ad hoc e-mail addresses put in the e-Conference Internet page.

This was the second Electronic Conference on LUCC, and it focused on more specific objectives than the first one, held in Spring 1997. A primary aim was the adaptation of the rationale and methods of land-use/land-cover change research, as defined for global issues in the IGBP-IHDP/LUCC Science Plan, to the specific and complex European reality. Another objective was to support the definition of requirements for consistent land use related research activities in the context of the European Union's Environment and Climate RTD Programme, with an emphasis on supporting the implementation of EU policies with a territorial dimension.

Specific questions debated include how LUCC science can contribute to the design of 'spatial development' policies; assist in anticipating opportunities and threats to long-term spatial development, and contribute to monitoring and evaluating ecological and socio-economic impacts of development trends and EU policy measures.

The Conference had a program structured in three Sessions, guided and moderated by Günther Fischer (IIASA), Eric Lambin (Université Catholique de Louvain) and Jill Jäger (IIASA), respectively:

- Session I: *Issues and priorities of LUCC in the European context.* The discussion started from the main conclusions and questions of the first e-Conference, and led to a better definition of a LUCC framework in Europe and to the identification of research priorities.
- Session II: *Science contributions to European policies.* Which scientific understanding and results can the scientific community contributes to the LUCC related EU policies? The debate incorporated several policy references, such as the ESDP document, Amsterdam Treaty, Transport Policy, or the EC Communication to the Convention on Biological Diversity.
- Session III: *From debate to implementation.* Is a European research agenda on LUCC needed? If so, how to implement it? What practical steps are needed to engage the LUCC community in achieving a comprehensive implementation strategy for the research agenda identified in the previous sessions? The discussion focused in the definition of this implementation strategy.

2.1. General conclusions of the conference

Land use conditions in Europe are specific and complex. A number of EU policy areas were identified, for which LUCC information is required or which would influence LUCC in Europe. The EU Environmental issues and the Common Agricultural Policy (CAP) are clearly some of these policy areas with specific needs for monitoring and inadequately understood territorial impacts. Further policy areas include the accession of countries from Central and Eastern Europe to the EU, the concerns of the Regional Policies and Cohesion Commission, and the EU Transport Policy, which can be expected to influence LUCC.

Clearly LUCC research in Europe is not only concerned with observing and describing land-use/land-cover changes, but must also contribute to public debate and spatial planning through identifying land-use patterns that can simultaneously satisfy various economic, social and environmental goals.

Several EU-specific topics for a LUCC research agenda were identified, these included: social and environmental dimensions of concentration and intensification processes in European agriculture, land abandonment and marginalisation, land-use/land-cover impacts of infrastructure development, landscape fragmentation and biodiversity loss, management of regional water systems and water quality, landscape and environmental effects of EU policies, and landscape impacts of climate change. In addition to Europe-wide topics, the boreal zone, the Mediterranean and mountain regions, and Central and Eastern Europe were identified as posing specific LUCC questions.

2.2. Data - Classification, monitoring and mapping

It was agreed that research on Europe-wide LUCC issues will require continued efforts to improve the quality, completeness, spatial and temporal consistency and compatibility of heterogeneous LUCC-related data. It is still debated how gradual land-use and land-cover change processes can best be detected and measured. It was acknowledged that different LUCC processes may necessitate different monitoring systems, and that the multi-scale data systems needed for LUCC research will also require further theoretical work, e.g. on efficient sampling, and on analysis and visualisation of complex spatial relationships. Furthermore, data compilation for Europe-wide research would benefit from harmonisation and streamlining of data collection and interpretation. Dataset development, integration of heterogeneous data sources, improved accessibility of data, data accuracy and consideration of error propagation, and construction of robust and relevant indicators are further issues that require attention.

2.3. Methodological issues

A number of important methodological issues were raised in the electronic conference. The contributions identified several clusters of research that will need to be addressed, including:

- decision making processes at the land-management level,
- river-basin level 'horizontal' bio-physical/geo-chemical and spatial economic relationships,
- the impacts of landscape changes on ecological complexity and on the quality attributes of environmental resource stocks,
- description and valuation of environmental functions and services of land and land cover (other than production),
- embedding of spatially explicit (biophysical, biological, ecological, etc.) research into economic analysis,
- integrated LUCC system modelling,
- cultural, ethical and normative aspects of land use.

Other methodological questions include investigating the causes of past land-use changes, irreversibility of LUCC, the integration of quantitative with qualitative methods of analysis, and critical appraisal of the appropriateness of different methodologies and models for various issues and scales of analysis.

2.4. Impact assessment

The capability to conduct LUCC-related impact assessments was seen as a key contribution to the policy debate in Europe. A long list of environmental, economic and social impacts were proposed for study. However, central to the debate of impact assessments was the recognition that appropriate tools for analysing complex interactions among several sectors and involving multiple actors are still poorly developed. While it is recognised that the complex European reality requires a more co-ordinated view across the traditional borders of agriculture, forestry, infrastructure and industrial development, tourism, and nature protection, there is awareness that fairly major gaps and shortcomings in both data and available methods exist that at present limit any attempts of truly comprehensive impact assessments.

2.5. Scenario development

The need for a broad and internally consistent set of European LUCC development scenarios was widely acknowledged. The scenarios should encompass the basic driving factors and trends, such as demographic changes, EU enlargement, globalisation and economic competition on world markets trends in information technology development, global climate change, etc. The scenarios should focus on those spatial levels and time scales most relevant for policy making at the present time.

3. The LUCC project network: Inventory of specific LUCC research projects

A formal status with the LUCC International Project has been created as a mechanism for allowing LUCC-related relevant research projects world-wide to join the LUCC scientific community and, by this mean, helping this community in their efforts towards a strengthening of links and an improvement of communication at the world level.

Applicants must be contributing to the LUCC research effort as defined in the LUCC Science Plan. A successful application will gain access to the LUCC network of projects, programs (including international and regional workshops), taking advantage of the networking issues of the IPO through its electronic correspondences and other initiatives. It is expected that formal LUCC status may assist individual projects in their search for funding.

There are recognised three types of applications as follows.

1. *Core research activities* have as their central objectives those identified within the formal LUCC agenda. These projects are initiated:

- directly by the Scientific Steering Committee of LUCC
- by individual investigators and national or regional entities who/which must apply for LUCC-status through the Scientific Steering Committee.

2. *Contributing research activities* need not conform to the formal LUCC agenda, but their objectives and outputs provide important insights for various parts of that agenda.

3. *Parallel research activities* may conceptually belong either to the first or second kind, but are undertaken by organisations that, for whatever reason, wish for independent status from of the IGBP-IHDP.

Approval Process: completed applications are sent to the IPO LUCC, which randomly choice three members of the Scientific Steering Committee to process and consider the activity in question. Those activities which receive formal LUCC status are required to provide performance reports for periodic review by the IPO and SSC of LUCC.

The Application Form is composed by these chapters:

A. LUCC status: Core, Contributing or Parallel research activity.

B. Project identification: Project title; Name and address of the Principle Investigator/Project Leader; and Lead research institution(s).

C. Project description: Objectives; Project approach and research design; and Program design (location of research fieldwork, research units involved and their tasks, duration and work schedule).

D. Project output: Expected results and outputs; and Application of results and outputs beyond the science community.

E. Contributions to the LUCC Science Plan, identified by research foci and/or integrated activity.

F. Project associations and affiliations: Relations to other IGBP and IHDP projects; and Relations to research projects and programs other than those of the IGBP and IHDP.

G. Project budget and funding: Overview for budget by year and unit; and Source and scheduling of financial support.

H. Resume: Bio-sketch and five publications pertinent to project for each principal investigator / major unit investigators; and Unit-sketch for each major research unit involved.

Current projects endorsed or under revision (http://www.lucc.icc.es/lucc):

SYPR
CIPEC
SIRCH
NE Thailand
ECOSSEN
PELCOM
INDAVOR / NFOSEUR
IGU-CSRS
Mod.& Forec.LU Changes in China S-Ec Drivers
Western Lithuania
CLUE

4. The need for an International initiative for a comprehensive Data Plan for LUCC research: The DAPLARCH initiative, 'coupling science and data'

In the near future, the global effects of land-use/land-cover changes may be important, even more than those produced by potential climate change. These changes and their impacts range from potential climate warming to land degradation and biodiversity loss and from food production to spread of infectious diseases. Still we lack some crucial knowledge about these important humans caused agents of global change. Thus, for instance, an accurate global map of agricultural activities does not exist now, nor do we have good measurements of agricultural expansion and the concomitant loss of natural ecosystems. Therefore we cannot model and project well the land surface transformations in an integrative way.

Ad hoc information for monitoring and modelling LUCC processes at regional to global level combining socio-economic and biophysical datasets has not been developed yet. Some critical gaps that illustrate the need for special efforts, which justify the development of a specific data plan for LUCC research, are:

1. The lack of databases on socio-economic driving forces associated with geo-referenced land-use/land-cover changes.
2. The lack of geo-referenced integrated land-use/land-cover data providing accurate information on their rates of change of use.
3. The lack of data for describing and characterising global-scale processes in the land surface (e.g., land degradation and changes in soil properties) and their interactions with global biogeochemical cycles and climate.

Despite this situation, some new monitoring initiatives addressing the problem of LUCC *ad hoc* information have been emerged.

Biophysical datasets are usually geo-referenced and globally available on a grid of a polygon basis. Relevant databases include: FAO/UNESCO Soil Map of the World, climatic data, World Map of the Status of Human-Induced Soil Degradation and various other compilations of relevant data such as topography and vegetation. Several international organisations (UNEP-GRID, UNEP-GEMS, FAO, ISRIC) and research programmes such as IGBP, WCRP and IHDP are currently also developing and compiling global datasets. New promising databases for the continental-scale studies are the land cover 1 km^2 developed by IGBP-DIS and GTOS. Other databases with a higher resolution can be used within the case studies.

There are also a number of socio-economic databases available, mainly at national level but also at the global one. Among others, FAO, OECD, the World Bank and IMF, the Stockholm Environmental Institute, and the World Resources Institute have developed appropriate datasets.

Concerning Land-cover mapping there are important existing programmes based on Remote Sensing techniques. The first one is the above mentioned improved IGBP-DIS global land-cover map, which is being generated using global 1 km^2 AVHRR dataset compiled through NASA and funded in co-operation with ESA. Among the international projects at regional and continental level, it should be highlighted the CORINE and CORINE-Phare Projects within the EEA, which is generating land-cover information for Europe using TM imagery, achieving high resolution and accuracy. Moreover, it should also be mentioned the Afri-Cover Project of FAO, which will provide high resolution land cover data for Africa.

But these ongoing initiatives cannot be always easily incorporated into land-use/land-cover change ongoing studies due to the fact that their use demands additional non-negligible efforts. Most of them should be integrated, in the sense of finding conceptual and geographical links with the specific data and information requirements of the land-use/land-cover change studies.

To respond to these needs a comprehensive data plan named DAPLARCH (Data Plan for Land-use/land-cover change research) was proposed within the IGBP-IHDP LUCC and IGBP-DIS projects, and officially approved by both Scientific Steering Committees. General objectives of DAPLARCH are:

- To harmonise international efforts on data systems.
- To determine the priorities of the needed datasets.
- To establish the methodologies and overall plan for specific datasets to be developed.
- To develop integrative procedures for establishing conceptual and geographical links between the existing data systems and the specific science requirements.
- To provide the basic knowledge necessary to promote operational data systems for monitoring and modelling.

DAPLARCH aims to establish data priorities for definition of needed datasets as well as to define integrative procedures and methodologies for the production of specific datasets according to the LUCC research agenda. It aims also to contribute to the reinforcement of the international co-ordinated initiatives for current and future monitoring, and to the establishment of an international scientific infrastructure able to provide base-line databases for monitoring and modelling. As a result, basic knowledge to promote operational data systems for monitoring and modelling of land surface transformations is expected.

The current state of the art is expected to be improved by promoting communication between data users and data producers. This is assumed to be achieved by means of a series of four international and interdisciplinary workshops during the next three years that will bring them together in a common objective of defining an efficient data plan.

1. Data Requirements Workshop (November 1997).
2. Data Gathering and Compilation Workshop (November 1998).
3. Data Organisational Needs Workshop (early 1999).
4. Data Systems Workshop (late 1999).

5. General conclusions of the data requirements workshop - DAPLARCH 1

The workshop held in Barcelona in November of 1997 convened around 70 relevant LUCC researchers to assess on the nature and significance of LUCC data needs, as well as to advance on a first statement of ranking of priorities for the streamlining or adaptation of existing datasets or the creation of new ones. The workshop was structured in alternative Plenary Fora and Break Out Sessions to allow insights, discussions and community consensus.

The general discussion on Data requirements was built on the exercise of the 'theoretical translation' of LUCC science objectives into data needs, the known problem of fit between data and science. Scientists were asked to identify major situations where the progress in LUCC research is inhibited because of the lack or unsuitability of data and, to articulate those impediments in terms of comprehensive and/or observable variables. In spite of the difficulties of this 'theoretical translating exercise' the general response was positive and the discussion very productive. Ranking of prior datasets was also a task given to the groups which was dealt with less success specially because the discussion eluded the matter, arguing either the lack of consensus on prioritisation or the need of wide range of data types rather than few specific baseline datasets.

5.1. The description of LUCC involves a wide range of types of observations

The assessment of current concepts, ideas, opinions and perceptions (conceptual analysis) of the nature of LUCC data, reveals that does not exists any single type of data, which can describe the sufficient variability necessary to understand LUCC. Very few data can be considered as automatically usable for LUCC research and the observations, even the simplest ones, involve rather complex approaches.

5.2. The largest gap in LUCC characterisation

The largest gap in LUCC characterisation is not the extent, pace and direction of land cover changes, which can be approached by means of Remote Sensing sampling, but the functional parametrization of land use dynamics, (e.g. Selection of variables able to characterise interrelations and interdependencies of the elements of a land use system, like land use purposes, land use interventions and their driving forces). A first attempt for this functional parametrization of land use should be based on the selection of variables whose values can be quantifiable. This quantification could be tackled through either direct observation (field measurements and interview), proxy or modelling.

5.3. Some identified constraints for the assessment of land use variables

- The lack of agreement on definition and nomenclatures.
- The biased availability of socio-economic data (different sources, levels of accessibility, levels of completeness, etc.).
- The lack of temporal consistency on existing statistical socio-economic data.
- The need of techniques of spatial desegregation.
- The need of further investigation on scaling issues, both temporal and spatial.

5.4. Some identified solutions

The problem of land use data is able to be tackled, in a viable way, by means of the development of a framework for conceptual modelling and data assessment in different LUCC situations. To face it two approaches are to be explored and developed:

1. An approach oriented to distinguish observable components of a LUCC system, based on pattern and/or process analysis, which is mainly dependent on observation capabilities *(systematic approach)*. This approach is critically conditioned and limited by the availability and quality of the different types of concerned data.

- example 1: 'from pattern to process' analysis describing the underlying processes of forest fragmentation. Characterisation based on direct observations of patterns of land cover dynamics and the analysis of the processes behind the pattern ant associated with socio-economical and other biophysical variables.
- example 2: analysis of land use intensification processes in agriculture based on the selection of significant measurable and spatially desegregated parameters of variables like: production system, input use, land structure, labor, capital, water resources, etc,)

2. An approach oriented to parametrise LUCC aspects with 'abstract pathway of functioning', namely aspects which are involved in processes, either gradual or step-like, operating in complex sequences and which are finally difficult to observe (e.g. types of purposes and interventions in a land use intensification context). This approach can be built on the qualitative analysis of the interactions between these 'abstract aspects' and their 'immediate tangible consequences' *(hierarchical approach)*.

- example 1: different land use interventions lead to three decreasing levels of environmental impact when interact with the following processes: changes on water management, on soil management, or on pest management; this type of ranking can be used to compare land use interventions,

- example 2: four aspects of land use identified by CLAUDE can be used to determine types of land use: different land use changes may imply changes in one or several of the following aspects: in spatial distribution -e.g. land cover-, in function and environmental character -e.g. soil characteristics-, in performance -e.g. potential yield, productivity,...-, and in management -e.g. land treatment, cultivation, ownership,...
- example 3: different land use changes imply different degrees of reversibility e.g. 'mining versus harvesting'.

Both systematic and hierarchical approaches should be compatible and allow the possibility to compare different LUCC situations.

5.5. Spaceborne remote sensors keep providing fundamental support for the observation of LUCC dynamics

Spaceborne remote sensors keep providing fundamental support for the observation of LUCC dynamics not only at global scale but also at regional and local ones. Nowadays RS observations constitute a unique tool for estimations of land cover dynamics, often used in an operational way. Nevertheless, there is still a need of further research on Remote Sensing and image processing, beyond land cover mapping, related to the characterisation of land biophysical features. The interpretation and evaluation of the effects of Land Use and Climate Change on land surface properties are crucial issues for the assessment, within the Earth System, of the impact of the processes occurring in the land surface interface. For LUCC modelling there is a clear need of such a kind of information, in concrete of spatial projections of biophysical responses to LUCC of terrestrial ecosystems, agriculture and terrestrial water/climate, as feed-backs in the land-use/cover system. Pilot studies based on airborne sensors can also lead to a significant progress on the remote discrimination of properties of land.

6. The Miombo CD-ROM project (http://www.icc.es/lucc): an example of data development at regional level

The Miombo CD-ROM (compact disk – read only memory) project arose out of the need to make data widely available to Miombo Network projects and to more generally, to regional scientists. Many interesting datasets are widely distributed via the web in the countries with access to the internet. However, most of Southern Africa has very limited access to the Internet, making these datasets essentially unavailable and unknown. Within the regions themselves, there are large datasets (unpublished or in national archives) that are generally inaccessible to the scientific communities either within the countries of the region or those doing regional research. The goal of the Miombo CD then, was to compile as many datasets as possible from both the international and regional communities and make these available in one medium to the regional community at large. This is being done at the beginning of the Miombo Network activities to provide everyone with a common starting ground, to reduce duplication of effort in compiling regional datasets where these exist, and to encourage development of new sets where there are obvious gaps.

The selection and gathering of existing data was made based on the criteria of data availability and usefulness to a broad variety of LUCC studies (a multipurpose oriented product). The datasets were identified in the framework of the Miombo Network Core Experiments. A good balance between socio-economic and biophysical data was sought. However difficulties were encountered in identifying socio-economic datasets at the sub-national to local level.

The CD is presented in a WWW format providing and all datasets were standardised in terms of geographical projection and co-ordinates systems and formats. This harmonisation makes it possible to translate to several formats compatible with the computer systems commonly used in the region (Arc/Info for vector information, Idrisi for raster information and DBF for tables).

The CD comes with a data archive with browse and visualization capabilities. Browse products include degraded scenes, samples of subsetted scenes and case studies. All data is geo-located, but with only limited co-registration at the finest scales. It does not contain, at this phase, remote sensing imagery at a full resolution, although some degraded samples are available. Besides, satellite (SPOT and Landsat) metadata is included to assist users in ordering complete data.

7. Next priorities for the LUCC project

The LUCC project is nowadays finalising the Implementation Plan in which 4 working areas will be considered as a priority:

1. The LUCC core research, this is the first area of priority which has to be built on the development of projects with clear objectives, deliverables and results leading to a progress on the understanding of the nature of the mechanisms driving LUCC. The structure of 3 Foci will keep providing the multidisciplinary framework for this area.

2. The regional approach of LUCC, which is crucial to better understand the nature of LUCC. The addressing of LUCC research questions at local/national/regional level involves relevant issues and concerns of political and social implications, which are specially critical to determine human drivers of global change. Therefore it is absolutely indispensable to set up a strategy oriented to the analysis of regional situations not only but specially in those areas in which major changes are occurring ('hot spots').

3. Collaboration to the development of an interdisciplinary and integrated approach for global change research, promoting links with other programme elements of IGBP, like GTCE (Global Change and Terrestrial Ecosystems), BAHC (Biospheric aspects of the Hydrological Cycle), LOICZ (Land-Ocean Interactions in the Coastal Zone) and PAGES (Past Global Change), and of IHDP, like IT (Industrial Transformation), GECHS (Global Environmental Change and Human Security) and IDGC (Institutional Dimensions of Global Environmental Change).

4. The participation of LUCC within the IGBP synthesis. The process undertaken in IGBP of summary, integration and synthesis of its first descriptive phase, has started to demonstrate the central role the socio-economical aspects and, in particular, land-use/land-cover change will play during the next decades, as a major driving force of global environmental change. To understand and assess the biophysical implications of these human activities as well as their linkages within the Earth System become a huge challenge, and in this context the LUCC project can be seen as a pioneer.

THE CLAUDE PROJECT

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1. Background

CLAUDE is a Concerted Action supported within the European Commission (DG XII) RTD Programme 'Environment and Climate', (area 'Human Dimensions of Environmental Change'). Its full title is: Co-ordinating Land-use and Land Cover Data and Analyses in Europe. Its purpose is to develop an internally consistent Europe-wide plan for land-use and land cover research, and to link this with other international programmes on these issues. An increase in awareness of land-use and cover change in the European Union (EU) and growing public demand for more environmentally friendly forms of land management highlights the need to develop a co-ordinated approach to these concerns. The CLAUDE Project is complementary to a number of other initiatives. These include, the LUCC (Land-Use and Land-Cover Change) Project sponsored by the IGBP and IHDP and IIASA's Land Use and Land Cover Project (LULC).

The CLAUDE project seeks to evaluate land use and land cover data collection methods and data base structures, as currently used and developed in several countries of the EU. This will allow the development of a better understanding of the assessment and monitoring of land-use and land cover changes. To do this the project aims to identify the suite of models currently available, working from the local to the supra-national. In addition to this, the project has sought to:

- assess methods of monitoring land-use/cover changes in Europe with emphasis on change and monitoring rather than on static data;
- investigate and improve comparability and integration of land-use/cover data;
- improve co-ordination between different EU partners in land-use and land cover research activities;
- improve linkages between EU and international efforts on land-use/cover research (eg LUCC, LULC, etc.);
- prepare a design for EU-wide land-use/cover research activities.

The Project has sought to focus on the users of land-use/cover information at national and EU levels. To meet users needs it is necessary to integrate land-use/cover data with information on performance and management. This has required developing inventories of major networks and activities in Europe. From this it has been possible to start to develop an understanding of how to harmonise data for both users and producers. Four case studies have been developed to assess the possibilities for harmonisation. These have been carried out in the Netherlands, Spain, Sweden and the United Kingdom.

In addition to the production of the case study inventories, the CLAUDE Project has held two workshops with the users and suppliers of land-use/cover data.

2. The Workshops and their outputs

2.1. Workshop on user needs for more harmonised land use information at the national and EU level, Wageningen, Netherlands, 22-23 may, 1997

This meeting discussed the needs of land-use/cover data users with respect to a more harmonised EU land-use initiative. The topics covered included:

- What degree of harmonisation is needed?
- How can the 'fitness for purpose' of land-use data be improved?
- In what way can the EU give added value to harmonisation?

The Workshop focused on three questions, as follows;

1. 'What are the drivers of land-use change in the EU?' These drivers fall into two categories: those, which inadvertently drive land-use change (for example, the common agricultural policy (CAP) and other polices relating to transport, energy and the environment); and, those which seek to protect land-use. These include, EU legislation such as, the Habitats and Birds Directives, the Agri-environmental Regulation and policies arising from the Rio Summit (i.e. Agenda 21) and the Climate, Desertification and Biodiversity Conventions.

2. 'What types of land-use change are occurring in Europe?' Four important trends in land-use were identified, these are:

- specialisation e.g. loss of mixed farming;
- intensification e.g. increased use of inputs;
- marginalisation e.g. socio-economic constraints on areas of low productivity;
- abandonment e.g. of areas with very low productivity or poor infrastructural provision.

In some areas, but not all, these trends are leading to geographical re-distributions of land-use, while elsewhere, the change is qualitative (e.g. in productivity rather than in land-use type). To be able to analyse these changes further, some assessment of the likely effects of change need to be made. For example: How easily can changes be reversed? What effect will change have on the landscape? Is it possible to predict change? Over what time period will these changes take place? This analysis suggests that land-use changes may imply changes in one or several aspects, each occurring at different levels, viz.:

- changes in spatial distribution, e.g. in land cover;
- changes in function and environmental character, e.g. in land-use, in floral/fauna composition, soil characteristics, etc.;
- changes in performance, e.g. in potential yield, in productivity, in carrying capacity, etc.;
- changes in management, e.g. fertiliser application, cultivation, ownership, structural arrangements, etc.

It was concluded that with respect to land-use change there is a need to monitor spatial distribution, function and environmental character, performance and management. This monitoring needs to be integrated, so as to enable increased understanding of the relationships between the changes. Additionally, it was noted that at present monitoring of land-cover change (a spatial aspect) takes insufficient account of other underlying changes in land use specifically those relating to the management of the land.

3. 'What are the needs associated with land-use data?' Four categories were identified: Firstly, there is a need to understand the spatial distribution of land cover. This requires the development of spatially comprehensive geo-referenced data, which are frequently up-dated. Secondly, users require information on the function and environmental character of the land cover. The collection of such data requires more intensive survey, often by field observation and using sample sites. Thirdly, it is important to have knowledge relating to the performance of particular areas. This necessitates the collection of data at the farm level. Fourthly, to enable an improved

understanding of the human processes driving change at the local level, we require more information on land management practices. In addition to producing some harmonisation between the types of data collected and their application, other problems such as accessibility, confidentiality and the costs of data also have to be addressed if there is to be closer co-operation between the producers and users of data.

2.2. Workshop on a design for land-use and land-cover modelling in Europe, Zell-am-See, Austria, 8-13 January 1998

The key themes explored in the Workshop were as follows:

- to identify the key characteristics of land-use and land cover in Europe now, and in the future (up to c.30 years ahead).
- to consider the main agents of likely change.
- to ask: what do we need to know about 1 and 2 above in order to inform policy makers, planners, environmental managers and researchers?
- to evaluate our ability to model / project future land use and what form these models / projections might take.
- to prepare an outline design for a research plan to produce this.

Six key questions were addressed, as follows:

1. What Are The Main 'Current' Land Use Trends? This examined the current changes affecting agricultural land-use, the pressures on semi-natural areas and landscapes, changes to soil and water resources and the effect these have on land-use change.
2. What Are The Likely Possible Future Land-Use Trends? This session discussed the impact of changing agricultural policy on land use in the EU and the threats imposed on semi-natural areas arising from increases in urbanisation and transport infrastructure.
3. What Are The Main Agents Or Drivers Of Land-Use Change? The policies driving land-use change were identified. These included Europe-wide policies e.g. CAP and economic policies, e.g. globalisation of agriculture. In addition, social trends, such as urban-rural migration and increased amenity use of land were examined.
4. What Information Is Needed By Whom And In What Form Regarding Future Land Use Change? Specifically this sought to examine the land-use and land cover data needs of policy makers and the research community.
5. What Is Our Ability To Monitor Land-Use Change? The different types of monitoring were discussed (i.e. remote sensing, statistical methods and social and economic monitoring).
6. What Is Our Ability To Predict Future Land Use /Land Cover Change Through The Use Of Modelling ? A number of land-use and land cover models were discussed so as to assess problems associated with scaling up/down information on land-use change.

3. Key research issues needing attention

The Workshop identified a number of key issues that need further attention.

Firstly, it is important to develop a greater understanding of human processes driving land-use change e.g. decision-making, perception and the incentives/disincentives that lead to certain forms of land management.

Secondly, it is necessary to identify more clearly the key valued attributes associated with land-use change. Four key attributes were specified: landscape quality, habitat or biodiversity, access, and sustainability. To assess these key attributes a set of indicators need to be produced.

Thirdly, improved knowledge is required of the horizontal interactions of between land use and other activities (e.g. the effects of transport, water use on land use). This would serve to inform policymakers in the non-land use sectors (e.g. transport) of their actions' implications for land use.

Fourthly, we need to cope better with the spatial heterogeneity of land-use/cover. This requires more effective bridging between socio-economic data on the drivers of change and data on the (physically) observed land-use/cover changes.

Fifthly, we need to anchor current research more closely to reality, perhaps by case studies.

Sixthly, a better understanding is needed of the different land-use changes occurring at different scales and the connections between them, so that knowledge can be 'scaled up' or 'scaled down'.

The seventh key issue relates to the need to develop common scenarios for drivers of land-use change in Europe that are more consistent with those currently used in international global change research (e.g. by the IPCC).

Finally, although perhaps most importantly, there is a need to incorporate more effectively the needs of the user in the research process ('stakeholder involvement'), and to produce more effective delivery systems for research products.

4. Key topics needing attention

In addition to the key research issues above, three topics were identified as needing priority attention: These include:

Effects on land-use of the expansion of the EU to include Central and Eastern European countries.

Policies affecting land-use, most notably agriculture, environment and regional development are expected to be radically reformed in the immediate future. For example, changes to the CAP arising from the WTO talks in 1999 and the subsequent adoption of Agenda 2000 will have a significant influence on agricultural land-use.

Rapid expansion of water usage will continue to have important effects on land-use in Europe.

5. The next steps

The Workshop recommended some immediate actions. In future a more European-wide framework for modelling future land-use change is probably needed. Although there is considerable research being undertaken in the EU at present, much is uncoordinated. Preliminary steps towards better co-ordination would include:

- Development of an inventory on current land-use change models in Europe (from the local scale to the EU level).
- Undertaking compatible case studies on
  - ◊ areas (e.g. coastal sites, city edges, wetlands), and
  - ◊ issues (effects of EU extension).
- Development of common sets of scenarios, particularly of the drivers of land-use change.
- Work to construct links between some existing (or currently being developed) models, e.g. between farm-level and regional land-use allocation models.
- Increasing user involvement in the research process. By doing this, the research questions are more likely to address stakeholders needs and so render a higher value to the information produced.

- Address key methodological questions such as: scale, heterogeneity, socio-economic dynamics, horizontal integration, etc. Developing a greater understanding of these issues it will enable a more co-ordinated approach to land-use change research in Europe.

THE LANES NETWORK

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1. Objectives and context

The management of various policies in domains such as environment, agriculture, forestry, urban areas or regional planning at different administrative levels in Europe requires access to both, spatial and statistical information on land cover / land use at different geographic scales and levels.

Existing information systems within Europe do not always match those requirements for various reasons: use of different approaches, problems of concepts / nomenclatures / scales / quality, adaptation to specific data collection tools, legal copyrights, prices, and technical problems of access and diffusion of information.

Earth Observation data may be considered as an important source of information for European harmonised land cover / land use data because of its characteristics (data collection over large areas and crossing frontiers, objective in terms of data contents - spectral reflection values -, possible multi-temporal coverage, possible automation of data processing etc.). The cost for acquisition of Earth Observation data and integration with other information using Geographic Information Systems technology remains a bottleneck for the single user. This situation demands for the development of multi-purpose information systems able to feed applications in different sectoral contexts with appropriate basic data. This requires co-ordination between the different sectoral user groups and co-ordination between data producers, value-adding companies and researchers involved in this domain.

The overall objective of the LANES concerted action is to contribute to the development of a harmonised and statistically sound framework for multi-purpose land cover / use information systems derived using Earth observation data. The global user community of land information – e.g. experts and researchers in agriculture, forest, environment, land cover / use change – as well as data / information providers and the specialised private sector – mapping agencies, earth observation data producers, value-added-product providers, statisticians – benefit from the LANES concerted action. A network comprised by 26 institutions from 13 countries in Europe concerned with land cover / land use information has been established.

Table 1: List of participating organisations to the LANES network

1. MINISTRY OF ENVIRONMENT, France
2. FINNISH ENVIRONMENT INSTITUTE, Finland
3. ORHA NORD - PAS-DE-CALAIS, France
4. IGN ESPANA, Spain
5. CNIG, Portugal
6. EUROSTAT, Luxembourg
7. FAO, Rome
8. CENTRAAL BUREAU VOOR DE STATISTIEK (CBS), The Netherlands
9. ISTITUTO NAZIONALE DI STATISTICA (ISTAT), Italy
10. BUNDESAMT FÜR STATISTIK, Switzerland
11. MINISTERIO DE AGRICULTURA (MAPA), Spain
12. STAT. LANDESAMT BADEN-WUERTTEMBERG (StaLA B-W), Germany
13. DEPT OF THE ENVIRONMENT (DoE), United Kingdom
14. SWEDISH SPACE CORPORATION (SSC), Sweden
15. GIM, Luxembourg
16. GAF, Germany
17. SCOT-CONSEIL, France
18. MACAULAY LAND USE RESEARCH INST. (MLURI), United Kingdom
19. THE WINAND STARING CENTRE , The Netherlands
20. EUROPEAN FOREST INSTITUTE (EFI), Finland
21. INSTITUTE OF TERRESTRIAL ECOLOGY (ITE), United Kingdom
22. UNIVERSITY COLLEGE DUBLIN (UCD), Ireland
23. UNIVERSITY OF STUTTGART, Germany
24. UNIVERSITY OF WALES, United Kingdom
25. JOANNEUM RESEARCH, Austria
26. CNES, France

Subjects of discussion during two workshops (April 1997 in Luxembourg and November 1997 in Rome) were comparability and harmonisation of data and information systems, interface between mapping and statistics, the development of statistical methodologies on nomenclatures, conversion methods, the integration of earth observation and geographic information system technologies in statistical information systems, quality aspects, cost-effectiveness and the development of multi-purpose applications of Earth Observation data.

The LANES concerted action is closely linked to the activities of Eurostat (the Statistical Office of the European Commission) with its land use statistics programme, the CORINE Land Cover project of the European Environment Agency, the methodological work of FAO on the AFRICOVER project, the CLAUDE concerted action (Co-ordinating land use and cover data and analysis in Europe) and national activities carried out by the members of the LANES network. The concerted action, funded by the European Commission's 4th RTD programme on Environment and Climate, started in November 1996 and has been concluded in March 1998.

2. Results

2.1. Review on existing information systems

A review on a sample of 37 existing land cover / land use information systems throughout Europe was carried out. Confusion between the terms land cover and land use was observed very often. As to be expected comparison between the data of the systems was hardly or not at all possible because of incompatibility of national systems, of nomenclatures and system parameters across the different sectoral applications and 'scales' respectively administrative levels. The following discussions focused on the problem areas of *nomenclatures* and *data integration.*

2.2. Nomenclatures

Nomenclatures are lists of categories used to structure information and to facilitate communication and exchange among users in a given discipline. Their functions are to identify, describe and classify. They are describing some aspects of the real world and partitions proposed indicate to the user that objective characteristics have been taken into account. Resulting aggregates at different levels of the tree are far from being natural for all the possible users. This leads to problems when comparing different nomenclatures.

Methodologies for building nomenclatures have been described. In general, building a nomenclature should be the result of an on-going dialogue between a systematic approach (structuration of information), a pragmatic approach (user's needs and existing information) and a contextual approach (specific rules for the geographic domain). Two fundamental constraints should characterise nomenclatures: completeness and absence of overlapping. Various complementary rules have then been described; general classification rules, definitions and explanatory notes, principles of coding, indicators for measuring the reliability of a nomenclature.

Practical problems linked to the use of nomenclatures have also been listed: inclusion of new objects, relevance-homogeneity of classes, aggregation processes. Main methodologies used in various domains of interest have been described and commented: elementary kernels, data analysis, top-down tree, bottom-up tree, systematic intersection and independent levels.

Land cover and land use nomenclatures have been introduced under their specific issues: geographic dimension, land cover vs. land use and their interrelationship, problems of observation units (what is an object) and scale issues. Specific constraints for building land cover and land use nomenclatures have been presented: spatial, semantic, temporal consistencies and compatibility with existing systems, independence from data collection and processing tools and the specific issue of multiple cover and use and their consequences on information systems.

Approaches facilitating the linkage between nomenclatures have been investigated. A "generative system of nomenclatures" consisting of a combinatory system applied on a common basis has been proposed. The basis is just a set of necessary characteristics to the descriptions of the objects. These characteristics, once identified and defined uniformly, allow, through combinations the definition of objects and the grouping of the objects for all possible nomenclatures. A theoretical approach has been proposed introducing concepts such as the meaning triangle, the properties of objects and classifiers and some principles for designing a system of classifiers /

attributes (clear separation of land cover and land use, economy of the number of classifiers, maximisation of the use of dichotomous keys). Existing initiatives in this field have been also investigated: the FAO system of classifiers and the ITE proposal of demonstrator for inter-comparison of classifications. These approaches have been described and commented and recommendations were made on basic possible classifiers on land cover (5 basic attributes) and land use (12 basic attributes based on socio-economic nomenclatures - NACE). Potential benefits of this kind of approach have been discussed: validation of existing systems, easier construction of new nomenclatures, harmonisation tool between existing systems, a common language on a restricted set of concepts, an easier way to integrate different types of data (in particular socio-economic data), rationalisation of data collection and interpretation process.

Role of Earth Observation data. Satellites only "see" land cover. The five basic attributes describing land cover (woody, herbaceous, bare soil, artefact, water) may be easily populated with earth observation data (both low and high resolution) on large areas for mapping purposes. For land use the situation is totally different: full coverage on land use does not exist, only partial information is existing through thematic maps or socio-economic statistics at various geographic levels. Role of Earth Observation data may be therefore twofold: providing a general spatial framework for information systems on land cover / land use and populating such information systems with basic attributes of land cover.

2.3. Data Integration

Problems concerned with *data integration* have been subject of discussion on the concrete example of the CORINE Land Cover project (CLC) in Finland. Differing from other CORINE Land Cover projects in Europe, the Finnish CLC follows a multi-source approach, integrating already existing geographic data from different disciplines in one geographic database. The problems related with the integration of these different data sets concern

- concepts: mapping / statistical approaches, in-compatibility of nomenclatures
- observation / implementation: different data collection methods, geometric scales and thematic detail, time periods
- quality and accuracy: error assessment, error propagation while data integration, generalisation errors
- techniques: format, conversion, generalisation

Conclusions drawn from the discussion on data integration maybe stated as follows:

- Implementation of quality assurance and control measurements (including Meta-data dictionaries, Best-Practise methods) is required.
- Development is required for the use of remote sensing imagery in data integration as tool for harmonisation of land cover data across administrative borders, automatic integration of statistics as a-priori knowledge in classification procedures, quality control procedures including thematic and geometric accuracy.
- Further research is required in the integration of statistical (sampling) data with geographic (full coverage) data, error propagation in multi-source geographic databases and in generalisation procedures.

3. Conclusions

In general LANES has been considered as a unique network where different disciplines have been represented and exchanges of points of view were fruitful. Various topics regards land cover / use information systems have been discussed, two topics (nomenclatures and data integration) have been investigated more in-depth.

The major result of the LANES concerted action is the facilitation of a dialogue between different communities concerned with land cover / use information. User groups coming from different disciplines and data producers have been made sensible for problems not recognised as such by them. The different points of view became visible during the project.

The LANES concerted action demonstrated also the role statisticians may play in the field of land information systems. Because of their technical expertise in data integration, creation of nomenclatures and classification systems and their multi-disciplinary working environment, statisticians are well placed to contribute and co-ordinate the efforts made by the different communities for setting up a multi-purpose land information systems. According to the LANES network, a mandate at the European level for this co-ordination is required. Eurostat is suggested to take the leading role to ensure a continuation of this fruitful dialogue.

4. Recommendations

Concerning recommendations, the discussions during LANES resulted in some elements for future activities:

- The development of a common terminology on land cover and land use information is required. This glossary should serve experts of different disciplines and different languages.
- The development of a "Best Practice" guide for data integration has been recommended. Topics such as scales, data quality, precision / accuracy and measurement procedures, data dictionary etc. should be tackled with.
- Efforts have to be made on the development of land use classifiers.
- The results of the activities should be widely distributed and complete documentation should be made available. The results and reports of the LANES concerted action will be made available through the Internet site of CESD Communautaire (www.cesd.lu).

The final report of the LANES concerted action is available on request. The report contains a background paper on nomenclatures and recommendations of the LANES network concerning data integration.

EUROSTAT WORKING PARTY ON LAND USE STATISTICS

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Eurostat recently resumed activities concerning land use statistics by picking up on the efforts of a working party, which had been active until 1990. In addition to compiling ongoing statistics on land use, Eurostat wishes to identify the Commission's requirements and to set up the tools to cater for these. One tool created for analysing available sources is a documentation base on European systems of information on land use. The concept of cores and margins is a tool to integrate data.

1. The Working Party on Land Use Statistics

1.1. Background

A working party on land use statistics met in Eurostat until the early 1990s. It was composed exclusively of agricultural statisticians from the Member States and the Statistical Office of the European Communities itself.

This working party concerned itself essentially with the distribution of agricultural land. The first objective was to estimate the area used for agriculture in the Europe of 9. The second objective was to distribute the various crops over this agricultural area. This led to the creation of tools for estimating agricultural areas, whether in production or not. These systems barely considered forest areas, and took no consideration of others.

1.2. Revival of the working party

In 1993, Eurostat resumed methodological approaches to land use, and in particular the concept of Utilised Agricultural Area (UAA) and the different types of land use between the countries of northern Europe and the Mediterranean countries. In 1994, Eurostat set out to describe the national systems in conjunction with the Member States. In 1996, Eurostat finally revived the Working Party on Land Use. It currently considers questions of the distribution of agricultural and non-agricultural land.

The working party is drawn from:

- Eurostat units responsible for statistics on agricultural and fishery products, the environment, regional accounts and indicators, population, the geographic information system, classifications and methodological coordination;
- Directorates General of the European Commission responsible for agriculture, the environment, nuclear safety, civil protection, regional policy and cohesion ;
- ancillary bodies of the Commission like the Joint Research Centre in Ispra and the European Training Centre for Economist Statisticians from the Developing Countries;
- Member States, represented by agricultural and environmental statisticians;
- other European countries and
- other international organisations such as the European Environment Agency, the European Topic Centre on Land Cover, the Organisation for Economic Cooperation and Development and the Food and Agriculture Organisation of the United Nations.

1.3. The Internal Working Party and the Interservice Group

An internal Eurostat working party and an interservice group were also set up to identify the requirements of the European Commission and to improve coordination between departments.

The internal Eurostat working party brings together those Eurostat units which are responsible for statistics on agricultural and fishery products, the environment, regional accounts and indicators, population, the geographic information system, classifications and methodological coordination. The internal Eurostat working party permits the exchange of information, coordinates work within the Statistical Office and prepares the meetings of the working party.

The interservice group brings together the Eurostat internal working party, the Directorates General of the Commission responsible for agriculture, transport, the environment, nuclear safety, civil protection, science, research and development, regional policy and cohesion, the Joint Research Centre in Ispra, the European Environment Agency and the European Topic Centre on Land Cover. This interservice group disseminates information on the use of land as a whole and coordinates initiatives within the European Commission.

2. The working party's activities

2.1. The working party's objective

The working party's objective is to integrate basic statistical information on land use and, in particular, to establish figures at Community level based on the information collected by the Member States.

National data must meet five criteria for integration purposes:

- exhaustiveness (the statistics must cover the entire territory);
- availability (they must be available soon after collection);
- comparability (they must correspond to concepts and definitions common to other available statistics);
- reliability (they must be compiled with little relative error);
- being up to date (they must be updated regularly).

The national statistics which may be integrated into Community statistics come from various fields, including agricultural statistics, environmental statistics and regional statistics.

2.2. The working party's approaches

The group's first line of work was to define the principal concepts of land use (occupation/use, landscape, purpose, scale, etc) and the methods of estimation or observation (statistics, cartography, nomenclatures, etc). This work yielded a reference document (Doc. LAND/2), which is available to the participants in the seminar.

The Commission's requirements in terms of data on land use were analysed (the second line of work). The various Directorates-General represented in the working party or in the interservice group described their current and future requirements on land use, and those same requirements are central to the organisation of this seminar. Their presentation has not been finalised as yet.

The third line of work was to identify the main approaches at regional, national and international level. This was completed with the creation of a documentation base which describes the various systems of information on land use which are available throughout Europe.

The fourth line of work, co-ordinating and integrating the data, requires the creation and deployment of tools which can compile whatever comparable, reliable and up-to-date exhaustive information is available at Community level.

The concept of cores and margins ("noyaux et marges" or "kern- und Rand-Elemente") has been put forward as an avenue to explore.

When these first four lines of work have been completed, the last line will be to present whatever solutions can be envisaged to meet the objective of integrating and disseminating data on land use statistics at Community level.

3. Documentation base

3.1. Creation of the base

The working party has sought to develop knowledge of the statistical and cartographic tools that are available at regional, national and European level. At the first meeting of the revived working party, in September 1996, it was decided to set up a data base to provide an inventory and description of existing systems.

A questionnaire (Doc. LAND/8) was sent to every country in Europe. It surveyed every system of information on land cover/use, statistical, cartographic, regional and national. A detailed description of these systems was requested, covering the following points:

- the body responsible for the system;
- the objectives of the system;
- the methodology (method, field of observation, survey units, scale, sampling, spatial resolution, timetable of operations, periodicity, error measure, accuracy and quality control);
- exploitation and dissemination of data (availability, georeferencing, tools for analysing changes);
- how the nomenclature was built up (basic principle, occupation/land use, systematic);
- the spatial dimension of the nomenclature;
- the temporal dimension of the nomenclature;
- future developments.

The information collected was compiled on an MS-Access database, and the initial results were presented at the working party meeting in June 1997. The base was completed and referred back to the countries for validation in December 1997. Once validated, this documentation base will be widely disseminated at European level.

3.2. Use and maintenance of the base

This documentation base is a tool for analysing local systems and sources on land use/land cover. It affords better knowledge of the characteristics of the systems and data, and constitutes the basis for the work of integrating data according to their intrinsic qualities.

It currently covers 79 systems in 16 countries, and is to be further developed, supplemented and updated. Certain tools have already been created to facilitate the analysis of large numbers of records classed by certain criteria (objectives pursued or method used).

The plan is to make this documentation base available to users via the Internet. The bodies responsible for the systems will be asked to update the base regularly to ensure that the information on it is always up-to-date.

4. The concept of cores and margins

4.1. Presentation of the concept

The working party is also working towards better integration of the data. No new nomenclature has been created. To retain a pragmatic approach and work using existing data, Eurostat proposed the concept of "cores and margins" ("noyaux et marges" or "kern- und Rand-Elemente"). Given that the existing systems do not all have the same objectives and sensitivities, the common aggregates which could provide a basis for merging data from different sources should be redefined.

With a view to one particular problem, classification items are aggregated to the point where they can be compared. The cores are then defined as the same aggregations from one issue to another. The margins are made up of classification items, which could be aggregated within one group or another according to the issue being considered.

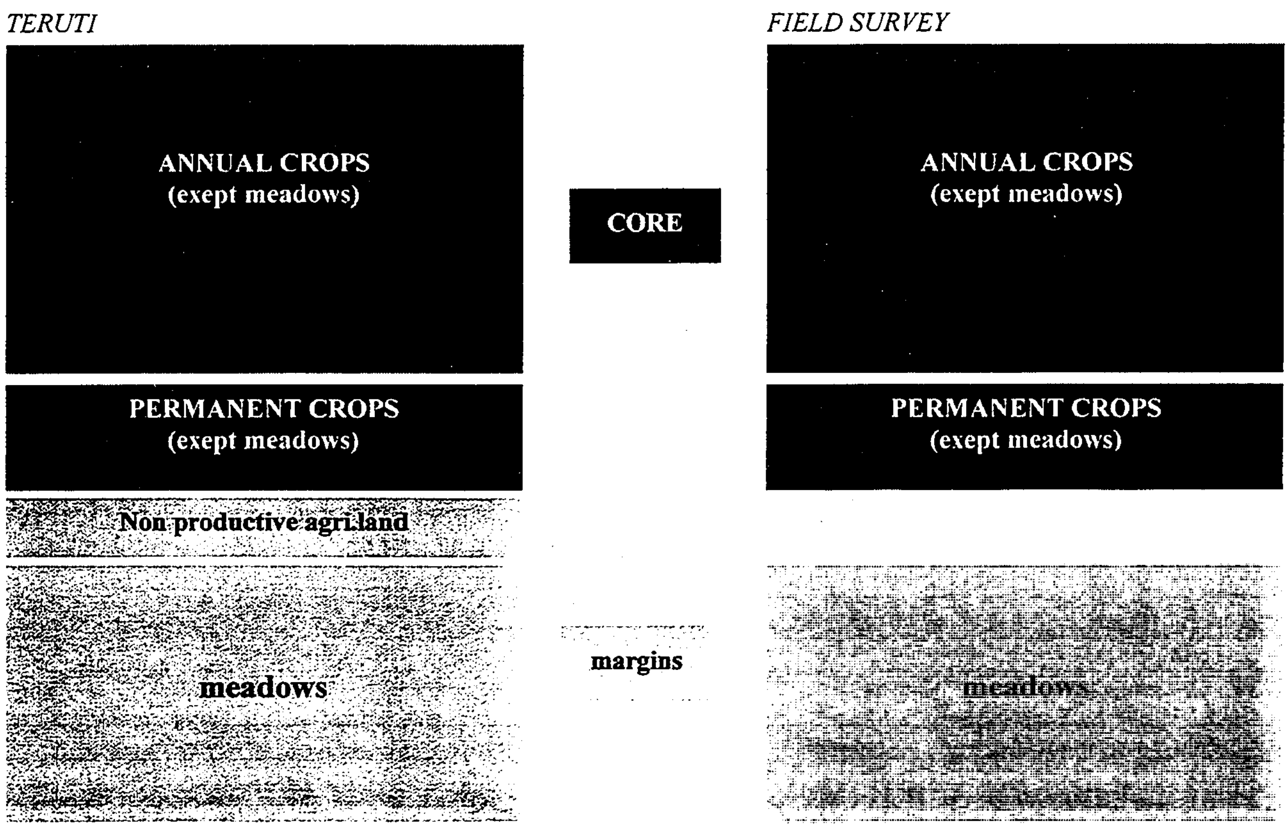
This concept of cores and margins is suited to high levels of aggregation: the distinction between agricultural use, forestry, inland waters and other land types is directly possible. In contrast, a more detailed level of aggregation needs to have the question defined. Aggregates will thus be proposed on the basis of the sensitivity of the tools used and the definitions governing the classification of parts of territory.

4.2. Utilised agricultural area as an example

Agricultural uses are the best known and also the easiest to describe. The core of agricultural uses includes "annual crops" and "permanent crops". According to the classification, the margins are "meadows" and/or "fallow and waste land".

Comparing the French TERUTI system and the United Kingdom's FIELD SURVEY system illustrates how a core common to the two systems is created (annual crops + permanent crops), along with margins which are either identical (meadows), or different (non-productive agricultural land).

AN EXAMPLE : UTILISED AGRICULTURAL AREA



Data on forestry uses are more difficult to aggregate because of the different thresholds for defining woodland. It is even more difficult to break other uses down because, in view of the scale of work of the available tools, fields such as urban uses or communication networks are poorly or not at all considered.

4.3. Development of the concept

The cores and margins concept can be used to compile basic statistical data at European level. It is also possible to compare countries in terms of the relative importance of each land use.

These uses are, however, confined to the highest degrees of aggregation (generally the only aggregates) on account of the differences in national systems. Low levels of aggregation depend directly on the classifications used, which themselves depend on the collection systems used. Thus, for example, while "agricultural area" features in every classification, the same cannot be said of "church".

Interconnection is therefore more difficult the lower the level of aggregation.

It is also possible to interconnect systems by the concept of cores and margins, but giving priority to aspects of changes in land use. In this case, the links are flawed, but are achieved at relatively low levels of aggregation to obtain pertinent information on changes in land use over time.

This second use appears more promising, because it is better able to meet the requirements and it also offers greater value added. This approach, which requires the expertise of statisticians, will be developed by the working party on land use statistics.

SESSION 3

A BETTER UNDERSTANDING OF THE DOMAIN

OBJECTIVES, TOOLS, NOMENCLATURES

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1. Foreword

Statistical information on land cover/ land use is needed for conducting policies as diverse as agriculture, forestry or regional planning. Existing statistical systems do not cater adequately for new multi-thematic needs such as environment, the new Common Agricultural Policy, measuring the evolution of urban areas and the management of transfrontier areas. Taking account of these various needs requires a consistent statistical framework which can contribute to the development of a harmonised information system on land cover / land use. It is important to recall some technical and methodological points to guide the future discussions of the land use statistics working group. The main objective of this paper is to provide some elements and to remind us of basic concepts on land cover / land use statistics. Some methodological points will be borne in mind on the description and analysis of landscapes, which can be described in terms of a combination between land cover and land use.

2. Introduction

Any given portion of the earth's surface can be observed and described in various ways, according to:

- the distance separating us from it,
- the instruments used to make the observation, (human eye, aerial photography, satellite sensors);
- the possible semantic description of the observation, (classifications, descriptors or classifiers);
- the use of the information provided by the observation, (statistics, inventory or mapping);
- the observation units,
- the observation period.

3. Land Cover and Land Use

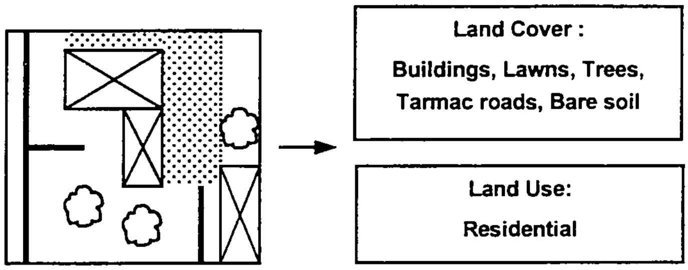
Information requirements relating to the study of the earth basically concern two types of description: land cover and land use.

Land cover (*biophysical dimension*) corresponds to a physical description of space. This description enables various biophysical categories to be distinguished - basically, areas of vegetation (trees, bushes, fields, lawns), bare soil and hard surfaces (dunes, rocks, buildings) and bodies of water (water surfaces and watercourses).

Land use (*functional dimension*) corresponds to the description of the same areas, but in terms of their socio-economic purpose: areas used for residential, industrial or commercial purposes, for farming or forestry, for recreational or conservation purposes, or without use.

It is sometimes possible to determine the functional aspect from biophysical aspect. A parcel of land covered by a field of wheat can reasonably be associated with agricultural use. Similarly, it is sometimes possible to infer - at least to some extent - biophysical aspect from functional aspect. An area used for forest production can reasonably be assumed to correspond to a biophysical class of the type "tree". By contrast, one and the same biophysical category may correspond to a large number of functional categories. Areas of grass may, for example, correspond to lawns in an urban area, an airport runway, a sown meadow, rough pasture, a golf course - or even a church roof in Iceland. Conversely, one and the same functional class may cover several biophysical categories: for example, a residential area consists of lawns, buildings, tarmac roads, trees and bare soil (*cf. Fig. 1*).

Figure 1



4. Interrelationship of different approaches

There are methodological and technical arguments in favour of systematically separating land cover from land use approaches. However, this separation is not fully justifiable when analysing both user needs and possible additional costs of simultaneously acquiring, using and managing data obtained using several approaches.

To meet both statistical and cartographical information requirements in order to conduct Community, national, regional or local policies in areas as diverse as agriculture, forestry, the environment, and urban/regional planning calls for a fairly pragmatic approach that takes account of both user needs and previous work. This is why a large number of studies combine land use and land cover.

For landscape, some studies start with an inventory of the objects present in the area under consideration. This inventory measures the combinations and spatial distribution of various types of land use/cover, so allowing synthetic landscape indicators to be constructed. Depending on needs and practices, this type of combined approach features investigation of the biophysical dimension (land cover) - e.g. forests or « natural spaces » - and/or the functional dimension (land use) - urban areas, farmland, etc.. Combinations of this type can be systematised by the hierarchical application of descriptors that are applied to each category of the classification.

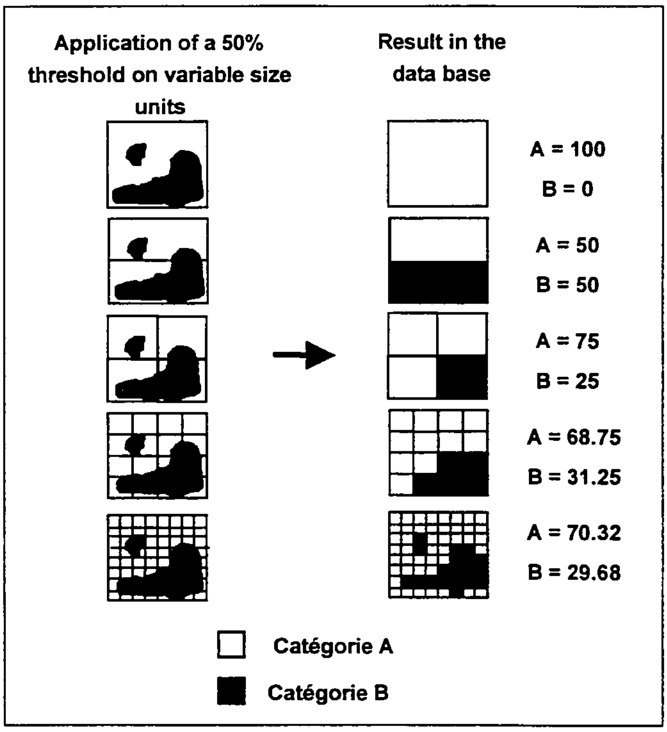
🗁 Landscape consists of discernible physical objects that always have one subjective aspect in common, namely the way in which they are perceived by the observer. Tools for quantitatively investigating areas of landscape use physical objects. In order to obtain a partial, sometimes "mappable" image of the landscape, descriptors are needed. These are often descriptors of land cover consisting of observable physical facts that are accessible via quantitative data only. The area covered by concrete objects consists of both the collection of natural components (rocks and earth, climate and vegetation, a given site's "natural history") and the traces left by the succession of societies that have inhabited these places. Thus, rural landscapes are characterised by settlements, monuments, buildings, communication routes, quarries or tips, and by the division of land and types of plant grown. Quantitative descriptors provide a partial image of the landscape, showing the concrete objects described above. This "landscape-object" features spatial continuity and has a spatial organisation that can be cartographically transcribed.

5. Objects and scales

The use of land use/cover and landscape as a geographical information poses specific problems concerning the actual concept of the object and/or spatial unit to be observed, the effect of geographical scales and their impact on the observation methods and results.

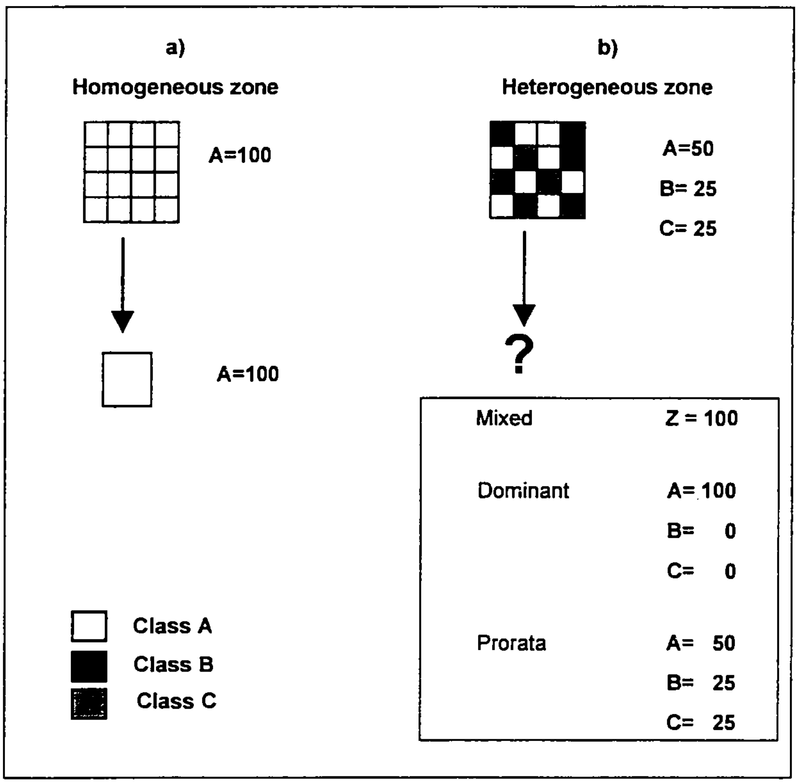
The meaning of object is a complex problem: the description (categorical classification) of part of the earth's surface pre-supposes that the area is fairly clearly defined in space. It is easily identifiable if the spaces are plots of farmland or built-up areas, as they have physical boundaries (enclosures, hedges, fences, clear division between crops). However, these boundaries become blurred in semi-natural or natural environments. Delimitation problems are compounded in transitional zones in particular: for example, in Mediterranean environments, where there is an indistinct transition in biophysical continuum between forest, scrub and dry grassland. Delimitation problems also arise when use is made of category definitions based on cover or use percentages (*cf. Fig. 2*).

Figure 2



Geographical dimension is particularly problematic when it comes to observation scales. An object identified at large scale (e.g. 1: 10.000) is not necessarily discemible at small scale. Ideally, it is merged with an object that is larger but of the same type, producing a homogeneous aggregate *(Fig. 3a)*. More often, it is included in a vague collection of unrelated objects, producing a heterogeneous aggregate that must be identified and named (*Fig. 3b*).

Figure 3



This distinction is critical, as it introduces the problem of the comparability of results from work carried out at different scales. It poses the problem of generalising information, which must take account of aggregation procedures in homogeneous zones and determination procedures in heterogeneous zones. This in turn raises the problem of compiling hierarchical classifications that can meet needs at the various scales.

6. Mapping / Statistics

A map is a representation at a clearly defined scale, of all or part of the earth's surface. It may be read via co-ordinates (geographical or others) for identification purposes, or via other attributes with a view to representing certain features that highlight spatial distributions and relationships. Compilation of land cover/land use maps for the whole of the territory under investigation is generally done by interpreting aerial photographs and interpreting processing satellite images. These inventories may be supplemented by ground surveys. Common observation scales are between 1: 10 000 and 1: 250 000.

With the exception of censuses, statistical surveys provide information on a sample only, this being selected according to the objective in hand. In the particular case of the observation of a geographical area, the sample must be represented as a set of statistical units. For building an area frame, the territory can be systematically divided up into a grid. Each area unit thus obtained constitutes a statistical unit. Sampling theory is then applied to the portion of land under investigation, the statistical units being considered separately. This is called area sampling. The collection of data on the selected units must meet theoretical requirements (sampling procedure must allow a statistical analysis that is as accurate but inexpensive as possible) as well as practical requirements (account must be taken of restrictions imposed by terrain and other information collection difficulties).

Generally speaking, the information collected does not give an exact indication of the real value of the variable under observation. An error shows the discrepancy between the result obtained and the reality. It has two components:

- the first stems from the fact that only a portion of the total territory is observed. This is known as the sampling error;
- the second is the result of errors connected with the actual observation. This is called the measurement error. In the case of area frame sampling, it may include a positioning error.

The sampling error depends on the mathematical tools used (sampling plan, estimator). It gives an indication of the sampling accuracy. If the tools have been judiciously chosen and a fairly large number of units observed, the error is small. In this case the error of measurement becomes important. To take an extreme example, if observation of area units is exhaustive (as in a census), the sampling error is zero.

The quality of statistical information depends on overcoming these two types of errors. Reducing the error of measurement is contingent upon practical considerations (observation scale, questionnaire, allocation of objects within the classification, training of enumerators, photointerpretation). In the case of a census, where a very large number of statistical units is observed, it is difficult and costly to check and improve the quality of the data supplied. As quality is much easier to control in a sample survey, the error of measurement may be smaller. If the sampling error is small, the total error may be smaller than when all statistical units are observed. This explains why a census may provide poorer quality results than a sample survey.

As with statistical information, cartographic information does not provide a sure measurement of the value of the variables observed. Here too, there is a disparity between the results obtained and the reality. This disparity can be broken down into errors connected with allocation of objects within the classification (semantic error), errors connected with the delimitation and positioning of objects (geometric error) and objects that are overlooked or added (exhaustiveness error).

In mapping, for reasons of cost and availability of reference data, quality control operations are either limited to visual validation or are done on the basis of a sample. Methods involving the separate measurement of error components have been devised, but can generally be applied only when tools such as Geographical Information Systems are available.

7. Nomenclatures

Nomenclatures are lists of categories that are used to structure information in a given field. They allow objects to be classified according to certain objectives and certain of their characteristics. Nomenclatures have three types of function: identification, description and classification. Nomenclatures of land use/cover should simultaneously take account of the following:

- constraints relating to the construction of nomenclatures or classification schemes: principles of exhaustiveness and non-coverage of categories, definition of objects and fields of application, rules governing the classification and description of objects,
- constraints linked to the geographical dimension of the field under investigation (restrictions regarding observation, the observation tool, scales and the temporal dimension);
- constraints regarding user needs and existing sets of statistics.

Nomenclatures must be the result of an ongoing dialogue between a systematic approach (how to structure information according to logical principles) and a pragmatic approach (how to take account of users' needs and the constraints described above).

As regards specific construction constraints, results should be comparable between different sites, regions or countries in the geographical field under consideration. This is the principle of spatial consistency.

The nomenclature must comply with the principle of semantic consistency. It must be exhaustive (cover all types of land cover/ land use) and allow the various types to be dissociated (principle of non-overlap). The nomenclature must divide up the various types of land use/cover rather than the territory itself. One nomenclature class must correspond to one land cover / land use category, and one only. One land cover/use must be allocated to one class, and one class only. Mixed classes should be systematically excluded.

Types of land cover/use must be recorded at the time of observation (by the observer, the enumerator or satellite sensor). The nomenclature must not therefore take account of previous or future states (e.g. planned building sites). Results must be considered as stocks, not flows (flows being measured by comparing two sets of stocks). This is the principle of temporal consistency.

A land cover/use nomenclature is invaluable for compiling a global statistical information system on land cover/use. However, creating a nomenclature for general use can be justified only if it provides a fairly high degree of compatibility with existing information systems. It is important to point out in connection with the mutual compatibility between systems that account must be taken of what can be called the general field of validity of land-use information systems. Comparability between systems is not limited to the question of nomenclature - it also incorporates aspects such as statistical populations, observation units, observation methods, classification principles, geographical level of results, temporal dimension, etc. The proposed nomenclature should thus be sufficiently compatible with existing statistical classifications.

In theory, the nomenclature should be constructed independently of the tools available for collecting information. However, practical experience has shown that it is difficulty to construct a nomenclature without being dependent on a particular observation method. As far as possible, the nomenclature should be free of cartographic restitution scales.

Individual users tend to compile their own nomenclatures according to their information and decision-making needs. Generally speaking, nomenclatures are constructed in tree form, i.e. hierarchically. Each of the successive partitions means that certain objective characteristics have been taken into consideration, and implies a conscious, if not subjective, choice. The constituent aggregates seem natural to specific users, but not necessarily so to other users. Other approaches should be tested.

8. Temporal dimension

In addition to the spatial dimension, territorial description tools must also take into account the temporal dimension. Requests are often made for changes in land cover/use to be analysed, or for changes to the landscape over part of the territory to be investigated. Analysis of such changes must answer two types of question - where are the changes taking place? (*spatial dimension*), and how far-reaching are they? (*quantitative dimension*). Ability to reproduce the application of methods is a fundamental pre-condition for providing a reliable measure of change.

Statistical surveys by points are an interesting way of analysing temporal trends in land cover/use. Once the unit area representing a point has been correctly located, land cover/use is recorded for this point only. If the survey is repeated periodically using the same points, the result is a set of data that allow changes to be measured.

Temporal changes can also be evaluated on maps. These must then be on the same scale and must use the same observation units and nomenclatures. As with statistical surveys by points, the existence of mixed classes within the nomenclature creates serious problems when it comes to measuring changes in land use/land cover.

One way of identifying diachronic changes might be to draw on both of the above approaches. This could be done either by superimposing the results of a points survey on a map, or by constructing unit areas on a map and then treating them as statistical units.

THE PROBLEM OF SCALE

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The choice of scale is not only a problem of geometry (detail, accuracy, etc.) but of the level of abstraction at which one wishes to work. It determines the basic concepts of analysis and representation as well as the density of information.

The EEA looked into this question in connection with the use of CORINE Land Cover.

The CORINE Land Cover (CLC) digital cartographic inventory is produced at 1/100 000 by computer-assisted photo-interpretation of satellite images. The land cover unit is a (relatively) homogeneous area of over 25 ha. The nomenclature used to classify areas comprises of 44 items structured in three hierarchical levels (CLC100_3). Complex landscapes (peri-urban, multiple cropping, mosaics of agriculture, forestry and natural areas) are described by mixed categories.

The problem of where CORINE Land Cover stands in the family of scales needs to be examined from two standpoints:

- greater detail;
- data aggregation.

[N.B.: In the notation of CORINE Land Cover levels used, the first figure refers to scale (100 to 1/100 000, etc.) and the second to the nomenclature levels]

1. More detail = larger scale ?

Information is frequently requested in greater detail than CLC100_3, the European standard level. These requests have met with a variety of responses, according to the specific requirements.

Here are some examples:

Since the first version of CLC, Luxembourg has produced a map of biophysical land cover at 1/20 000 (Biophysical Cover of Land, Luxembourg = CLC20_6)

The geographic information system on the Black Triangle (southern Germany and Poland, plus the northern Czech Republic) includes a layer at 1/50 000 (CLC50_5).

With the IFEN, the Parc Régional Naturel de la Brenne, in France, has developed CORINE Land Cover mapping at 1/25 000 in five levels (CLC25_5) to make a bridge to the CORINE Biotopes nomenclature.

In Andalusia, the introduction of a level 2b describes the structure and density of vegetation.

The EEA Land Cover Topic Centre, with the support of the Joint Research Centre at Ispra, has evaluated the experiments conducted and drawn up recommendations. The conclusions are as follows:

a. It is possible to develop detailed cartography while maintaining the basic CLC100_3 structure. This guarantees a minimum level of comparability between independent projects conducted with an eye to specific objectives.

b. The detailed nomenclatures examined present both similarities and peculiarities, and the more so the greater the level of detail. Standardisation is therefore only partially possible.

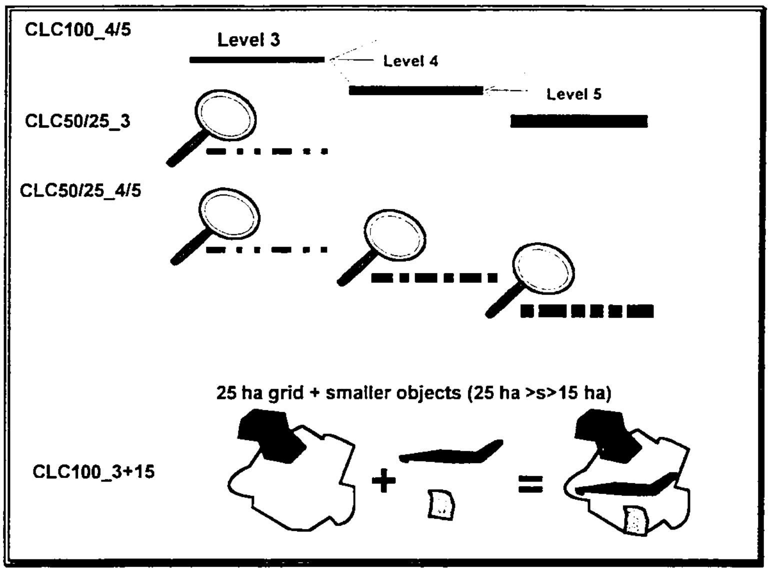
c. In numerous cases, the demand for more detailed information does not require larger-scale mapping. This demand can be met by:

- creating a layer of small objects (little lakes, small woods, villages, etc.);
- creating a layer describing the structure and density of vegetation;
- crossing CLC100_3 data with the Digital Elevation Model or other geographical layers;
- combining mapping and a statistical approach:
  - ◊ results of official surveys further broken down by biophysical grids using CLC;
  - ◊ sampling based on land cover.

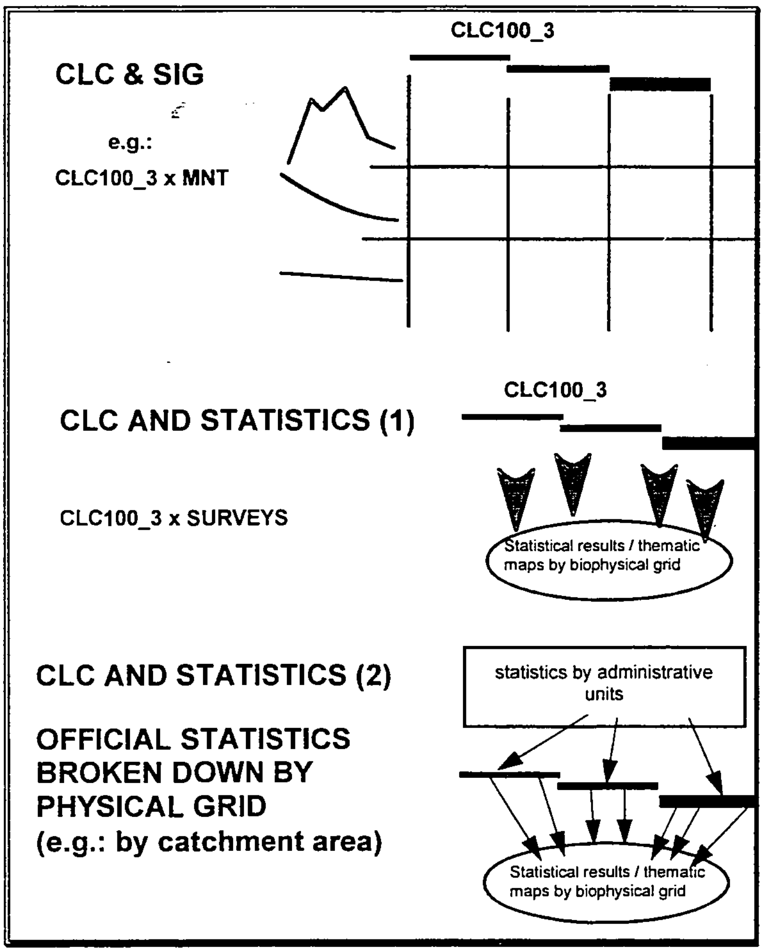
Although there is no absolute distinction, it will be observed that changes in scale are more often than not for monitoring purposes, while cartographic and statistical data are generally cross-referred for the purposes of analysis and evaluation.

The various possibilities are set out below:

CARTOGRAPHIC METHODS



OTHER METHODS



The following are (provisional) recommendations for developing cartographic information via CLC100_3:

a. confine standardisation of large scales (CLC50/25_5) to major European policies:

- Nature protection (NATURE 2000)
- Coastal monitoring (LACOAST 2)
- Towns
- Wet lands, notable biotopes (out of N 2000)

b. respond to local, regional or sectoral requests by providing a guide to producing detailed mapping compatible with CLC100_3;

c. make better use of Geographic Information Systems;

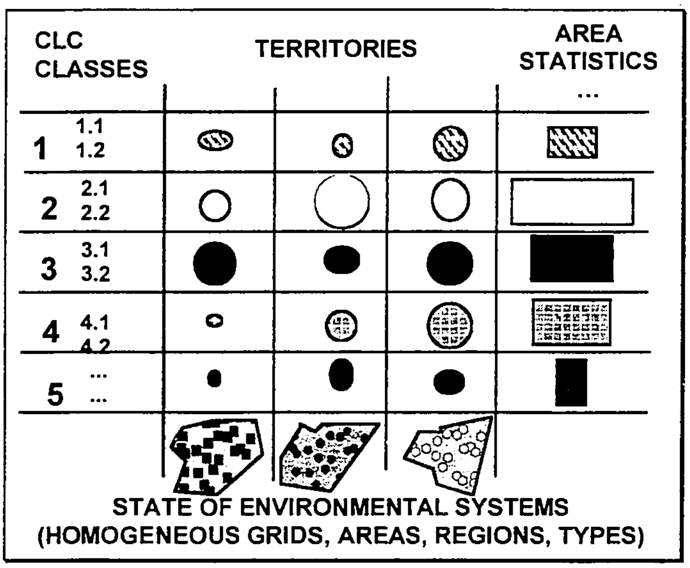
d. improve cartographic and statistical integration.

2. Smaller scale: data aggregation and integration

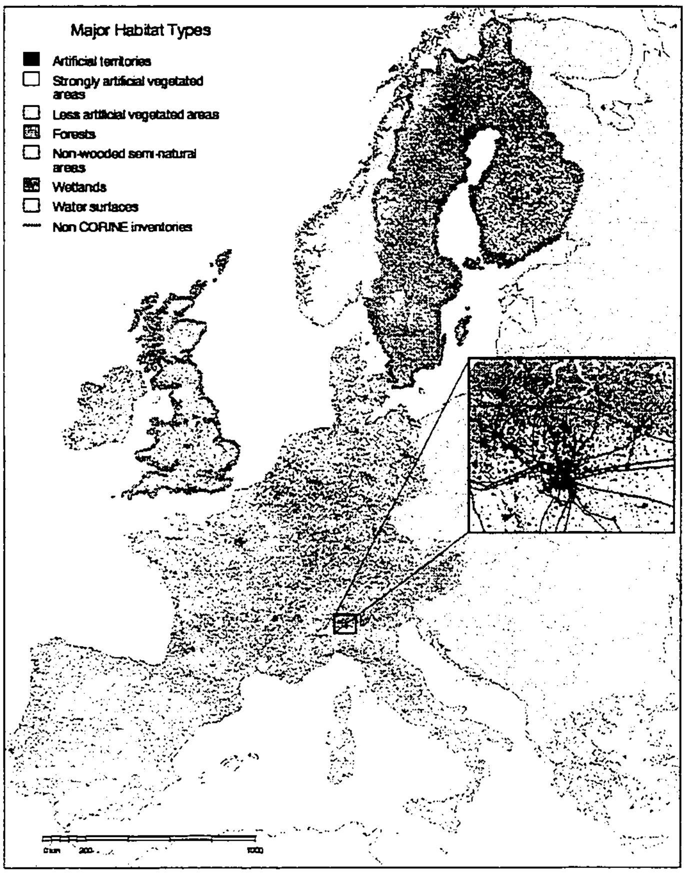
In numerous cases, available data need to be aggregated for the purposes of geographical and/or statistical analysis of phenomena and changes therein. This need may be dictated by the bulk of files, the complexity of matters hampering an understanding of the essential features, or even the need to integrate other data into a systems analysis which requires a specific grid system.

Aggregation can be approached in two ways, either within the framework of the hierarchical structure of the reference nomenclature which determine allocation to a class, or via systems analysis. The statistical indicators obtained from the two approaches will not have the same significance: they will be more quantitative in the former case, and more structural and qualitative in the latter.

HIERARCHICAL AND SYSTEMATIC AGGREGATION



AN EXAMPLE OF HIERARCHICAL AGGREGATION



Source : EEA, 1998

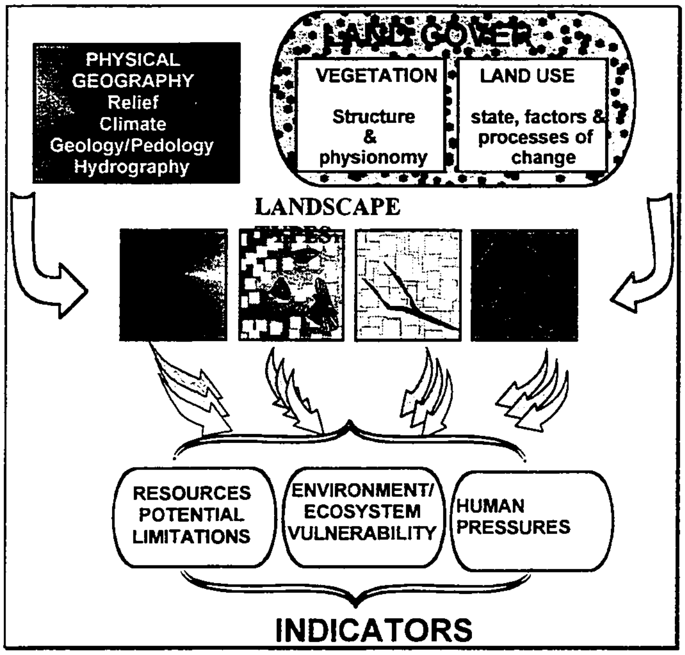
Aggregation of CORINE Land Cover classes (excl. GB, Su and FI)

Aggregating land cover statistics by homogeneous geographical grids permits indicators of structure and state to be produced. These grids may correspond to physical entities such as catchment areas, mountain ranges, coastal areas, or they may be defined by multivariate analysis of basic parameters to do with physical geography, vegetation and land use. It is thus possible to describe ecocomplexes, geosystems, pedological areas or sectors, forest regions, ecological or phyto-ecological regions. This grid system generally has an associated typology. It is then possible to produce statistics and indicators to describe interactions for homogeneous units or for homogeneous classes of units.

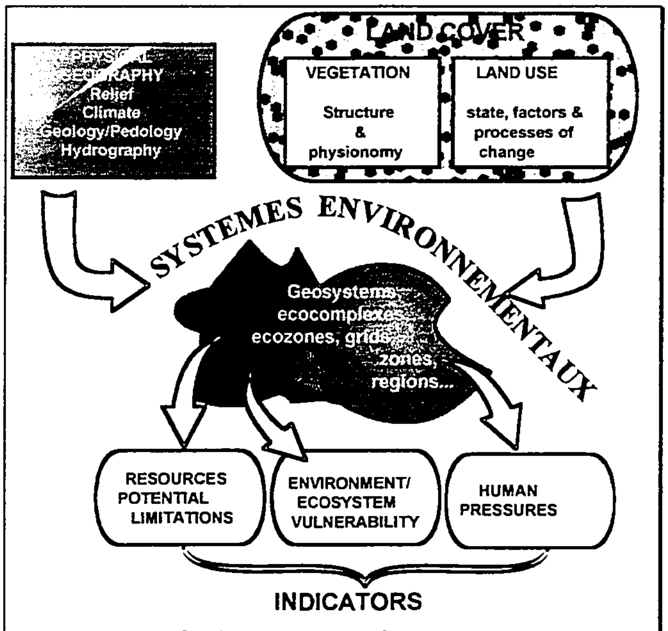
Land cover, or rather changes therein, is therefore one of the descriptors of changes in the state of the homogeneous grids under consideration. This description should, where appropriate, be supplemented by other information collected by other methods (monitoring, sample observations, exhaustive surveys) and restored to the appropriate geographical scale to examine the phenomenon under investigation.

The principles of landscape analysis (in the sense of the biophysical elements of landscapes) are set out in the following graphics. Further illustrations round off this presentation.

PRINCIPLES OF LANDSCAPE ANALYSIS (1)

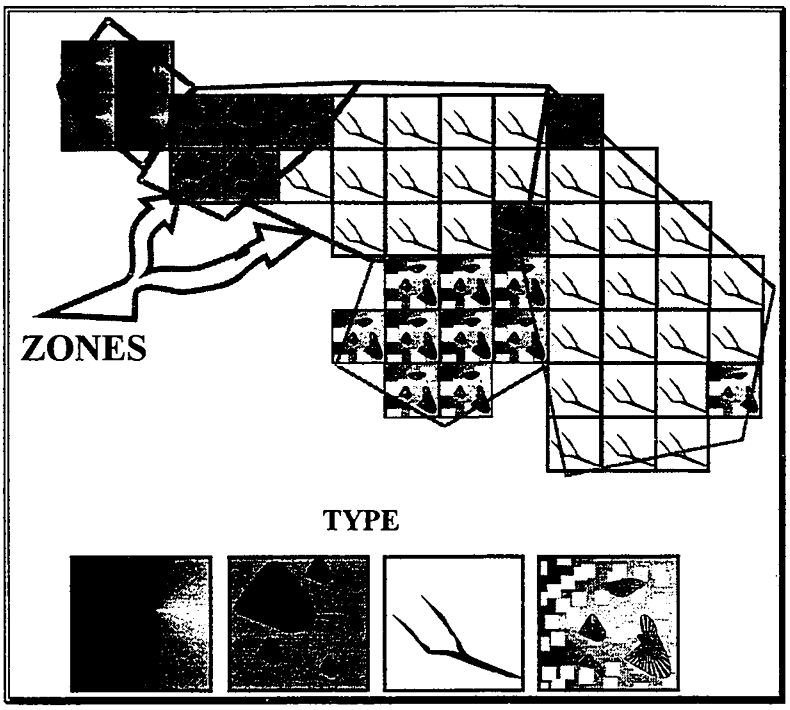


PRINCIPLES OF LANDSCAPE ANALYSIS (2)



(after Eloisa Domingues and Teresa Cardoso da Silva, 1996)

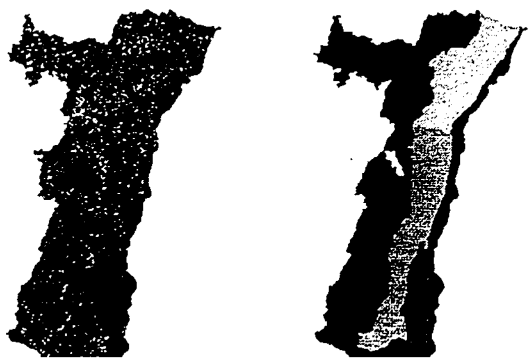
LANDSCAPE ZONES AND TYPES



The grids or zones thus established have no binding political character. They certainly do not replace the operational zones established as a function of administrative or institutional divisions or even as a function of the bounds of action of programmes or plans. The grids themselves therefore have to be grouped or subdivided to correspond to operational zoning.

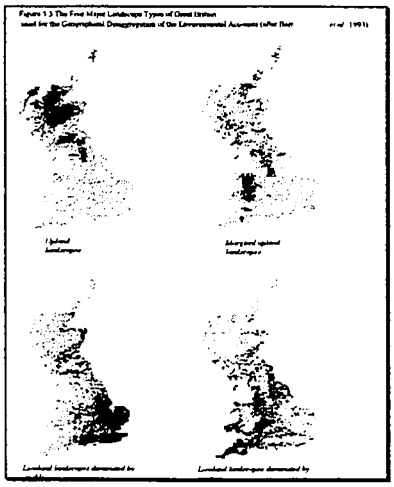
EXAMPLES OF GRID SYSTEMS

(1) : CORINE LAND COVER AND FOREST REGIONS

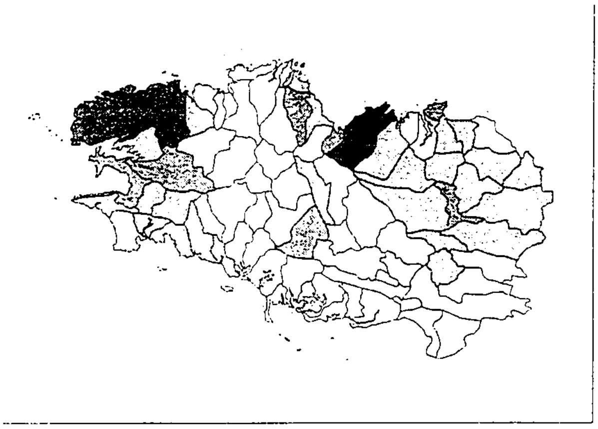


(National forest inventory and Ifen, 1995)

(2) : (AGGREGATED) LANDSCAPE TYPES USED IN GREAT -BRITAIN FOR LAND USE AND COVER ACCOUNTS

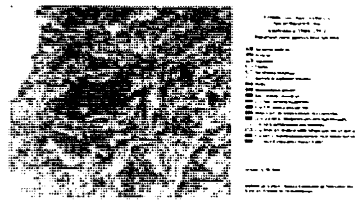


(3) : CALCULATION OF EXCESS NITRATE BY CATCHMENT AREA IN BRITTANY



(Beture and Ifen, 1997)

(4) : FRANCHE-COMTE, CHANGES BY ECOZONE 1984-1992



(Unisfere and Ifen, 1997)

3. CONCLUSION

To conclude, the following summary table may be proposed:

SCALE	INFORMATION
Station, biotope, plot, holding, etc.	Land use, physical modelling, modelling practices and dynamics
Land cover units (CLC)	Ex-post monitoring of change, composition, structure of territories
Regions/Zones/Landscape Types	Distinguishing between territories, horizontal integration, statistical correlation, indicators, generalising dynamic models
Global level	Major balances, trends

THE PROBLEM OF OBSERVATION UNITS

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1. Introduction

When the Common Agricultural Policy (CAP) was reformed in 1992, Regulation (EEC) N° 1765/92 (establishing a per-hectare support system for cereals, oilseeds and protein crops), Regulations (EEC) N° 805/68 and 3013/89 (establishing an aid scheme for producers of beef and sheepmeat, subject to compliance with a per-hectare density factor) - accounting for a total of 48 million hectares declared by 3 million producers - together with Regulation (EEC) N° 2328/91 (since repealed by Regulation (EC) N° 950/97 on compensatory payments for the rearing of cattle, sheep, goats and equidae in less-favoured areas, 7 million ha, 1.1 million producers) were supplemented by legislation setting up an Integrated Administration and Control System (IACS Regulations (EEC) N° 3508/92 and 3887/92).

Since then, rice (Regulation (EC) N° 3072/95, 0.4 million ha) and grain legumes (Regulation (EC) N° 1577/96, 0.5 million ha) have been added to the list of arable crops covered by IACS. At the same time, legislation on accompanying measures (Regulation (EEC) N° 2078/92 and 2080/92), cotton (Regulation (EEC) N° 1201/89, 0.5 million ha) and dried fodder (Regulation (EC) 603/95), in which aid is linked indirectly to area, has been amended to ensure that the declaration system is similar to that used in the Integrated System and a single Parcel Identification System is used.

Commission proposals are currently being drafted or examined for other sectors (vines, 4.2 million ha and 1.6 million producers; olives, 4.4 million ha and 2.5 million producers; tobacco, 0.14 million ha and 0.12 million producers, and hops, 27,000 ha). Again, the approach used for IACS has been taken as a model.

The upshot of this is that, directly or indirectly, some ECU 27 billion, corresponding to some 55 million hectares of land farmed by 4 million farmers, are currently managed using a declaration system defined by IACS. In terms of utilised agricultural area, IACS contains 41% of the 135 million hectares of UAA in the Europe of 15.

2. Data to be transmitted to the Commission

In order to meet its commitments as regards financial management (drafting and monitoring of budgets), sectoral management (preparing reforms, adapting the set-aside rate), fraud prevention and monitoring of the Member States (compliance with basic areas and mean yield, acceptance of a minimum check rate), the Commission requires that it be sent certain data on arable crops and fodder areas (cf. Regulation (EC) N° 658/96).

Data are on three main components:

- number of requests per scheme (simplified, general, other - five-year set-aside, fodder areas, etc.)
- yields
- and areas.

In all, statistics on 23 types of land use are to be transmitted annually. These include:

- six for cereals,
- four for oilseeds,
- all protein crops,
- all non-textile flax,
- nine for set-aside,
- and, finally, all arable crops declared as fodder.

Data are to be sent in by 15 September (provisional data) and 15 January (definitive data) of the year following the declaration, the deadline for which varies from February/March (Portugal, Spain) to May (United Kingdom, Finland, Austria, etc.), the Member State being free to chose.

In the other sectors (cotton, vines, olives, etc.), declaration dates and obligations regarding the annual transfer of data to the Commission vary considerably according to the growth pattern of the crop in question and sectoral regulations.

3. Possibility of using these data for statistical purposes

The collection of statistical data has always been based on census or sample-survey operations. For reasons of economy and reliability, the sample survey has gradually established itself as the most effective format. Other than under exceptional circumstances - elections, for example, where equal rights mean that every individual must be allowed to make his choice known - the census has generally been used only to periodically readjust surveys.

However, once we begin to collect administrative data - such as those disclosed in applications for area support under IACS - for reasons other than statistical purposes, there is every reason to ask whether such data could not meet needs that were previously satisfied by agricultural surveys. Given the lack of budgetary resources, it is difficult to justify continued investment in surveys in the agricultural sector, which is becoming less and less important in terms of European GDP, if an alternative exists for easing the burden of red tape on farmers.

Article 1(3) of Regulation (EEC) No 3508/92 allows the Member States to use IACS data for statistical purposes. However, that is not the end of the problem. Quite apart from the fact that there is no obligation under current legislation to transmit detailed data, it is important to assess whether data declared for IACS purposes tally with those required by the statistical surveys introduced by Regulations (EEC) N° 571/88 (structures), 837/90 (cereals) and 959/93 (crops other than cereals). There are a number of problems, including the compatibility of classifications and observation units, which directly affect the possible bias and accuracy of the estimates obtained.

4. The problem of nomenclatures

For the IACS area declaration, data are collected to justify the payment of compensatory aid for certain types of land use. One particular feature is that the same area may not receive a double payment. Consequently, both declaratory priorities are linked to the location of the areas declared and their use. Land cover is not a priority. In some cases - cereals for example - utilisation is in fact quite academic, as the farmer may declare them as fodder land (assuming compliance with a maximum density of livestock per hectare), even though the land is actually used to produce grain.

The list and presentation of the data gathered vary greatly from one Member State to the next. In decentralised countries such as Germany, Spain and the United Kingdom, forms are drawn up regionally, thus pushing up the number of forms that must be considered before we have a full picture of the options available under the IACS in the EU from 15 to over 50.

Although some Member States such as Finland and Austria have merged support measures and national measures on the IACS forms, each Member State (or region/nation) has defined the list of eligible crops at specific levels of detail. In some countries, the forms contain tables showing parcels for each type of use (Italy). In other countries, the main feature is the parcel of land, one characteristic of which is utilisation as shown by a predetermined list (United Kingdom, Netherlands, Portugal, etc.) or not (Ireland, Luxembourg, Sweden). Consequently, the length of the form varies from two pages in Ireland (where crops not covered by IACS are grouped into a single category "other") to 51 pages in Sweden.

Thus, with the exception of the list of data contained in Annex VIII of Regulation (EC) N° 658/96, all statistics on groups of crops (total cereals, total arable land) must be investigated in detail before it can be said whether the Integrated System can directly provide the data traditionally gathered via statistical surveys.

5. The problem of observation units

5.1. Definitions

The Integrated System defines the notions of farmer, holding and agricultural parcel:

- farmer: the individual agricultural producer, whether a natural or legal person or a group of natural or legal persons, whatever legal status is granted the group and its members by national law, whose holding is within Community territory;
- holding: all the production units managed by a farmer situated within the same Member State's territory;
- agricultural parcel: a continuous area of land on which a single crop is raised by a single farmer. There are special rules that define mixed crops and jointly used areas.

5.2. The notion of the holding

The first difference between IACS and many of the statistical surveys is the notion of the holding. In order to ensure compliance with the set-aside obligation for holdings declaring areas under cereals, oilseeds or protein crops equivalent to more than 92 tonnes of cereals, the definition of the holding requires that production units be grouped together. These may consist of farms located in different regions. The largest holdings have thus been surveyed by the Court of Auditors (8 916 ha in Germany, 6 449 ha in the UK, 4 125 in Spain, 3 405 ha in Italy and 1 785 ha in France). Furthermore, all applications for amounts over ECU 50 must be accepted, which is way below the minimum set for holdings that are the subject of agricultural statistical surveys (minimum of 5 ha in Denmark since 1993). In Portugal, the number of applications for area aid rose from 59 000 in 1993 to 250 000 in 1997, once farmers had become better acquainted with the aid system and once support measures had gradually been incorporated.

5.3. Administrative groupings

The calculation of statistics by administrative units (NUTS regions) must also be checked. Although all land obviously has a physical location, the Integrated System calls for the supply of totals by production region and by regional base area within the meaning of Regulations (EEC) N° 1765/92 and 1098/94. Depending on the Member State and the crop, the situation may be straightforward (Austria, Denmark, Greece, Finland, Luxembourg) or complex (France, Portugal, Spain). Then there is the provision that areas outside a Member State can be declared within that country, providing a minimum proximity ruling is complied with.

5.4. Diachronic changes

Areas and uses that are the subject of aid applications may change over time. Until 15 May, the applicant is free to change his application according to changes in his cropping plan. In certain cases, this option is extended until the sowing date, which in the Scandinavian countries may mean 15 June. Finally, areas may be withdrawn voluntarily if no checks are scheduled and obvious errors may be taken into account at any time. Furthermore, checks obviously reduce the areas declared. Consequently, the areas declared vary over time, and it is impossible to obtain a definitive value before the January following the declaration deadline.

The declarant and administrative authorities may not be equally familiar with the official reference of an agricultural parcel. A farmer may, for example, submit a declaration based on parcel modification that has been recorded locally but not yet updated in the central databases. The reverse may also be true. These problems complicate management of declarations: each year, some 5% of declarations present such problems.

Furthermore, the shape of an agricultural parcel often varies between successive declarations, which makes it very difficult to monitor it over time (monitoring of this kind being necessary for eligibility checks, amongst other things).

5.5. The declaration unit and the identification system

Under the Integrated System, the agricultural parcel is the declaration unit. This means that, for each agricultural parcel, the farmer must stipulate a use, an area and a location. Furthermore, depending on the country, he must declare the total area and, in some case, the official area as shown in the land registers eligibility (in relation to 1991) and net area.

Not all the Member States have adopted the same structure for the declaration forms. Some group parcels together by crop, whilst others leave it up to the declarant to decide on an order. Some countries subdivide the agricultural parcel if it comprises more than one land register plot (Italy provides for a notional multiplication of land parcels), whilst other countries do not require area to be broken down by parcel, this being the case in France under the simplified system (area by crop and municipality) and the general system (area by crop and by block).

The rules allow location based on an identification system that is different from the agricultural parcel, e.g. the land register plot or the block. Thus, the Member State structures its forms in three different ways:

- priority given to the agricultural parcel and listing of all references relating thereto (cf. the land register plot),
- priority given to the identifying unit and listing of all parcels/uses located within it,
- combination of agricultural parcels and identifying units.

Some Member States have thus taken over the basic land register system (Spain, Italy, England), others use it once they have asked the declarant to restructure it into stable units (France, Germany, Austria, Luxembourg), whilst other have felt the need to create a system of blocks (Denmark, Greece, Portugal, Ireland, Finland, Sweden, Scotland, the Netherlands). Some Member States have taken the legislation literally and created an ad hoc parcel system (Northern Ireland, Belgium).

As a result, in some Member States the identifying unit may contain:

- a single agricultural parcel and a single farmer (Belgium, Northern Ireland),
- a single agricultural parcel and several farmers (jointly farmed land - United Kingdom, Austria, etc.),
- several agricultural parcels and a single farmer (France, Germany, Luxembourg, Austria, Scotland),
- several parcels and several declarants (Netherlands, Greece, Portugal, Sweden, Finland, Denmark, Ireland).

One final difference between the Integrated System and conventional statistics may arise from the notion of area. Apart from the fact that the areas declared are projected areas (as shown in the land register), the declared areas must be sown areas and not gross areas, even though the total area may be taken into consideration if it is fully utilised according to the standards applied in the Member State or region concerned. In particular, a parcel containing trees must be recorded and deducted ("headage" in Ireland, trees in Portugal).

6. Parcel management; advantages of the GIS/orthophotography approach

In most of the Member States that have defined a new identification system, parcel management is now based on geographical information systems (GIS) -Belgium, Denmark, Scotland, Finland, Greece, Ireland, Italy, the Netherlands, Portugal, Sweden. This type of spatial georeferencing of declared information has one major advantage over purely alphanumeric approaches. The use of a graphic approach is also preferable with a view to spatialised statistical exploitation.

For the Member States that have opted for GIS techniques - with the exception of Belgium - software and technology are fairly standard (Unix and Windows NT, ESRI system or Intergraph). However, it is often very difficult to use these graphic databases (e.g. 40 million objects to be managed in Italy, database of around 30 GB).

For around half of the Member States, declaration is still based on orthophotography (Belgium, Denmark, Finland, Greece, Ireland, Italy, Portugal). This approach improves the quality of declarations, as it simplifies location for the declarant and allows graphic information to be updated using sector-specific programs.

7. Conclusions

Great care has always been taken to avoid confusing checks and statistical operations. After all, statistical confidentiality should guarantee that declared data will not be used for individual purposes. Bringing these two operations together thus calls for special care if we are to ensure that statistics as a source of information are not lost in areas not covered by administrative information of the Integrated System type.

One feature of the Integrated System is the great freedom given to the Member States/regions/nations for drawing up the declaration forms. With the exception of a minimum number of data to be forwarded annually, Member States' obligations principally concern compliance with rules regarding deadlines, modification possibilities and the running of checks. Even in this field, subsidiarity imposes obligations in terms of results rather than means.

In the livestock field, few data are transmitted annually to the Commission, and those that are barely meet statisticians' expectations. As the applicant may submit several applications, the number of applications is not in itself very telling. If, however, the Member States made a little more effort, more data could be extracted from databases containing identifiers and aid applications.

There is not a 100% match between the population covered by the IACS and that of official surveys. If necessary, a multiframe approach such as the one used by the USDA's NASS could be defined on the basis of the Integrated System in order to collect information from the IACS declarant population, the remainder of the farm population being covered by survey.

However, if current requirements in the field of agricultural statistics are to be met in this way, forms will have to be harmonised. Although this is feasible under IACS rules, it would appear to be contingent upon good will.

The danger of breaks in series must be evaluated, both for past time series and for the future in the event of the hectare-based aid scheme being discontinued (or not introduced in the new Member States), a few years after the current surveys are discontinued.

Given the importance of the sector, the Commission's requirements regarding the implementation of components of the IACS and the financial consequences of failure to comply with the rules, Member States are still faced with basic problems that have financial ramifications. Asking them to make an effort for statistical purposes is not likely to be easy.

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THE PROBLEMS OF CURRENT LAND COVER CLASSIFICATIONS: DEVELOPMENT OF A NEW APPROACH

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1. Abstract

Despite the high demand for environment and natural resources information, many existing maps and digital databases are not specifically developed to meet the various user requirements. One of the main causes, though generally underestimated, is the type of classification or legend used to describe basic information such as land cover and land use. Many of the existing classifications are generally not comparable with one another and are very often single project oriented or taking a sectoral approach. Though many classification systems exist throughout the world, there is no single internationally accepted land cover or land use classification system.

The FAO developed a new Land Cover Classification System (LCCS) to try to address this situation. This system is a comprehensive standardised a-priori classification system, designed to meet specific user requirements and to assure a high geographic accuracy. The classification takes a parametric approach and uses a set of well-defined independent diagnostic criteria, the so-called classifiers, that allow correlation with existing classifications and legends. Thus, this system could serve as a reference base for land cover. The developed methodology is applicable at any scale and comprehensive in the sense that any identified land cover anywhere in the world can be readily accommodated. Furthermore, the system can also be used to analyse the consistency of existing classifications. Because of the complexity of the classification and the need for standardisation, a software program, of which the beta version has been developed, will assist the interpretation process. This program facilitates the standardisation of the interpretation process as well as contributing to its homogeneity. The next step will be to develop a reference base for land use, being based upon the arrangements, activities and inputs people undertake on the land. At present efforts are being made to develop a methodology to describe land use in a comprehensive and consistent way taking a multi-user oriented approach. This should result in a first approach for a land use classification.

2. Introduction

There is a high demand for improved land cover and land use information because of an increasing need to be able to precisely describe and classify land cover and land use in order to develop sustainable land use systems. Land use reflects the land's importance as a fundamental factor of production. Land needs to be better matched to its uses to increase production, while at the same time attempting to protect the environment, biodiversity and global climate systems. It is, therefore, essential to have detailed and in-depth knowledge of potentials and limitations of the present uses in order to project future trajectories. Despite the high demand for environment and natural resources information, many existing maps and digital databases are not specifically developed to meet multi-user requirements. As a result many classification systems and innumerable map legends exist and maps and statistics from different countries and in many cases even from the same country, are incompatible. No global agreement on internationally accepted land cover and land use classification systems exists (UNEP/FAO, 1994).

3. Problems of current classifications

Many existing land cover and land use data sets, although valuable, are heterogeneous with respect to quality, nomenclature, scale and geometry. Moreover, in many countries the data are often only partial in coverage. The data frequently have inappropriate classes for a variety of user needs (e.g. statistical or rural development needs), have a spatial resolution related to a specific purpose and are mostly obsolete. Furthermore, factors are often used in the nomenclature or classification scheme which result in an undesirable mixture of potential and actual land cover (e.g. climate). The use of such predictive parameters in any classification considerably limits usefulness, particularly in applications involving global change modelling. One of the main problems, though generally underestimated, is however the type of classification or legend used to describe land cover and land use.

The reasons why none of the current classifications (Danserau, 1961; Fosberg, 1961; Eiten, 1968; UNESCO, 1973; Mueller-Dombois and Ellenberg, 1974; Kuechler and Zonneveld, 1988; CEC, 1993; Townshend, 1992; UNEP/FAO, 1994; Duhamel, 1995; Belward, 1996; Thompson, 1996) could serve as a reference base are manifold as will be explained below.

3.1. Problems related to purpose

A proportion of the existing classifications are either vegetation classifications (e.g. Danserau, 1961; Fosberg, 1961; Eiten, 1968; UNESCO Vegetation Classification, 1973; Mueller-Dombois and Ellenberg, 1974; Kuechler & Zonneveld, 1988), mixtures of land cover and land use (e.g. CORINE Land Cover in CEC, 1993; Duhamel, 1995), broad land cover classifications, or systems related to the description of a specific feature (e.g. agricultural areas). Thus, they are limited in the ability to define the whole range of possible land cover classes. An illustration is the UNESCO Vegetation Classification (designed to serve primarily vegetation maps at the scale of 1:1,000,000) which considers only natural vegetation, while all other vegetated areas such as cultivated areas or urban vegetated areas are not considered. Other vegetation classifications, even if they consider agricultural areas, do not describe these classes with the same level of detail as used for the natural vegetation ones. On the other hand, systems used to describe agricultural areas give very few details in their description of natural vegetation.

Many systems have been developed for a certain purpose, at a certain scale and using a certain data type (e.g. the International Geosphere-Biosphere Data and Information Systems IGBP-DISCover global 1km data set based on NOAA-AVHRR; Townshend, 1992; Belward, 1996). This results in the fact that the derived classes are strictly dependent on the means used (e.g. in the example classes will be only those that can be detected using NOAA).

Many current classification systems are not suitable for mapping and subsequently monitoring, purposes. If categories are as broad and few as those used to describe land cover in the FAO Production Yearbook (e.g. "forest and woodland", "arable land" and "permanent meadows and pastures"), then forest thinning, increased intensification of cultivation and overgrazing will not be registered. For monitoring, land cover changes take two forms: conversion from one category to another (e.g. from forest to grassland) and modification of condition within one category (e.g. from rainfed cultivated area to irrigated cultivated area). The broader and fewer the categories used to describe land cover, the fewer the instances of conversion from one to another. In the example given the classes identified in the field will not register as conversion nor as modification. Modification, however, is of extreme importance in the land use and land cover change as it relates to the more subtle changes that are thought to have a considerable impact (Turner et al., 1993). A multi-user oriented classification system should capture the full spectrum of alterations from modification to conversion.

3.2. Problems related to consistency

In most current systems the criteria used to derive classes are not systematically applied. An example is the use of different ranges according to the importance given by the user to a particular feature (e.g. in many systems the canopy density ranges used to distinguish tree-dominated areas are many, whereas only one single range is used to define shrub or grass dominated areas).

In some classifications the class definition is imprecise, ambiguous or absent. This means that these systems fail to provide internal consistency (e.g. the frequency with which classes in the CORINE Land Cover overlap with classes elsewhere in the same classification; CEC, 1993). The type of diagnostic criteria and their arrangement to form a class is very often in contrast to the ability to define a clear class boundary. This is, however, a basic requirement for any system.

The full combination of diagnostic elements describing a class is usually not considered (e.g. a system that wants to describe vegetation with the diagnostic criteria of three ranges of cover density matched with three ranges of height must consistently apply these ranges for all life forms considered). The reason why most systems fail in application of this basic classification rule is that the entire combinations of the possible classifiers would lead to a vast number of classes which cannot be handled with the current methods of class description (e.g. imagine in the example above 10 classes of each leading to 100 combinations). Therefore, the current systems often create gaps in the systematic application of the diagnostic criteria used.

Threshold values are very often derived from knowledge of a specific geographic area. The result is that the class boundary definition between classification and classification may become unclear, that is with overlaps or gaps. In these cases inter-comparisons will be impossible or inaccurate.

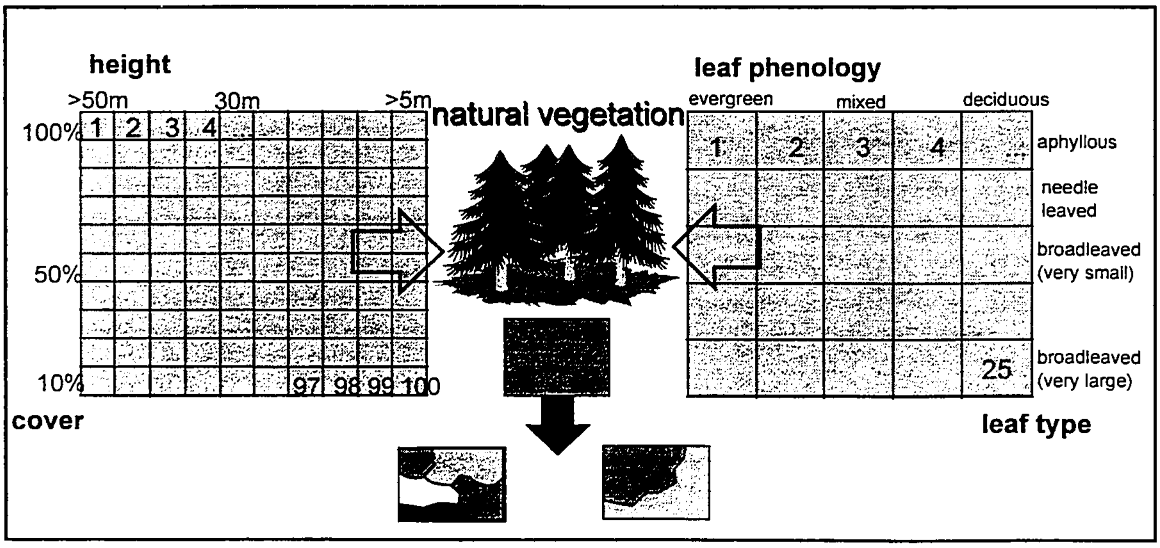
Very often the systems contain a number of classes which due to their interrelation and hierarchical structure appear to be a proportion of a broader set of classes. Thus, these types of systems are mere legends. The characteristic of legends is that only a proportion or subset of the entire range of possible classes is described. The disadvantage of having a legend is that the user cannot refer back to a classification system that leads to the impossibility of making inter-comparisons with other systems.

3.3. Problems related to lack of clear definition of the underlying common principle

An underlying common principle has often not been defined in land cover classifications. A mixture of different features is used to define a class, especially features such as climate, geology and land form (e.g. in the word tropical rain forest the term "tropical", which usually relates to climate, is used to describe a certain floristic composition). These factors influence the land cover but are not inherent features of it. This type of combination is frequently found and is often applied in an irregular way without any hierarchy. This may lead to confusion in the definition of the class.

Classification of vegetation using the diagnostic criteria of "height" and "cover" will lead to a different perspective of the same feature compared to the use of "leaf phenology" and "leaf type" (Figure 1). It is therefore important to come to a basic understanding of the criteria to be used as underlying principle for land cover or land use description.

Figure 1: Example of description of a land cover using a different underlying principle.



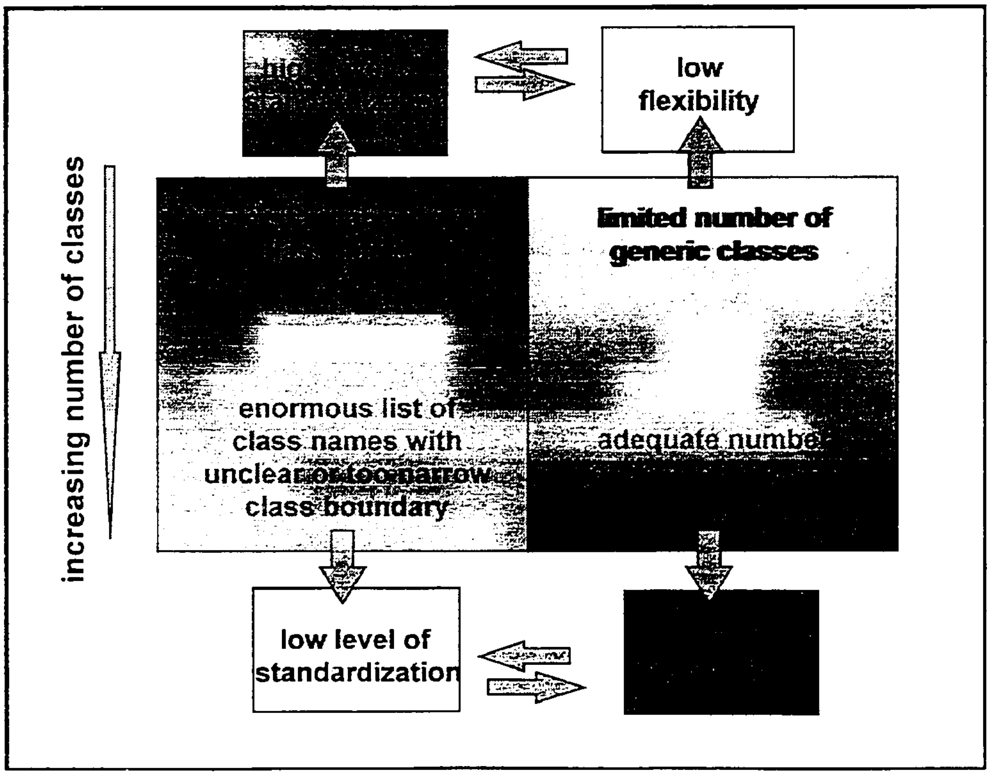
3.4. Problems related to a-priori classification systems

Often an a-priori classification system is used in which classes are arranged. However, the use of such a classification assumes that all possible classes any user may derive, independent of scale and tools used, are included in the system (Figure 2). Having all classes pre-defined in the system is the intrinsic rigidity of a-priori classification. The main advantage, though, is that it is the most effective way to produce standardisation of the classification results between user-communities. The disadvantage is that in order to be able to describe in a consistent way any land cover occurring anywhere in the world one needs an enormous amount of pre-defined classes. Such a system should be flexible in the sense that any occurring land cover should be accommodated. However, how can one introduce this type of flexibility using the "classical" approach of class names and descriptions.

By increasing the number of classes in an a-priori system, the problem arises of how the users will find their way through a "jungle" of class names. Furthermore, this situation aggravates the standardisation, namely that every user may have a slightly different opinion on how to interpret some classes because the class boundaries between classes will be based on very slight differences. The wrong, or different, designation of the same land cover feature to different classes will affect the standardisation process that is one of the main objectives of the classification system. Finally, the attempt to harmonise will fail. The a-priori classification approach seems a vicious circle: if one attempts to create this type of classification as a tool for standardisation, one is obliged to fit the enormous variety of occurring land cover classes in a limited number of more "generic" classes. If one wants to try to create more classes, thereby attempting to minimise this problem, one will increase the danger of having a lack of standardisation, which was the very basic principle used as starting point.

The above illustrates that there is not as much compatibility between classification systems, or between classification and legend, as may be desired in an ideal situation. There are numerous inconsistencies in definition of classes, class boundaries, in the use of threshold values, etc. However useful the current classification systems may be, the above hampers the possibility of the use of such classification results by a large audience for a broad range of applications. In the context of developing a new system it is fundamental to identify the criteria to which any classification, to the extent possible, should adhere (box 1).

Figure 2. The apparent contradiction between an a-priori classification and flexibility.



Box 1. General criteria for a classification.

General Criteria for A Classification:

- be comprehensive, scientifically sound and practically oriented.
- meet the needs of a variety of users (not single project oriented nor a sectoral approach); users may use only a subset of the classification and develop from there according to their own specific needs.
- could serve as a common reference base. It could serve as a system for inter-comparisons of classes derived from different classifications.
- be a flexible system that can be used at different scales and at different levels of detail allowing cross-reference of local/regional with continental/global maps without loss of information.
- be able to describe the complete range of land cover features (e.g. forest and cultivated areas as well as ice and bare land, etc.). Each class boundary definition must be unambiguous and unique.
- be adapted to fully describe the whole variety of land cover types with the minimal set of classifiers necessary (the least classifiers are used in the definition, the less the error expected and the less time and resources necessary for field validation).
- a clear and systematic description of the class exists. The diagnostic criteria used to define a class must be clearly defined: pure land cover classifiers (e.g. structural physiognomic) versus environmental classifiers (climate, landform and altitude). The latter influence land cover but are not inherent features.

4. Development of a new approach

The common integrated approach initiated by FAO defines land cover as the observed (bio)physical cover on the earth's surface, but in addition to this it is pointed out that a land cover must be considered as a geographically explicit feature. Land is a basic source of mass and energy throughput in all terrestrial ecosystems, land cover and land use represent integrating elements in sustainable economies. The world ecosystem productivity is mainly governed by primary production. Land cover is the expression of human activities and as such changes with modifications in these activities. Therefore, land cover as a geographically explicit feature may form, thus, a reference base for other disciplines such as land use, climatic and ecological studies (Di Gregorio & Jansen, 1996; FAO, 1997).

The approach to create a standardised, hierarchical, consistent, a-priori classification system containing systematic and strict class boundary definitions leads to the basic requirement of having to increase the flexibility in the classification system. In this context flexibility has two different meanings. First of all, flexibility should address the possibility of the classification system to describe and accommodate the whole variation of existing land cover as described above. At the same time, however, flexibility should adhere to the strict class boundary definitions that should be unambiguous and clear. Secondly, the classes in such a system should be as neutral as possible in order to answer to the needs of a wide variety of end-users.

Many current classification systems are not suitable for mapping (and subsequently monitoring) purposes. The integrated approach considers the clear boundary definition between classes essential. Furthermore, the use of diagnostic criteria and their hierarchical arrangement to form a class should be a function of the mapability, that is the ability to define a clear boundary between two classes. Hence, diagnostic criteria should be hierarchically arranged in order to assure at the highest levels of the classification a high degree of geographical accuracy.

How to increase the flexibility of an a-priori classification while maintaining the principle of mapability and aiming at standardisation? These prerequisites can only be accomplished if the classification has the possibility to generate a high number of classes with clear class boundary definitions. In other words, it should be possible to delineate a larger number of classes in order to suit the enormous variation of land cover features, while maintaining the clear distinction of boundaries between classes. In the current classification systems this possibility of clear distinction of classes is hampered by the manner in which these classifications are set up. Differences between classes can only be derived from class descriptions. Therefore, it would be very difficult for the user to distinguish between such classes just based upon class names or unsystematic descriptions as is the case with most of the current classification systems.

One of the basic principles adopted in the new approach is that a given land cover class is defined by the combination of a set of independent diagnostic attributes, the so-called classifiers. The increase of detail in the description of a land cover feature is linked to the increase in the number of classifiers used. In other words the more classifiers are added, the more detailed the class. The class boundary is then defined either by the different amount of classifiers, or by the presence of one or more different types of classifiers. Thus, the emphasis is not given anymore to the class name, but to the set of classifiers used to define this class.

The straightforward application of using a set of independent diagnostic criteria is hampered by two main problems. First, land cover should describe the whole observable (bio)physical environment and is, thus, dealing with a heterogeneous set of classes. Evidently a forest is defined with a set of classifiers that differ from those to describe snow-covered areas. Therefore, the definition of classes by classifiers should not lead to the use of an impractical set of classifiers. Instead of using the same set of classifiers to describe such heterogeneous features, in the new approach the classifiers are tailored to each land cover feature. According to the general concept of an a-priori classification, it is fundamental that all the combinations of classifiers must be created in the system. By tailoring the set of classifiers to the land cover feature all combinations can be made without having a tremendous number of theoretical combinations of classifiers that would not have any relation to specific land cover features. Secondly, two distinct land cover features having the same set of classifiers to describe them may differ in the hierarchical arrangement of these classifiers in order to ensure a high geographic accuracy.

5. The land cover classification system

5.1. Design and Concepts

Addressing the issues mentioned above without incurring the difficulties mentioned, is the objective of the design of the Land Cover Classification System. Land cover classes are defined by a series of classifiers, but due to the heterogeneity of land cover and aiming at a logical and functional hierarchical arrangement of the classifiers, certain design criteria have been developed.

The Land Cover Classification System is designed according to two main phases (Figure 3):

1. a higher Dichotomous Phase where a subdivision is made to define eight major land cover types:

- Cultivated and Managed Terrestrial Areas
- Natural and Semi-Natural Terrestrial Vegetation
- Cultivated Aquatic or Regularly Flooded Areas
- Natural and Semi-Natural Aquatic or Regularly Flooded Vegetation
- Artificial Surfaces and Associated Areas
- Bare Lands
- Artificial Waterbodies, Snow and Ice
- Natural Waterbodies, Snow and Ice

from which point onwards,

2. a lower so-called Modular-Hierarchical Phase starts. In this phase the creation of a land cover class is based on the combination of a set of pre-defined classifiers. These classifiers are tailored to each of the eight major land cover types.

Three classifiers are used in the Dichotomous Phase, that is primarily vegetated, terrestrial and artificiality. These three classifiers have been hierarchically arranged. However, independent of this arrangement one would reach the same eight major land cover types, they would only appear in a different sequence. The hierarchical arrangement is thus unimportant in this Phase.

5.2. Formation of Classes and Class Descriptions

The tailoring of classifiers in the Modular-Hierarchical Phase allows the use of the most appropriate classifiers to define land cover classes derived from the major land cover types and at the same time reduce the total number of impractical combinations of classifiers. This results in a land cover class defined by:

- a Boolean formula showing each classifier used (all classifiers are coded);
- a unique number for the GIS; and
- a name that can be the provided standard name or a user-defined one.

6. The software program

Because of the complexity of the classification and the need for standardisation, a software program, of which the beta version has been developed, will assist the interpretation process. This software program facilitates not only the standardisation of the interpretation process but also contributes to its homogeneity. Despite the huge number of classes one can generate, an interpreter is dealing only with one classifier at a time and each class is built up by stepwise selection of each classifier. So one does not need to scroll inside a big list of class names to select the appropriate one, but one is simply aggregating a number of classifiers to derive the class. This will assist in reducing heterogeneity between interpreters and with interpretations over time.

The software program consists of four modules:

1. Classification: provides a standardised approach for classifying land cover classes.
2. Legend: provides the possibility to save, edit and addition of user-defined attributes as well as storage of the legend, its standardised class descriptions and used classifiers.
3. Field Data: provides structured storage for field observations according to a minimum, customised or full list of items selected for description (will be included in release 1.0).
4. Translation: provides the possibility to correlate and inter-compare classifications and legends using the Land Cover Classification System as a reference base.

The next step will be to develop a reference base for land use, being based upon the arrangements, activities and inputs people undertake on the land. At present efforts are being made to develop a methodology to describe land use in a comprehensive and consistent way taking a multi-user oriented approach. This should result in a first approach for a land use classification with a structured hierarchical format offering a high degree of flexibility and the ability to accommodate different levels of information. This classification is to be linked with the Land Cover Classification System.

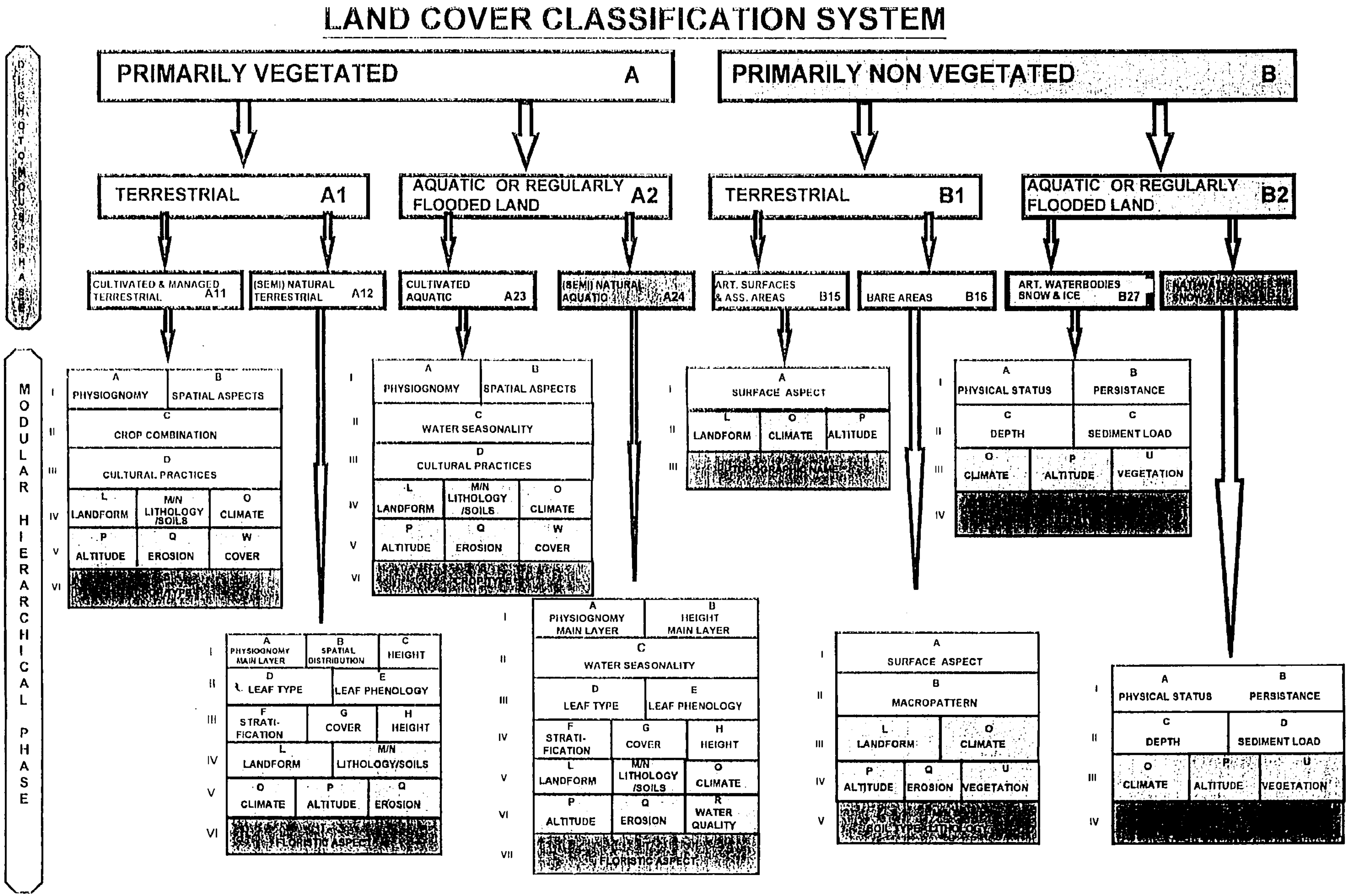


Figure 3. The Land Cover Classification System, its two Phases, classifiers and attributes.

7. Conclusions

The developed classification system is a real a-priori classification system in the sense that, for the classifiers considered, it covers all their possible combinations. Furthermore, a given land cover class is clearly and systematically defined making a clear differentiation or use of the classifiers as follows:

- pure land cover classifiers;
- environmental attributes (e.g. climate, land form, geology, etc.);
- specific technical attributes (e.g. Floristic Aspect for (Semi) Natural Vegetation, Crop Type for Cultivated Areas).

Therefore, all classes within the system are unique and unambiguous. The result is that the system is internally consistent and the systematic description of the class is a basis for objective and replicable classification.

The classification system is truly hierarchical. The class hierarchical arrangement is a basic component of the mechanism for class formation. The difference between a land cover class (at a more general level) and a further subdivision of it, is given by the addition of new classifiers (or a more detailed level of the one forming the previous class). The more classifiers used, the greater the detail of the defined land cover class.

The classification may be used as reference base for two main reasons:

- the classification contains a large number of classes, that is all classes of existing classifications and legends can be readily accommodated; and
- the emphasis is given to the set of classifiers, instead of to the class name, which allows easy correlation even when a range of values, for instance percentage of cover of a given life form, do not fit with the proposed one. The dissimilarity is clear and remains limited to only a portion of the classifiers forming the class. However, the cases in which a class cannot be correlated should be extremely rare due to the different levels and detail of classifiers.

The classification system is designed to collect information at a variety of scales, from small- to large scale, independent from the tools used. The design allows easy incorporation and integration into (geographic) information systems in order to give the user the ability to manipulate the results in various ways. The manner in which classes are built up facilitates overlay and query procedures.

The present classification system considers two types of final users: (1) the ones that use the classification to built up the database (the user essentially doing the data collection); and (2) the ones that are the final users of the created database. The system obliges the first user to follow specific rules in the combination of classifiers in order to assure a standardisation and comparability of the data set. The second user, however, is free in re-combination of the used classifiers and in re-aggregation of the original data. Because the class definition is linked with the classifiers' Boolean Formula this process becomes relatively easy. The possible re-combinations of classifiers are enormous and some combinations may be illogical, but this relates to the concept of multi-users with each one having very specific needs that are difficult to forecast.

The classification system facilitates the standardisation of the interpretation process contributing to its homogeneity. Despite the huge number of classes the interpreter can generate to suit the whole variety of land cover, one is dealing only with a limited number of classifiers. One must simply aggregate a restricted number of well-defined classifiers. This will reduce heterogeneity between interpreters and with interpretations over time, thus adding to the overall consistency of the final product.

A new procedure of accuracy analysis is possible with the classifier approach. Until now the accuracy analysis was carried out for single classes, from now on it will be possible to assess the accuracy not only for the entire class but for each of the classifiers forming a specific class. This will give a high flexibility to the establishment of final land cover classes. For example, if a class formed by five classifiers shows an accuracy too low according to the established general standard, the influence of each individual classifier to the overall class accuracy can be analysed. If in this example the last classifier has a much lower accuracy than the previous four, this last classifier can be eliminated in order to have a final class with less detail but with an appropriate accuracy according to the standard.

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SESSION 4

IMPROVING COORDINATION OF TECHNICAL APPROACHES

THE IMPLEMENTATION OF ONE SYSTEM: THE CASE OF SIAGRO

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1. Introduction

In Portugal, the system of annual agricultural statistics is essentially based on the collection of data from surveys among farms, the use of information sources of an administrative nature and on the opinions of regional or national experts connected with the agricultural sector.

In any event, the bulk of the data is derived from information provided by farmers, which implies - in the case of surveys – the availability of an updated register of farms. It is in this context, reinforced by the specific characteristics of agriculture in Portugal, i.e. the significant number of small holdings, the age and level of education of farmers, as well as the difficulty in maintaining an updated register, that alternative methods could bring significant gains in terms of the collection of information and reliability of data.

The use of aerial surveys in agricultural information systems and the more recent introduction of remote sensing data (aerial photography and satellite imagery) could lead to an improvement in the current system and enable observation to be extended throughout the territory.

Portugal carried out a whole series of projects connected with the use of remote sensing techniques for agricultural statistics under the MARS and SPOT5 programmes. These studies, though experimental or pre-operational in nature, have enabled the development of a technical and methodological reference framework from which it is possible to structure and plan a system at regional or national level.

The SIAGRO (Agricultural Information System for the Ribatejo e Oeste) is a project aimed at bringing an agricultural information system into operation that meets the needs of agricultural statistics programmes, while enabling analysis of the evaluation/development of land cover and use.

This presentation will cover the general organisation of the project, the technical choices and the main problems encountered.

2. Organisation of the project

In view of the requirements of the project in terms of development and operationalisation, the knowledge required and the nature of the tasks to be performed, a working team composed of the National Statistical Institute (INE), the National Geographical Information Centre (CNIG), the Ministry of Agriculture, Rural Development and Fisheries (MAD) and the University of Lisbon (UL) has been formed.

The INE is responsible for the coordination and methodological definition, with the University of Lisbon providing specific support for methodological questions; the CNIG is responsible for preparation of the orthophotographic base, and the Ministry of Agriculture conducting the surveys.

3. Execution of the project

3.1. Preparation of the cartographic base of the survey

The aerial photographs used for this project date back to 1995. The average scale is 1:40,000 using a Zeiss chamber RMK TOP 15/23. The films used are KODAK CIR 2443 "false-colour" films.

The CNIG makes it possible to use these aerial photographs, providing the technical homogeneity of production and cover for the whole national territory.

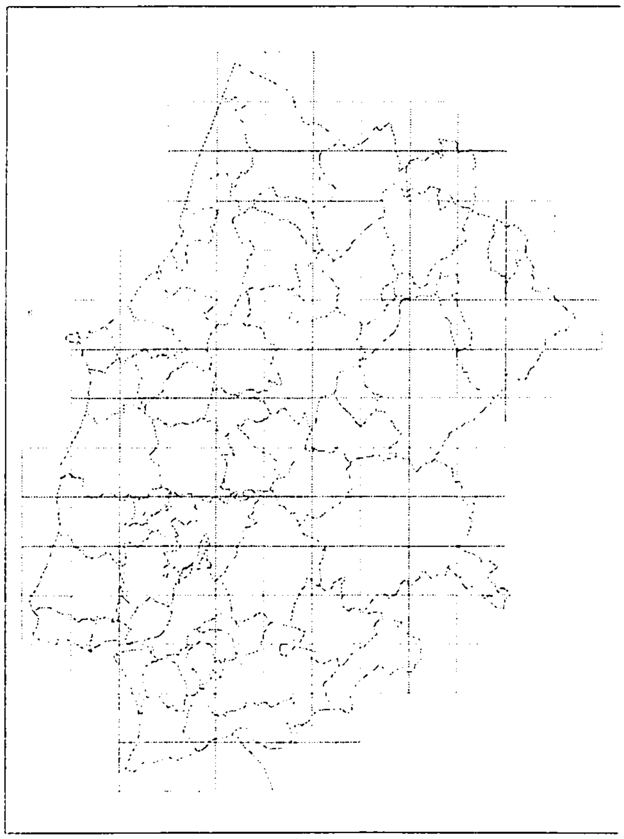
Slides are transformed into "raster" format using a Zeiss PS1 scanner, with 25 micron steps, in three bands (infra-red, red and green). Orthorectification is carried out with the aid of digital terrain model at 1:25,000.

This option enables the execution a high-quality base, with expected geometrical accuracy of 2.5 m (RMS) and a resolution of 1m. This type of orthophotographic base enables the survey points to be located unambiguously and provides field documents of a high quality. Therefore, unlike the TER-UTI system (a survey on land use carried out by the French agricultural statistical services) there are no limitations in terms of how precisely the points can be located: the 9m² points of the TER-UTI system are justified by the scale and the preparation method of the documents used for locating the points.

In this case, with a geometrical resolution of 1m, any point can be located unambiguously, with the exception of objects with a resolution below 1 metre.

3.2. Sampling plan

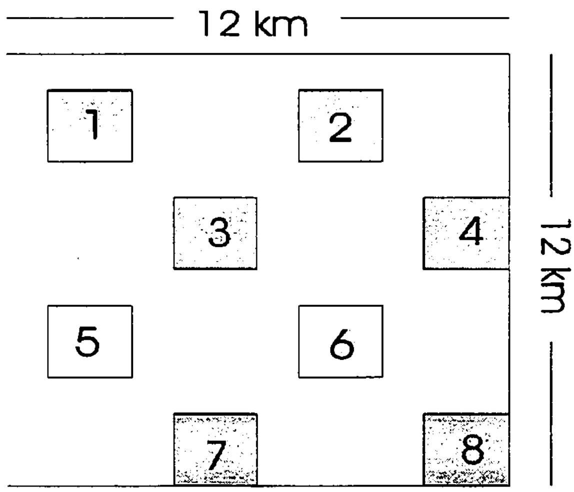
The sampling plan used for the Ribatejo e Oeste region is based on the system used by the SCEES in France: 12x12 km cells are superimposed on the map of the region, as the graph below demonstrates:



Ribatejo e Oeste region - 12x12 km cells

Inside each cell, eight square segments 2x2 km are systematically defined according to the following procedure.

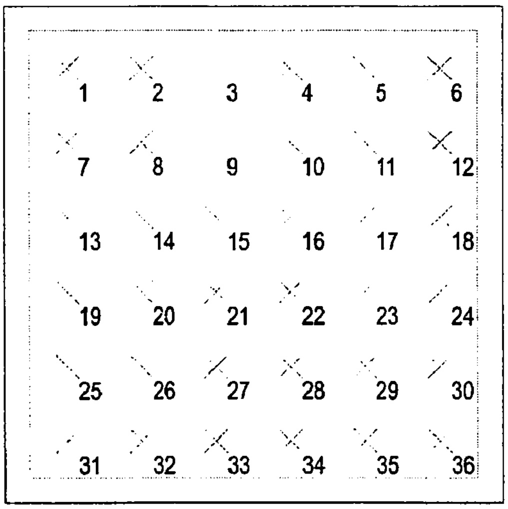
All eight segments, though already a representative sample of the total surface area of the territory, correspond to this end to the observation universe, the sample of segments observed being selected from this universe.



Location of the segments in a 12x12 km cell

The segments corresponding to positions 1, 2, 5, 6, which form the observation units for the SIAGRO project, are then selected. The segments corresponding to the positions 3, 4, 7 and 8 will be observed if the survey needs to be backed up.

Each segment corresponds to a numerical orthophoto map on the scale of 1:5000, format 50x50 cm, on which 36 observation points are defined, 300 m apart in both directions of the cartographic map (North-South and East-West).



Location of the observation points in a segment

The Ribatejo e Oeste region has a surface area of 1.200,000 hectares, the sample is set at 360 orthophoto maps resulting in 12 960 points to be observed.

3.3. Nomenclature

Defining a nomenclature is essential to develop an information system (agricultural, territorial or other).

Since a nomenclature is no more than a list of categories used to organise information, it is easy to understand that the options taken for its development condition and determine the possible reading using the same basic information.

Portugal does not have a nomenclature of its own on land cover/use. The main nomenclatures used are those associated with statistical surveys of the type used in agricultural censuses.

The nomenclature that must be defined for SIAGRO must take account of the principles of construction underlying the nomenclatures, the objectives of the project, the methodology used, and enable the results to be compared with statistical data based on existing classifications.

The intention is therefore to structure a nomenclature that is universal, formed so as to allow specific characters of a regional nature to be included, or to take account of new situations, without calling into question the architecture of the nomenclature.

From an organisational viewpoint, the nomenclature will be made up of two parts. One will correspond to the physical coding, aimed at describing the biophysical categories of land cover; the second, of a functional nature, will correspond to land use from a socio-economic viewpoint.

3.4. Field work

The surveys will be carried out by investigators specially trained for this purpose and supervised by regional technicians from the Ministry of Agriculture.

Aspects relating to the training of the investigating teams are essential to test the suitability of the methods and to provide reliable results.

Investigators should be able to locate unambiguously the observation point and assign to it a physical and functional code, recording this information in a suitable form.

The field documents necessary to carry out this work are: a military map at 1:25,000, an orthophoto map indicating the location of the observation points, a nomenclature and an observation sheet. Any additional information enabling *a posteriori* better nomenclature of the land cover/use of the observation points will be recorded in a notepad.

3.5. Processing of information

The observation sheets will be processed in computerised form, using a computer application allowing the result to be given for the various levels of organisation, with usable statistical parameters to evaluate the reliability of the results.

4. Questions remaining open

Although the methodology used for this project is similar to that developed by the SCEES in France, the situation in Portugal will involve a number of adaptations. The main aspects to be brought to our attention and for which solutions will need to be provided are as follows:

- Sampling plan:

  The use of the selected method assumes that the 36 points to be observed in each segment correctly express the variability of land cover/use within each segment. In other words, the sample is representative of the total territory and minimises the variance associated with the estimates.

In view of the different agricultural situation in Portugal, particularly regarding land tenure (the size of plots) and aspects of land cover (crop combinations, crops under cover, etc.), the definition of the sampling plan and any adaptations it may have will be the subject of an analysis.

- Observation window (what size for the observation point?)

  In the French system, the observation window, i.e. the size of the observation point, is $9m^2$. However, in view of the agricultural systems in Portugal, the size of the observation window should be revalued. Indeed, if we find ourselves in a plot with wheat under cover of cork-oak or olive trees, the $9m^2$ limit could lead to the wheat alone being coded, with a loss of information. Recognition of these situations could entail enlarging the observation window.

- Observation in real time

  The method used identifies the land cover/use of the territory at the time of observation, unlike the surveys conducted among farms.

  Therefore, the choice of when to carry out the observation according to the crop season is essential for the provision of agricultural statistics. Moreover, it must be remembered that a single observation rarely allows the simultaneous collection of all forms of agricultural land cover. This is the case for successive fodder crops, for example, which will never be properly represented unless a specific mechanism is included in the method. In Portugal, successive fodder crops are significant and should be the subject of special treatment.

- Nomenclature

  The French nomenclature does not take account of frequent situations in Portugal, in particular crops under permanent crop cover or under forestry cover and crop combinations. One of the objectives of the project will also be to develop a nomenclature adapted to the situation in Portugal, which may, nonetheless, be compatible with those of the other countries and those of other statistical surveys.

THEMATIC MAPS AND STATISTICS

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1. Introduction

The paper deals with the links and the relationships between thematic maps and statistics. These links have become closer in the last years, due to the availability of remote sensing data and Geographic Information Systems (GIS).

Thematic maps are very useful for the production of agricultural or environmental statistics, particularly for large territories; in fact, a good map can be a precious base for estimating parameters of spatial variables, through area frame survey designs. When land cover maps are produced for statistical purposes, their main role is the creation of an area frame (based on physical or regular limits) and of a stratification to improve estimate precision. Land cover maps created to be the basis for area frame surveys do not require many different classes. Remote sensing is very useful for this application and the cost is in general not particularly high. When creating the stratification, it is very important to take into account the area sampling unit (segment) size and the number of segments that can be allocated in the area of interest; thus maps created for area frame surveys are generally different from maps produced for cartographic purposes and much cheaper.

Sometimes, maps or GIS layers are used as auxiliary variables to improve the precision of statistical estimates; a common example is the automatic classification of pixels of remote sensing images. The usefulness of such auxiliary variables is a function of the correlation with estimated variables.

Maps can also be useful to give an idea of the spatial distribution of estimated variables, but should not be used as a direct tool to estimate spatial variables, since there are important risks in this approach: photo-interpretation and automatic classification errors tend to be systematic, and there is no compensation between commission and omission errors. Another source of bias comes from the fact that a smallest mapping unit has to be adopted.

On the other hand, statistics has an important role in the production of land cover maps, since maps can really be used if an evaluation of their accuracy, based on statistical criterion, has been carried out. Accuracy is generally evaluated on the basis of a comparison with a representation of reality which is considered more accurate than the map that has been produced. To reach good accuracy, it is important to control all the phases of the map production process; if a database instead of a map is produced, more aspects have to be controlled. Thus, a detailed quality control has to be carried out for all the phases of the process.

In this paper, some considerations on outlined subjects are proposed. The presentation of statistical results for spatial variables is not treated.

2. The role of thematic maps in area estimation

If one's purpose is the estimation of the area or of the area change of some land covers, a thematic map can contribute in several ways. The main use is in area frame construction and stratification. In fact, stratification is the most widely used method to improve the precision of estimates. The stratification of an area frame is generally based on a land cover map, often created on the basis of photo-interpretation of remote sensing images or of aerial photos.

When choosing the method to create a land cover map to be used in stratification, it is very important to take into account the sample size. In fact, on the one hand, a very simple stratification can produce low efficiency; on the other hand, a too detailed stratification can need a sample size not compatible with the budget of the project, since all strata have to be represented in the sample. Thus, the stratification should be the result of a balance of the desire to create very homogeneous strata and the budgetary constraints.

The segment size also has an important role. When the land cover map is too detailed compared with the segment size, the size of the polygons that constitute the strata is not a multiple of the target segment size. Consequently, if the area frame is based on physical boundaries, the real segment size varies considerably and the estimator variance increases. If an area frame with regular segments is adopted and the land cover map is too detailed, the stratification is not efficient, due to the large number of segments with different land cover classes.

If the land cover map is extremely detailed, a possible solution could be taking into account this fact in the sample design. Particularly, it is possible to adopt an unclustered point sample design. Effectively, only a small circular or rectangular area is observed around each sampling point. However, such a sample design does not generally maximise the precision of estimates under a fixed budget, since high average travelling costs don't allow to survey a high number of points.

Sometime, unclustered point sampling is performed to identify farms for the ground survey. In this case, each point corresponds to a farm; farms can be selected more than once and with a probability proportional to size. This sample design is efficient only if the spatial autocorrelation between farms in a stratum is very high. On the other side, travelling costs are high and, should the survey be based on farmers interviews, if a farmer cannot be found or refuses to co-operate, the travel is useless since a missing datum corresponds to the point. Finally, if farms are large, a farm can belong to different strata.

Where points are clustered in squares (as in the French TER-UTI system), the problems found in the use of a stratification based on a too detailed land cover map are very similar to the ones described for area frames based on regular grids.

3. Stratification of an area frame based on permanent physical boundaries, using land cover maps not created on purpose

If a land cover map is available, although not created for statistical purposes, budgetary constraints can suggest to use it for the stratification of an area frame. Indeed, if an area frame based on physical boundaries has to be created, segments, and consequently primary sampling units, need to have permanent and well recognisable physical boundaries. If a land cover or a land use map has not been created on purpose, its strata do not necessary present permanent physical boundaries. Thus a substantial work has to be done in order to force the strata borders to follow permanent physical boundaries.

Where primary sampling units have already been outlined using a land cover map created on purpose and another map can give non-redundant information, then the latter information layer can be overlaid on the primary sampling units map and the intersection of the two maps gives the final stratification. It is important to remember that primary sampling units cannot be split, thus the intersection of the two maps has to be modified in order to assign each whole primary sampling unit to one stratum.

An experiment was carried out in some Italian regions (Marche, Campania and Veneto) by ITA Consortium (Consorzio ITA, 1992, 1993) for the estimation of main crop areas at province level. Primary sampling units were outlined through photo-interpretation of SPOT satellite images and the second kind of information utilised was a cluster of Municipalities, based on data of the Agricultural Census carried out in 1990.

4. Stratification of an area frame based on a regular grid, using land cover maps not created on purpose

When an area frame is based on square segments without permanent physical boundaries, a square grid is overlaid on the land cover map. Since segments have theoretical and not physical limits, strata are not forced to follow physical boundaries; thus the use of a land cover map not created on purpose is easier. The attribution of each segment to a stratum is made according to a specific criterion. In any case, if the land cover map has many small polygons, then a very large number of segments will have a mixed land cover and the relative efficiency of the stratification is poor. Very often, for agricultural estimates, an efficient and low cost stratification is based on percentages of agriculture.

For the attribution of segments to strata, the criterion of majority is often used; in essence, the stratification is adapted to the sampling grid. Each square of the sampling grid is simply attributed to the stratum with the highest share, but part of the information in the stratification is lost. Strata limits that are at the same time regional borders should not be adapted to the sampling grid, specially in the case of coastal lines, since that would mean removing pieces of coast and adding pieces of sea. A better approach is keeping only the coastal pieces of segments and to remove the pieces of sea. The result is that coastal segments are not squares and have a smaller size. If the percentage of the land cover types is estimated, the increase of variance due to varying segment size of a small number of segments is not relevant.

Another way is to keep only the largest piece of the segment in one stratum and discarding all other pieces. This approach is not supported by a theoretical background, but just by the intuitive assumption that small pieces removed are compensated by the increase of weight of large pieces that count as much as a complete cell. However this presumed compensation has not been sufficiently tested in real examples.

In the European Union, using the CORINE Land Cover map, the various options described have been tested (see Gallego et al. 1998), together with another approach: splitting border segments into pieces that belong to different strata. This option keeps more strata information, but may be complex to manage. Estimates of the different strata are not independent, since the selection of segments is not independent in the different strata; hence this is not properly a stratification and the total variance cannot be calculated simply combining the estimator variances of the different strata; covariance should be taken into account. The latter approach has given moderate values for the relative efficiency of stratification, probably due to the poor relative location of ground survey units and strata limits. The large piece approach has given the best relative efficiencies, a bit higher than the efficiencies obtained with the majority criterion.

5. The use of land cover maps for determining an area frame sample design

One of the crucial points in area frame sample design is the determination of the segment size. If a previous survey has been carried out for similar variables, then these data can be used to improve the sample design (Carfagna and Gallego 1995 a, b). One of the ways to use previous data is calculating the correlograms for each variable observed, on the basis of a grid overlaid on the map. An analysis of correlograms gives many suggestions for the optimum segment size and for the number of stages to adopt to maximise the precision of estimates under a fixed budget and a given cost function (see Carfagna 1998).

In a similar way, where data have not been collected by a previous sample survey but a land cover map with classes similar to the ones to be estimated by the sample survey is available, then this kind of information could be used to calculate correlograms. With this approach, the results can be influenced by the fact that the correspondence between the classes of the land use map and the variables of interest is not perfect; usually, the classes of the land cover map are aggregations of the variables of interest; thus the sample design is optimised for these aggregations.

Land cover maps can be used as previous survey data only if the difference between the scale of the map and the scale of data acquisition in the sample survey is not too big. In essence, if a sample survey with ground truth collection is foreseen, then the smallest mapping unit of the land cover map should be small. Where the data acquisition of the sample survey is based on photo-interpretation of satellite images, then less detailed maps could be used.

Sometimes, correlograms have different trends when calculated on the basis of grids of different sizes (Arbia 1986); thus it is better to calculate correlograms for different grid sizes and to compare the results. If the trend doesn't change, correlograms can be used to determine the optimum sample design.

The use of CORINE Land Cover map for determining an optimum sample design is being tested now in the FMERS project (Forest Monitoring in Europe with Remote Sensing) of the Joint Research Centre/CEO.

6. Thematic maps used as auxiliary variables for area estimation

Thematic maps can be used as auxiliary variables to improve the efficiency of estimates. The regression estimator is generally used for this purpose (Cochran, 1977, Chhikara et al. 1986, Consorzio ITA 1987, González and Cuevas 1993, Gallego et al. 1993). The land cover generally involved is the classification of a satellite image, which is often performed by maximum likelihood discriminant analysis (Anderson, 1984).

The use of remote sensing data as auxiliary variable through the regression estimator allows us to improve the precision of estimates based on a ground survey carried out on a sample of segments with physical or theoretical boundaries. In the latter case, some phases of the procedure are easier, since segments have a regular shape, so as the pixels of a satellite image.

If the precision to be reached for the estimates is fixed, then the regression estimator can be used to reduce the amount of ground data to be collected. On the contrary, if sample size is fixed, the regression estimator allows to improve the estimates' precision.

The crucial point is the cost effectiveness of the method. The use of the regression estimator for remote sensing data has been studied for a long time in the framework of Regional Inventory action of the MARS project. It is operational but not cost effective due to the costs of satellite images (see Taylor et al. 1998). A completely different evaluation is given by ITA Consortium (Giovacchini and Brunetti, 1992), which states that if the procedures of satellite data acquisition, correction, enhancement and so on are optimised and automated in an operational project, then the use of the regression estimator with remote sensing data is cost effective; moreover the optimisation of the procedure has an influence also on the linear correlation between remote sensing data and the ground truth, which affects the efficiency of the regression estimator.

Anyway, since the only problem concerning the use of the regression estimator for remote sensing data is the cost, it's probable that in the not too distant future it will become cost effective, since the cost-quality ratio of computers and satellite images is decreasing.

7. Other ways to use land cover maps for area estimation

Many other ways to use land cover maps to produce agricultural and environmental statistics can be conceived. We mention only some of them. One way is creating an index of agriculture intensity for crop estimation, or ecological sensitivity or forest complexity and so on, for environmental variables. These indexes should be calculated for each cell of a regular grid overlaid on the land cover map. Then a sample of segments can be selected with a probability proportional to the adopted index.

If, for reasons of economy, the information necessary to calculate the index can be collected only on a sample of the cells of the regular grid a two-phase sampling can be set up. The second phase is a sub-sampling with a probability proportional to the index.

An experiment carried out on data collected in Spain in 1992 has shown that proportional probability sampling is very efficient when the ancillary information is highly accurate, but can be disastrous if a moderately high amount of errors appear in the ancillary information. 8017 segments on which ground truth was collected in Spain in 1992 have been used as the whole population, from which a sub-sample of 80 segments has been selected with probability proportional to total arable land observed on the 8017 segments in 1992. A simulation has been carried out to estimate the relative efficiencies (compared with simple random sampling) for main crop area estimates and for crop area changes. Values obtained are high: minimum value 2.39, maximum value 7.07, mean 3.91 and median 3.08 (Carfagna and Gallego, 1998). Using CORINE Land Cover to calculate the index of agricultural intensity and selecting the subsample of 80 segments with probability proportional to the index, the values of the relative efficiency are very different: most of them are below one, minimum value 0.01, maximum value 3.25, mean 0.65 and median 0.43. Better results have been reached transforming the index into four strata (Gallego et al. 1998).

Land cover maps are often used for excluding some areas from ground surveys. If crop estimates have to be produced, points or segments are not allocated in non-agricultural strata. In fact, in some cases, like in very high mountains, this is an efficient practice; but in most cases, it is risky, since very often agricultural fields are present in strata that have been identified as "non agricultural". A study has been carried out using CORINE Land Cover to identify "agricultural" and "non agricultural" areas. 2357 of the 8017 segments surveyed in Spain in 1992 turned out to be located in the areas classified as "non agricultural" by CORINE Land Cover. Estimates performed using only segments in agricultural stratum, are much lower than the ones obtained using all the segments. A bias around 4% has been detected for most crops in 1992 and in 1993, an unacceptable bias for crops estimated with a coefficient of variation of 1% or 2% (Gallego et al. 1998).

8. Pixel counting is a biased estimator of spatial variables

Land cover maps are generally produced through classification or photo-interpretation of satellite images or aerial photographs. These maps should not be used in general as a direct tool to estimate spatial variables, since there are important risks in this approach, although it may be tempting because all the territory is observed and thus there is no sampling error.

When a supervised classification is used to estimate the area covered by a land cover type in a region, the estimator generally adopted is given by the proportion of pixels classified as the land cover type multiplied by the total area of the region for which the estimation is carried out. This estimator is known to be strongly biased (Card 1982, Hay 1988, Czaplewski and Catts 1992). It produces reasonably good estimates only if spectral signatures are very clearly discriminated, for example when the area of irrigated crops is estimated on a summer image in a very dry region.

The most widely used method to produce a supervised classification is the maximum likelihood classifier (Anderson 1984). When it is used with uniform prior probabilities, large classes tend to be underestimated and small classes tend to be overestimated. On the contrary, if some information is available on the approximate proportion of the different land cover types, a proportional prior probability may be used; but in this case large classes tend to be overestimated and small classes are underestimated or even disappear.

The bias appears also where the theoretical conditions on multivariate Gaussian distribution are true, as shown by a simulation (Gallego and Carfagna 1998). Three classes with proportions p(a)=0.6, p(b)=0.35 and p(c)=0.05 were considered. Each pixel was described by two radiometric values (channels). 10000 training pixels and 10000 test pixels were generated with independent Gaussian distributions. A maximum likelihood classification with uniform priors was performed. It correctly classified about 56% of the pixels, which is a rather mediocre, but frequent, result in remote sensing.

Then, pixel counting was used as area estimator, class "a" was underestimated by 47%, and class "c" was overestimated by more than 400%. Then priors proportional to the real proportions of the classes were used; although this information is not available in real applications. 71% of the pixels were correctly classified; class "a" was overestimated by 25%, class "b" was underestimated and "c" practically disappeared in the classification.

Let us recall some definitions to clarify the risk of bias. If λ_{AA} is the number of pixels of class A that have been classified or photo-interpreted as A

$$\text{Commission error } \varphi_A = 1 - \frac{\text{pixels of } A \text{ correctly classified}}{\text{total pixels classified as } A} = 1 - \frac{\lambda_{AA}}{\lambda_{+A}}$$

$$\text{Omission error } \psi_A = 1 - \frac{\text{pixels of } A \text{ correctly classified}}{\text{total pixels of } A \text{ (ground truth)}} = 1 - \frac{\lambda_{AA}}{\lambda_{A+}}$$

The bias of a pixel counting or a photo-interpretation measurement estimator is:

$$\text{relative bias} \quad b_A = \frac{\lambda_{+A} - \lambda_{A+}}{\lambda_{A+}} = \varphi_A \frac{\lambda_{+A}}{\lambda_{A+}} - \psi_A$$

For example if the classification accuracy is expected to be at least 70%, commission and omission errors should range between 0 and 30% without any reason to compensate. Moreover changing classification parameters or photo-interpretation keys generally makes one type of error grow when the other decreases, so that the only way to tune for compensation is knowing a priori λ_{A+}, i.e. the area you are trying to estimate. The bias in our example will be somewhere between -30% and +1.3*30=39%. With some luck you can hope that it will be about 15% in one or another sense.

A useful rule of thumb is that the expected commission and omission errors of the observation approach selected as basic source of data for area estimation should be lower than the targeted accuracy. For example if you want to have a maximum error of 5% in your area estimation, you can use pixel counting if the expected identification accuracy is above 95%.

Another source of bias, when using a classification of a satellite image as direct source for area estimates, is given by pixel size. In case pixel is quite large, if compared with the modal size of polygons of some land covers, area estimate is seriously biased. Some land cover types represented on the territory by many small polygons could disappear although the area covered is not negligible. The rule of thumb given above must be reviewed if the image resolution is relatively coarse, i.e. if there is a considerable proportion of mixed pixels for the objects whose total area is being estimated.

9. Photo-interpretation and bias

Photo-interpretation by polygons as direct source for land cover statistics is also a risky approach. The argument of the preceding paragraph applies again: photo-interpretation errors tend to be systematic and there is no compensation between commission and omission errors, i.e. the areas of a land cover type A photo-interpreted as land cover type B are not compensated by the areas of land cover type B photo-interpreted as A. For the application of the rule of thumb above, scale considerations linked to the minimal size of units to be mapped are particularly important in this case. Let us suppose that the minimal size to be mapped is 5 ha with a boundary tolerance of 30 m. Mapping accuracy of urban may be very high (say 98%) in the sense that only in 2% of the cases the mapping specifications are not respected, but a serious bias may be introduced in area estimation if the definition of total urban area includes smaller patches or implicitly has a more restrictive boundary tolerance.

Non sampling errors are more frequent and relevant when a large area is completely photo-interpreted. Non-sampling errors can be substantially reduced through more accurate measurements on an area sample. The sum of sampling and non-sampling errors in sample surveys is often smaller than non-sampling errors in a census.

An example of some problems that can arise is given by a comparison between forest official statistics produced by ISTAT (Italian Statistics Office) in 1994 and estimates derived from CORINE Land Cover by simply measuring photo-interpreted polygons. At a regional level, a big difference is present in most regions. For nine regions the difference is above 20 %.

Some discrepancy is probably due to the different reference date: forest statistics refer to 1994 while CORINE Land Cover was produced by photo-interpretation of TM satellite images acquired in the late eighties. Definitions can also explain part of the discrepancy. Forest statistics consider "forest" all the polygons whose size is at least half hectare and where trees, when grown, have a crown cover of at least 50 % of the surface. According to CORINE Land Cover nomenclature, forest (3.1. Vegetation formation composed principally of trees, including shrub and bush understories) is given by the sum of 3.1.1. broad-leaved forest, 3.1.2. coniferous forest and 3.1.3 mixed forest; a crown cover threshold is not taken into account.

Scale and minimal mapping unit are likely sources of disagreement, as well as the existence of mixed classes. CORINE Land Cover has a working scale of 1 : 100 000 and the area of the smallest mapping unit is 25 hectares. This size of the smallest mapping unit has determined the attribution of quite a large surface of complex territory to mixed classes, such as "heterogeneous agriculture", that can include arable land, permanent crops, pastures, forest and natural vegetation, as well as some built areas. Thus it is interesting also to compare forest statistics with data derived from the land cover map produced by ISTAT by photo-interpretation of SPOT satellite images, scale 1 : 25,000. Forest category includes: broad-leaved wood, coniferous wood, mixed wood, mixed forest, with a coverage of at least 20 %; burnt areas, poplars, chestnut wood and shrub. Forest statistics show values much lower than the photo-interpretation of SPOT satellite images, for fifteen regions the discrepancy is more than 20 % and at national level it is 45 %. One reason for such a big difference is the coverage threshold.

As said before, the scale of maps has an important effect on classification and on photo-interpretation results. The comparison of forest estimates from photo-interpretation of SPOT satellite images and CORINE Land Cover can give an idea of the scale effect. The most important aspect is that estimates derived from SPOT images, scale 1 : 25 000, are always higher than the ones based on CORINE Land Cover (scale 1 : 100 000). Discrepancy is over 20 % for seven regions out of twenty and reaches the highest values in Sardegna, Sicilia and Campania.

Table 1: Comparison between "Forest" estimates by ISTAT, from Forest Statistics, year 1994, estimates from photo-interpretation of SPOT satellite images, years 1990 - 1991 and from CORINE Land Cover.

* 1000 ha	Forest Statistics	SPOT 1990 - 1991	CORINE Land Cover	% SPOT Forest stat.	% CORINE Forest stat	% CORINE SPOT
*Piemonte	663.0	929.0	641.4	40.1	-3.3	-31.0
*Valle D'Aosta	79.2	88.9	77.1	12.3	-2.7	-13.3
Lombardia	493.9	647.7	608.2	31.2	23.2	-6.1
Trentino A.A.	620.2	719.4	593.4	16.0	-4.3	-17.5
Veneto	271.4	427.1	346.1	57.4	27.5	-19.0
Friuli V.G.	183.1	329.3	293.6	79.8	60.3	-10.9
*Liguria	288.1	326.3	331.9	13.3	15.2	1.7
Emilia Romagna	402.2	464.6	410.7	15.5	2.1	-11.6
Toscana	888.6	1040.4	955.4	17.1	7.5	-8.2
Umbria	263.9	345.7	308.7	31.0	16.9	-10.7
Marche	159.2	245.7	197.7	54.4	24.2	-19.6
Lazio	381.9	590.1	420.8	54.5	10.2	-28.7
Abruzzo	224.9	396.5	346.9	76.3	54.2	-12.5
Molise	70.6	162.9	110.9	130.7	57.0	-31.9
Campania	288.9	488.5	250.8	69.1	-13.2	-48.7
Puglia	115.9	143.4	121.3	23.8	4.7	-15.4
Basilicata	191.6	310.5	233.9	62.0	22.1	-24.6
Calabria	479.3	614.5	509.4	28.2	6.3	-17.1
Sicilia	212.8	281.2	134.8	32.1	-36.7	-52.1
Sardegna	472.8	1217.0	340.8	157.4	-27.9	-72.0
Total	6751.4	9768.6	7233.6	44.7	7.1	-26.0

10. Quality control of a land cover map

When a land cover map is produced by supervised classification or photo-interpretation, all the phases of the process should be controlled, to have an idea of the quality of the product. Statistics can be very useful to plan the quality control of the process, since many quality control methods have been developed for factory products. These methods can be borrowed by quality control procedures for thematic maps, in order to produce statistically sound results, in the framework of hypothesis testing. Generally, a parametric approach is adopted and the null hypothesis is that the quality of the result of a specific phase of the procedure meets specified requirements. This null hypothesis is tested against an alternative hypothesis. Main aspects of the quality control process are the probability of accepting a lot whose quality is not the one specified by the null hypothesis, the probability of rejecting a lot whose quality is coherent with the null hypothesis, sample size, sample design and so on. Statistical methods have been developed for the different problems and can be applied in many real situations.

Indeed, in the context of quality assessment of land cover maps, the main problems concern the identification of the "articles of a lot" (pixels or polygons), the kind of measurement or of observation that should be done to accept or reject an article of a lot. Many problems arose, linked to the specific aspect of articles: e.g. polygons have different size and shape. Often, stratification is used to create relatively homogeneous lots. Stratification is generally based on category and size of polygons. A big problem is the subjectivity of the photo-interpretation process. In fact, in many cases, it is difficult to identify the true label and shape of a polygon. An interesting experiment (Gross and Adler, 1996) was carried out in two areas, in Germany and Italy, in forest areas with little management activity. Colour-infrared photographs were used, scale 1 : 7 000 in Germany and 1 : 20 000 in Italy. Three levels of difficulty were considered and ten experienced photo-interpreters delineated the polygons. In areas of medium difficulty, a buffer of 12 meters was necessary to include 90 % of delineated lines, at scale 1 : 7000; in the case of scale 1 : 20 000, a buffer of 22 meters was necessary. These results suggest that the delineation of the polygons border can be another source of bias.

11. Accuracy of a land cover map

Described quality control can guarantee that the map has been correctly produced, on the basis of chosen methodology, but does not say anything about the correspondence between the map and reality; thus another analysis is necessary to evaluate the accuracy of the map. The accuracy of a land cover map can be defined as a measure of its agreement with the reality that it represents. However reality is usually not known (otherwise the land cover map would be a useless exercise). Hence the comparison has to be made with another representation that we accept to be more reliable. In practice accuracy measurements are indexes of agreement with another representation of reality, generally known only on a sample.

Accuracy is evaluated on the basis of a confusion matrix, that should be representative of the confusion matrix at a population level. Thus sample size and sample design have a very important role and statistics can help in planning the sample survey, creating an optimum area sample design in presence of spatial autocorrelation and periodicity.

When the accuracy of database instead of a map has to be assessed, the problem is much more complicated, since a study should be done on the propagation of errors included in the various GIS layers after GIS operation. Some papers have been published on this subject (e.g. Arbia et al. 1998), but much work still has to be done.

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DATA INTEGRATION: CORINE LAND COVER IN FINLAND, AN EXAMPLE

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1. History

Ten years ago the Technical Research Centre of Finland and the National Board of Waters and the Environment (now Finnish Environment Institute, FEI) finished a study called 'Inventory of River Basin Characteristics in Finnish Conditions Using Satellite Imagery' (Kuittinen et. al, 1987).

This method (slightly modified) was then used to classify land use/cover and forests for the whole Finland in co-operation with five Finnish Institutes. The project was led by the National Land Survey of Finland (NLS).

The first version of this classification called SLAM was completed in 1991, second in 1994 and in 1997 the third version was finished. The interpretation methods have changed between the versions, so they are not comparable. The main characteristics of the third version are: Satellite images (Landsat TM) are classified by a non-parametric k-NN estimation and rule based decisions by using field sample plots from National Forest Inventory as training areas (Vuorela, 1997). Several digital map masks are also used (peat mask, cultivated area mask, densely built areas). As a result Finland has a raster (25m * 25m) Land Cover Database having about 80 classes (including a rough estimate for the volume of growing stock).

The main classes in this non-hierarchical classification are: water bodies, cultivated areas, clear cuttings, open lands, built-up areas, industrial areas, peat production areas, open peat lands, spruce dominated peat lands, deciduous-coniferous mixed peat lands, pine dominated peat lands, pine dominated mineral soil forests, spruce dominated mineral soil forests, deciduous dominated mineral soil forests, pine-spruce mineral soil forests, coniferous-deciduous mineral soil forests, forest plantations, alpine birch forests and bare mountaintop.

In 1992, when Finland started to plan to make the CORINE Land Cover classification, it was decided that Finland shall do the work by automatic methods using existing data. The Geodetic Institute in Finland developed methods for automatic generalisation of land cover data in close co-operation with FEI (Jaakkola, 1996). The aim of this co-operation was to develop methods to produce and combine different data to 25m * 25m raster, to change the classification of the Finnish Land Cover to CORINE classification and to generalise the 25m * 25m raster data in order to fulfil CORINE demands (25 hectare minimum size, 100m minimum width...).

2. Today's situation

The first version of the CORINE Land Cover Finland is planned to be finished in by the end of 1998. The CORINE land cover Finland -database is derived with automatic generalisation methods from a detailed Finnish land cover. The input data includes data from satellite image classifications, map masks, statistical records with co-ordinates, and digitised data. All the data is rasterised and combined to a single coverage. This coverage has no nominal scale; minimum mapping unit (MMU) varies from class to class, the smallest is 0,0625 hectares, i.e. one pixel. The accuracy varies also accordingly from 60 to nearly 100 percent, where the most certain classes come from map masks and statistical records. It is therefore quite heterogeneous input data, and the purpose of generalisation in this case is not only the reduction of complexity and improvement of legibility, but also to great deal homogenise output data.

The automatic generalisation of land cover data is resolved with raster methods using a formal language of the Map algebra. The generalisation process includes several independent generalisation operations which are run sequentially. The operations are reclassification, aggregation, merging and statistical comparison, amalgamation, smoothing, and raster-vector conversion with simplification. The operations iteratively increase the minimum features size, and thus produce multi-scale land cover data.

The result of CORINE land cover generalisation seem to be satisfactory, the standards for attribute accuracy (85 % correct) and for positional accuracy (better than 75 meters) are fulfilled. The changes in summary statistics have been minimised by comparing different generalisation results with each other (**Figure 1**). There are still certain systematic changes, however considering that the manual generalisation is more inconsistent, the result is acceptable. The borderlines of the main classes, e.g. water bodies, forests, and agricultural areas, are preserved quite nicely. In overall, the classes covering small areas with small average feature size tend to decrease in area or disappear totally, and the classes covering large areas with large average feature size tend to increase in area during the generalisation process. Most of the errors in input data are small and, noting the definitions for output data, eliminated during the generalisation process.

The used generalisation operations and parameters are easily modifiable according to the needs, e.g. it is possible to change the size (Figure 2) or the width of the minimum feature etc. Automatic generalisation provides a tool to propagate updates of land cover maps at various scales of detail. The integrity of different scale products is kept, and the automatic generalisation provides an economic and fast method to produce consistent and accurate land cover data.

Figure 1. The relative shares (%) of original, 1, 5 and 25 hectare (CORINE) land cover classes. Figure is from the testing phase. CORINE classes: 111=continuous urban fabric, 112=discontinuous urban fabric, 121=industrial or commercial units, 122=road and railroad networks, 142=sport and leisure facilities, 211=non-irrigated arable land, 311=broad-leaved forest, 312=coniferous forest, 313=mixed forest, 324=transitional woodland shrub, 332=bare rock, 412=peatbogs, 512=water bodies and 523=sea and ocean.

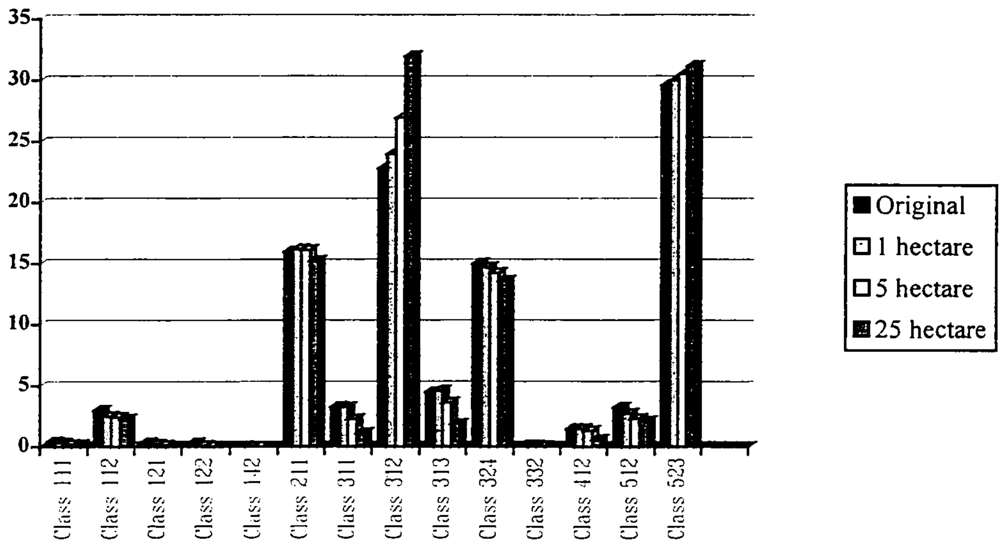
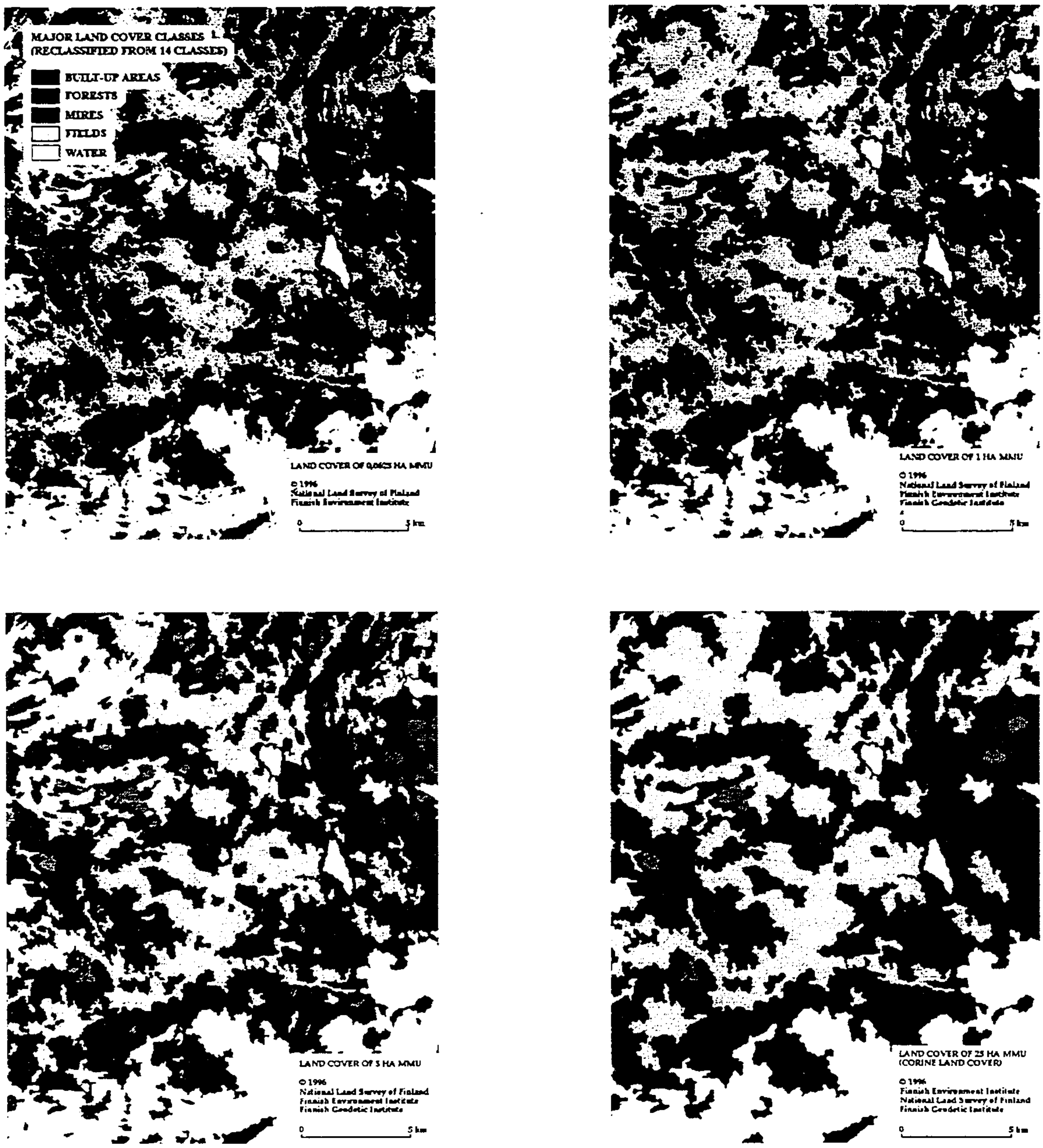


Figure 2. The original land cover (MMU 0,0625 hectare), and the generalised land covers of 1, 5, and 25 hectare. Figures are from the testing phase.



3. Future

During the past ten years the requirements of land use and land cover data have changed and become more precise. Also national and international demands for such data has undergone similar changes. Towards the end of 1996 it was decided that a project was to be started from scratch for the study of this question. The aim was not to develop the SLAM data, but rather to plan a completely renewed LU/LC classification and data collecting method for Finnish circumstances.

The project was launched by NLS in early 1997. A project steering group was set up. This consisted of experts from many different organisations. The objective was to find the answers to these questions, among others:

- In what way should LU/LC information be produced in Finland?
- What are the national and international requirements for LU/LC material?
- How can existing data sources be utilised most efficiently?

The first tasks of the project involved charting the needs and the present situation. In view of experiences from the use of SLAM data it was concluded that there are only a few organisations in Finland which utilise LU/LC material on a regular basis and on a national scale. But the organisations using LU/LC material regionally and locally, as well as only occasionally, amounted to a larger number. The following are nation-wide users:

- The Environmental Administration: Environmental and water basin inventories CORINE Land Cover
- The Finnish Forest Research Institute: The National Forest Inventory (land use data)
- The Defences Forces of Finland: Transportation, land cover and fortifying analyses
- The Statistical Centre of Finland: Compiling statistics on land use, national accounts
- Certain companies: Land cover analyses, regional planning

The needs of the national organisations have been investigated mainly by interviewing experts. The following conclusions were drawn based on the investigations:

- Information on land use, land cover, soil type and land use restrictions is needed
- GIS data is required for statistical analyses and follow-ups
- Both raster and vector format data is needed
- There is a demand for data covering the whole of the country
- It must be possible to update the database in order to make for example change detection
- Uniform, well described methods should be used

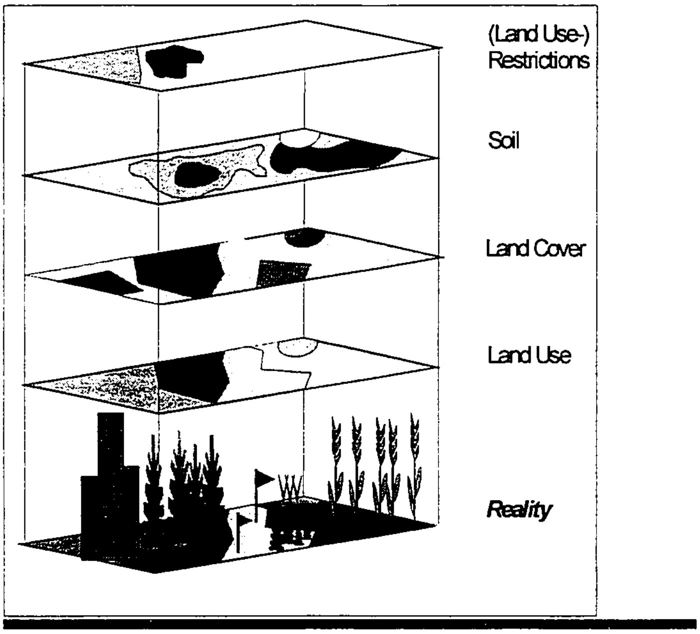
The international requirements have mainly been estimated on the basis of what LU/LC data international organisations collect from Finland. The following organisations were studied: EEA (the European Environment Agency), EUROSTAT, FAO and OECD. Of these four, it is only the needs of EEA that concern GIS data (CORINE LC), the others collect mainly statistical data. The aim was set at creating a LU/LC system in Finland, which as far as possible would fulfil both national and international needs keeping priority on national needs.

Some international LU/LC nomenclatures were studied in connection with the project. These were CORINE LC, CLUSTERS, UN/ECE and the Land Use classification in the Nordic countries. It was established that not one of these nomenclatures meets the national or general international requirements, and thus is not suitable as such to be used for Finnish conditions. Consequently, the classification system had to be re-developed. One of the goals was that the land use classification system to be created would be confirmed as a standard in Finland.

At an early stage of the project it was established that it is extremely difficult to create only one single nomenclature with corresponding data which would contain all the information needed by the users. Therefore it was decided that instead of one system, the objective should be to create four separate classifications.

The situation is illustrated in Figure 3. If one wishes to receive information about all four attributes of a certain feature the most practical alternative is to create four separate nomenclatures and layers of data, instead of only one. Using these elements and GIS analyses it is possible to calculate the data combination each user requires. Since the system contains separate nomenclatures and layers of data for land use, land cover, soil and land use restrictions, it was called SLICES (Separated Land Use/Land Cover Information Systems.

Figure 3. The classification system.



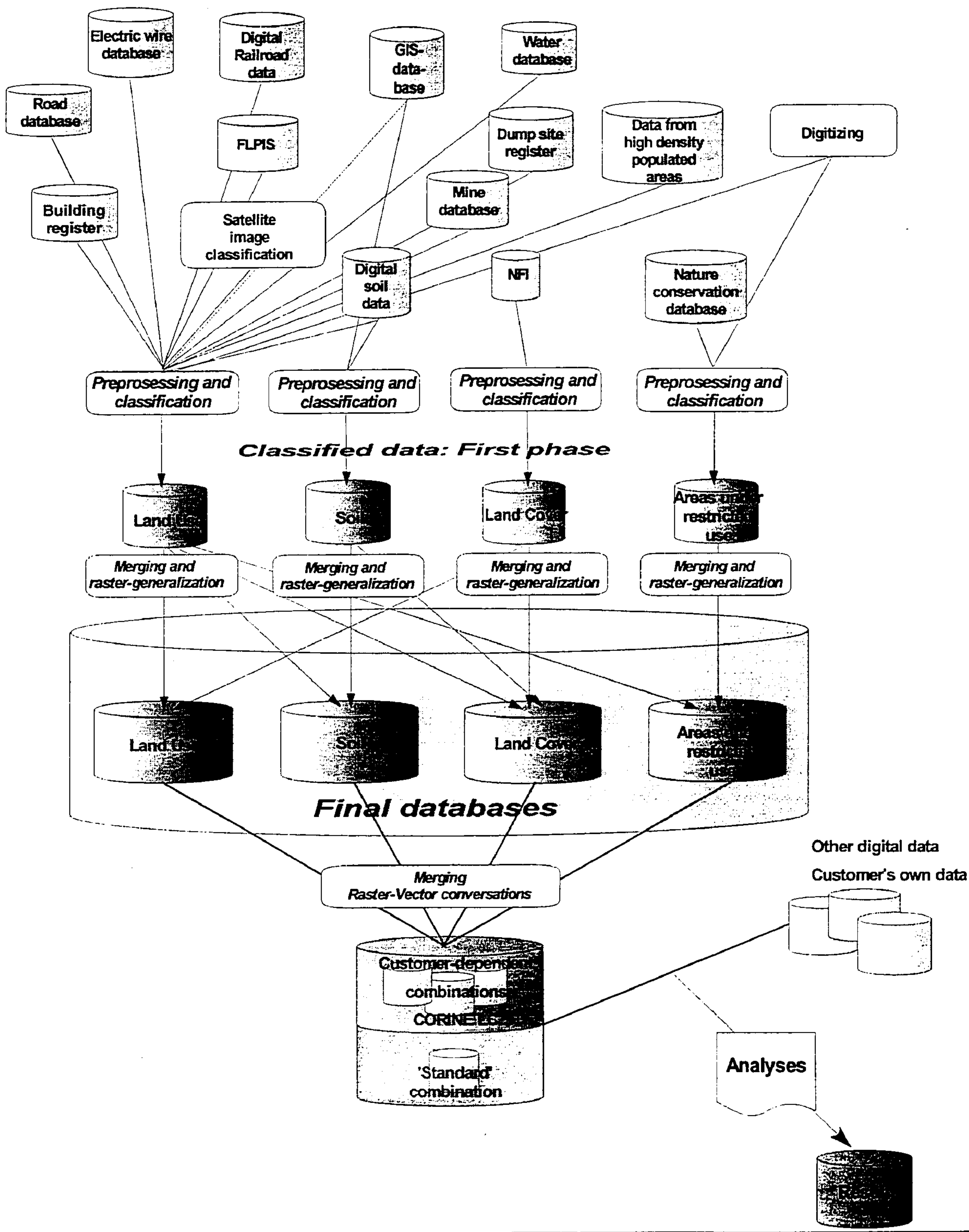
The nomenclatures are not final, so some changes are to be expected. The nomenclatures are hierarchical and contain, depending on the class, 2–4 hierarchical levels. The amount of classes varies between 14 and 38 in each nomenclature. The nomenclature for land use restrictions has not been created yet. It is to contain data regarding areas for nature conservation, military training areas, protected forest areas, areas under restrictions in zoning maps etc

The main result of the project is planned to be a raster database of the four elements having a pixel size of 25m*25m. The production will be partly done in 10m*10m pixel size. Also generalised versions and vectorised versions will be produced as well as element combinations.

Several sets of GIS data covering the whole of Finland have been produced. These sets, as such or slightly altered, serve as useful source data for LU/LC classification. In order to achieve a cost-efficient and speedy classification process these existing data will be used to as large an extent as possible when creating the SLICES material. The data will be pre-processed and combined through GIS analyses. The automatic generalisation of the material will be carried out using a method which has been developed at the Finnish Geodetic Institute (Jaakkola, 1996). The whole planned 'system' is described below.

SLICES -project 1997-98

LCS -databases (Land use, Land cover, Soil, (LU-) restrictions)



4. The present situation and the future

In 1997 a feasibility study was made. During a continued project in 1998 the production process – including pre-processing, data transfer between elements and generalisation – will be perfected. If called for, alterations to the preliminary nomenclatures will be made and trial production of data covering a fairly wide test area will be started. The completed data covering the test area will be delivered to the nation-wide users for test use.

There are plans for starting the actual production in early 1999. The goal is to complete the nation-wide data (at least the land use and land cover data) in 2–3 years. The basic data used for the land cover classification is the data derived from the National Forest Inventory.

Since data from many different organisations is used in the project, questions relating to copyright and pricing are also considered.

As a recommendation from the feasibility study four separate classifications were recommended:

4.1. Land use nomenclature, draft

A. Built-up areas/artificial surfaces

- A1. Residential areas
- A2. Industrial and commercial areas
- A4. Transport areas
- A5. Mines, quarries; other extraction of commercial minerals and peat
- A6. Recreational areas; parks, green areas, sporting areas
- A7. Other built-up areas and waste land (human made)

B. Agricultural areas

- B1. Fields, arable land, areas under regular grazing
- B2. Permanent pastures (pastures outside rotation system)
- B3. Land for permanent crops (fruit trees, (commercial) greenhouses, nurseries)
- B4. Other agricultural land (land for protective purposes etc)

C. Forests and other land; productive and non-productive areas

- C1. Forest covered areas or only temporarily non-forested areas: productive areas
- C2. Permanently low density or non-forested areas: non-productive areas

D. Waters

- D1. Inland waters; fresh water bodies
- D2. Sea and coastal waters; salt waters

4.2. Land cover nomenclature, draft

A. Forest covered areas

Classes A11-A23 include also classification by the volume of growing stock:

Classes: *0 - 50, 50 - 100, 100 - 250 and over 250 m3/ha*

- A1. Forest covered areas with high density of wood (Tree crown cover > 30 %)
  - A11. Coniferous forests
  - A12. Deciduous forests
  - A13. Mixed forests

A2. Forest covered areas with medium density of wood (Tree crown cover 10 - 30 %)
A21. Coniferous forests
A22. Deciduous forests
A23. Mixed forests

B. Other wooded land and areas covered by other vegetation (Tree crown cover < 10 %)
B1. Forest covered areas with low density of wood and bushes
B2. Grasslands
B3. Alpine areas with low density of vegetation, moors (lichen, heather etc)

C. Permanently non-vegetated areas
C1. Rocky areas and areas with loose soil
C11. Cliffs and bare rock: cliffs, open rocks, alpine rocks; mines
C12. Areas with loose soil: sand, peat, ...
C2. Artificially covered areas: open built-up areas, open waste land, traffic areas, ...
C21. Open areas
C22. Areas mainly covered by buildings
C3. Other non-vegetated areas

D. Waters
D1. Open water
D11. Littoral areas
D12. Other open waters ('deep water' areas)
D2. Water areas covered by vegetation

4.3. Soil nomenclature, draft

A. Cliffs and mineral soils
A1. Cliffs and rocky areas (stratum less than 1 m)
A11. Open cliffs
A12. Open rocks
A13. Cliff areas covered by thin mineral soil (less than 1 m)
A2. Mineral soils (stratum over 1 m)
A21. Moraine areas
A22. Other mineral soils

B. Peatlands and other wetlands
B1. Organic soils and peatlands with stratum over 1 m
B11. Mud (stratum over 1 m)
B12. Sedge (peatland with *Carex*; stratum over 1 m)
B13. Curd (peatland with *Sphagnum*; stratum over 1 m)
B2. Other peatlands (stratum 0 - 1 m: 'thin peatlands')
B21. Peatlands over cliff
B22. Peatlands over moraine
B23. Peatlands over other soils

C. Filled lands (artificial)

(D. Waters)

5. References

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SESSION 5

UPDATE AND USE OF THE SYSTEMS

AREA STATISTICS IN SWITZERLAND: THE FOLLOW-UP SURVEY

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1. Introduction

When depicting and classifying the landscape, we are obliged to use a system of values in order to make rational decisions as to which elements of the landscape should be recorded and represented, and which should not. All systems of values are time-dependent. What we need, therefore, is not a rigid, fixed classification, but a flexible one that can be adapted to new value systems, interests and requirements. The search for the optimum classification is thus never-ending.

2. Survey method

In Switzerland, area statistics were published in 1912, 1923/24, 1952 and 1972. For various reasons, these were not methodologically consistent and were not therefore of use for many purposes, particularly diachronic comparisons. In 1982, therefore, the new area statistics survey in Switzerland took as its starting point the interpretation of aerial photographs of permanent samples. Conventional black-and-white photographs at a scale of approximately 1:30 000 were overlaid with a transparent film carrying a grid of sample points at 100 m intervals. For the 4.1 million sample points, cross-checked photo-interpretation of land use was done using a stereoscope according to a land-use classification comprising around 70 categories (see Fig. 1). The results of this nation-wide land-use survey - the 1979/85 area statistics - appeared in 1992 after several years of survey work. These data describe the situation in the early eighties.

Fig 1: Mapping technique: one permanent sample point per hectare.

Wooded areas

Wood (excluding mixed woodland/bushes)	Normal wood Strips or pockets of woodland Plantations Areas of damaged trees Open forest (on non-productive land) Open forest (on utilised agricultural land)	Copses	Field woodland, hedges Groups of trees (on utilised agricultural land) Other copses
		Mixed woodland/bushes	Mixed woodland/bushes

Utlised agricultural area

Meadows and arable land, farm pasture	Rich meadows and arable land Other meadows and arable land Farm pasture Bush-covered meadows and farm pasture Continuous vineyard		
Utilised alpine area	Spring pasture, alpine meadows, mountain pastures Rich pasture (Alps, Jura) Stoney pasture (Alps, Jura) Bush-covered pasture (Alps, Jura) Alpine pasture for sheep grazing Rough mountain meadow	Fruit, vines, horticulture	Vineyards Pergola vines Orchards Planted stands of fruit trees Irregular stands of fruit trees Horticultural land

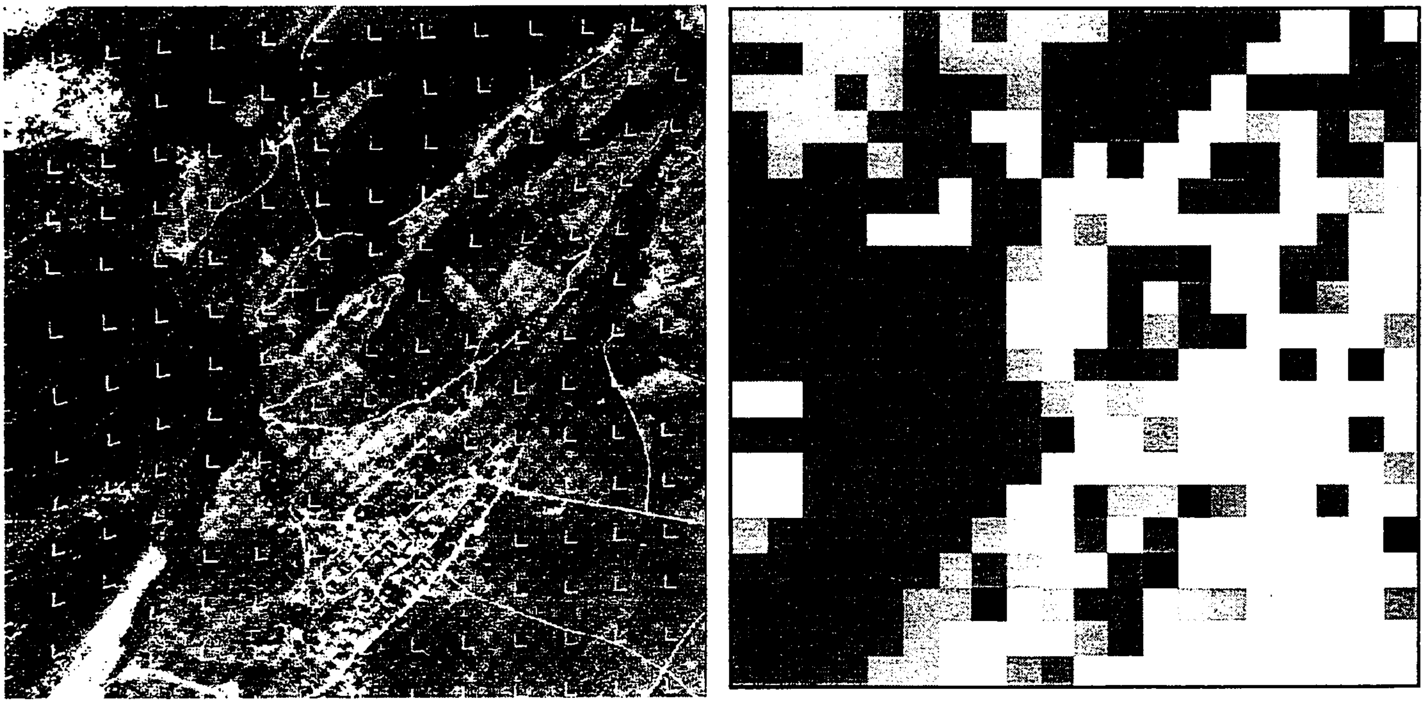
Developed areas

Built-up areas (excluding industrial)	Detached and semi-detached houses Terraced houses Blocks of flats Farm buildings Buildings (unspecified) Area around detached and semi-detached houses Area around terraced houses Area around blocks of flats Area around farm buildings Area around unspecified buildings	Industrial land	Industrial buildings Areas around industrial buildings
		Recreational and green areas	Buildings in recreational areas Open-air sports complexes Allotments Camp sites, caravan parks Golf courses Cemeteries Parks
Transportation infrastructure	Motorways Green areas adjoining motorways Streets, roads Green areas adjoining streets Parking areas Railways (above ground) Green areas adjoining railways Railway stations and associated land Airfields and airports Air strips (grass), green areas adjoining airfields and airports	Specially developed areas	Buildings on specially developed areas Power stations Wastewater treatment plants Other utilities and disposal facilities Quarry Landfill Construction sites ruins

Unproductive areas

Standing water	Standing water	Areas not covered by vegetation	Cliffs, sand, scree Glacier, névé
Running water	Running water Embankments Flood defences	Unproductive vegetation	Bushes, shrubs Marshy areas Riverbank vegetation Unproductive grass/weeds Avalanche defences

Fig 2: Swiss area statistics: mapping technique (the field of view is identical in both images)



Aerial photograph with DTM-generated sample point overlay. The distance between the sample points is 100m on the ground. Land use is determined at the point of intersection of the lines.

The result of photo-interpretation: the raster image shows land use for each sample point. In statistical terms, each square represents a hectare.

3. Follow-up survey

In late 1992, an immediate start was made on a follow-up to these statistics using aerial photographs from 1992 (western Switzerland) to 1997 (south-eastern Switzerland). Results of the 1992/97 area statistics for the whole of Switzerland are expected to be published in late 2000. Use of exactly the same survey method and of the permanent sampling procedure will ensure that, for the first time in the history of Swiss land-use surveys, we have statistically sound and spatially differentiated information on land-use changes for the entire country.

3.1. Stringent quality requirements

If meaningful data on changes in land use are to be obtained, stringent demands must be made of the survey method. The production of high-quality area statistics for Switzerland is contingent upon the following:

- Identical placement of sample points in the initial and subsequent survey. In addition to the orientational references on the aerial photograph, use is made of a close-mesh (25m) digital terrain model in order to calculate the exact position of the sample points on the analogue aerial photograph.
- A clear, accurate list of categories with plenty of examples and illustrations.
- Fully trained image interpreters.
- In order to properly determine changes in land use, it is essential to view the old and new situations simultaneously (using two stereoscopes).

- In order to properly determine changes in land use, it is essential to view the old and new situations simultaneously (using two stereoscopes).
- Twin interpretation of each point by two independent specialists with subsequent discussion of discrepancies.
- Field verification of problematic sample points.
- Twin recording of interpretation codes by two independent individuals with subsequent correction of discrepancies.
- GIS-based plausibility checks on data, e.g.: new settlements outside construction zones; fruit trees over 1000 m above sea level or alpine meadows in municipalities with no alpine land register.

3.2. The revised 1979/85 data set

In order to accurately determine changes in land use, the photointerpreter must compare the old and new situations as shown on the aerial photographs. This involves not only recording actual changes in land use since the first survey, but also making improvements and corrections to the old dataset (1979/85 area statistics). Back corrections of this type affect some 5% of all sample points and are more or less offset by corrections in the opposite direction, particularly as aggregation of use categories increases. In order to ensure that users do not draw on the old figures when making comparisons, the revised 1979/85 dataset has been incorporated into the new publications. All studies of changes in land use are based on this dataset.

These subsequent improvements and corrections are basically necessary, since the old images must be consulted in order to make sense of the current situation:

<u>Correction of definitive sample point positions:</u>

Major positioning errors in the sample points caused by the old, coarse-meshed RIMINI terrain model had to be corrected for technical reasons. The new positions (and associated land uses) have been calculated with the more accurate DHM 25, which is now considered definitive.

<u>Differentiation of building use:</u>

With the help of the digital residential building co-ordinates from the 1990 census of buildings, differentiation of building use can be improved during the follow-up survey. Consequently, a large number of buildings that were allocated to "non-differentiated built-up area" can now be allocated more accurately in both the old and new data sets.

<u>New categories:</u>

The list of data in the follow-up survey includes new categories ("Landfill", "Flood defences", "Avalanche defences") which should realistically be incorporated into the old dataset as well, as very few of these features are actually new (cf. Fig. 1).

<u>Superimposition of glacier data:</u>

Another new category was introduced - "Glacier, névé" - by superimposing the corresponding characteristics from the Geotechnical Map of Switzerland. As these data were recorded at the smaller scale of 1:200 000, displacements of up to several hundred metres show up on the aerial photographs and must be corrected.

<u>Multiple information based on two different images:</u>

Comparison of two images taken at different points in time, and often during different seasons, produces a wealth of data that facilitates the allocation of actual use and may also lead to a different interpretation.

Improved image quality:

Some of the images from the first survey were of such poor quality that certain use categories (pastures, thickets) could only be guessed at. With the new, improved imagery, these can now be identified unambiguously and sometimes allocated to another category of land use.

Unidentifiable image portions in the initial survey:

Portions of images that could not be made out in the first survey owing to shadow, cloud, snow or skewed forest boundaries can now be distinguished and their use correctly allocated.

Interpretative errors in the initial survey:

The uniform allocation of land use on the basis of aerial photographs calls for a complex system of identification criteria. Photointerpreters need to be highly consistent and concentrated in their work if the system is to be applied correctly. Not surprisingly, therefore, when a photograph is re-examined, the allocation of land use may prove to be wrong (i.e. fails to meet the criteria) and may need to be corrected.

Recording and transcription errors in the initial survey:

Recording errors were largely avoided by using a dual recording system. However, in some cases, transcription errors or illegible handwriting produced false data. These come to light during the follow-up survey and must be corrected.

3.3. The new dataset (1992/97)

When planning the 1992/97 area statistics, a follow-up interval of 12 years was assumed, in accordance with the flight plan for the update of the 1:25 000 map published by the Federal Office for Topography, copies of the latter's aerial photographs being used as the basis for area statistics. As the flight plan cannot always be adhered to, basically because of weather conditions, the actual interval for aerial photographs is 10-13 years between the first survey (1979/85) and the follow-up (1992/97). The boundaries between the photo series made at different times reflect national mapping zones since they are cut across administrative divisions, this makes it much more difficult to convert to annual values. Thus, all the tables show, for each spatial evaluation unit, the survey time, i.e. the date on which the base data were collected (aerial photograph). If, for a given evaluation unit, there is more than one survey year - as in the dataset for the whole of Switzerland - the earliest and latest image dates are separated by an oblique stroke.

Examples:

- Travers (municipality): 1979 (initial survey), 1990 (follow-up survey)
- Signau (district): 80/81 (initial survey), 1993/94 (follow-up survey)
- Uri (canton): 80/85 (initial survey), 1993/97 (follow-up survey)

By February 1998, 63% of the land area (2.6 million hectares) had been evaluated under the follow-up survey. Results for this area show a total change of 130 000 hectares, or a good 5%. In the space of 12 years (1982–1994), urban development has increased by 24 000 hectares or 13%. Most of this increase has been at the expense of farmland, which decreased by 31 000 hectares (-2.9%) over the same period (cf. Fig.3). Extrapolated to Switzerland as a whole, the loss of cultivated farmland translates as 1.3 m^2 per second and an urban development rate of 1.0 m^2 per second. At this rate, sustainable development in Switzerland will never be achieved (cf. Fig. 4).

Most applications of spatial data are based on the combination of various GIS datasets. For example, runoff models can be generated for catchment areas (cf. Fig. 5). These provide excellent estimates of volumes of water at the point of runoff for any amount of precipitation and of the volume of nutrients from diffuse sources.

Fig 3: changes in land use between 1979/85 and 1992/97

Arealstatistik 1992/97: provisorische Daten aus 62,7% (2 588 998 ha) der Landesfläche (Auswertestand Ende Februar 1998)

Four main areas	1985	1997	Increase/decrease (absolute)		Increase/decrease (percent)	
			total	Per year	total	Per year
Wooded area	774 421 ha	780 025 ha	5 604 ha	467,0 ha	0,7%	0,1%
Utlised agricultural area	1 058 056 ha	1 027 272 ha	- 30 784 ha	- 2 565,3 ha	-2,9%	-0,2%
Developed areas	180 808 ha	205 017 ha	24 209 ha	2 017,4 ha	**13,4%**	1,1%
Unproductive areas	575 713 ha	576 684 ha	971 ha	80,9 ha	0,2%	0,0%

Aggregation by 15 types of use	1985	1997	Increase/decrease (absolute)		Increase/decrease (percent)	
			total	Per year	total	Per year
Wood (excl. mixed woodland/bushes)	691 125 ha	696 421 ha	5 296 ha	441,3 ha	0,8%	0,1%
Mixed	15 610 ha	16 895 ha	1 285 ha	107,1 ha	**8,2%**	0,7%
Copses	67 686 ha	66 709 ha	- 977 ha	- 81,4 ha	-1,4%	-0,1%
Fruit, vines, horticulture	56 174 ha	48 457 ha	- 7 717 ha	- 643,1 ha	-13,7%	-1,1%
Meadows and arable land, farm pasture	718 369 ha	704 019 ha	- 14 350 ha	- 1 195,8 ha	-2,0%	-0,2%
Utilised alpine area	283 513 ha	274 796 ha	- 8 717 ha	- 726,4 ha	-3,1%	-0,3%
Built-up areas	87 479 ha	101 910 ha	14 431 ha	1 202,6 ha	**16,5%**	1,4%
Industrial land	11 749 ha	14 710 ha	2 961 ha	246,8 ha	**25,2%**	2,1%
Specially developped areas	12 365 ha	11 655 ha	- 710 ha	- 59,2 ha	**-5,7%**	-0,5%
Recreational and green areas	10 193 ha	11 870 ha	1 677 ha	139,8 ha	**16,5%**	1,4%
Transportation infrastructure	59 022 ha	64 872 ha	5 850 ha	487,5 ha	**9,9%**	0,8%
Standing water	106 459 ha	106 372 ha	- 87 ha	- 7,3 ha	-0,1%	0,0%
Running water	16 488 ha	16 549 ha	61 ha	5,1 ha	0,4%	0,0%
Unproductive vegetation	108 307 ha	110 889 ha	2 582 ha	215,2 ha	2,4%	0,2%
Areas not covered by vegetation	344 459 ha	342 874 ha	- 1 585 ha	- 132,1 ha	-0,5%	0,0%

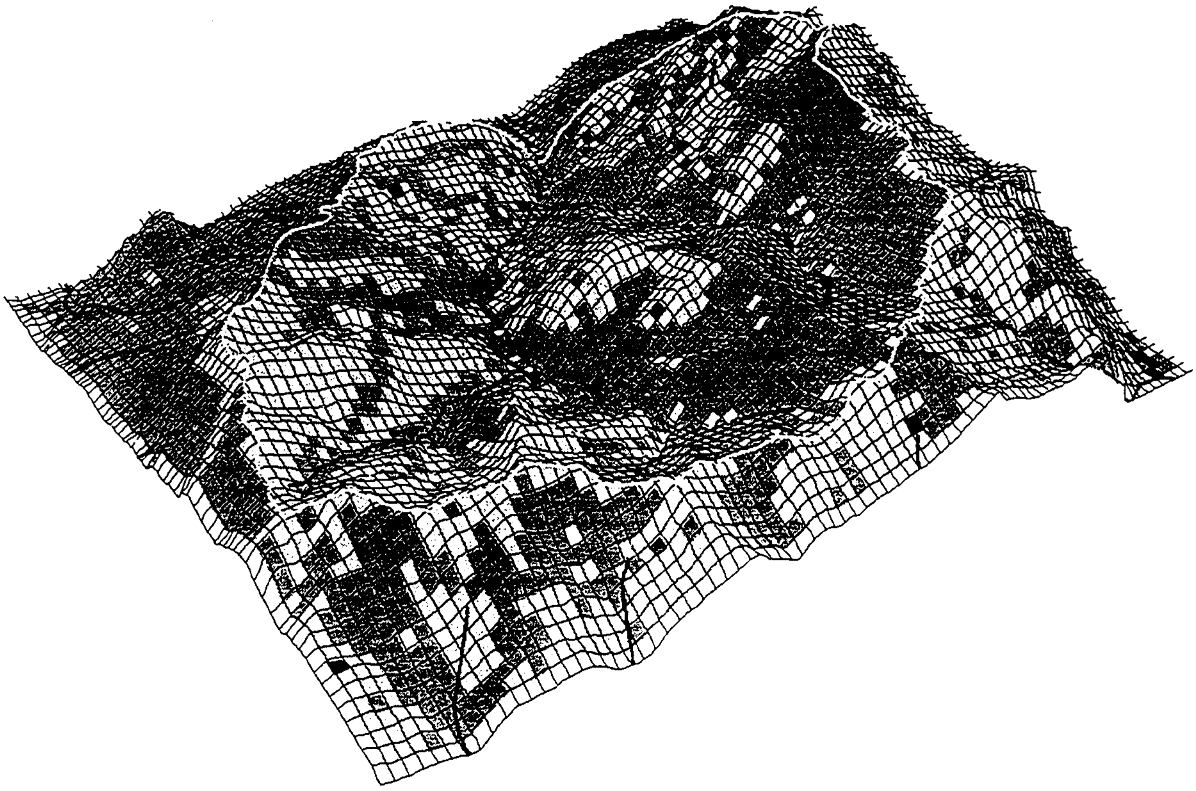
Fig 4: Changes in land use on a one-square kilometre plot of the municipality of Grindelwald (BE)

Upper left: aerial photograph from 1949

Bottom left: aerial photograph from 1960

Bottom right: aerial photograph from 1993

Fig 5: Combination of GIS data as a basis for runoff models of catchment areas



Example of a catchment area (boundaries in white) combined with digital terrain model (mesh), digital waterway system (black) and land use raster (shaded mesh)

4. Proposal for a pragmatic approach for the European harmonisation of land-use data

The analysis of the earth's surface is still in its infancy. As this science develops, we must add new components and possibilities to our activities. We must thus see harmonisation as a gradual process and look to the future.

We would advocate a pragmatic approach for the European harmonisation of land-use data, the key being co-operation between national bodies (national know-how) and a Eurostat unit specialising in land use (development of European know-how). The specialist Eurostat unit would stipulate which data were needed (precisely defined categories and scale). The best way of meeting needs using available national data is currently being sought in conjunction with national bodies.

In the longer term, we will be able to discern components (categories or resolutions) that are required more often. Such components could then be used as harmonisation parameters.

5. A parting thought

As the Earth Spirit says to Faust in Goethe's tragedy, "You resemble the spirit you embrace, not me! ". The answers we get depend on the questions we ask. In the same way, our systems constantly reflect the observer and must periodically be brought into line with the spirit of the times.

6. Sources:

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Swiss Federal Statistical Office: GEOSTAT – Benützerhandbuch / Manuel d'utilisateur [User manual]. Bern, 1992

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GISCO: THE COMMISSION'S GEOGRAPHICAL INFORMATION SYSTEM

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1. Introduction

The use of the GIS[1] at the Commission really began with the CORINE project carried out by DG XI[2]. As from 1990, an internal task force had been instructed to evaluate the needs of the departments as regards geographical information and geographical information systems.

The final report produced by this task force stressed the usefulness of GIS as tool for integrating data collected from very diverse sources (socio-economic, environmental, transport, etc.). This led Eurostat to create the GISCO project (Geographic Information System for the Commission) in 1991, which is managed by unit E4[3].

The GISCO database is acknowledged today by all the Commission's departments as the reference geographical database. It contains a very varied set of basic topographical and thematic data covering the entire European territory.

2. Mandate of the GISCO team

The objectives of the GISCO project are as follows:

2.1. Within Eurostat

- Sensitise Eurostat's personnel to the possibilities offered by the GIS as tool for integration and analysis of statistical and geographical data.
- Promote the use of the GIS at Eurostat.
- Define a policy regarding the use of the GIS (R&D, standardisation, classifications, distribution, data suppliers, copyright, etc.).
- Provide a decentralised map-making service for Eurostat's departments.
- Manage the GISCO reference database.
- Ensure quality control of Eurostat's GIS products.
- Act as the reference for all matters pertaining to map-making and spatial analysis at Eurostat.
- Supervise Eurostat's projects using GIS technologies.

1 Geographical Information Systems

2 DG XI: Environment, nuclear safety and civil protection

3 Regional accounts and indicators, population and geographical information system

2.2. Within the Commission

- Manage the GISCO reference database for all the Commission's departments (including the definition of the database's structure and architecture, transfer of data and management procedures).
- Organise annually and chair a committee of GISCO reference database users.
- Interpret the needs of the users in terms of software and hardware associated with the use of the GIS.
- Take an active part in all the co-ordination activities within the Commission in the fields of GIS and geographical information.

2.3. Within the Framework of the European Statistical System

- Promote the geographical referencing of statistical data and encourage the use of the GIS in the National Statistical Institutes (NSI).
- Promote collaboration between the NSI and the national map-making agencies.
- Promote the harmonisation of the GIS used in the various NSIs.
- Promote the standardisation and harmonisation of the procedures for exchanging geographical information between the Member States and Eurostat.
- Co-ordinate the participation of the European statisticians in the activities related to geographical information and GIS; ensure that their needs will be taken into consideration by the market.

2.4. Within the Framework of International Co-operation

- Promote the co-operation of map-making agencies in Europe, encourage the harmonisation of their approach regarding technical subjects and commercial policy (pricing policies and copyright).
- Seek the co-ordination of the initiatives of the Union and the international activities in the broad sense in the field of geographical information.
- Take part in GIS-related projects initiated by other international statistical organisations.

3. Contents of the database

The GISCO reference database contains basic topographical and thematic data which is described in appendix. The principal users of the database are the Directorate-General XVI[4], DG VI[5] and the Joint Research Centre in Ispra, which have their own GIS sites (Arc/Info). DGs are responsible for the thematic layers pertaining to their activity. DG VII [6] has also established a more modest site (ArcView) in order to update thematic data layers and carry out spatial analysis in the field of transport. DG X[7], for its part, publishes maps of Europe (political, Structural Fund, forests, etc.).

Right from the onset of the GISCO project, the team was confronted with the lack of homogenous geographical data covering the European territory.

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4 DG XVI: Regional Policies and Cohesion

5 DG XV: Agriculture

6 DG VII: Transport

7 DG X: Information, Communication, Culture and Audio-visual

The principal problems can be summarised as follows (and the list is not exhaustive!):

- Difficulties with access to information (insufficient metadata on all levels).
- Different map projections and scales.
- Observation date seldom mentioned.
- Prohibitive cost of the data.
- Absence of standardised transfer format.
- Absence of standardisation in the codes used.
- Variations in the quality of data from one country to another at the same geographical level.
- Absence of long-term solutions (supply of snapshot dumps, absence of information on changes).
- Etc.

During its eight years of existence, the GISCO team endeavoured to set up a geographical information system while trying to overcome these difficulties as they encountered them. The provisional assessment, without being negative, is nevertheless not completely satisfactory.

Two data layers covering European territory exist in 1:100.000 scale: CORINE Land Cover and the SABE file (Seamless Administrative Boundaries of Europe) from MEGRIN. The former was carried out on the initiative of the Commission over a ten-year period; the latter constitutes a first stage towards a set of basic geographical data for Europe. MEGRIN provides Eurostat with snapshot dumps harmonised at the European level. It also establishes the link between the national territorial classifications and the NUTS[8] code defined by Eurostat.

The other data of the GISCO database is mainly available in 1:1.000.000 scale. It was gathered from various agencies (taking into account budget constraints) or was integrated and harmonised by the project team from very diverse sources.

Eurostat (together with colleagues of the other DGs concerned) took a number of initiatives to try to improve the situation. Joint meetings between the National Statistical Institutes and the European map-making agencies are organised in order to create or intensify the relationships between these agencies within their borders and throughout Europe.

This work led to the creation of a task force involving representatives of the national statistical institutes of France Germany, Italy, England, The Netherlands and Sweden as well as of representatives from Eurostat.

Among other things, the mandate of this task force covered the needs of the European statisticians as regards geographical information.

The principal proposals of this group were as follows:

- A European geo-statistical system that meets the needs of the public and private sectors must be developed.
- The NSI must collaborate together with Eurostat to create products that make it possible to cover cross-border areas.
- Coherence of the geographical information and standardisation of the codes used to geocode the statistical data must be ensured.
- The perennial nature of the solutions, and consequently the availability of updates, must be prioritised.
- An effort must be made to standardise the processes that Member States use for producing derived information.

8 NUTS: Nomenclature of Statistical Territorial Units

The mandate of this group was not to find solutions to all these questions but to define what actions should be undertaken next in order to gradually solve the various problems in a co-ordinated manner (by working in networks).

4. Organisational aspects

The Commission chose a decentralised organisation built around the GISCO geographical reference database.

There are three levels of database users, as follows:

4.1. Advanced User

This involves teams of GIS professionals managing a GIS site (implemented using Arc/Info software) on behalf of a DG (examples: DG XVI, DG VI). These teams are responsible for the thematic data pertaining to their activity, they have a local database and transfer to the GISCO database any data that they wish to pool (example: the layer relating to the Structural Funds managed by DG XVI). The DG responsible for the subject must scrupulously respect the technical specifications defined by GISCO so that the transfer is carried out under the best conditions. DG is also responsible for the metadata pertaining to these subject layers.

4.2. Intermediate User

The introduction of ArcView for PCs will create a new generation of users. They not only will be able to produce thematic maps but, using the spatial analysis modules available on this type of product, they will also be able to undertake more sophisticated studies. Because the individual investment in time and training required is considerable, these products should not be installed on each PC. Eurostat has chosen to train one or two persons per Directorate.

4.3. End User

This includes all the personnel of the Commission. When the new architecture is set up, these users will have access through the Intranet to user-friendly applications related to their sphere of activity. These applications, of various complexity, will not require any specific training on the part of the users. At this stage, geographical information will form an integral part of all the databases available at the Commission.

Moreover, GISCO continues to produce various spatial analyses, which it presents in seminars organised for the Commission's personnel. These sessions are geared to sensitising the staff to the potential of GIS and to the use of the geographical information within the framework of the studies that they carry out.

5. Distribution of the Data

Eurostat distributes only the geographical data for which it holds the copyright. The appendix contains a list of the layers available to the datashops' network. This data is available on three CD-ROMs, whose numbers are indicated in the "Status" column.

As for CORINE Land Cover, the distribution is ensured by the Environment Agency in Copenhagen.

6. Appendix

DATA THEME DATA LAYER	DESCRIPTION OF CONTENTS	RESOLUTION/ SCALE	SPATIAL EXTENT	VOLUME (Mb)	COPYRIGHT AND SOURCES	REFERENCE CODE	STATUS	PRICE (ECU)
BASIC REFERENCE DATA (TOPOGRAPHIC DATA)								
GISCO THEMATIC DATA								
1. Industrial themes (ID)								
Energy production Pan-Europe (EP)								
Power stations, EU	Thermal and hydro-power stations	Location of station	EU15		CEC - Eurostat/GISCO from different sources	EPECEL	PROD	
Energy transport Pan-Europe (ET)								
Electricity lines and transformation stations, EU	High tension lines and transformation stations	1/3 000 000	EU15		CEC - Eurostat/GISCO from different sources	ETECEL	PROD	

DATA THEME DATA LAYER	DESCRIPTION OF CONTENTS	RESOLUTION/ SCALE	SPATIAL EXTENT	VOLUME (Mb)	COPYRIGHT AND SOURCES	REFERENCE CODE	STATUS
BASIC REFERENCE DATA (TOPOGRAPHIC DATA)							
1. Administrative Boundaries (AD)							
NUTS regions EU (Nomenclature of Territorial Units for Statistics) (NU)							
NUTS version 5 (1992-1995), 10 million	Boundaries of 1 044 NUTS regions 4 hierarchical levels	1/10 000 000	EU12	0.7	CEC - Eurostat/GISCO: modified from W.H.O.	NUEC10MV5	REF
NUTS version 5 (1992-1995), 3 million	Boundaries of 1 044 NUTS regions 4 hierarchical levels	1/3 000 000	EU12	4.1	CEC- Eurostat/GISCO and DG XI Administrative map of the EC (1:3 Mio)	NUEC3MV5	CD1
NUTS version 5 (1992-1995), 1 million	Boundaries of 1 044 NUTS regions 4 hierarchical levels	1/1 000 000	EU12	4	CEC - Eurostat/GISCO: derived from old Commune Data Base	NUEC1MV5	CD1
NUTS version 6 (1995-1998), 10 million	Boundaries of 1 031 NUTS regions 4 hierarchical levels	1/10 000 000	EU15	0.8	CEC - Eurostat/GISCO: modified from W.H.O.	NUEC10MV6	REF
NUTS version 6 (1995-1998), 3 million	Boundaries of 1 031 NUTS regions 4 hierarchical levels	1/3 000 000	EU15	4.1	CEC- Eurostat/GISCO and DG XI Administrative map of the EC (1:3 Mio)	NUEC3MV6	CD1
NUTS version 6 (1995-1998), 1 million	Boundaries of 1 031 NUTS regions 4 hierarchical levels	1/1 000 000	EU15	4.5	CEC - Eurostat/GISCO: derived from old Commune Data Base	NUEC1MV6	CD1
NUTS version 7 (1998-), 1 million	Boundaries of NUTS regions 4 hierarchical levels	1/1 000 000	EU15 (except UK); EFTA	4.5	MEGRIN, CEC - Eurostat/GISCO: derived from SABE Commune Data Base	NUEC1MV7	REF
Administrative Regions Pan-Europe (AR)							
Administrative regions version 5, 1 million	3 hierarchical levels	1/1 000 000	Pan-Europe	3.7	CEC - Eurostat/GISCO derived from NUTS 1 million version 6, updated with boundaries of Political map of DGX	ARNE1MV5	REF
Administrative regions version 6, 1 million	3 hierarchical levels	1/1 000 000	Pan-Europe	3.6	CEC - Eurostat/GISCO derived from NUTS 1 million version 6, updated with boundaries of Political map of DGX	ARNE1MV6	REF
Administrative regions version 7, 1 million	3 hierarchical levels	1/1 000 000	Pan-Europe except EU15 and EFTA	3.6	MEGRIN, CEC - Eurostat/GISCO derived from NUTS 1 million version 6, updated with boundaries of Political map of DGX and with SABE	ARNE1MV7	REF

DATA THEME DATA LAYER	DESCRIPTION OF CONTENTS	RESOLUTION/ SCALE	SPATIAL EXTENT	VOLUME (Mb)	COPYRIGHT AND SOURCES	REFERENCE CODE	STATUS
Administrative regions version 3, 10 million	3 hierarchical levels	1/10 000 000	Pan-Europe	0,9	CEC - Eurostat/GISCO modified from WHO	ARNE10MV3	CD1
Communes EU (CM)							
Commune boundaries (1981), 100 000	Boundaries of 90 581 communes, in map library	1/100 000	EU12	93	National sources + Eurostat/SIRE	GISCO MAP LIBRARY Communes Layer CM81 (CMEC81)	REF
Commune boundaries (1991), 100.000	Boundaries of European communes, in map library	1/100 000	EU15 (except Scotland and the new Länder DE)	230	MEGRIN/SABE + Eurostat/SIRE	GISCO MAP LIBRARY Communes Layer CM91 (CMEC91)	REF
Commune boundaries (1995), 100.000	Boundaries of European communes, in map library	1/100 000	EU15 (except DE, ES, GR, IE, UK)		MEGRIN/SABE + Eurostat/SIRE	GISCO MAP LIBRARY Communes Layer CM95 (CMEC95)	REF
Points of gravity of communes (1981)	90 581 communes	Location of gravity point	EU12	6.4	CEC - Eurostat/GISCO	CMECPT81	REF
Points of gravity of communes (1991)	88 773 communes	Location of gravity point	EU15	6.4	CEC - Eurostat/GISCO	CMECPT91	REF
Generalised commune boundary coverage (1981), 1 million	Boundaries of 90 581 communes	1/1 000 000	EU12	50	CEC - Eurostat/GISCO	CMEC1M81	REF
Generalised commune boundary coverage (1991), 1 million	Boundaries of 88 773 communes	1/1 000 000	EU15 (except Scotland and the new Länder DE)	52	CEC - Eurostat/GISCO	CMEC1M91	REF
Generalised commune boundary coverage (1995), 1 million	Boundaries of 56 981 communes	1/1 000 000	EU15 (except DE, ES, GR, IE, UK)		CEC - Eurostat/GISCO	CMEC1M95	REF
2. Infrastructure (IN)							
Airports (AP)							
Airports Pan-Europe	Location of 1 610 airports Attributes: name, different codes, type, altitude	Location of airport	Pan-Europe	0.1	CEC - Eurostat/GISCO: modified from various sources	APEU	CD2
Airports eligible to Trans European Networks program	Location of 344 airports, 9 airport systems Attributes: name, different codes, type	Location of airport	EU15	0.1	CEC - Eurostat/GISCO	APEUTNV2	CD2

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Ports (PO)							
Ports Pan-Europe	Location of 1 575 ports Attributes: name, different codes	Location of port	Pan-Europe	0.2	CEC - Eurostat/GISCO	POEU	CD2
Ports eligible to Trans European Networks Program	Location of 174 ports Attributes: name, different codes	Location of TEN port	EU12 + EFTA	0.2	CEC - Eurostat/GISCO	POEUTNV1.INF	CD2
Road infrastructure (RD)							
Road network Pan-Europe, 1 million	Major Road Network + Access points Attributes: road type, different road numbering	1/1 000 000	Pan-Europe except former USSR	7.2	IRPUD	RDEU1MV2	REF
Road Network eligible to Trans European Networks Program	TEN road network Attributes: road type, different road numbering	1/1 000 000	EU15	7.2	CEC - DG VII and Eurostat/GISCO based on IRPUD	RDEUTNV2DS	REF
Railway infrastructure (RW)							
Railway network Pan-Europe, 1 million	Major Railway Network + Access points Attributes: railway type, owner	1/1 000 000	Pan-Europe	6.7	IRPUD	RWEU1MV2	REF
Railway Network eligible to Trans European Networks Program	TEN railway network Attributes: railway type, owner	1/1 000 000	EU15	6.7	CEC - DG VII and Eurostat/GISCO based on IRPUD	RWEUTNV2DS	REF
Ferry Links (FL)							
Ferry links eligible to Trans European Networks program	TEN ferry links	1/1 000 000	EU12 + EFTA	0.1	CEC - Eurostat/GISCO	FLEUTNV1	REF
Settlements (ST)							
Urban centers Pan-Europe	Location of 3 655 urban centers (> 20 000 inhabitants) Attributes: name, area, population number	Location of center	Pan-Europe	0.3	CEC - Eurostat/GISCO: modified from WHO	STEU	CD2
Urban center being national/regional capital, EU12	923 urban centers	Location of center	EU12	0.1	CEC - Eurostat/GISCO	STNUCPV5.INF	CD2
Urban center being national/regional capital, EU15	985 urban centers	Location of center	EU15	0.1	CEC - Eurostat/GISCO	STNUCPV6.INF	REF
Urban center being national/regional capital, EU15	1017 urban centers	Location of center	EU15	0.1	CEC - Eurostat/GISCO	STNUCPV7.INF	REF
Urban center being national/regional capital, pan-Europe	353 urban centers, non-EU	Location of center	Pan-Europe (without EU12)	0.1	CEC - Eurostat/GISCO	STARCP.INF	CD2

DATA THEME DATA LAYER	DESCRIPTION OF CONTENTS	RESOLUTION/ SCALE	SPATIAL EXTENT	VOLUME (Mb)	COPYRIGHT AND SOURCES	REFERENCE CODE	STATUS
3. Hydrography (HY)							
Water pattern Pan-Europe (WP)							
Water pattern Pan-Europe, 3 million	Most important rivers and lakes 6 159 river segments and 2 068 lakes	1/3 000 000	Pan-Europe	3.1	CEC - Eurostat/GISCO	WPEU3M	CD2
Water pattern Pan-Europe, 10 million	Most important rivers and lakes 1 100 river segments and 330 lakes	1/10 000 000	Pan-Europe	0.9	CEC - Eurostat/GISCO	WPEU10MV2	CD2
Inland waterways eligible to Trans European Networks Program	629 river segments	1/3 000 000	Pan-Europe	0.2	CEC - Eurostat/GISCO	WPEUTNV2	CD2
Inland navigable waterways Pan-Europe, 1 million	Navigability of rivers and canals 2 283 river segments	1/1 000 000	Pan-Europe	0.4	CEC - Eurostat/GISCO	WPEUNV1M	REF
Watersheds Pan-Europe (WS)							
Watershed boundaries Pan-Europe, 10 million	190 drainage basins defined	1/10 000 000	Pan-Europe	0.9	CEC - Eurostat/GISCO	WSEU10M	CD2
Watershed boundaries Pan-Europe, 3 million	240 drainage basins defined	1/3 000 000	Pan-Europe	0.2	CEC - Eurostat/GISCO: modified from various sources	WSEU3M	CD2
4. Altimetry (AL)							
Digital elevation model Pan-Europe (DE)							
Digital Terrain Model Pan-Europe, 20 million	Digital Elevation (altitude in meters) Grid for Pan-Europe 5 minutes longitude/latitude resolution	1/20 000 000	Pan-Europe	1.7	US NGDC: Etopo-5	DEEU20M	CD2
Digital Terrain Model Pan-Europe, 3 million	Digital Elevation (altitude in meters) Grid for Pan-Europe 30 seconds longitude/latitude resolution	1/3 000 000	Pan-Europe	40	EDC	DEEU3M	REF
5. Support (SU)							
Geographical grid Pan-Europe (GG)							
Latitude/longitude grid for Pan-Europe	Parallels and meridians each degree	1 degree	Pan-Europe	5	CEC - Eurostat/GISCO	GGEU	REF
Gazetteer (GZ) Inventory of major landmarks, EU	45 525 points, of relevance for spatial queries and cartographic output	1/100 000 to 1/500 000	EU12 (except former DDR)	11.6	CEC - Eurostat/GISCO	GZEC	REF

DATA THEME DATA LAYER	DESCRIPTION OF CONTENTS	RESOLUTION/ SCALE	SPATIAL EXTENT	VOLUME (Mb)	COPYRIGHT AND SOURCES	REFERENCE CODE	STATUS
Map Sheets (MS)							
Map sheet boundaries, EU	Inventory of 1 818 national topographic map series	1/100 000 (except UK and AT: 1/50 000)	EU12 (+ AT)	1.2	CEC - Eurostat/GISCO - DG XI/CORINE	MSEC	REF
GISCO THEMATIC DATA							
1. Community support frameworks (CS)							
Interregional EU (IG)							
Interreg I (1989-1993)	201 NUTS 3 regions eligible for Interreg I	NUTS regions	EU12	0.1	CEC - Eurostat/GISCO and DG XVI: Regional Policy	IGECV1.INF	REF
Interreg II (1994-1999)	321 NUTS 3 regions eligible for Interreg II	NUTS regions	EU15	0.1	CEC - Eurostat/GISCO and DG XVI: Regional Policy	IGECV2.INF	REF
LEADER Program (Liaison Entre Actions de Développement de l'Economie Rurale) EU (LD)							
Leader zones EU version 1 (1991-1994), 1 million	217 local action groups	1/1 000 000	EU12	2.1	CEC - Eurostat/GISCO	LDEC1MV1	REF
Structural funds EU (SF)							
Structural funds EU version 1 (1989-1993), 3 million	NUTS III regions eligible for structural funds	1/3 000 000	EU12	1	CEC - Eurostat/GISCO and DG XVI: Regional Policy	SFEC3MV1	REF
Structural funds EU version 2 (1994-1999), 1 million	NUTS III regions eligible for structural funds based on commune boundaries	1/1 000 000	EU12	2	CEC - Eurostat/GISCO	SFEC1MV2	REF
Structural funds EU15 version 3 (1994/1995-1999), 1 million	NUTS III regions eligible for structural funds based on commune boundaries	1/1 000 000	EU15	2.2	CEC - Eurostat/GISCO	SFEC1MV3	REF
Structural funds EU15 version 4 (1994-1999), 1 million	NUTS III regions eligible for structural funds based on commune boundaries	1/1 000 000	EU15	2.2	CEC - Eurostat/GISCO	SFEC1MV4	REF
2. Infraregional statistics (IR)							
Degree of urbanisation EU (UR)							
Urbanisation EU, 1 million, 1981	Classification of communes into 3 density classes: - densely populated areas - intermediate areas - thinly populated areas	1/1 000 000	EU12	5	CEC - Eurostat/GISCO	UREC1M81	REF
Urbanisation EU, 1 million, 1991	Classification of communes into 3 density classes: - densely populated areas - intermediate areas - thinly populated areas	1/1 000 000	EU15	5	CEC - Eurostat/GISCO	UREC1M91	REF

DATA THEME DATA LAYER	DESCRIPTION OF CONTENTS	RESOLUTION/ SCALE	SPATIAL EXTENT	VOLUME (Mb)	COPYRIGHT AND SOURCES	REFERENCE CODE	STATUS
Urban regions used for Labour Force survey, 1 million, 1992	Delineation of urban regions used for Labour Force survey. Attributes: regional code, name and corresponding NUTS code	1/1 000 000	EU15	2	CEC - Eurostat/GISCO	URECLF1M92	REF
Urban regions used for Labour Force survey, 1 million, 1996	Delineation of urban regions used for Labour Force survey. Attributes: regional code, name and corresponding NUTS code	1/1 000 000	EU15	2	CEC - Eurostat/GISCO	URECLF1M96	REF
3. Industrial themes (ID)							
Nuclear power stations EU (NP)							
Nuclear power stations EU	151 reactors Attributes: capacity, type of reactor, energy production	Location of nuclear station	EU12	0.8	CEC - Eurostat/GISCO Eurostat, 1990 Operation of Nuclear powerstations 1989	NPEC	REF
Energy production Pan-Europe (EP)							
Electricity power and transformation stations Pan-Europe	938 power and transformation stations Attributes: type, name, class	Location of station	Pan-Europe	0.1	CEC - Eurostat/GISCO	EPEUEL	REF
Energy transport Pan-Europe (ET)							
Electricity lines and power/transformation stations Pan-Europe	Electricity lines and power/transformation stations Attributes: tension class, status	1/20 000 000	Pan-Europe	0.2	CEC - Eurostat/GISCO	ETEUEL	REF
Terminals and refineries for transport of oil and gas Pan-Europe	256 terminals and refineries Attributes: type, name	Location of terminal/refinery	Pan-Europe	0.1	CEC - Eurostat/GISCO	ETEUOGPT	REF
Pipelines and terminals/refineries for transport of oil and gas Pan-Europe	Pipelines and terminals/refineries Attributes: type, capacity, status, name	1/20 000 000	Pan-Europe	0.2	CEC - Eurostat/GISCO	ETEUOG	REF
Planned electricity projects eligible for the Trans European Networks Program Pan-Europe	Planned electricity projects	1/20 000 000	Pan-Europe	0.1	CEC - Eurostat/GISCO - DGXVII	ETEUELTNPR	REF
Planned oil and gas lines and terminals eligible for the Trans European Networks Program Pan-Europe	Planned oil and gas projects	1/20 000 000	Pan-Europe	0.1	CEC - Eurostat/GISCO - DGXVII	ETEUOGTN	REF

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4. Land resources (LR)							
Climate EU (CT)							
Climate data base EU	19 climatic variables for 5 308 stations	Location of station	EU12 (except DDR)	2.4	CEC - DG XI/CORINE: obtained from Meteorological services of Member States	CTEC	CD3
Fishing areas Pan-Europe (FA)							
Fishing areas Pan-Europe, 3 million	Subdivision of Marine area's for statistical purposes	1/3 000 000	Pan-Europe	1.2	CEC - Eurostat/GISCO	FAEU3M	CD3
Fishing areas Pan-Europe, 10 million	Subdivision of Marine area's for statistical purposes	1/10 000 000	Pan-Europe	0.4	CEC - Eurostat/GISCO	FAEU10M	CD3
Land Cover (LC)							
Inventory of land cover, Pan-Europe	Inventory of biophysical land cover 44 class nomenclature (vector data)	1/100 000 (vector format)	EU12 (40% complete)	423	CEC - Member States, EEA	LCEU	REF
Inventory of land cover, Pan-Europe	Inventory of biophysical land cover 44 class nomenclature (raster data)	250 m resolution (raster format)	EU15 (except SE FI UK) + Some PHARE countries (PO CZ SV RO HU BG) + Parts of Morocco and Tunisia	32	CEC - Member States, EEA	LCEUGR250	REF
Inventory of land cover, Pan-Europe	Inventory of biophysical land cover 44 class nomenclature (raster data)	100 m resolution (raster format)	EU15 (except SE FI UK) + Some PHARE countries (PO CZ SV RO HU BG) + Parts of Morocco and Tunisia	200	CEC - Member States, EEA	LCEUGR100	REF
Soil map (SL)							
Inventory of soil units of EU, according to FAO nomenclature	15 843 polygons Soil mapping units and their characteristics; soil typological units and their characteristics	1/1 000 000	EU12	11.5	CEC - DGXI/CORINE and JRC-IRSA at ISPRA	SOIL	REF

DATA THEME DATA LAYER	DESCRIPTION OF CONTENTS	RESOLUTION/ SCALE	SPATIAL EXTENT	VOLUME (Mb)	COPYRIGHT AND SOURCES	REFERENCE CODE	STATUS
5. Nature resources (NR)							
Biotopes (BP)							
Inventory of sites of major importance for nature conservation	7 740 sites Attributes: site identification, site location, ecological information, site description	Location of center point of biotope	EU12 + Finland	38.4	DGXI - TF - EEA, CEC - Eurostat/GISCO	BPECV2	REF
Biogeographical zones (BG)							
Biogeographical zones of EU	Delineation of 5 different biogeographic zones as defined in the framework of the Council Directive 92/43/EEC	1/20 000 000	EU12	0.4	CEC - Eurostat/GISCO - Council of Europe	BGEC	CD3
Designated areas (DA)							
Inventory of sites designated under community legislation and international conventions	1 812 points Attributes: site identification, site location, site description	Location of center point of designated sites	Pan-Europe and Northern Africa	0.4	CEC - DG XI/CORINE modified from Ramsar Convention Bureau - UNEP-MAP - Council of Europe - Unesco - WCMC	DAEUINPT	REF
Landscapes Pan-Europe (LS)							
Landscape types Pan-Europe	Landscape type of Europe 30 landscape types in 8 landscape complexes	1/6 000 000	Pan-Europe	0.2	CEC - Eurostat/GISCO - DGXI - TF-EAA	LSEU	CD3
Natural potential vegetation (VG)							
Inventory of the natural vegetation according to phytosociological associations	4 160 polygons 232 vegetation types	1/3 000 000	Pan-Europe (except East European countries)	3.5	CEC - Council of Europe - Eurostat/GISCO	VGEU	CD3
6. Environment (EN)							
Coastal Erosion (CE)							
Inventory on coastal morphology and erosion risk, 100 000 scale	17 051 coastline segments Attributes: morphological criteria, evolutionary criteria, presences of manmade defensive structures	1/100 000	EC12 (except Greek Islands, former DDR, Madeira and Acores)	4.8	CEC - DGXI/CORINE	CEEC	CD3
Inventory on coastal morphology and erosion risk, 1 million scale	14 231 coastline segments Attributes: morphological criteria, evolutionary criteria	1/1 000 000	EC12 (except Greek Islands, former DDR, Madeira and Acores)	1.7	CEC - DGXI/CORINE	CEEC1M	CD3

DATA THEME DATA LAYER	DESCRIPTION OF CONTENTS	RESOLUTION/ SCALE	SPATIAL EXTENT	VOLUME (Mb)	COPYRIGHT AND SOURCES	REFERENCE CODE	STATUS
Land Quality (LQ)							
Potential land quality in Southern Europe	3 646 polygons Attribute: land quality potential index	1/3 000 000	Southern Europe	2.2	CEC - DGXI/CORINE	LQSUPO	CD3
Soil Erosion Risk (SE)							
Actual soil erosion risk in Southern Europe	4 551 polygons Attribute: actual soil erosion risk index	1/3 000 000	Southern Europe	2.7	CEC - DGXI/CORINE	SESUAC	CD3
Potential soil erosion risk in Southern Europe	3 665 polygons Attribute: potential soil erosion risk index	1/3 000 000	Southern Europe	2.2	CEC - DGXI/CORINE	SESUPO	CD3
7. World data bases (WD)							
World administrative regions (WA)							
World administrative regions, 3 million	Administrative regions of the world in geographical coordinates Attributes: different codes, names in different languages	1/3 000 000	World	13	CEC - Eurostat/GISCO - ESRI Arcworld	WAWD3MGG	CD1
World administrative regions, 25 million	Administrative regions of the world in geographical coordinates Attributes: different codes, names in different languages	1/25 000 000	World	6.3	CEC - Eurostat/GISCO - ESRI Arcworld	WAWD25MGG	CD1
Altimetry World (AL)							
Digital Terrain Model World	Grid coverage in geographical coordinates 5 minutes latitude/longitude resolution	1/20 000 000	World	16	US NGDC: Etopo-5	ALWDGG	CD2
Geographical grid World (GG)							
Geographical grid World	Geographical grid each degree, in geographical coordinates	1 degree	World	22.3	CEC - Eurostat/GISCO	GGWDGG	REF
Fishing areas World (FA)							
Fishing areas World, 25 million	Subdivision of Marine area's for statistical purposes	1/25 000 000	World	5.6	CEC - Eurostat/GISCO	FAWD25MGG	CD3

MULTIPLE APPLICATIONS OF A SURVEY OF LAND COVER/USE : THE TER-UTI EXAMPLE

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Document prepared in conjunction with SCEES - the Ministry of Agriculture's Central Service for Statistical Surveys and Studies - using data obtained from the SCEES's Agreste database

1. Ter-Uti: a survey for an inventory of land cover and land use

1.1. Origin and objectives of the survey

This survey was developed in France in the 1970s, with the principal aim of monitoring changes in areas under various crops. The Ministry of Agriculture developed the survey in response to internal concerns for the purposes of forecasting harvests and recording changes between censuses of agriculture. However, its design provides general information on the territory as a whole, agricultural and non-agricultural. It was designed – particularly in terms of the definition of classifications - in conjunction with the ministries responsible for agriculture and the environment. The survey is intended to yield results which can be used at the level of each département.

The features of the survey are set out briefly below, and some of its potential applications are considered.

1.2. Main features of the survey

An exhaustive grid system (4 700 12 km x 12 km grids) is superimposed on the territory of mainland France. This serves to define two successive levels of sampling before observation (see sampling system, annex 1).

1.2.1. Sampling

First-level spatial sampling

The "photograph". Each grid cell accommodates four sites[9] defining the position of the aerial photographs (each of which represents an area of approximately 2 km x 2 km). These provide the basis for the second-level sampling. The photographs are not interpreted; they simply serve as a support for locating the survey points.

Second-level spatial sampling

Each "photograph" is marked with 36 "points" corresponding to the sites to be visited by the surveyors who record how they are covered/used. The 36 points form a grid covering the photograph in the form of six rows and six columns at intervals of 300m (see illustration in annex 1). Every site is visited once a year by a surveyor who has been especially trained for this work. At every point, one single observation is made of the cover (physical nomenclature), and some information is recorded on the use (functional nomenclature). Each point represents 100 hectares for the interpretation of results.

[9] Or eight sites for small *départements*

1.2.2. Nomenclatures

Land cover nomenclatures (physical nomenclatures)

This consists of 82 particularly detailed classes of cover to identify the various crops or fruit. The accuracy of crop identification is therefore excellent. Land cover may refer to very small areas (built-up areas, artificially coated land, isolated trees) or very large unit areas because the observation concerns the "point" identified by sampling. Unlike a map legend, this kind of classification also identifies the proportion of land cover in small unit areas, whereas these land cover types are inevitably under-represented in any map (on paper or in a GIS).

Land-use nomenclatures (functional nomenclature)

This nomenclature consists of 25 classes, and enables to distinguish between the various forms of use made of areas even with the same physical cover. This information cannot be obtained by any means other than direct surveying in most cases.

1.2.3. Survey periodicity and availability of results

The surveys are carried out in late spring every year. The information is processed in early summer, and the results are available in the summer of the survey year. They are stored on databases, and can be used to monitor changes over time, at least for periods when the same samples are observed.

2. Examples of how the survey is used

The database compiled from this survey can serve any number of purposes. A few examples follow which draw on information which goes beyond agricultural areas, or the département level traditionally used by the Ministry of Agriculture for its own purposes.

The information may be spatial, time-series based or a combination of both. Some examples cross-refer information from TerUti with data from other databases.

2.1. Spatial information and cross-referring databases

The information can also be used, with due caution in interpretation, at spatial levels other than the department. The minimum spatial unit is the department. It is, however, possible to divide geographical areas into spatial units with an area similar to a département but with different geographical boundaries if the areas represented are similar to the area of a département. This approach was taken in a study of potential nitrogen pressures on catchment areas (POIRET, VIDAL, 1992).

This study compared flows of nitrogen measured in water from 153 catchment sub-basins with variables likely to contribute to the transfer of nitrates to the water or to hydrological dynamics. Several of these variables are linked to land cover (areas of bare land in winter, areas under leguminous vegetables, proportion of hedgerows, areas under grass, wooded areas, areas which have been rendered waterproof) or to changes in land cover (meadowland ploughing). Others come from a range of other sources (mineral pressure linked to fertiliser use, organic pressure linked to the spreading of livestock manure, domestic pressure and industrial pressure).

Most of the data on land cover and changes therein were drawn from the TerUti survey. The processed results reveal that marked flows in winter and spring were features of agricultural sub-basins, whereas strong summer and autumn flows tend to be associated with urban sub-basins.

2.2. Land cover dynamics

The principal benefit of the TerUti survey is that it provides results from observations made over a short period (annual), and that the information is available very soon. It is therefore possible to monitor changes in land cover or use from one year to another. To this end, it is necessary to work on a spatially constant sample, and certain data series are therefore truncated when the sample is rotated. For optimum information, it would be necessary to ensure stable sampling in the long term.

The survey can provide information on frequencies of change in cover - or use - by geographic entity: département, region, or even the entire national territory[10] - and make use of more or less highly aggregated nomenclature headings.

The information has also been used at spatial levels other than the département (grid[11], 36-point grid[12], or point[13]).

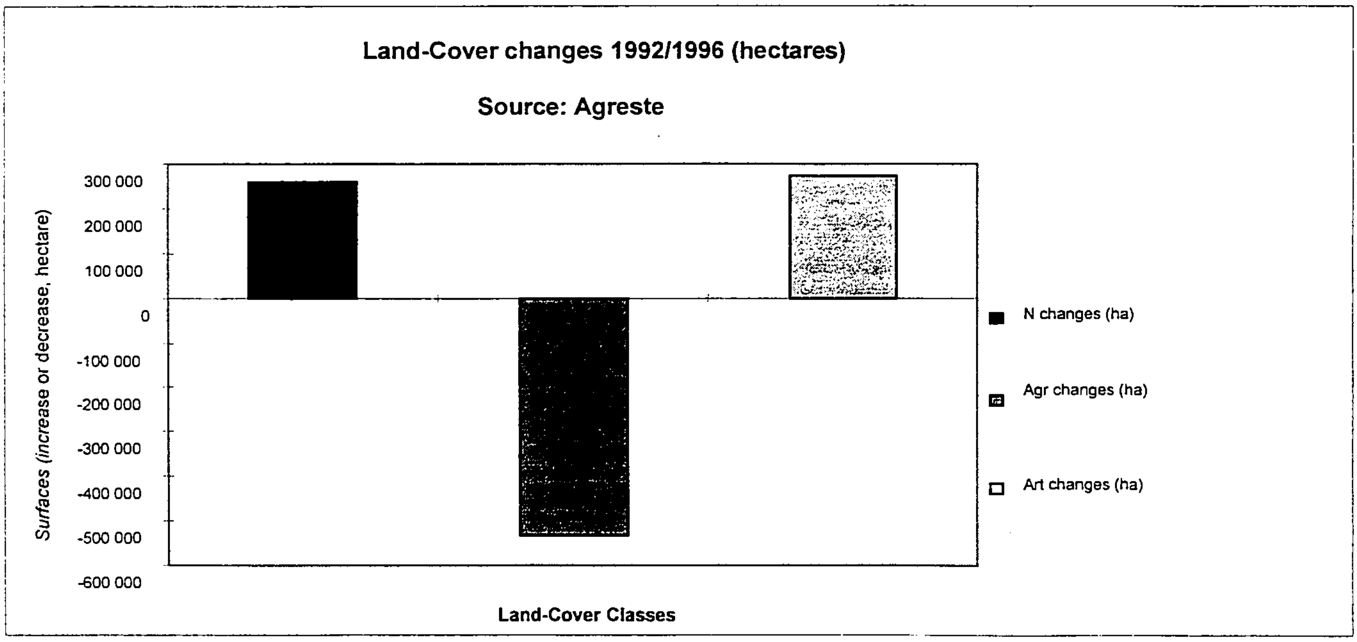
2.2.1. Study of changes in land cover and use in France (1992-1996)

Nationally, changes in cover and use can be represented in a simplified form using aggregations of headings from physical or functional nomenclatures. Thus, for example, by grouping the 82 headings of the physical nomenclatures in three principal categories (see Annex 2), it is possible to show trends in changes between broad categories of land cover.

It is thus possible to present the major events observed over the period under review (see figure No. 1).

Over the period under review, the dynamics reflect a considerable decline in agricultural areas to the benefit of forests and urban cover. In environmental terms, this may point to habitat changes caused by such developments, but also to changes in the degree to which areas have been rendered waterproof, or even to changes in landscapes (cf. 2.2.3).

Figure No. 1 refers to all of France. It is, of course, possible to calculate these changes at other spatial scales, or for other aggregates. The IFEN obtained results on changes in grassland at national level in this way (BABILLOT, 1996).

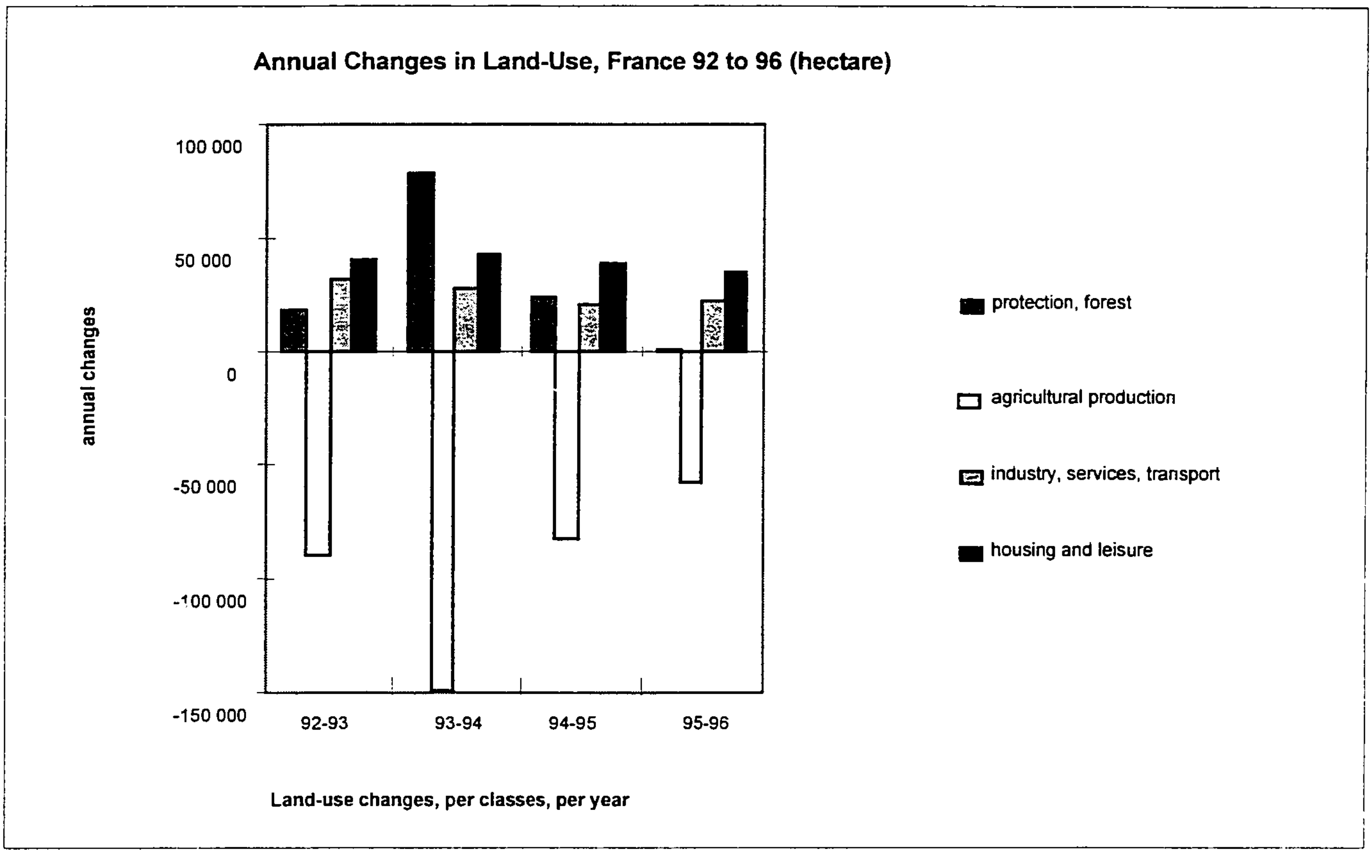


[10] see 2.2.1

[11] see 2.2.2

[12] see 2.2.4

[13] see 2.2.3



It is also possible to represent changes in land use by aggregating functional classifications (see figure N° 2).

This illustrates the constant increase in areas given over to housing and leisure, industry, services and transport. On the other hand, the increase in protected areas or forest production is much more irregular, and also accounts for irregularities in the decline of areas used for agricultural production.

2.2.2. Study of changes in grassland and tilled land in France (1982-1990)

This information is exploited by grid arrays representing 4 grids of points, or 144 survey points.

The study highlights the decline in grassland and the concomitant increase in arable land (POIRET, VIDAL, 1993).

These developments reflect changes in production during this period, which in turn reflect technical changes (drainage, irrigation, maize-based animal feedstuffs) and market fluctuations in relation to agricultural policies (production surpluses, milk quotas and increases in areas under oilseeds and protein crops up to the end of the period).

Such changes have repercussions on the appearance of landscapes and on other environmental parameters. For example, meadowland ploughing is accompanied by intense mineralisation of organic matter, which is a source of nitrates on the one hand (and thus contributes to water pollution) and of carbon dioxide on the other (which contributes to the greenhouse effect); the characteristics of water penetration into soil are also affected, and this combination may make soils fragile and increase the risk of hydric erosion. Grassland habitats may also be important from the point of view of their biodiversity.

Figure N°. 3 shows increases in areas of tilled land and reductions in grassland. Figure N°. 4 presents the increase in areas under peas and the increase in areas under sunflowers during this period. The size of the dark areas corresponds to the extent of the changes (>10 points out of 144 for the smallest, >20 points for the average and >30 points for the greatest). One point represents 100 hectares.

Figure N° 3: on the left, the location of increases in areas of tilled land between 1982 and 1990; on the right, the location of reductions in grassland (POIRET, VIDAL, 1993, source: Agreste)

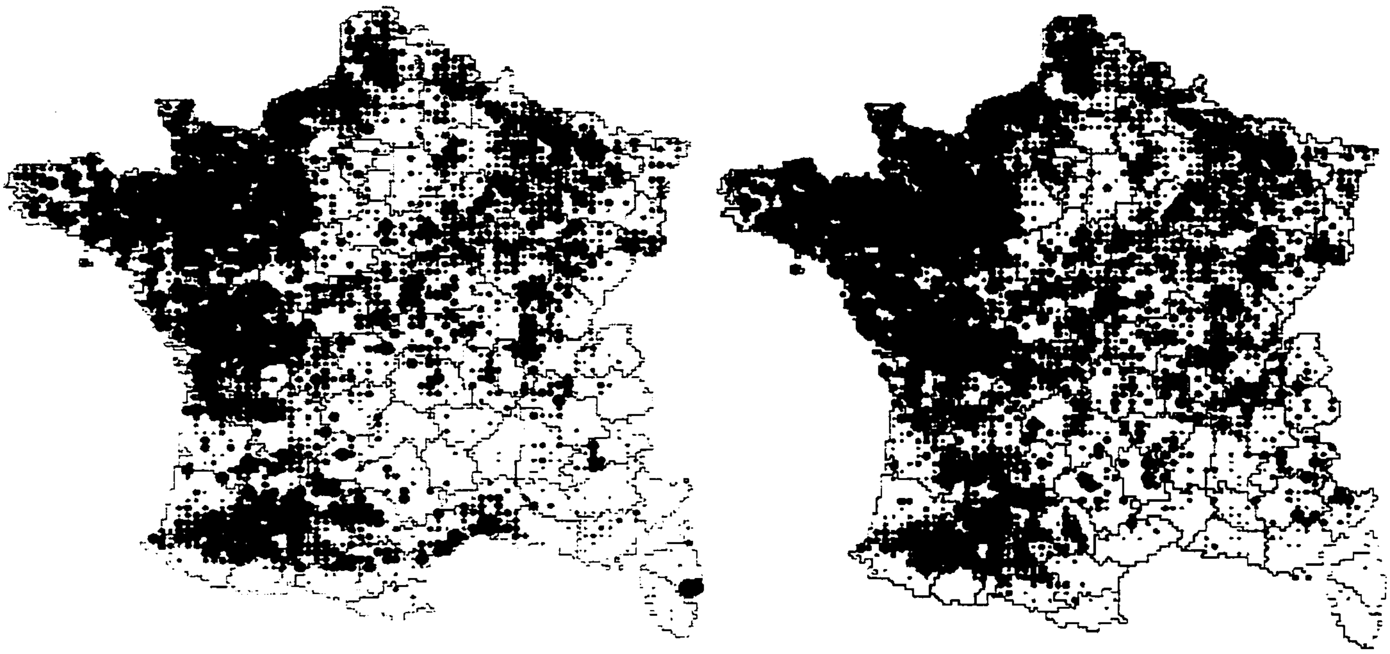
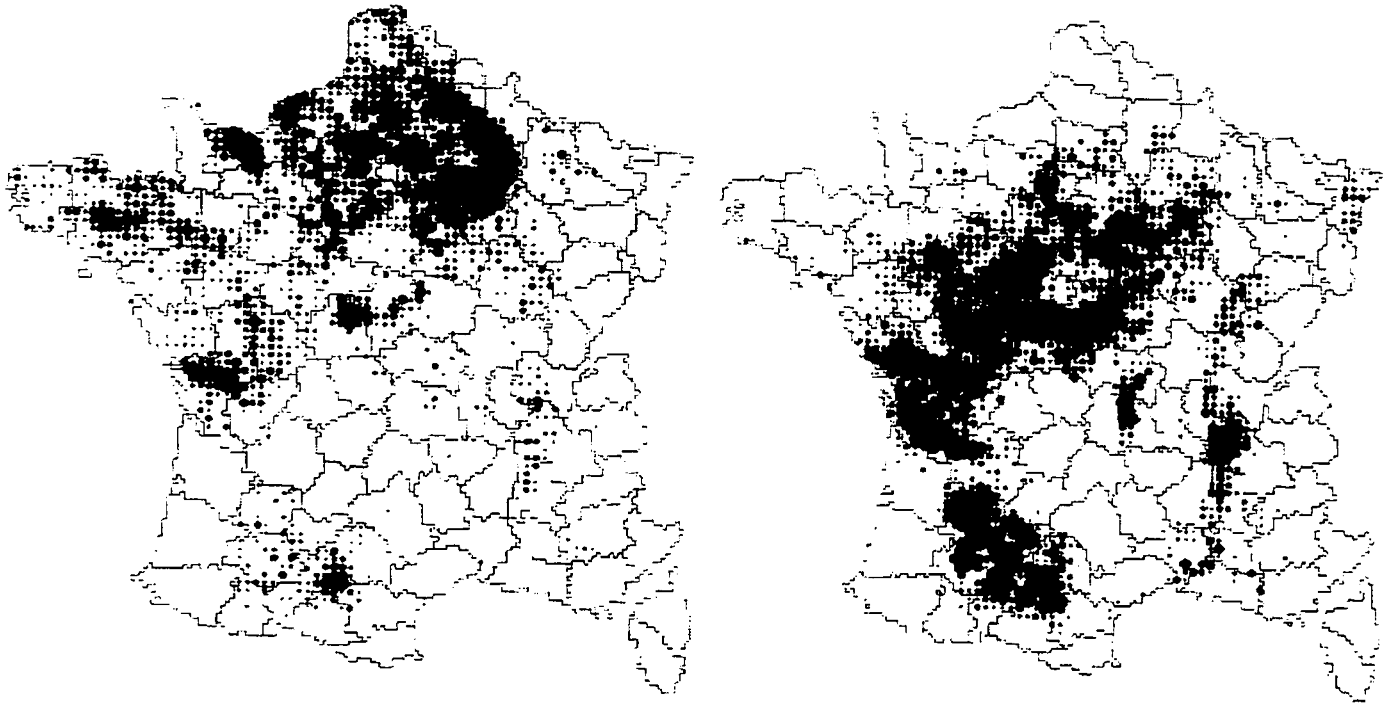


Figure N° 4 shows, on the left, the increase in areas under peas and, on the right, the increase in areas under sunflowers between 1982 and 1990 (POIRET, VIDAL, 1993, source: Agreste)



2.2.3. Study of crop rotation in France (1982-1990)

This example concerns the use of information by points.

Crop rotation can be monitored over a period if the same points are visited. It is then possible to detect what sort of rotation is used and to distribute types of rotation territorially (JEZEQUEL, VIDAL, 1993). This study was conducted across France as a whole for the longest period entailing no change of sample.

Traditional rotation practices aimed to reconcile agricultural and economic imperatives, and generally mixed cereals and a break crop (industrial crops, grass or fallow). Technical progress and economic fluctuations linked to the CAP have brought about profound changes in these practices.

Such analysis involves identifying the rotation of cereals over 220 000 ha nationally (including rice growing). Generally, long sequences of cereals are more frequent than real single-crop farming. On the best farmland, not only is rotation frequent, but cereals are planted between break crops (crops offering greater returns during that period, before changes in the CAP).

It is also possible to detect rotation corresponding to more typical single-crop farming: maize growing, for grain or fodder production.

Another assessment of rotation by points is currently being made to monitor the reforestation of agricultural land.

2.3. Study of land cover structures and the link with landscapes

The database permits changes in land cover to be processed.

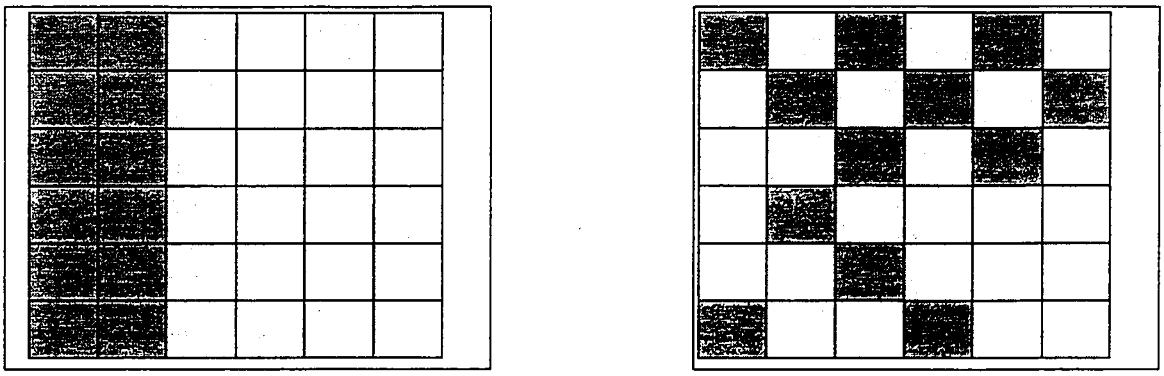
These changes partly reflect changes in landscapes which are generally hard to describe. An initial trial description was proposed in 1995 (SLAK, VIDAL, 1995, (1)). Changes in cover were described using the information by grids of points, and examining which were the preponderant covers by aggregating categories as described in annex 2 (SLAK, VIDAL, 1995, (2)).

2.3.1. Study of land-cover structures

Experience revealed, however, the shortcomings of only monitoring land cover frequencies, because two identical frequencies may concern two markedly different spatial structures, and therefore two different landscapes (see figure N° 5).

In conjunction with the SCEES, the ENITAB Soil and Landscape Laboratory therefore proposed indicators of land cover structures (SLAK, 1997). These indicators permit homogeneous or heterogeneous areas to be detected in relation to covers chosen or aggregated amongst the classes of the nomenclature (in this case, aggregation to three categories as in annex 2).

Figure N° 5: different spatial structures for two covers with the same frequencies; each point on the grid is here extended to the surrounding area.



The sampling structure permits the spatial organisation of covers to be described at considerable levels of aggregation of the classification for the areas covered by the survey. It is thus possible to describe "cover structures" which may prove to be close to landscape structures.

2.3.2. Study of land cover structures in Gironde 1982, link with landscapes

The setting up of groups for the spatial organisation of points on the grid in 1982

By classification, and using structural indicators (SLAK, 1997), the grids for the 1982 survey were allocated to 6 groups for Gironde. These were: homogeneous agricultural structures, homogeneous natural structures, heterogeneous agricultural structures, very heterogeneous structures, heterogeneous natural/agricultural structures and homogeneous urban structures.

We can establish the composition of the different groups set out above on the basis of their homogeneity. Histograms of the frequencies of the different categories of land cover were compiled to this end for each one (see aggregation in 10 categories, Annex 2).

It thus emerged that the «homogeneous natural » group actually consists of coniferous forests covering the entire west of the departement. The «homogeneous agricultural» group corresponds to the wine-growing regions, and the histogram shows that vines are accompanied by other crop types. These types of structures are found in particular in all of the Blayais, Libournais and Côtes du Bordelais, as shown on the map setting out the results for 1982 (cf. Slak, 1997). Vines are still the predominant cover in the «heterogeneous agricultural» group, although deciduous forest is in more marked evidence. In this group, vines are more dispersed than in the previous one. The «very heterogeneous» group is characterised by periurban areas, which have gradually been eaten into by the advance of the suburbs. The histogram shows approximately one-third forest cover and one-fifth "non-natural" cover, with farmland dominated by grassland mixed with vines and little tilled land (a distribution which corresponds to a very traditional type of agriculture, which is even in decline in this sector: the pressure from urban development has no doubt played a part in braking agricultural dynamics). Its geographic distribution in 1982 ran to the very edge of Bordeaux. The grids of the «natural/agricultural» group were carved out of the forest of "Les Landes" or are on its edges. According to the spatial organisation indicators, coniferous forests are grouped in homogeneous areas, but are close to agricultural structures. The predominant cover frequencies are coniferous forests, while the bulk of farmland is grassland and tilled land (vines are in evidence, albeit a more marginal presence). The «homogeneous urban » group is only typical of the centre of Bordeaux, where non-natural, built up or artificially coated land accounts for an average of nearly 20 out of 36 instances of cover.

Comparison between landscape types and statistical results

The results obtained by processing the data from the Ter-Uti point grids were compared with an empirical classification of the areas surveyed by a landscape architect (who observed the entire field of vision from the centre of each grid area). This work therefore constituted a different approach to the areas studied for the survey.

Tables of equivalence were compiled between the groups observed by the landscape architects[14] and the groups established on the basis of the spatial structures.

Automatic classification of the grids makes for relatively faithful transcription to the classifications of landscapes made by human observation of the terrain. These classifications also reveal the extent of the difference between a subjective and a statistical approach.

For example, allocations are much less clear-cut in so-called "transition" groups, which are characterised by variable proportions of covers. Similarly, for the "clearings" subset, more grids are grouped in the "homogeneous natural" category than in "less heterogeneous natural/agricultural ", no doubt due to the fact that, even if the cover is predominantly forest - by area -, the predominant impression of this type of area is of alternating open ground and covered areas.

This study enabled land cover structures to be mapped at different times, showing that Ter-Uti can also constitute an indicator of change in landscapes on the ground covered by the survey.

[14] 25 landscapes were described; they were allocated to six main types for the purposes of comparison.

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Annex 1:

Schéma du maillage de base de TER-UTI

La France est quadrillée :

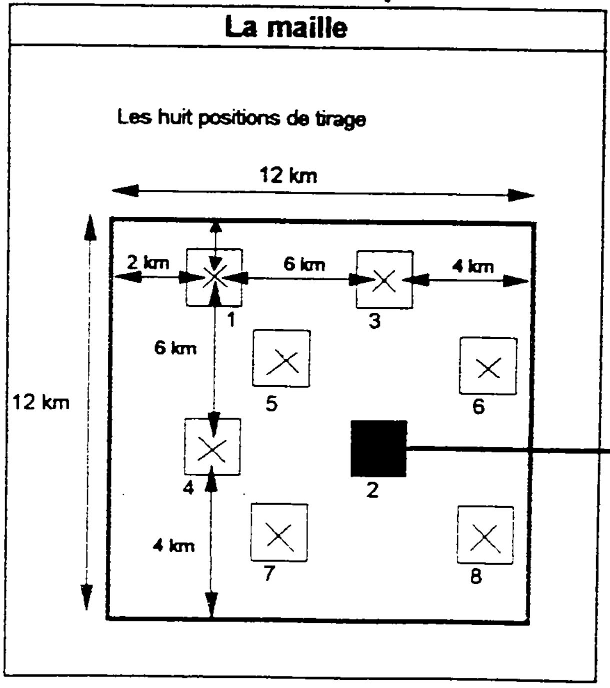
4.700 MAILLES
pour la couverture du territoire : 12 km X 12 km

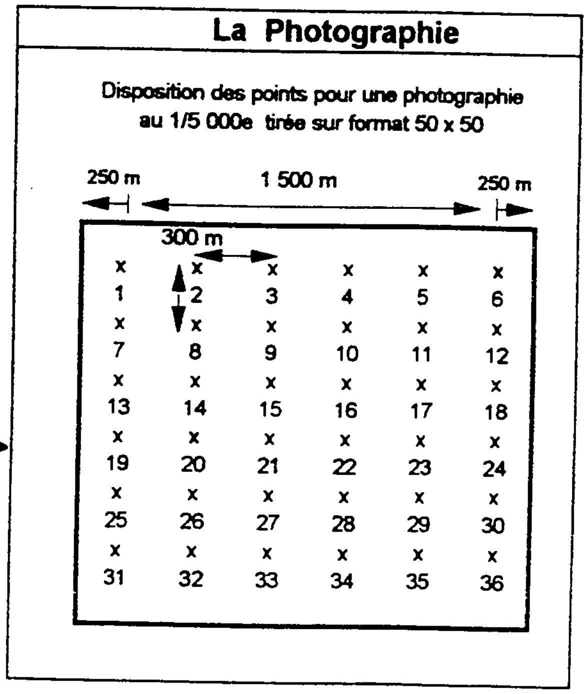
Dans chaque maille

8 POSITIONS
DE PHOTOGRAPHIES
distantes de 4,2 km

36 POINTS
à enquêter par photographie

La superficie de la France est de 55.000.000 ha,
555.904 points observés
1 point = 100 ha environ





Annex 2

Compilation of categories by combining TER-UTI physical classification headings (after SLAK M.-F., VIDAL C., 1995)

Survey physical code	Sub-category	Secondary category	Major category
15, 16 11, 17 12, 13, 14 49 50, 69, 70, 71 18 19, 20, 21	rocks, glaciers, scree dunes, beaches, salt marshes fresh water high mountain pasture heath, common land deciduous forest coniferous forest	rock and water heath, common land high mountain pasture forests	"natural"[15]
72 22, 23, 26 24, 25 73 53 à 66 43 46, 47, 48, 51 27 à 42, 44, 45, 52 67	hedgerows sparse woodland poplar plantations roads vineyards, orchards perennial crops grassland annual crops kitchen gardens	h, a, p, c vineyards, orchards perennial crops grassland annual crops	"agricultural"[16]
68, 84 74, 75, 76, 78 85 à 91, 77, 79 80, 81 82, 83	non-natural, green non-natural, deteriorated non-natural, built-up non-natural, parking non-natural, roads		"non-natural"[17]
99			Forbidden areas[18]

15 This refers to the intensity of land use: this category includes types of land cover where harvests are not annual, but the land is used productively (forests).

16 In addition to areas with an annual harvest, this category also includes types of land cover forming an integral part of farmland: h, a, c, p.

17 Includes all types of cover where land has been destroyed and is no longer used for agricultural purposes.

18 areas not surveyed (e.g. military areas).

SYSTEMS FOR MEASURING CHANGES

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SESSION 6

PROPOSALS FOR A FRAMEWORK FOR FUTURE WORK

SYNTHESIS OF CONCLUSIONS AND RECOMMENDATIONS

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Three important points requesting adequate measurements have been raised during this seminar:

1. The dialogue at the level of the European Commission services on this horizontal domain concerning various Community policies should be improved;

2. The need to provide comparable data to meet the varied needs of different policies is certainly far from facilitating the work of data producers and providers as well as of co-ordination;

3. Technical problems remain, at the level of the concepts used, the nomenclatures and of the complementarity of statistical and cartographic tools.

In order to meet these needs several types of actions have been proposed:

A. setting-up an inter-institutional co-ordination group between Eurostat, the Joint Research Center and the European Environment Agency; a restricted group to which other Commission services, national experts in the domain or experts of other international organisations (OECD, FAO, UNDP) could be associated. It is proposed that Eurostat should lead this group.

B. creating a focal point on land cover, land use and landscape with the following objectives to disseminate information on existing projects and initiatives, to ensure the co-ordination between the various existing networks and to foster the development of projects or partnerships in these fields.

C. Launching technical activities in support of the two preceding initiatives:

- preparation of a manual of concepts and terminology related to land cover, land use and landscape;
- preparation of a guide of best practice illustrating the principal characteristics of cartographic and statistical approaches as well as their necessary complementarity;
- updating and extending the existing database on information systems on land cover and land use towards:
  a. regional systems within Member States,
  b. existing systems in Central European and Eastern Countries and EFTA countries,
  c. information systems on landscape.
- Lastly, the publication of a Newsletter.

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