Technical report 59

Towards spatial and territorial indicators using land cover data

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Contents

1. Introduction 5

2. Context of the report 6

3. Land cover and sustainable development indicators 8

3.1. Indicators in general 8
- 3.1.1. Selecting an indicator system 8
- 3.1.2. Common ground 8
- 3.1.3. Fundamental criteria for indicators 9
- 3.1.4. A pragmatic proposal 11

3.2. Spatial and territorial indicators 12

3.3. Directions for the development of indicators 12

3.4. The land-dimension of indicators 13

4. Indicators based on land cover policy issues at all levels 17

4.1. Land Cover supporting EU-level policy-making 17
- 4.1.1. The natural environment 17
- 4.1.2. Agricultural and rural policy 23
- 4.1.3. Coastal policy 24
- 4.1.4. Transport policy 26
- 4.1.5. Spatial planning 29

4.2. Land Cover for the national and regional levels 31

5. Best practices using CORINE land cover data 35

5.1. Detailing the CLC mapping 37
- 5.1.1. Identification of small land cover features 37
- 5.1.2. Detailing the classification (level 4) at the basic CLC scale (1/100 000) 38
- 5.1.3. Production of targeted land cover maps at a greater level of detail 38

5.2. Digitised analysis of geographical information 39

5.3. Geo-statistical analysis 39
- 5.3.1. Weighted allocation of statistics to CLC classes 40
- 5.3.2. Design of sampling patterns 41
- 5.3.3. Aggregation 43

5.4. Integration of environmental and economic data: accounting and modelling 44
- 5.4.1. Accounting for land cover and land use 44
- 5.4.2. Environmental modelling 46
- 5.4.3. Integration of the social dimension 47

5.5. The issue of time 47

6. Conclusions 49

List of figures

Figure 1	DPSIR scheme for Land Cover	10
Figure 2	Climate change effects on the mountain vegetation	13
Figure 3:	Fragmentation of forests by transport networks	18
Figure 4	Major land cover types in and near major wetlands	19
Figure 5	Forest around major cities in Europe	21
Figure 6	Monitoring risks to population	23
Figure 7	The dynamics of change in the Belgian coastal zone, LACOAST 1976-90	25
Figure 8	Example of land cover changes within coastal zones	26
Figure 9	Average daily land take by new motorways – EU15 (in hectares per day)	27
Figure 10	Land take by transport infrastructure as % of total country area (1996)	28
Figure 11	Potential pressure by intensive agriculture in the East of France	32
Figure 12	Erosion risks during the autumn months	33
Figure 13	Noise trouble around the Toulouse-Blagnac Airport	34
Figure 14	Action and policymaking: interactions between the local and global scales	35
Figure 15	Action and policymaking: levels of information required	36
Figure 16	Using CLC to create an additional layer of information	37
Figure 17	Detailing CLC classification and/or scale	39
Figure 18	Method to reallocate conventional statistics to CLC	40
Figure 19	Population density reallocated to CLC, the example of Denmark	41
Figure 20	Individual river catchments classified according to (cumulated) pressure by agriculture	42
Figure 21	Proposal of a subset of water pollution monitoring stations, statistically representative at the European level	43
Figure 22	New perspectives for mapping, a methodology for smoothing detailed data	44
Figure 23	Land accounting following the UN-ECE approach	45
Figure 24	Analytical economy-environment modelling with CLC – the LUCC approach	47

1. Introduction

The Commission, in cooperation with EU Member States and the European Environment Agency (EEA), is developing sets of indicators for the integration of the environment in different economic sectors (transport, energy, agriculture, industry). These indicators will be used as a tool for communications between policy makers and other players, and will become part of the sectoral environmental reporting process. The European Environment Agency's Topic Centre for Land Cover (ETC/LC) is contributing to this agenda with CORINE Land Cover (CLC) and other environmental datasets.

The objectives of the present report on land cover based indicators include:

- to illustrate what spatial and territorial indicators can be developed with CORINE Land Cover data for environmental reporting;
- to prepare indicators that quantify environmental concerns;
- to supply methods whereby the environment is inter-linked with sectoral issues;
- to point the way forward to better and more precise indicators and territorial assessment methods.

This report uses the same definitions and frameworks for describing indicators as used in other EEA publications, such as the regular indicator report *Environmental signals 2000.* The present report is written in light of the needs as expressed by the European Environment Agency and other Commission services, to have ready access to meaningful and feasible environmental indicators. This work is timely for the current political agenda of the European Union.

This report has been prepared, as part of the 1999-2000 work programme of the ETC/LC, by the French Institute for Environment (IFEN), with support from Geographic Information Management SA, Luxembourg (GIM).

2. Context of the report

This report touches upon a range of issues having significance for the current political agenda: environment and sustainability, the local-global link, key aspects of methodology and technical issues.

The current political agenda

There is a considerable need for information on the territory of the European Union. This report proposes and demonstrates that the territorial dimension of the EU can be gauged and interpreted through land cover change. Already the need for such information is recognised, but only a few applications are readily available to satisfy requirements. Many of the applications and analyses being made available are derived from the CORINE Land Cover 1990 (CLC1990) dataset either alone or in combination with other datasets.

Plans are being laid to update CLC, providing a new snapshot of the European situation for the year 2000 (CLC2000). The resulting time series and trend analyses will open up a wide range of possibilities to support the policy-making process. That is why CLC2000 is held as a key initiative, one that will yield better indicators and the development of more important and meaningful datasets. The timing is excellent to be in line with new EU policy requirements.

As stated in the report on community policies and spatial planning (Working document of the Commission services, 1998)[1], there is a need to develop a strategy that will guide the development of the European territory. In addition, sectoral policies must now converge and be inter-linked to environmental issues.

Although the regions vary greatly throughout Europe, they play the same roles of providing the physical base for productive activities, the life support system for people and natural resources, the place where the impacts of policies are seen and felt.

Territory (the land) is the unique medium for developing a crosscutting, multi-sectoral perspective. Land Cover is useful in this regard, and especially to develop instruments enabling a reliable analysis of the European territory and its different elements, the definition of clear medium-term aims and targets and adequate coordination, delivery, monitoring and assessment mechanisms. This is exactly the approach needed in light of the requirement to integrate environmental policy in other policies. Integration will be a difficult job, often requiring policy makers to confront conflicting priorities, and to be accountable for the costs and implications, which may be required to achieve integration.[2]

Land Cover provides a practical basis through which the European Institutions may increase the awareness of the territorial dimension in the formulation of new policy guidelines as well as in the implementation of current Community policies. As a data and information base, CLC will help the examination of territorial issues in the desired prospective manner and help to strengthen coordination and cooperation in policy formation.

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[1] Available on the inforegio website (http://www.inforegio.org/wbdoc/docoffic/official/sdec/sdec4_en.htm)

[2] Speech by Ritt Bjerregaard, 5 February 1998. http://europa.eu.int/comm/commissioners/bjerregaard/data/980205.htm

Traditionally, the objectives of Community policies do not have an explicit territorial character. Nevertheless these policies (sectoral, structural, horizontal) exert significant impacts on the territory of the Union. There is the need to provide more factual geographical options for spatial development useful to the evolution of a vision for the future of the European territory. Choices and decisions must be based upon reliable, up to date and harmonised information systems covering the territorial features of the European Union. This is the idea of 'territorialisation' of information and its representation by means of geographic information.

Unlike the areas of economic and social cohesion, European spatial development and spatial planning in general, relies on policy options that tend to be of a qualitative nature, and may not have been translated into precise indicators. That is a challenge to which this report can respond, by demonstrating the nature and range of indicators and assessments possible.

In fact, there are many Community policies that use or refer to different territorial categories and concepts. That is why it will be necessary to have a reference framework to ensure coherence amongst these policy directions. Land Cover should be part of that reference framework. The land as represented by CORINE Land Cover can be used to study the dynamics of Community policies and their actual impacts.

CORINE Land Cover as a key database

At the 1997 workshop on the applications of land cover data[3], EEA initiated a new phase in environmental assessment related to land issues. This meeting also served two other purposes: first, the continuation of research on environmental indicators, and secondly as the clear expression of the willingness of EEA to put the nearly completed CLC for Europe to work for policy makers.

Indeed, environmental indicators based on land cover data were acknowledged at this time as a new vision useful for reporting purposes as well as policy-making. Areas such as nature conservation and land planning – in the broader sense – were identified as domains of application. River assessments by catchment basin or intensive land use by urbanisation and economic activities have also been recognised as possible areas for development of methodologies based on land cover inventories.

As a result of this workshop there came a clear call for EEA contributions to provide input into the strategic assessment of the Trans-European Network of transport. An additional and important element was the proposal to have CLC as a basic input for the production of maps to be included in the then draft European Spatial Development Perspective, and as a possible basis for future work in agriculture and nature conservation.

[3] Proceedings Workshop on Land Cover Applications – Needs and Use, Copenhagen 12-13 May EEA, 1997

3. Land cover and sustainable development indicators

3.1. Indicators in general

Clearly indicators have become a hot topic[4]. There are many ideas and definitions about what an indicator is or should be. As a point of reference, the following is a short summary of what is an indicator and how this report proposes to support the development of indicators that integrate environmental concerns into sector-based issues.

Communication is the main function of indicators. Environmental indicators provide information that is considered to be critical to understanding the development of environmental problems. It is on this information base that decision-makers decide whether or not to take action. Indicators are not a picture of reality, rather they are an approximation of the truth, presenting information that is derived from analysing the raw data and other information.

Indicators can be used to express the condition of complex systems, condensing the complex into a manageable and understandable message. Each indicator by itself tells a part of the story, and only by combining indicators is it possible to gain the necessary view.

3.1.1. Selecting an indicator system

Indicator systems are one way to make relevant information accessible to policy-makers. Since the 1991 meeting of environmental ministers in Dobris Castle (near Prague) there has been enormous interest in the development of (environmental) indicators. As a result, today we find an abundance of indicator systems from which to choose.

Indicators can be either input or output oriented. Most environmental indicators that are input oriented include information on consumption. Examples are: the consumption of land, energy consumption, water use, and the built-up land area.

When organisations (such as EEA and Eurostat) prepare sets of indicators, these will normally reflect what have been identified as priority areas for policy making, but will also depend upon data availability. Thus most indicator systems will generally consider the outputs of economic activity. Examples are emissions to air and water, noise, generation of solid wastes and hazardous substances.

3.1.2. Common ground

The first point, which underlies all the others, is that an indicator is a communication tool. To some extent it has to allow the communication between scientists and policy- makers, between policy-makers and the public, and between scientists and the public.

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[4] Key references include: *The Concept of Environmental Space* (1998), by John Hille; *Europe's Environment: The Second Assessment* (1998), EEA; *Spatial and Ecological Assessment of the TEN: Demonstration of Indicators and GIS Methods* (1998), EEA; *Environment in the European Union at the turn of the century* (1999), EEA; 'Indicator Fact Sheet Model', guideline document for the forthcoming Yearly-indicator based report (1999), EEA; *Towards environmental pressure indicators for the EU* (1999), Eurostat.

This means that indicators need to be:
- as explicit as possible;
- understandable;
- commonly agreed by the social partners.

This principle of communication means that there should not be too many indicators, nor should they be overly complex in description. The balance for indicator development must be in line with the concepts of what are termed Background or Descriptive indicators, and Foreground or Headline indicators, as well as Synthesis or Operational indicators.

ETC/LC proposes that CLC is ideal as the common ground for numerous new and important environmental indicators.

3.1.3. Fundamental criteria for indicators

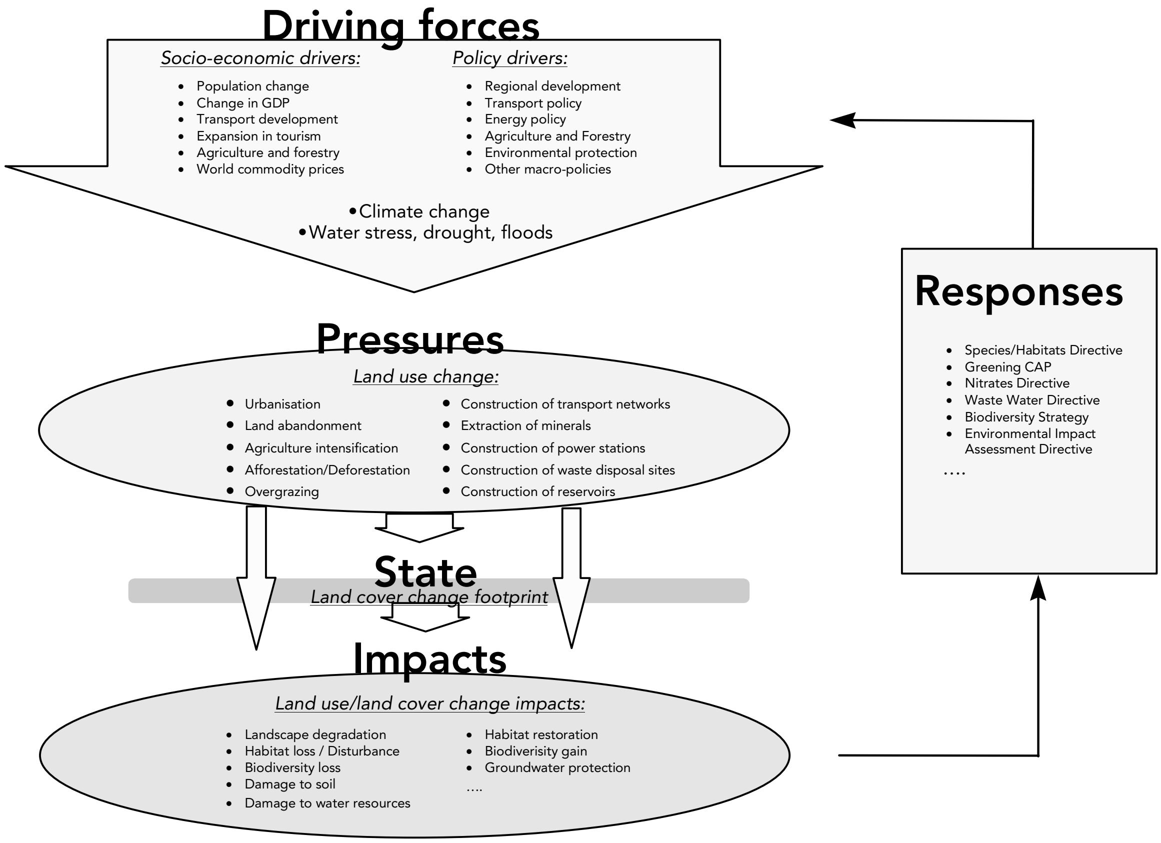
Consider the three classical requirements for indicators (as stated by OECD):
- policy relevance;
- scientific soundness;
- feasibility due to the availability of data.

Policy relevance
Policy relevance means that the indicator helps in policy making and assessment. In the past, statistics have often been adopted for use as indicators by simple virtue of their existence. This is now recognised as not best practice. Instead, indicators (useful for policy and decision making) should be developed when explicit policy relevance is taken as a basic quality. Relevance is now commonly assessed with reference to the Pressure/State/Response system (PSR) developed by OECD, or the expanded version known as the Driving forces/Pressure/State/Impacts/Response (DPSIR[5]) assessment framework adopted by EEA.

The DPSIR framework addresses the causal chain of:
- driving forces: human activities such as production, consumption, transport, housing;
- pressure: emission of pollutants, deposition of waste, extraction of natural resource, land use;
- state: effects of pressure on the physical media (quality);
- impacts: effects of pressure and of the quality of physical media on the state of ecosystems, public health and conditions of life;
- response: the societal responses to environmental issues.

[5] The D-P-S-I-R framework refers to (environmental) issues that are identified as Drivers – Pressures – State – Impacts – Response. The EEA framework is an extension of the OECD P-S-R concepts of earlier years. Both the EEA and Eurostat are supporting the DPSIR assessment framework, as demonstrated by current publications.

Figure 1. DPSIR scheme for Land Cover



Source: EEA

Under the DPSIR framework, another useful distinction can be proposed between indicator categories, namely:

- Environmental performance indicators: these aim at comparing the relation of the present pressure or state to reference values (standards) to which the country has committed at international (conventions), European (directives, regulations) or national (laws, regulations) levels;
- environmental trend indicators: the reference values are, in this case, no longer defined by law but by science and/or by reference to a past situation;
- early warning indicators: these provide alerts on short-term environmental risks for public health or security. They are of a local nature in most cases.
- sectoral indicators: which focus on interactions of specific policies (such as transport, agriculture, tourism ...) with the environment. Driving forces, pressure and responses are their main concern;
- sustainable development indicators: their purpose is to present a balanced and integrated vision of the social and economic development in connection with the constraints resulting from the scarcity of natural resources and the maintenance of good environmental conditions. The long-term vision is essential in this last approach.

There are different types of indicators useful in the context of supporting environmental policy. The EEA uses the following: descriptive indicators, performance indicators and efficiency indicators.

Descriptive indicators exist for all elements in the DPSIR framework, and show the development of a variable related to an environmental issue. In fact, all indicators are descriptive but not all indicators are performance indicators. Performance indicators can be used to measure if things (such as resource consumption) are moving in the right or wrong direction, and at what speed. This type of indicator may also be used to indicate the causes of these movements, and if actions are required, for example to stop a wrong movement or to speed it up if a situation is moving too slowly in the right direction. Performance indicators can also be linked to quantified targets (such as policy targets or sustainability targets), and can be used to measure the achievement of stated objectives or compared to a specific set of reference conditions.

Scientific soundness
Scientific soundness means that the parameters as observed provide correct information about the system that is being described. As everything cannot be measured or integrated in a complex index, the selection process leading to the choice of an indicator has to be managed very carefully in order to avoid misleading users. The imprecision of the observation should be reflected in the name and the definition of the indicator. The gap between what is available and what should be available must also be stated.

Feasibility
The feasibility due to the availability of data is often a decisive question. In many cases, indicators are proposed that cannot be compiled, even in the long run. The OECD has recommended that indicators be classified according to the availability of the data: short term, medium term, long term. This approach helps in clarifying the status of the short-term indicators, the need for better and/or additional indicators, and the requirements in terms of data collection.

3.1.4. A pragmatic proposal

In practice, these three 'classical' requirements, in many cases, turn out to be contradictory. In the first place, the quality of the data is often below the requirement of scientific soundness. From the point of view of practical use, high-quality detailed scientific data may actually be of no operational interest. And users are not always able to formulate their requirements in terms of data. Therefore, in order to arrive at a set of useful indicators, a step-by-step, and iterative, approach is necessary. Throughout this process, one of the major challenges is to avoid the endless quest for perfect new data and instead to use as much as possible existing databases.

In the following parts of this report, priority will be given to the policy relevance and the communication aspects of indicators. This is one of the major inputs of land cover data in the work to define and create environmental and sustainable development indicators. Indeed, the introduction of the spatial dimension in the definition of indicators makes them very often more explicit because:

- they describe the variety of the situations, sometimes hidden by excessively aggregated average values,
- they are closer, in many cases, to the level where the DPSIR causality chain is understandable,
- they are closer to the level of action and therefore to the perception of the policy makers and the public.

The limited availability of the data, on the one hand, is a constraint. Accordingly, priority will be given to short-term results, although difficulties may result in the absence of a sufficient quality of the data. CORINE Land Cover, on the other hand, is a very valuable dataset, which can be used, alone or combined with other datasets, for producing new indicators.

Improving the overall information system by structuring it on the basis of landscape patterns is a major advance, one that is both possible and feasible. In particular, geo-statistical techniques allow the reprocessing of current statistics and the production of better estimates. One may also take into account the high level of comparability of CORINE Land Cover data and the consistent reference it may offer for many purposes. Finally, a systematic approach allows the possibility to identify gaps and to propose step-by-step improvement to the scientific soundness of indicators.

3.2. Spatial and territorial indicators

This section is the core of this report and picks up the interest of much of current political debate on the future of policy making. There are increasing demands for spatial and territorial analysis to support policy developments at all political levels. For the EU there is a need to satisfy the requirements of Spatial and Ecological Assessments (SEA), Environmental Impact Assessments, the Natura 2000 work, etc. Much information that is available for use today is or can be spatially referenced.

3.3. Directions for the development of indicators

Since the pilot work programmes of the UN-ECE (in the early 1980s) and OECD (beginning in 1989 and still ongoing), the issue of environmental and/or sustainable development indicators has been addressed in many fora: Agenda 21 and the Sustainable Development Commission, UNEP, World Bank, SCOPE programme (which integrates efforts of various institutions of the UN family as well as WRI and others), Mediterranean Action Programme, Eurostat (Pressure Index Project) and EEA**.**

Currently, a new impetus for the harmonisation and development of (sectoral) indicators has been given by the Cardiff meeting of the Council of Ministers, with a priority for energy, tourism and transport. Agriculture and spatial development are other areas that will be considered as well.

In order to streamline these demands and to foster better cooperation between the users and the producers of (environmental) indicators, the Environmental Policy Review Group (EPRG) has established an expert group on indicators for environmental integration policies.

At the national level, indicators are published by many countries on a more or less regular basis. Some focus on headline indicators, others on environmental performance indicators. Recently, the UNSDC proposed to test a rather long list of sustainable development indicators. And many other players in the field of scientific research also have more or less detailed indicator lists.

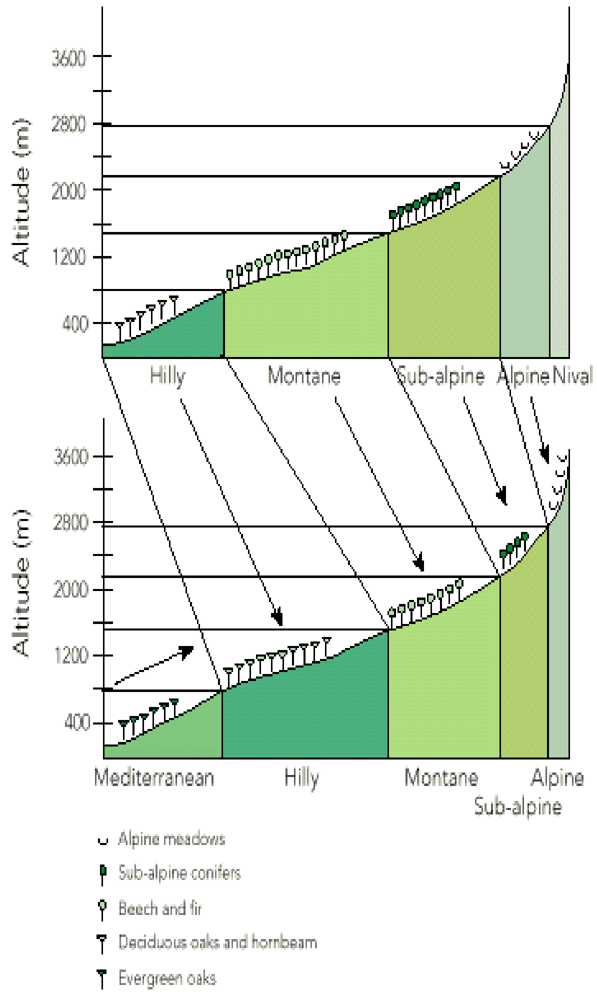
Unfortunately such over-abundance generates questioning, doubts and criticism. The expression ‘graveyards of indicators’ exactly summarises this problem. When indicators are expected to help in decision-making and assessment, the presence of too many indicators creates ‘noise’ instead of enlightening the situation. Furthermore, many relevant indicators are still not feasible to develop. For reasons such as lack of data availability or sufficient funding these indicators will remain unrealised well into the medium or even the long term.

3.4. The land-dimension of indicators

Land use and land cover change is significant to a range of themes and issues, being inter-linked in every aspect. For example, land use/land cover plays a central role in the study of global environmental change and the alterations that such change will bring about to the surface of the earth. Here are found major implications for sustainable development, livelihood systems and the biogeochemical cycles of the earth, as well as atmospheric levels of greenhouse and other trace gases.[6]

To put these ideas into concrete terms, consider the situation facing Europe's mountainous regions (see also figure 2). The prospect of a warmer climate has significant implications, ranging from reduced alpine zones and the subsequent endangering of animal and plant species to the indirect impacts on populations and ecosystems in adjacent plains, which depend upon the water supplied from mountain regions.[7]

Figure 2. Climate change effects on the mountain vegetation



Source: EEA

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6 B.L. Turner II, David Skole, Steven Sanderson, Gunther Fischer, Louise Fresco and Rik Leemans, *Land-Use and Land-Cover Change (LUCC) Science/Research Plan*, IGBP Report No. 35 and HDP Report No. 7, ICSU and ISSC, Stockholm and Geneva, 1995.

7 For further reading, chapter 3.15 'Mountain areas', in *Environment in the European Union at the turn of the century*, Environmental assessment report No.2. European Environment Agency, 1999.

Like climate change, there are a number of other global change themes that can be examined with land use and land cover change information. Sustainability issues are at the top of the list, and include topics such as:

- Soil use and erosion rates;
- Soil nutrient maintenance;
- Water use;
- Agro-ecological potential/support capacity;
- Rural planning/environment and development;
- National and international policy.

Land use and land cover change information is also suited to support and even to drive developments in integrated modelling and assessment. What is on the horizon and will be of interest for end users? The outlooks for modelling developments using CORINE Land Cover information have been elaborated and include the following[8]:

- Land cover atmosphere interactions;
- Biogeochemistry (e.g. atmospheric chemistry, water and energy);
- Biodiversity (e.g. ecosystem structure and function, species and genetic diversity, land cover fragmentation);
- Response to global climate change (e.g. land sensitivity to climate change, land use for mitigation).

In Europe, where economic development relies heavily on imports of energy and raw (natural) material, land appears as a key resource in a sustainable development perspective. Land is both a non-renewable and a renewable natural resource, the latter perspective being essential both for economic and environmental management. As a renewable resource, the qualitative aspect is as important as the quantitative one. This means that the degradation of land can be assessed in terms of resource depletion.

The depletion of resources which are renewable (or potentially renewable) is an issue composed of two parts: the first part considers the *availability* of the resource for various uses (both present and future) and the second part looks at the *potentials* for renewal. This means that not only must the changes in volume of a resource be considered, but also their characteristics, including the capacity for renewal. The implications expressed here cannot be over-stated, since they are of the utmost importance for all policy work on-going in Europe.

Ecosystems are valued as resources, as well as the land which supports them. It also means that degradation leading to losses in terms of uses or leading to irreversible changes must be considered as a depletion of an *available* resource of a determined quality or of a *potential* for reproducing this resource.

Thus, political/policy objectives should be to maintain, or improve, the availability of these resources for the various uses and to conserve their potentials for renewal. Future policies will need to adopt an overall approach due to the changes in both the natural systems and the human demand. And due to the competition, which may result from multiple uses of the same resources, the definition of optimal policies requires debates and consideration of trade-offs for the various options available.

[8] IGBP the LUCC Science/Research Plan, 1995.

The spatial dimension of European policy[9]
A spatial approach is essential when studying and reporting on the European environment, especially when intentions are to provide support to policy framing and evaluation. A spatial (geographic) approach is needed because no clear line can be drawn between the different processes or systems. Instead, there is a convergence of issues and agendas, conflicts in priorities and competition for the limited resources.

The European Communities – and now the European Union – has prepared, adopted and implemented policies having profound territorial impacts, and hence having drastically affected environmental and geographical patterns. Paradoxically, the broad policy agenda of the last four decades has been very involved in Land Planning at a European scale, while at the same time this grand project has been carried out in the absence of an explicit territorial agenda or even territorial awareness.

This absence of intent is well illustrated by the fact that despite a common denominator (the use of land) EU policies have been fragmented, the orientations having been confined to closed domains such as agricultural areas and transport networks in connection with urbanisation growth.

Indeed, when we consider the last 40 years, territorial changes and the implications of these changes have been enormous, the patterns of distribution and concentration of human settlements, not to mention the infrastructure networks, having been drastically modified. All the while, changes in urbanisation patterns in Europe have been continuous, with a significant growth in the amount of land and resource given over to the cities.

Productivity, efficiency and profit. Today, all EU countries can boast to have at least 80 % of their territory given over to 'productive' uses like agriculture, forestry, urban centres, transport and industry. But what does this kind of information reveal? In the past, 'traditional' indicators adopted to measure the impacts of policy and the welfare of the citizenry has been almost exclusively tied to quantifiable economic descriptions. Now the current political agenda requires something more.

Looking back. Since the 1970s the area of land classified as productive agriculture has in fact fallen by 5 %. Losses in agriculture area have been balanced by increases in urban areas, the abandonment of some land and a small increase in forests. The vast majority of Europeans live in urban environments, there has been a remarkable tendency since the 1950s for dispersal and sprawling of urban settlements. This has translated into lower urban population densities, greater requirements for transport and other infrastructures, and the permanent conversion of land from other uses. Consider that a 5 % increase in population will, according to present trends, require an equal increase in the take of urban land. EU, national and regional policies seem to work towards encouraging these sprawling trends: consider that, on current projections, before the next 10 years is out, the length of motorways will be increased by more than 12 000 km, and road traffic – passenger and freight – will have doubled.

The 'family farm' has lost its place as a key element in the economic structure of the EU, and the agrarian and farming traditions of most EU people have ended This is something that is strange and unsettling to many people, it seems to touch on historic land values but where the land uses are now gone or different. These fundamental structural changes have been developing since the end of the 1970s, but the reality has been hidden behind our regional differences and the huge expanses of territory that remain given over to agriculture. Today more than 83 % of EU land is identified as being either agriculture or forest. What is most striking is that EU-wide employment in the agriculture sector has declined to around 6 %, although some regions – particularly in Spain, Portugal, Ireland and Greece – continue to maintain larger numbers of the active population employed in this sector. What is clear is that the main changes in the agriculture sector have been towards greater productivity and specialisation of output, but with a very reduced workforce. This intensification of production is also occurring in rather limited areas with good soil, good climate and good access to markets.

Looking forward. From an overall environmental perspective the EU territory has experienced and will continue to see change brought on from a number of issues of global and regional importance: climate change, acidification, biodiversity loss, over-burdening of the environment with nutrients, extreme demands for water, degradation of soils, the sudden exposure to hazardous substances as well as the slow amassing of wastes. How these changes are experienced will be very dependent on the regional differences: political, social, cultural, economic and environmental.

Assessing the consequences to the environment of human activities requires an accurate description of the major interactions between individual or collective

[9] For further reading, chapters 3.12 – 3.15 the 'Spatial Chapters', in *Environment in the European Union at the turn of the century; Environmental assessment report No.2*. European Environment Agency, 1999.

behaviours, decisions and the natural base upon which they rely. The DPSIR framework provides a convenient basis to connect the description of the state and trends of the environment and the forces (either driving or responding) that influence the situation. Knowing these connections is a pre-requisite for action, for changing behaviours as well as for defining and assessing policies. By using CLC information together with other information, not only can DPSIR causal links be studied, but also the effects and costs of policy response can be estimated. Furthermore, by inter-linking CLC with environmental targets established by convention, regulation or law, scenarios can be constructed that will assess environmental performance, giving information for reporting on the compliance with the agreed targets or standards.

The DPSIR framework is a logical approach. Nevertheless, actual and satisfactory implementation is difficult. For example, due to the lack of available statistics, assumptions are commonly made – but statistical assumptions are not always acceptable. To illustrate, consider the distribution in space of species compared to their actual number, or the size of individual ecosystems compared to their total surface. When the geographical distribution is not uniform, the standard deviation, which is a common way of describing the dispersion in the observations, is insufficient to supplement the message conveyed by the average value. That is one of the reasons why geographical descriptions should be introduced into the assessment process (and the DPSIR framework) in order to better isolate those situations where pressure concentrates or where the impacts are likely to be the most harmful.

4. Indicators based on land cover policy issues at all levels

It is necessary to introduce to policy-making the notion that territory (land) is a limited resource. Land management and land planning are issues to be taken on board at all levels: European, regional, and local. Managing European land resources needs to have both long-term perspectives and coordination nationally and internationally, but final success depends on regionally and locally experienced situations and actions.

4.1. Land Cover supporting EU-level policy-making

In the last few years the close relationship between population, development and the environment has been reflected in EU policies[10], providing the CAP reforms, the greening of the structural funds, the development of spatial and ecological assessments of the TEN, a willingness to adopt directives for strategic impact assessments of plans and programmes, and the Fifth Environmental Action Programme which is a progressive policy instrument used by the Commission to encourage greater consideration of environmental issues throughout all levels in the EU. All of these topics areas either are or could be supported by land use/land cover information.

In the following sections of this report a selection of policy perspectives is provided from the point of view offered by CORINE Land Cover.

4.1.1. The natural environment

Nature conservation: fragmentation of forests
The fragmentation of forests by transport networks is a major concern. Work in this field leads to indicators describing the sustainability of forest ecosystems and biodiversity, and can eventually be linked to other topics such as 'rural' tourism.

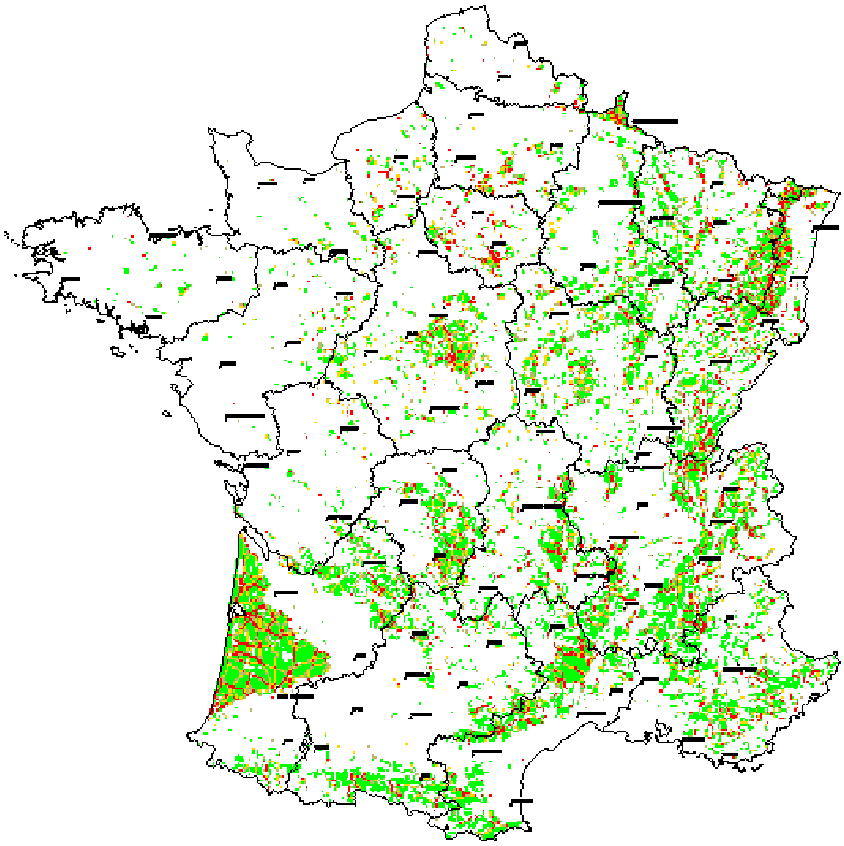
The impacts of transport networks on forest ecosystems are assessed and the pressure on biotopes resulting from specific land use can now be located. There are different ways to manage the idea of fragmentation in relation to policy. With this example it is possible to measure the partitioning (or barrier) effects generated by the built infrastructure in the forest environment. From here assessments on the sustainability of forests can be made, as well as having a better understanding of the frailty of the forests.

The example illustrated in figure 3 was created by an overlay of CLC class 'Forests' with transport networks in France. A statistical analysis of the content of 2.5 x 2.5 km grid cells was performed to determine the kilometres of road per cell.

This indicator is interesting in that the data requirements are feasible for presenting results in the short term. These results are useful immediately for regional, national and trans-national analysis. The same work can be applied to a Europe-wide need.

[10] European Communities. 1997. *Agenda 21, The First Five Years*. Luxembourg, OPOCE.

Figure 3.: Fragmentation of forests by transport networks



Source: IFEN and IGN, France

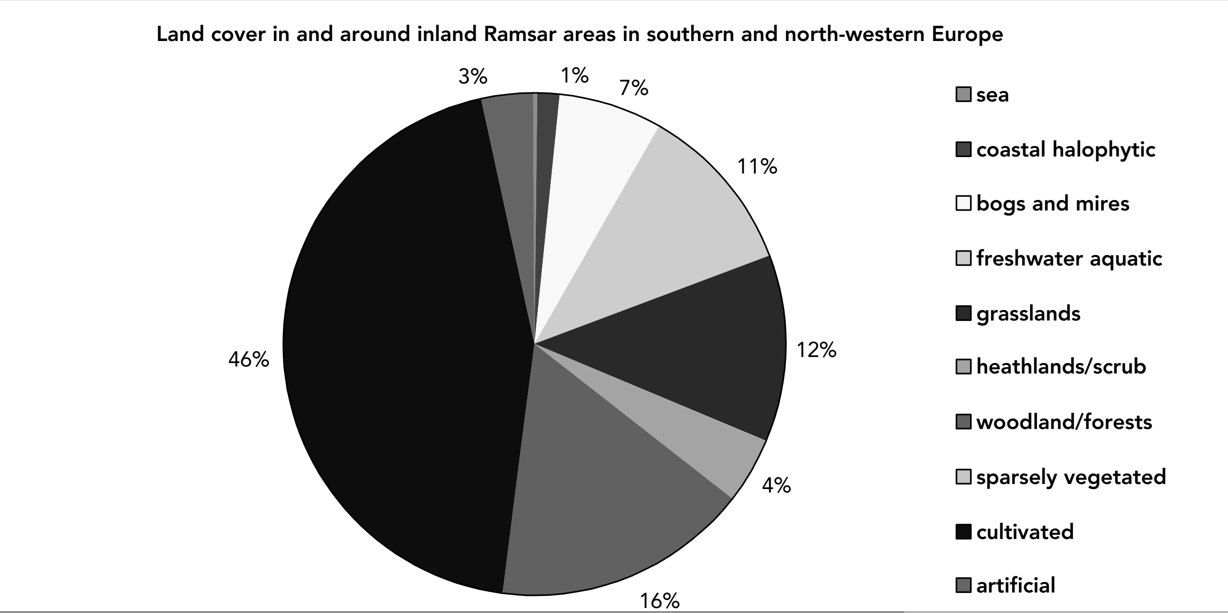
This type of indicator work is promising for other purposes, such as the strategic assessment of Natura 2000 sites (thematic and geographic balance), calculating pressure by land use and identifying trends linked to the tension between conservation and development prospects for environmentally sensitive areas. Also, by using other CLC classes and/or regroupings it is possible to map landscapes under pressure.

Nature conservation: Wetlands

European wetlands constitute a group of ecosystems clearly subject to environmental pressures from land use and pollution. Despite increasing awareness of their ecological value, as well as threats upon them, European wetlands are under particular pressure due to neighbouring high population densities and the resulting intensity of human activity.

Wetlands react to internal and external pressures rapidly and these reactions are quickly perceptible. Environmental stress has important effects on the functional capacity of wetlands to support high levels of biodiversity. An identification of major land cover types within and in the surroundings of European Ramsar sites (sites listed under the Ramsar Convention) and major wetlands (under management) provides a good indication of the main pressures. This indicator shows the proportion of major land cover types falling within the neighbourhood of European Ramsar sites and major European wetlands.

Figure 4. Main land cover types in and near major wetlands



Source: EEA, ETC/LC

In this example, each Ramsar site has been simulated by a circle centred on the site's central point, and the radius was determined by the surface area of the site.

Although based on very simplified spatial assumptions, this method quickly delivers some indications of the pressures that are impacting sensitive areas of environmental importance. The method can be applied to all sites throughout Europe. Also, the choice of Ramsar sites is good because they include the various types of wetlands (coastal, floodplains, marshes, ponds, lakes, etc.), and thus they provide a broad sample of European wetland types and situations.

In the future it will be necessary to have access to the actual site boundaries (using GIS coordinate data) and official surface area statistics of the sites to provide a more detailed analysis. It will also be necessary to develop better methods for assessing marine sites as opposed to land based sites. The buffering method (IZs) should be reconsidered, and the exercise refined to use catchment areas, for example.

Forests and people

Forests are an important resource, providing amenities for humans, biodiversity, offering an important component in soil conservation, but subject to damage by fires etc.

Impacts from urbanisation to nearby forest areas can be either positive or negative. Negative examples include increased water run-off (quantity and speed of flows) and the sudden and concentrated loading of pollutants into water drainage systems carried by the run-off, deforestation and soil erosion, habitat fragmentation, change/loss in biodiversity, etc. Positive impacts are a forestation in order to enhance recreation amenities and (drinking) water infiltration, conservation and improvement of the biodiversity.

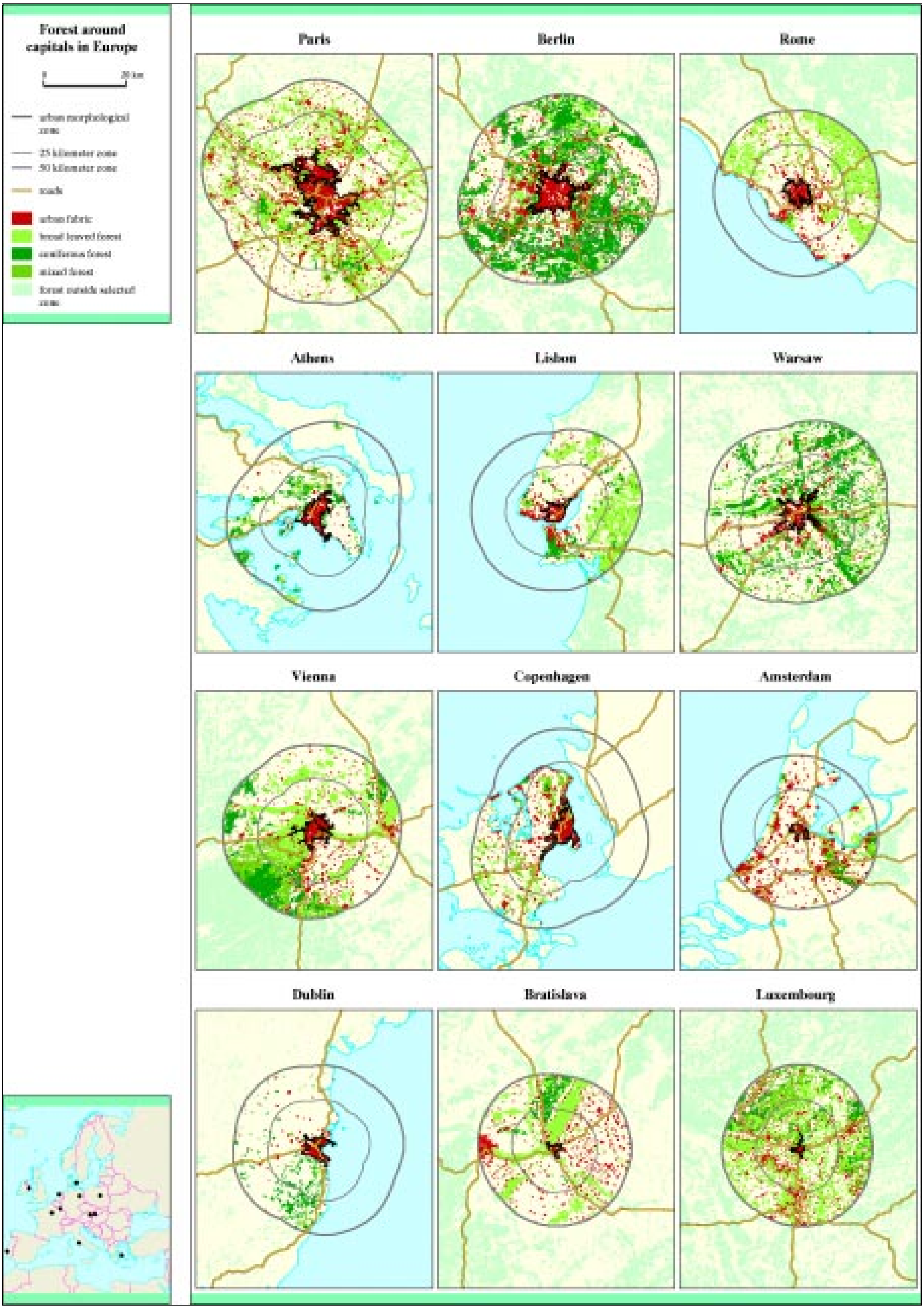
Forests are important to the urban inhabitant and also the urban tourist. The use of the landscape around cities depends on the accessibility and availability of nature areas such as forests. The amount of forests situated within 50 km from cities varies greatly across the EU; the CLC has been used to quantify this information. Findings show that in central, eastern and northern Europe the forest areas near cities tend to cover larger areas. Surveys show that most urban dwellers live within a 15-minute walk of at least one green area, although the actual access to green spaces varies considerably from one city to another. Cities fortunate enough to have a high ratio of near-by forests are also the most likely to have forests at high risk of fragmentation.

There is a great usefulness offered to policy makers with indicators such as the quantification of the different relationships between forests and (urban) populations. Relevant issues should include conservation, sustainability with respect to forest ecosystems, water supplies, urban tourism, sprawl, and transport links.

In figure 5, the surface area of the CLC class for built-up area (the urban footprint) was enlarged outward for a distance of 50 km. Classes of urban fabric, broad leaved forest, coniferous forest, mixed forest falling within this 50 km zone were calculated and compared.

The strength of this indicator is that it offers comparable results across Europe, and it is easily obtained. This indicator could also be improved via the following work areas: historical analysis (trends) to study the impacts or the success of regional forest management programmes; linking forest health with urban emissions to air and/or water, forests (urban green) as an attraction feature for new citizens/households or tourism.

Figure 5. Forest around major cities in Europe



Source: EEA

Water management and quality
A French example proposes the design of a European monitoring strategy for water quality based on catchment patterns and a typology derived from land cover and associated data on population and agriculture. The result provides indirect estimations of anthropogenic pressures through the calculation of driving forces:

- Urban pressures: the cumulated population density was calculated over the entire upstream catchment for each zone;
- agricultural pressures: intensive agricultural land cover was calculated over the entire upstream catchment of each zone.

To study this issue of water management, a selection was made of monitoring stations that were representative of the general status of river quality in relation to nitrogen and phosphorus in the period 1987-1996. A selection of input variables and indicators available from these stations was then made, and included values for total nitrogen, nitrate, ammonium, and total phosphorus. For certain stations, adjustments were necessary for calculated values, but this was depending on the location of the monitoring station within the hydrographic zones.

This indicator's work is achievable since the catchment areas are simple to calculate and compare. In the future, different types of pollution sources could be considered within this approach: point and non-point pollution, pollution from agriculture, urbanisation, industry – but data availability will depend on improvements in national emission inventories and global pollution models for use at the hydrographic zone scale. The method for calculating population densities over the entire upstream catchment should be refined or replaced with other more realistic approaches, e.g. weighting the population density in the upstream zones according to the river flow distance. Also, other presentation criteria and classes (e.g. different geographical regions, physical nature of rivers, definition of cluster types, etc.) should be explored.

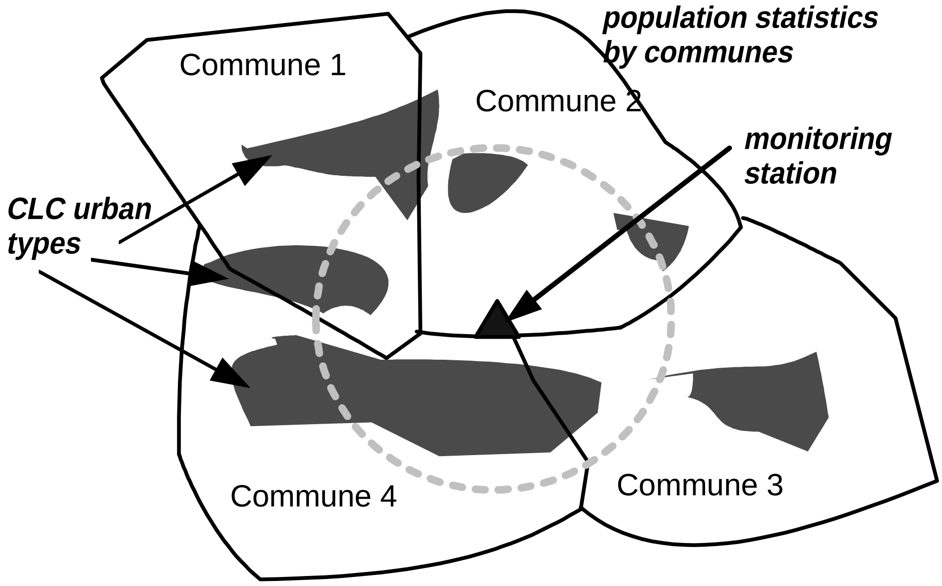
Air quality
Assessing the risks posed by air pollution to populations and ecosystems is feasible when combining datasets such as CLC with population statistics and the emission (or deposition) measurements collected from monitoring stations. Particular care must be taken to select monitoring stations that use comparable methods of data gathering in order for the results to yield indicators for Europe wide monitoring and evaluation.

Figure 6 shows how a population in the vicinity of a monitoring station can be assessed. This is a simple geo-statistical analysis that uses established sampling patterns framed within the definition of CLC. This approach is useful in that it allows for the transformation of statistics gathered at the administrative level (such as communes, or similar administrative/statistical units) into data for the physical zones.

This type of information will be helpful as a component in the monitoring of the impacts of transboundary air pollution and the need to meet policies as set out in the UNECE Convention on Long-range Transboundary Air Pollution (CLRTAP, 1979), subsequent CLARTAP protocols and other EU legislation, such as the Air Quality Framework Directive and other similar 'daughter' directives, the Fifth Environmental Action Programme's emission targets, etc.

Monitoring the speed of progress towards objectives is important. For example, projections for the year 2010 show that, despite expected emission reductions, several areas in EU and Accession Countries will continue to be affected by excess deposition of acid and nitrogen[11].

Figure 6. Monitoring risks to population



Calculation of the population within the circle

Source: IFEN

4.1.2. Agricultural and rural policy

Landscapes and land cover

The study of landscapes and the role they play in environmental relationships is important to the eventual decision-making by policy-makers throughout Europe – at all scales of government. For example, EU environmental policies are becoming more important in rural areas, particularly with respect to the protection of important biodiversity resources and water resource management[12].

The environmental impacts of different EU policies and regional trends (for example development) can be expressed in terms of land use and landscape changes, as well as by environmental pollution, changing demographics, biodiversity loss etc. Landscapes provide the setting for our lives, and the quality of that setting affects the quality of our lives, whether we live in cities or in the countryside. Europe's different landscapes vary in their character and quality.

The CLC data offers a comparative advantage in the study and assessment of European landscapes. For example, with CLC it is possible to see the territorial impacts of structural changes in agriculture, and to consider prospects and scenarios for a (rediscovered) multifunctional production in rural areas.

On-going changes in landscape are often irreversible and depend on natural, social, economic and political conditions. Likewise, the analysis of landscape

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[11] Chapter 3.4, Transboundary air pollution, in *Environment in the European Union at the turn of the century,* Environmental assessment report No.2, *EEA 1999.*

[12] Chapter 3.13, Rural areas – our link to the land, in *Environment in the European Union at the turn of the century,* Environmental assessment report No.2. EEA 1999.

changes is important when assessing natural and socio-economic processes, their dynamics and causes, as well as calculating possible future trends and developments.

Land cover is a suitable indicator of changes occurring in landscapes, and allows the study of their rate of change and quality. The study of change is necessary for the analysis of the causes and consequences of natural and artificial processes, impact assessments, the maintenance of ecological stability and its observation in decision-making and planning. The analysis of land cover changes can help to reveal the connections of socio-economic and political interventions.

The analysis of change also provides for the assessment of developmental trends from the ecological and environmental point of view. Thus it is possible to evaluate landscape characteristics such as diversity, ecological importance, carrying capacity, stability and attractiveness (these being the attributes essential for assessing the eco-stabilising functions of landscapes). In this sense, landscape change analysis offers an important contribution to landscape planning and management.

Land cover change as an indicator is useful for several reasons:

- understanding of the socio-economic pressures as potential causes of the main types of landscape changes;
- statistics and maps work together to bring forward relevant information on the magnitude and spatial distribution of change;
- reclassifying CORINE Land Cover classes into the main landscape changes makes this type of analysis policy relevant (concerns include: urbanisation, deforestation, etc.);
- Information about landscape changes combined with intensity intervals for these changes, and recalculating the changes to a grid presentation provide suitable mapping presentations.

4.1.3. Coastal policy

In Europe, as elsewhere, the impacts of a healthy or unhealthy coastal environment are far reaching. For a number of reasons, human activities are particularly concentrated in and near coastal areas. These areas harbour the greatest convergence of human activities (economic, social, cultural) and environmental concerns (major habitats and sensitive ecosystems, rich spawning grounds for fisheries). The coastal zones are singular in their importance and complex in their diversity, touching 200 million EU citizens and nine regional seas with a water surface that covers millions of square kilometres.

These are the coastal zones which are under direct pressure from increasing patterns of urbanisation, industrial activities and tourism. At present an estimated 86 % of Europe's coastal ecosystems have a potentially high to moderate risk of damage resulting from such development pressures. Discussions are leading to the conclusion that perhaps the only way to ensure the continued health of Europe's coastal zones is through coordinated programmes of Integrated Coastal Zone Management (ICZM).

Policy areas that have direct influence on the situation include: coastal zone management, mountains (e.g. Alps Convention), tourism, agriculture and transport. Turning to the example of the LACOAST project[13], the main trends of

[13] LACOAST: *Land Cover Change Mapping in Coastal Zones*, JRC 1999

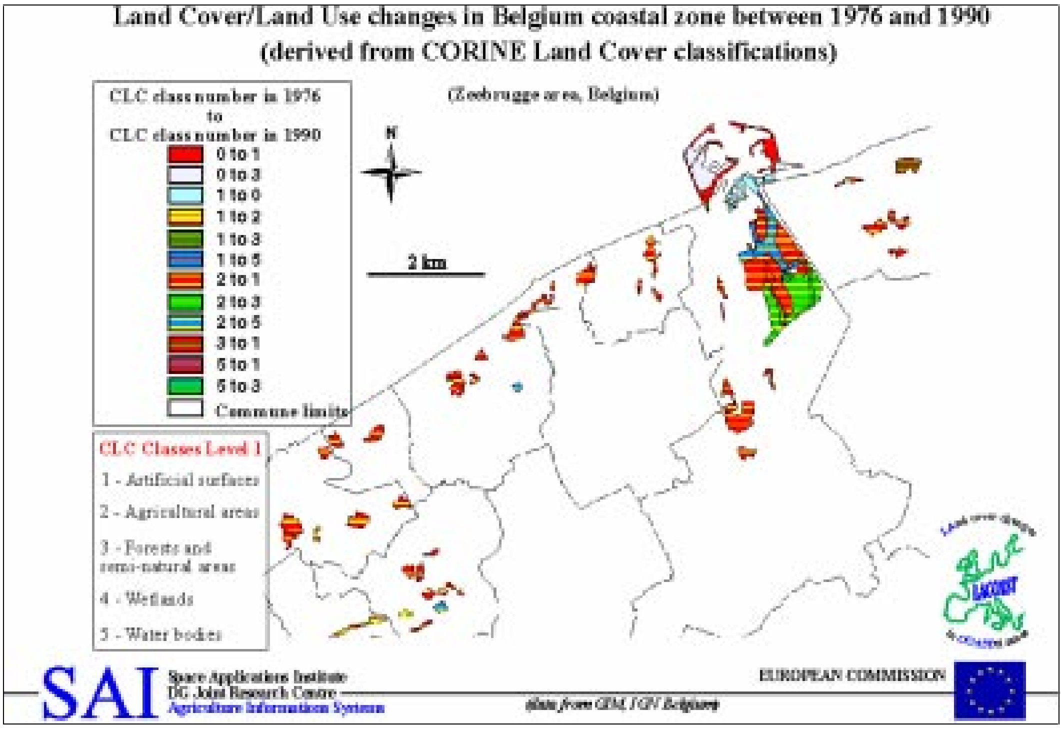
artificialisation – surface sealing by construction – and its consequences on agriculture and the natural environment are visualised in cartographic and statistical forms.

Figure 7 and 8 show examples of the LACOAST results.
The analysis of coastal zones in Europe is a topic of high priority in Europe. Poor planning and management of human activities in coastal areas and associated upland and marine areas have increased coastal strip fragmentation as well as the risk for natural hazards. ICZM is seen to be an important solution because it promotes sustainable management through cooperation and integrated planning, bringing into play all of the relevant actors at each appropriate level.

The European Commission's Integrated Coastal Zone Management (ICZM) programme identified the provision of appropriate, reliable and timely information as a major requirement for an improved coordination of EU policies in order to meet 'integrated' goals for coastal management. The success of EU policies can only be monitored when certain indicators of Europe's Environment are assessed on a regular basis. That is one of the requirements that the EEA and its Topic Centres are working to meet.

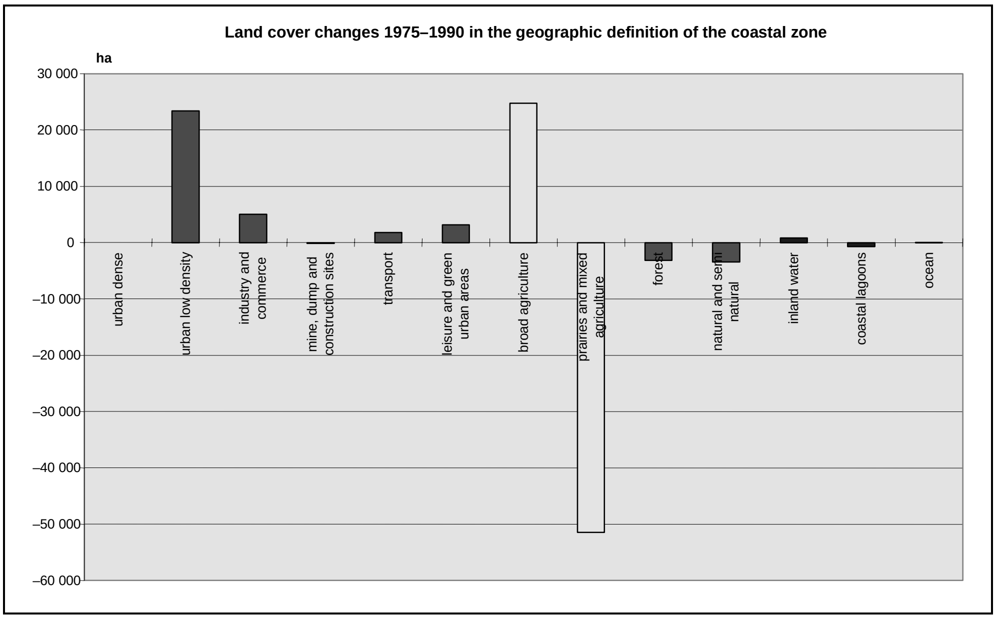
During 1999 a project was run by the ETC/LC which considered a selection of environmental indicators based on land cover and land use changes in the coastal zones (the INDILAC project). Results from the French LACOAST exercise were called upon to develop indicators for a restricted region and to assess their feasibility for an analysis of all European coastal zones based on comparable base data. The following graph shows a summary of the results from the overall analysis work. These changes represent the total land cover changes in the complete coastal zone.

Figure 7. The dynamics of change in the Belgian coastal zone, LACOAST 1976-90



Source: JRC

Figure 8. Example of land cover changes within coastal zones



Source: IFEN, GIM

The indicators presented in the INDILAC work are based on the following methodology:

- Land cover changes between 1975 and 1990: Land cover changes are calculated for the different definitions of the coastal zone (geometric and geographic). The changes are presented in the form of graphs and tables. The common trend in all strips is an increase in urban areas and intensive agriculture along with a decrease in extensive agriculture (prairies and mixed agriculture).
- Population changes: The population changes are related to the changes in urban areas. The change in urban areas between 1975 and 1990 is presented in tabular form. The most obvious growth takes place in the class 'sport and leisure facilities'. These facilities include camping grounds and golf courses in popular places along the coast.
- Protected areas in coastal zones: The change in land cover/land use is compared for communes with protected areas and communes without protected areas. No influence on the land cover change behaviour can be interpreted irrespective of the presence or absence of protected areas in a commune.

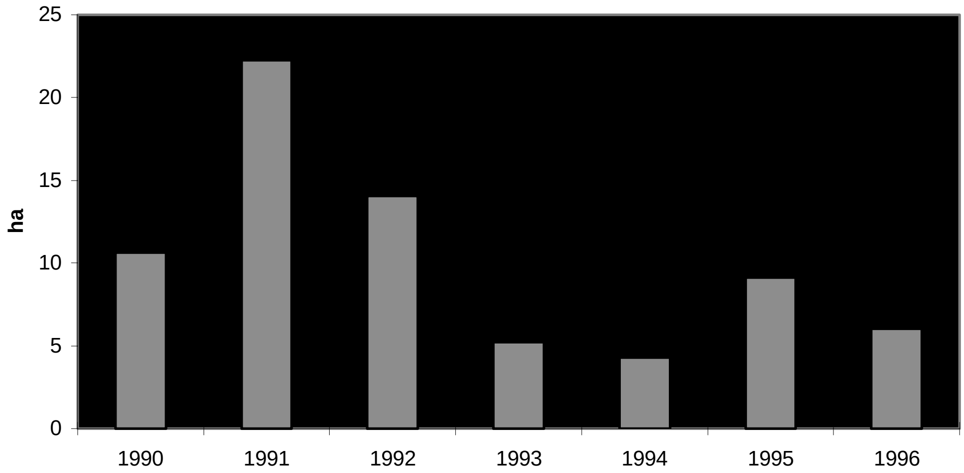
The LACOAST project has shown that there is a strong need to have harmonised definitions of the coastal zone and its breakdown into smaller units. Further work has suggested that the breakdown of the coast into smaller units should not be based solely on terrestrial attributes, the marine influence on the coast and its hinterland must also be taken into account. At this point the project offers several potential selection criteria (e.g. coastal morphology, units for marine environment monitoring), which need to be further explored in the future. One clear need is identified and that is the stronger integration of marine and terrestrial information in a common information system in order to better monitor and manage coastal zones.

4.1.4. Transport policy

With respect to the environment, changes brought on by human intervention are usually permanent. One appreciation of the measure of change is found in the

footprint it leaves behind; the footprint of the transport sector has been particularly large.
The land is under continuous pressure to build new transport infrastructure. It is estimated that during the period 1990 – 1996, approximately 10 ha per day of land were taken in EU for motorway construction project. Land take for transport in natural areas may lead to a decrease of biodiversity, whereas land take in urban areas could represent the risk of impacts on humans (safety and noise).

Figure 9. Average daily land take by new motorways – EU15 (in hectares per day)



Source: EEA/Eurostat

Land resources in Europe are relatively scarce, and reaching a sustainable balance between competing land uses is a key issue for all development policies. New initiatives, such as the European Spatial Development Perspective, specifically address the impact of European policies (including transport) on the European territory for better spatial planning.

There are few concrete (quantified) targets for this indicator. The Common Transport Policy advocates an optimal use of existing infrastructure, and some Member States have thereafter developed land use policies and plans (restricting additional developments in certain areas).

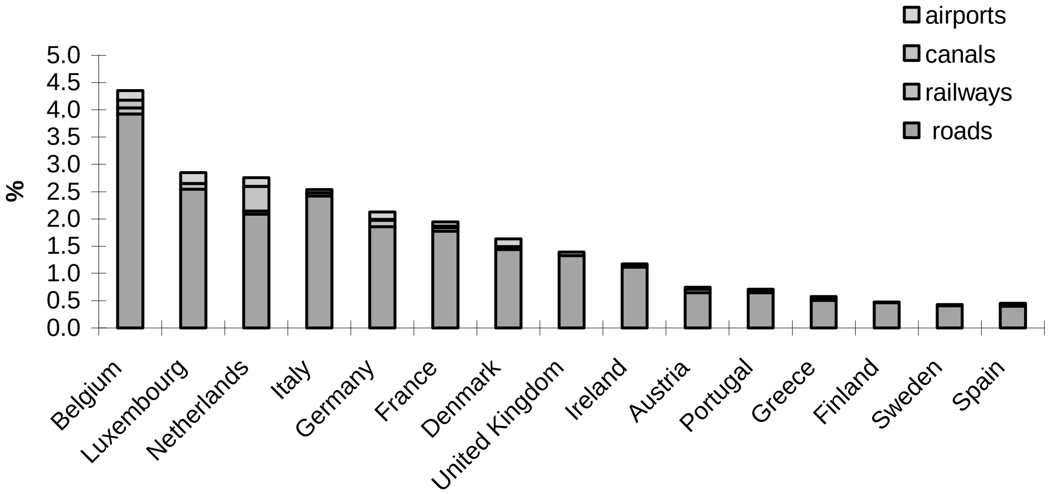
For the Environment Barometer for Germany (which uses the indicator 'increase per day in area covered by human settlements and traffic routes'), a target was proposed of 30 ha per day by 2020, compared to 120 ha per day in 1997.

This indicator considers direct land take as well as indirect land take. The use of land does not only refer to the transport construction itself, but also to the areas impaired by their use for transport facilities and by the transport process: airports, parking lots, road junctions, etc. (see Box below*:* **Direct and indirect land take by transport**).

The surface covered by transport infrastructure is directly related to its construction characteristics. Because these are increasingly set to international standards, the variations between different countries and data sources are marginal. For the estimates of the area by land cover type, available datasets on planned networks were combined with the CORINE Land Cover database.
The road network (motorways, state, provincial and commune roads) consumes 93 % of the total area of land used for transport in the EU15. Rail is only

responsible for 4 % of direct land take. The total area covered by airports in Europe (including military airports) is 1 546 km², or slightly more than the area covered by canals for water transport.

Figure 10. Land take by transport infrastructure type as % of total country area (1996)



Source: EEA/Eurostat

To get an indication of the land use efficiency of each mode, the land take must be put into the perspective of the related traffic capacity that the infrastructure offers.

In terms of passenger transport, railways show a 3.5 times lower specific land use in comparison to passenger cars, in terms of freight transport railways require only one fifth of the land used by lorry transport. Rail transport therefore is the most land efficient transport mode.

The potential impact from land take depends on the type of land that is affected, including its immediate surrounding. An analysis of existing TEN infrastructure shows that 58 % of the area used for road transport is located in agricultural areas and 17 % is located with urban areas[14].

Besides taking land out of use, a linear development such as a road, railway or canal creates an obstruction between one part of a block of land and another, upsetting its homogeneity. A new line may therefore reduce agricultural productivity or prevent easy movement of people or wildlife. In the case of railways, disused railway land is a valuable resource. Its disposal and reuse is an important development opportunity with considerable environmental implications. By returning this land to nature, the success of terrestrial habitats may depend upon protection or management for particular species[15].

[14] *Spatial and Ecological Assessment of the TEN.* 1998. European Environment Agency.
[15] Carpenter, 1994, *The environmental impact of railways.*

Direct and indirect land take by transport
Direct land take of transport indicates the area covered by the transport link infrastructure. The direct land take of a four-lane motorway amounts approximately 2.5 ha/km
Indirect land use refers to the average of overall land use by the transport mode, including space for noise protection, embankments, security areas, motorway junctions, service areas reaches, etc.
For this indicator following *average* values were used for calculating the direct and indirect land take:

	Road				Rail	Water	Air
	Motorway	State road	Provincial road	Commune road	Conventional + high speed rail	Canal	
Direct	2.5 ha/km	2 ha/km	1.5 ha/km	0.7 ha/km	1 ha/km	5 ha/km	None (runways not considered)
Indirect	7.5 ha/km	6 ha/km	4.5 ha/km	2 ha/km	3 ha/km	10 ha/km	airports

In the EU the trend towards land-extensive urban structures and the increasing separation between activities has done a lot to help the growth of car-borne traffic. By the year 2010 car ownership will have increased 25 % from 1990 levels, and the demand for passenger transport is expected to jump over 40 % over the same period. Objections to the transport sector and policies in the EU are well known and illustrate the dimension of the problem. In the first place, EU transport policies have focused on minimising outputs such as vehicle emissions and noise, rather than on inputs such as consumption of land and other materials. Secondly, EU policies have focused mainly on local and regional impacts while overlooking the global impacts. Recall the TEN priority projects, which required localised EIAs, but paid less attention to spatially distant impacts. Finally, many policies in place have been too weak or off target to solve particular problems. Policies too weak to be fully realised include those targeting the reduction of CO_2, the containment of NOx emissions, the lessening of noise pollution, and the management of water quality[16].

4.1.5. Spatial planning

European territorial policy
The European Spatial Development Perspective (ESDP) proposes seven criteria for differentiating the components (regions, cities, axes, etc.) of the European territory: geographical position, economic strength, social integration, spatial integration, land use pressure, natural assets, and cultural assets. A set of indicators (of a quantitative, or, if necessary, qualitative nature) can be developed to enable scoring of spatial components according to these criteria. The indicators will be selected according to their capacity to accurately mirror the reality on the ground and changes over time. Selection will also depend on the quantity and coherence of information available for the entire Community territory as well as their ability to perform as indicators of reference for the assessment of development trends. The indicators may cover questions such as central/peripheral position, integration with the competitive economic model, level of territorial inter-linking and potential for sustainable development.

EEA gives priority to supporting the ESDP process. Now that the ESDP has become a political reality, this may yield concrete demands for land cover-derived, environmental indicators. In this event, the role of EEA and the demands for

[16] Hille, J. 1997. *The Concept of Environmental Space Implications for Policies, Environmental Reporting and Assessments*. In Experts, Corner No 1997/2. Copenhagen, EEA.

datasets such as CORINE Land Cover and applications turning upon this data will become very much in demand. Some of the most obvious requirements for such indicator-based work will come from the Study Programme for European Spatial Development Programme (SPESP).

In and around Europe's most densely populated areas are significant quantities of land that is used for agriculture, forests, parks, recreational areas, and home to important habitats. By their proximity, these areas are under strong pressure from urbanisation. Most Europeans – more than 70 % – now live in urban areas, and some areas, such as the Rhine-Ruhr, are now massive conurbations. The risk is that the regions will see continued demographic imbalances of consumption and production activities and disproportionate concentrations of wealth, expertise and innovation. The process of urbanisation in the EU is dynamic and is subject to patterns of sprawl and all the attendant problems of pollution and waste. And although the total EU population is relatively stable, the profile of this population is changing in noticeable ways, for example, the number of one-person households is growing. As a result, land demand is high and urban sprawl patterns are mainly located in the suburban and peri-urban areas.

Spatial planning indicators

- With respect to the development of environmental indicators by the SPESP, EEA is encouraging efforts to 'cross-fertilise' work. This cross-fertilisation could be occurring with respect to the development of different indicator reports underway.

The areas of the SPESP which EEA and ETC/LC are able to support include:

- Natural Assets
  - need for exhaustive knowledge of available data and cartographic (re)sources;
  - need for a common cartographic and statistical/spatial data base;
  - time periods for data that is available, and other meta data;
  - to evaluate the loss of landscape quality and landscape assets;
  - to make the policy link, to find out and show which policies have environmental impacts that are either direct or indirect;
  - to show the historical development in natural assets, and why this is now important.

- Cultural Assets
  - to measure the significance and the sustainability of urban cultural assets;
  - to consider physical issues (cities, buildings, sites and monuments);
  - to consider cultural landscapes;
  - issue of geographical scale is important and difficult, especially since much of the proposed indicators are site/monument specific. How to present these in a regional way.

- Land-use Pressures
  - Typology I: Urban diffusion, Agri-intensification, Land Abandonment;
  - Typology II: Expansion of Natural Reserve Areas, Expansion of ground water protection sites, Expansion of cultural sites;
  - land use pressure is a cross-cutting issue in most other thematic and sector areas;

- indicators needed in the near term and the medium to far-term;
- issues of scale;
- to describe pressure in a policy context; thus to learn more about the relevant policy issues and to focus on what is of policy and political interest.

- Rural and urban: major importance is attached to the issue of Spatial Differentiation within the Rural/Urban areas and the cities. EEA should be prepared to have inputs into this topic area.
  - metropolitan;
  - polycentric urban, mixture of high and low density;
  - urbanised rural (accessible rural) areas influenced by the urban environment;
  - rural profound (not accessible rural areas);
  - peripheral – a very ‘relative’ idea/term;
  - for the ESDP, polycentricity is a policy tool to achieve more global competitiveness and a better balance in the EU. The question to explore and answer is how realistic is this policy tool. Will the tool at the EU level apply to areas or levels of smaller size?
  - importantly (spatially): it has been proposed that the footprint of the agglomeration might be compared to functional regions.

- Spatial integration: the idea of spatial integration has evolved since the Noordwijk version of the ESDP, where it was first defined. This topic will cover three issues:
  - networks and connectivity: the flows and interactions between areas, where Interaction will look at transport links, ICT links (Internet, telecoms), and population movement.
  - to identify discontinuities
  - scales of integration

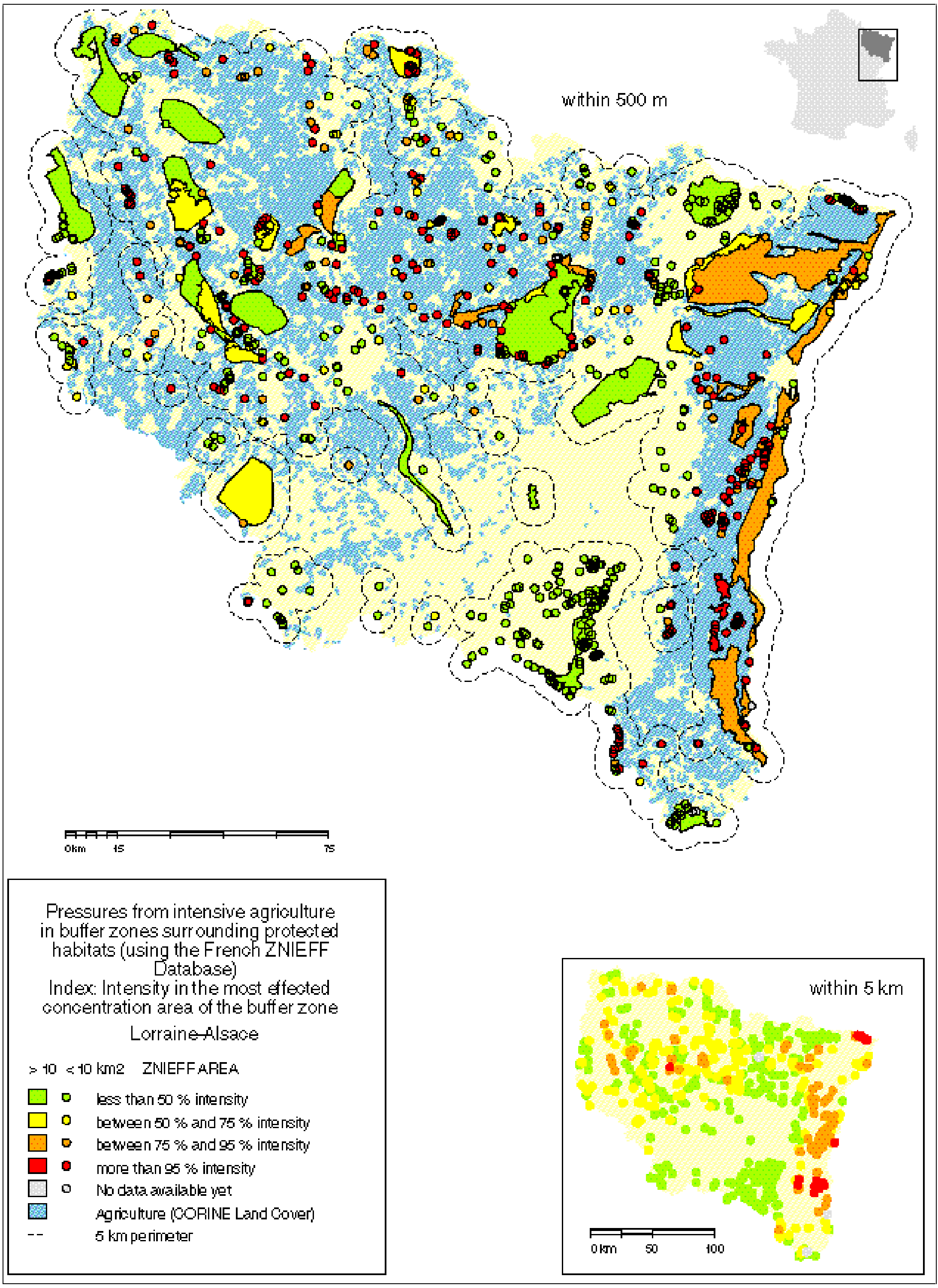
4.2. Land Cover for the national and regional levels

European level decisions, laws and requirements are implemented at national, regional and local levels. As stated in the first report of the ESDP document[17], key economic and market activities in the EU have been greatly influenced at the European level. Actual spatial development policies were (are) still being devised at the national level, and lower. Thus there is an important discrepancy that was built into the system, making it difficult to exploit the full opportunities for spatial development for Europe. The diversity and complexities of the regions, and the requirements for a better balance of resources and opportunities throughout the EU requires the development and implementation of an integrated approach. Information must flow in both directions: from the EU level to the local level. To this requirement, the CLC database offers potential solutions and a common framework.

The following regional snapshot shows potential pressures being put on designated sites by land use (urbanisation, transport networks and intensive agriculture). This picture serves to indicate the conflicts that may well arise between the EU vision put forward via Commission policies and the interests of regional spatial plans.

[17] European spatial development perspective, First official draft. Noordijk, 9 and 10 June, 1997.

Figure 11. Potential pressure by intensive agriculture on protected habitats in the East of France

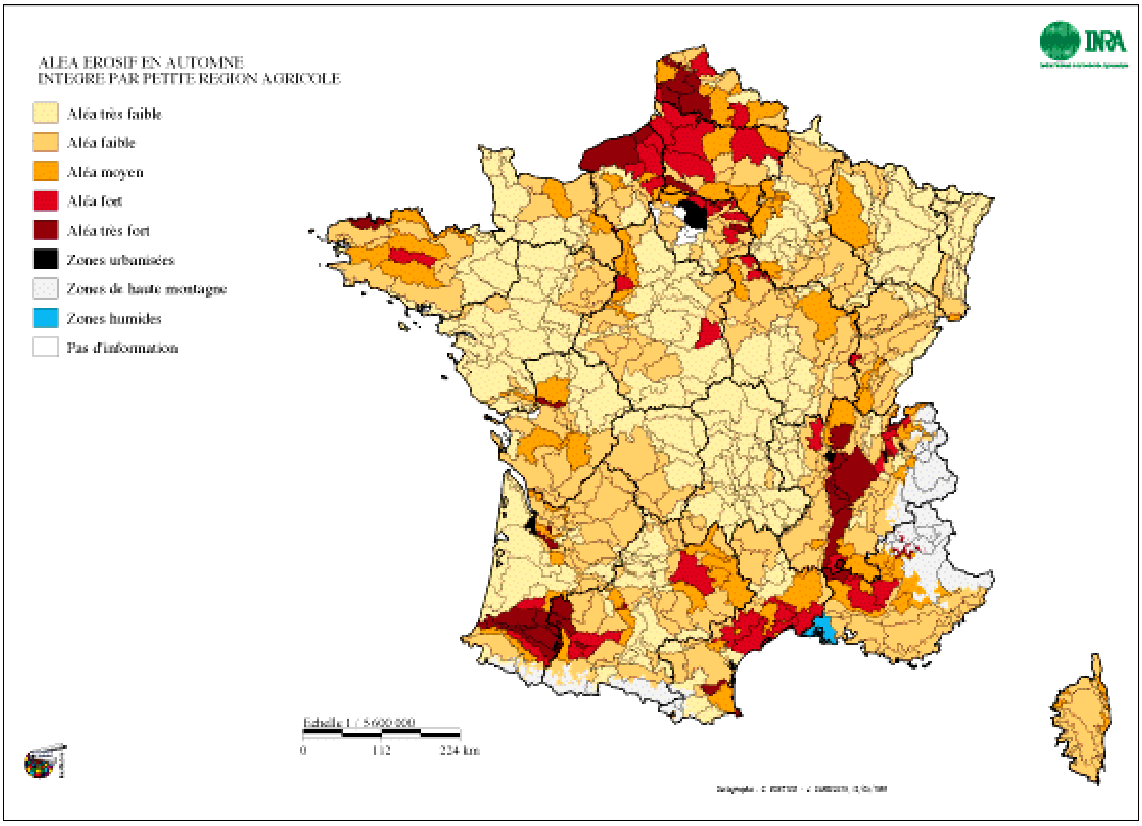


Source: IFEN, GIM & JRC

There are many different needs at the national and regional levels for which the CORINE Land Cover database may be applied. Examples include: land planning, impact assessment, noise abatement, monitoring of risks, soils erosion, advanced nature protection policies, prevention of forest fires, water management.

Example: Soil erosion risk
For an example at the national level: the following is the cartographic results of an application run with CORINE Land Cover data. In this example data on topographic relief, rainfall, and land cover have been combined; the result is a description of the potential for soil erosion. This type of information will prove very useful when developing perspectives about the impacts of environmental phenomena and the potentials or risks for certain types of land use.

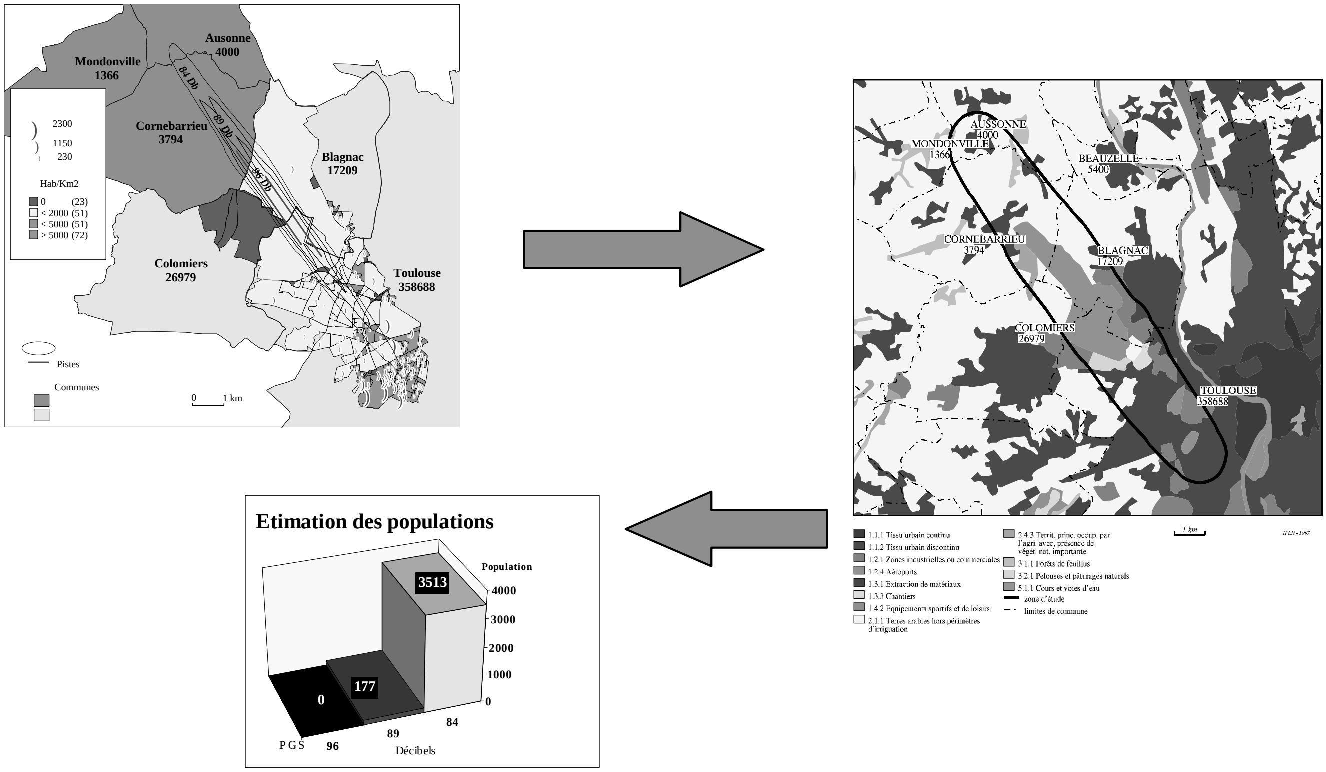
Figure 12. Erosion risks during the autumn months



Source: INRA, IFEN

Example: Local needs
With respect to policy development, implementation and follow-up, it is ultimately the local level where change will occur.
The following example suggests how the CORINE Land Cover database is useful to fulfil reporting requirements of local bodies to national and European institutes. The possibilities and practical uses for CORINE Land Cover at a local perspective include: to demonstrate both eligibility for European funding and compliance to European regulations, as well as risk assessment for populations exposed to noise pollution and air pollution, flooding, other natural hazards, etc.

Figure 13. Noise input around the Toulouse-Blagnac Airport



Source: IFEN

5. Best practices using CORINE land cover data

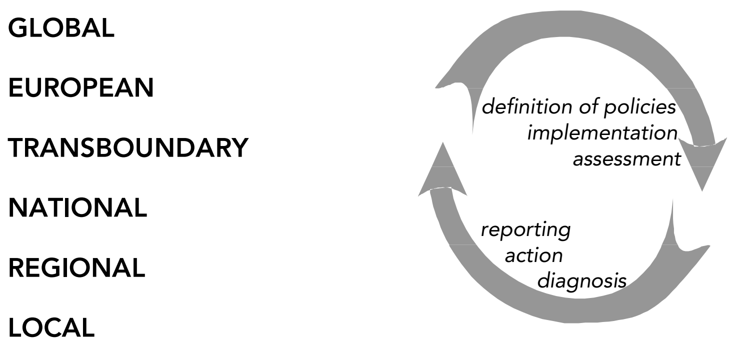
In this report attention has been placed on spatial and territorial indicators. Spatial data is categorised according to the following feature types: points, nodes, lines, links, chains and rings, polygons, pixels and grid cells. *Spatial analysis* is performed using spatial data, and the analysis includes methods used to explore the spatial relationships between features both real and theoretical, the process of extracting or creating new information about a set of geographic features (techniques to determine the distribution of a spatial feature; and the relationships between two or more features, the location of, proximity to, and orientation of these features in space), and the study of the locations and shapes of geographic features and the relationships between them. *Territorial assessment* is the consideration of the management and state of the land as it is divided up into political and administrative territories.

The picture given by CORINE Land Cover results from a choice, a compromise between constraints related to the data: completeness, comparability over Europe, timeliness, possibility of updating, minimum accuracy and finally, costs of acquisition. The range of applications based on CLC is rather wide. However, CLC is not *the* universal tool and, on many occasions, CLC data needs to be supplemented with other data on land cover to provide a sound and relevant source for the production of useful information.

In fact, this is not a problem of CLC but something more general related to the multiplicity of levels and dimensions both in the process of decision-making and in the information system required to support it. The levels refer to the scales at which the things occur, the dimensions are those many aspects (including the socio-economic ones), which are to be integrated in an environmental and sustainability perspective.

Two simplified schemes will serve to summarise the issue of multiple scales. The first describes the interactions between the local and the global scales when we consider action and policy making. Six levels are identified, and none of the six is more important than the others.

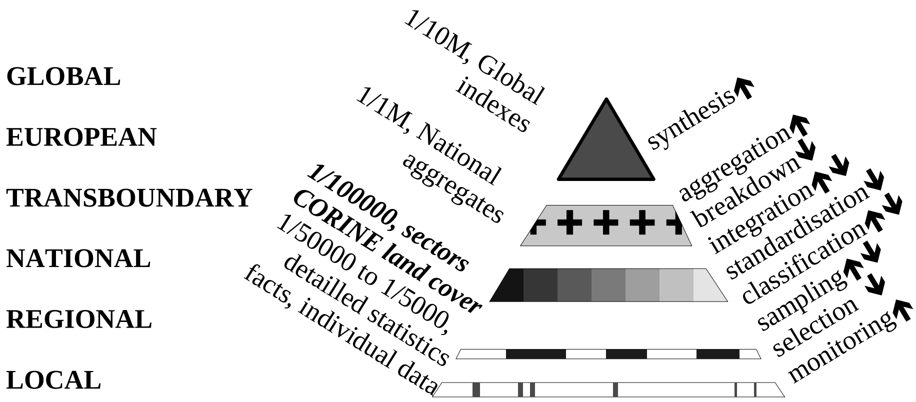
Figure 14. Action and policymaking: interactions between the local and global scales



Source: IFEN

Mirroring this first drawing, one can represent the various levels of information which are required (see figure 15). At the top of the triangle, global indexes and small scale maps aim at producing aggregated and exhaustive information. At the bottom, facts and individual data are surveyed by ground data collection, and by either statistics surveys or large scale maps; in many cases, detailed statistics and maps do not cover a territory in an exhaustive way. In the middle of the triangle, several levels of aggregation and integration of the data can be identified. As a summary picture, CLC stands in the middle, in a position equivalent to the economic sectors or industries currently used in the economic statistics (between 30 and 100 items). From the upper part of the diagram, one can represent the national aggregates and countrywide maps.

Figure 15. Action and policymaking: levels of information required



Source: IFEN

On the right side of the picture, the main procedures required to shift from one level to another have been included. Some of them are bottom-up (synthesis, aggregation, monitoring), others are top-down (breakdown, standardisation, selection), while others have the two aspects at the same time (integration, classification, sampling).

A first idea drawn from these schemes is one of detail. It is evident that there is not only a demand for greater detail, but also for less.

An important aspect is that CLC can be supplemented with additional data. It is always possible to use various types of (specific) data to address specific issues. However, as long as both environmental science and policy deals with interactions, an approach in terms of an information system in which the various datasets are coordinated is valuable. From a cost-effectiveness point of view, a systematic approach may also offer some benefits in terms of data collection: new surveys can be avoided when similar information can be obtained by re-processing datasets.

In this section of the report, the possibility of developing various data and information sets around CLC are discussed in order to be able to answer policy requirements in a more efficient way.

The issues, which will be covered, are:

- the possibilities of detailing the CLC mapping;
- the generation of details by overlaying CLC and other layers of information in a GIS;
- the combination of geographic and statistical methodologies;
- the integration of environmental and economic data: accounting and modelling;
- the issue of time.

5.1. Detailing the CLC mapping

The need at the national, regional or local scales for more detailed information can be satisfied, partly at least, in a way which is consistent with the CLC database. Therefore, consistency and comparability are maintained as far as possible, and relevant information is delivered. Several solutions can be proposed, according to the different requirements. These solutions are based on the (re)interpretation of the satellite images database previously used for the production of CLC (an additional benefit of this methodology is the savings in terms of purchasing and processing of satellite images).

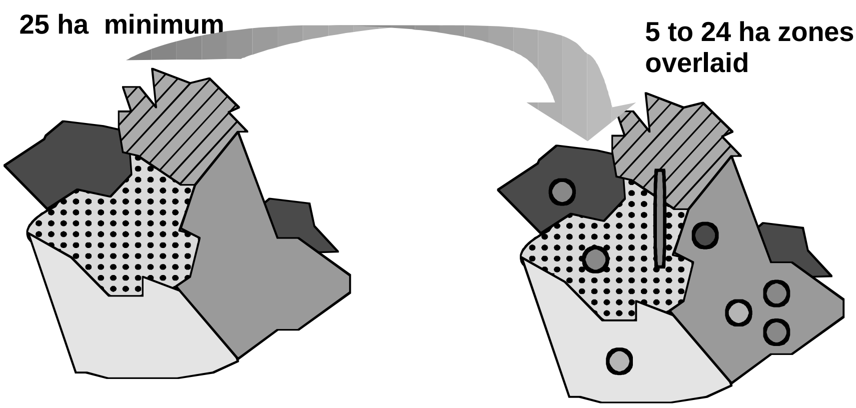
Technically, three solutions can be envisaged:

- Identification of small land cover features;
- detailing the classification (level 4) at the basic CLC scale (1:100 000);
- production of targeted land cover maps at a greater level of detail.

5.1.1. Identification of small land cover features

Small land cover units can be mapped, at the scale of 1:100 000, going down to 5 ha or less, according to the accuracy of the satellite image that is available. Therefore, it is possible, without changing the definitions of the standard CLC classification, to create an additional layer of information.

Figure 16. Using CLC to create an additional layer of information



Source: IFEN

This solution is relevant when the identification of small areas (smaller than 25 ha) is important. For practical and economical reasons, it is not possible to map every item with a level of detail of the order of magnitude of 5 ha, especially in the agriculture areas. In this latter case, the distinction of small pastures against cereal fields may be difficult and will require additional data (e.g. multi-temporal data) for sufficient accuracy. From an environmental point of view, some land cover types have a particular importance in terms of description of the complexity and diversity of a landscape. These types are mainly villages, woods, lakes and wetlands.

With this method, the scale and classification of CLC can be kept. There is no problem in integrating this data in indexes of number of zones. Indicators describing the diversity of the landscape will be significantly improved. In terms of surface areas, for agricultural items these very small units do not cover very much area. A (small) bias can be accepted in the statistics, or, more simply, statistics for these zones can be computed separately.

5.1.2. Detailing the classification (level 4) at the basic CLC scale (1/100 000)

With the experience gained in CLC, it appears that some land cover types, which are not retained in the standard CLC classification, are of importance, at least in some European regions. In fact, these land cover types should require the splitting of the CLC level 3 classes in order to produce the relevant information. Two types of refinement of land cover information are relevant to this methodology:

- Specific land cover description:
  - Broad leaved forests: the poplars and the eucalyptus forests that are managed in a way similar to agriculture should be mapped separately.
  - Sub-alpine grassland has also been identified as a topic that should require a specific photo-interpretation.
- Additional characteristics of land cover classes: defining a classification implies making choices. For example, a temporarily flooded meadow can be classified as grassland or wetland. In CLC, characteristics such as the density or the humidity of the vegetation have not been kept as criteria for level 3. As long as they can be derived from satellite images and identified by photo-interpretation two characteristics could be considered for level 4: the density and structure of forests and shrubs and the temporary humidity of grassland.

5.1.3. Production of targeted land cover maps at a greater level of detail

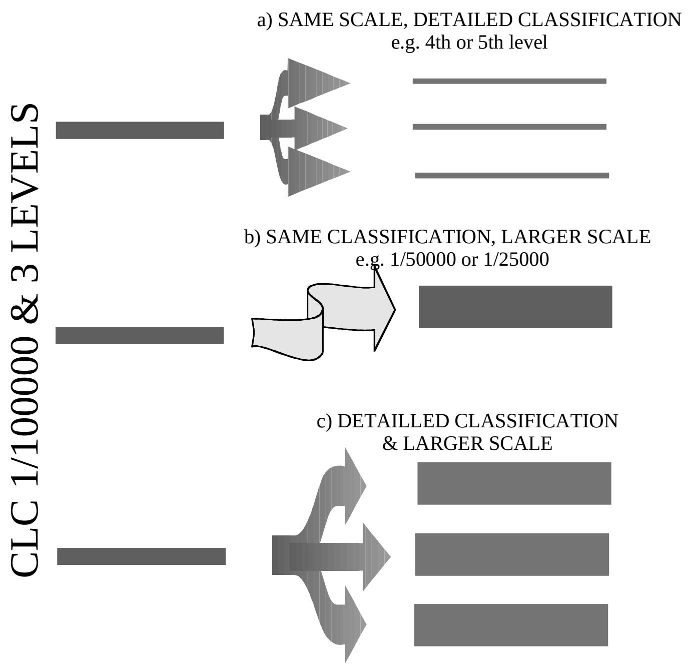
Considering a scale of e.g. 1:50 000 and classification levels 4 and 5, experience shows that it is very often possible to refine the photo-interpretation of the satellite images, especially when their resolution is high. It is therefore possible to produce maps that are more detailed in terms of geometry and themes than the standard CLC. Two questions are raised at this stage:

- First, we may debate the consistency of such approaches with CLC because the definition of the landscape unit (specifically the analytical unit) is no longer the same when the scale is changed. This objection is correct. However, enhancing CLC in this way is efficient because of the gateway between scales, which is implicit in such a methodology.
- Second, the cost. It is certain that when photo-interpretation is pushed up to more detailed scales, the time spent to do this work increases more or less geometrically: at the scale of 1:50 000, four sheets are needed to cover 1 sheet of 1:100 000. The cost is increased again when going in more detail because of the limits of the satellite images and the increasing need for additional data.

Accordingly, the present methodology for more detailed maps should be restricted to specific areas such as urban areas, the coastal zones or protected areas.

These methodologies based on photo-interpretation along the CLC principles can be summarised by the scheme below:

Figure 17. Detailing CLC classification and/or scale



Source: IFEN

5.2. Digitised analysis of geographical information

In many cases, it is possible to obtain the information required by policy makers simply by using GIS resources systematically.

For example, there is no need to spend time and money in photo-interpreting linear features (such as roads and rivers) and point features when this data is available from other sources. It is much easier to overlay this type of geographic data with the CLC. The only possible difficulty lies in the geometric compatibility between CLC and the other geographic databases. This point has to be tackled in an early stage of the CLC process of production. The minimum target is a high standard in the geometric correction of the satellite images. When an official national cartographic database exists, the best compatibility with it has to be obtained.

Another way of producing greater detail with a GIS is by dint of breakdowns of CLC classes according to various zoning. Typically, the overlaying of CLC with the Digital Elevation Model (DEM) is an easy way of producing maps, e.g. maps of forests according to their altitude or according to the magnitude of the slope (e.g. mapping the 'protection forests'). Coastal wetlands or rocky land can be identified in the same way, without changing anything for the CLC. Other overlays can be produced by taking into account the geology or climate.

5.3. Geo-statistical analysis

Using basic functions of a GIS, it is possible to derive new data from the existing database or to improve the information system by combining geographical and statistical methodologies.

Three examples will be given below:

- the weighted allocation of statistics to CLC classes;
- the use of CLC for optimising sampling patterns;
- the statistical generalisation realised through smoothing methods.

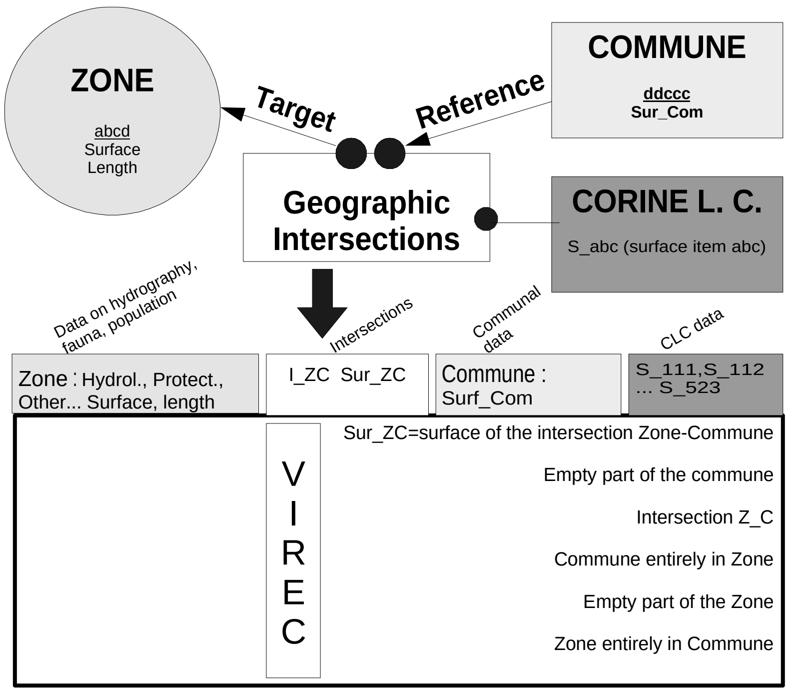
5.3.1. Weighted allocation of statistics to CLC classes

This option is used to overcome insufficient detail in current statistics.

Most conventional statistics are collected by reference to administrative units. In some cases, this geographical breakdown is not sufficient or not relevant for environmental analysis. It is not sufficient when, for example, the precise location of people is required according to their exposure to a risk (e.g. air pollution, floods, noise). It is not relevant when the phenomenon cannot be studied in the context of administrative regions, and instead need to be studied in terms of relevant physical regions (airsheds, catchments, etc.)

When this difficulty occurs, it may be possible to re-allocate the conventional statistics to the CLC zones according to reasonable assumptions. The conceptual model HYDROSOL was developed by IFEN and is presented below. HYDROSOL was in the first place an application developed to assess the use of fertilisers in small river catchment areas.

Figure 18. Method to reallocate conventional statistics to CLC

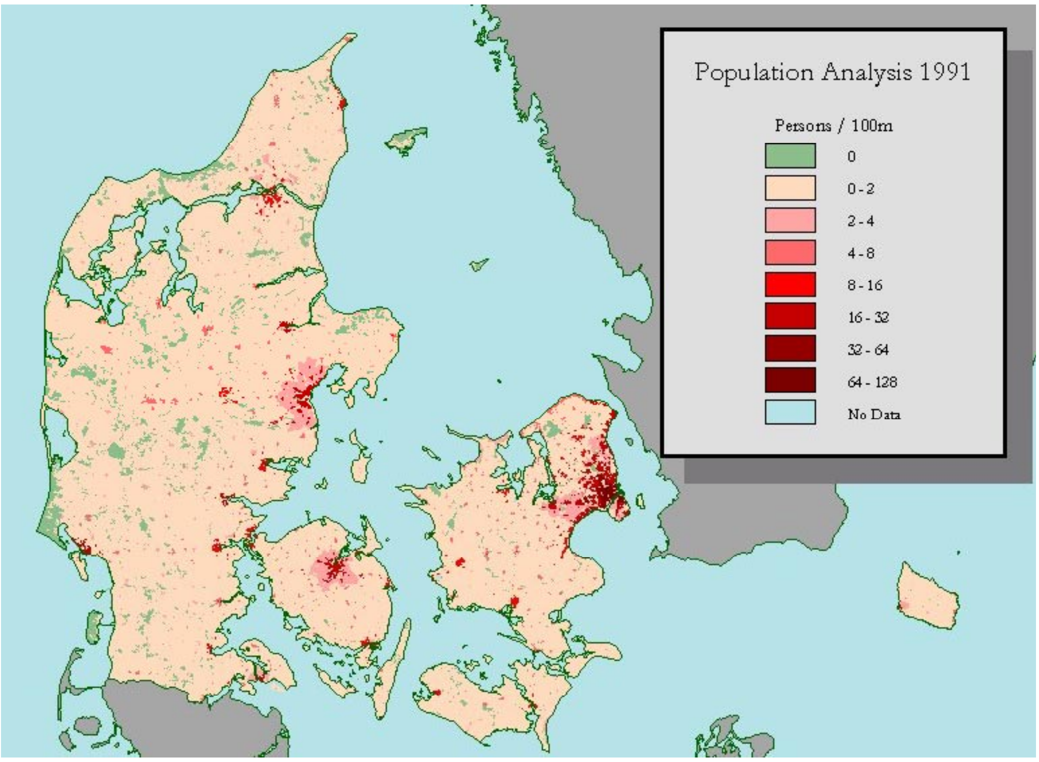


Source: IFEN

After the first application in the domain of inland water, the HYDROSOL methodology was used to assess the population in, and in the surroundings of, NATURA 2000 sites in France.

Recently, EEA implemented a similar methodology and produced a map of the actual density of population of Europe. The resulting map (and the new statistical data that it represents (available for all of EU)) is one of the possibilities to redistribute statistical data using land cover data.

Figure 19. Population density reallocated to CLC, the example of Denmark



Source: EEA

5.3.2. Design of sampling patterns

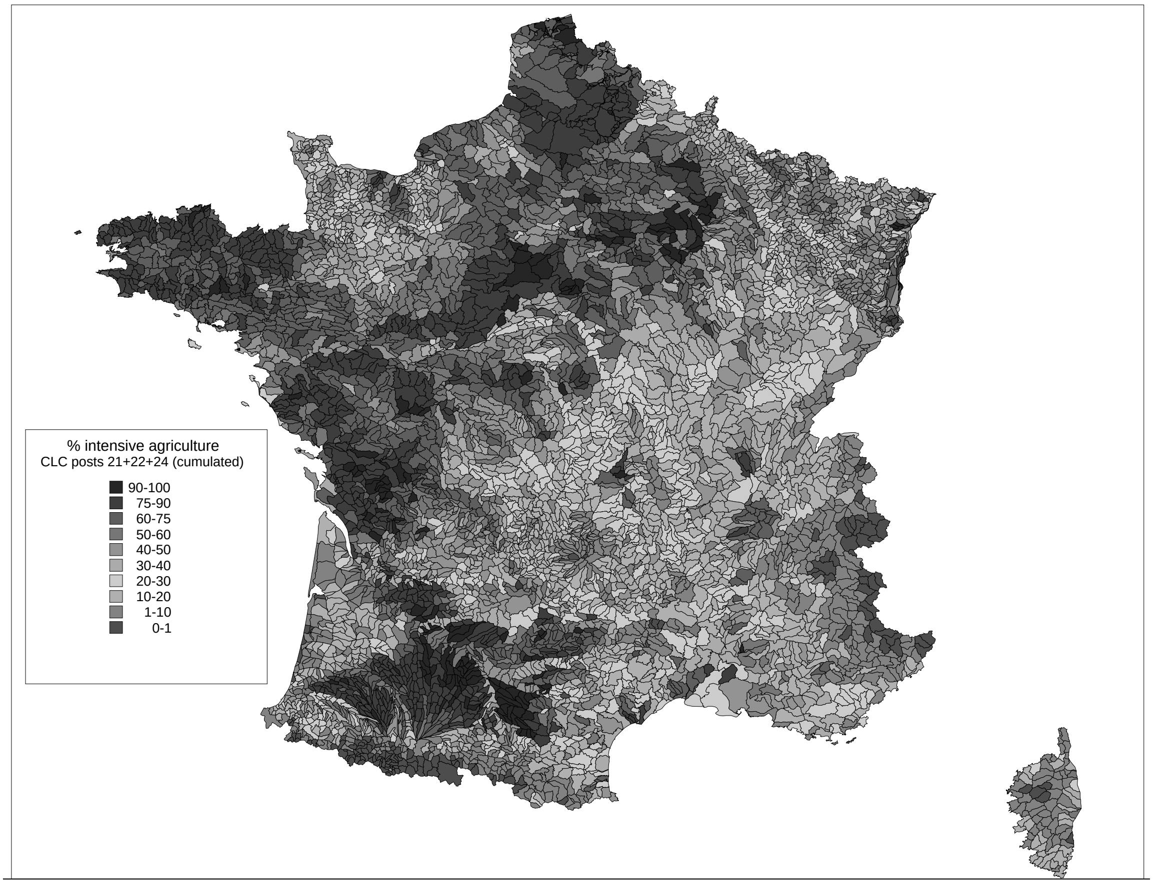
One of the major difficulties in terms of the comparability of environmental data over all Europe is the heterogeneous nature of the monitoring network. Basically, a monitoring network (for water quality, air quality, …) provides a sample. Practically, most networks do not provide truly representative samples since they are designed to provide operational data for the day-to-day management of problems. Therefore, their statistical quality is generally low in terms of broad representativity. One way to overcome this difficulty is to assess the statistical representativeness of the sample, in order to propose improvements (e.g. increase in the number of monitoring stations) and/or an ex-post stratification. In the second case, a representative sub-sample will be defined.

When geography matters, the representative character of the sample has to be established according to data which is geographically referenced. This is more or less the case for demographic data (with the limitations stated above). The geographical breakdown of economic data is often too low to be useful in this process.

The methodology proposed for EUROWATERNET, the representative network proposed by the EEA for monitoring water quality, uses CLC data (and demographic data) to define the characteristics of the reference 'population' of river catchments.

Basically, each catchment has a value in terms of population and agriculture, which is the cumulated sum of what is in its boundaries and what is in the catchments that are upstream (and discharge their pollution downstream). In the example below, the individual catchments are ultimately grouped in four classes according to the direct and indirect (from upstream) pressure: agriculture, mixed (agriculture and urban), urban and lastly, other (neither urban nor agriculture).

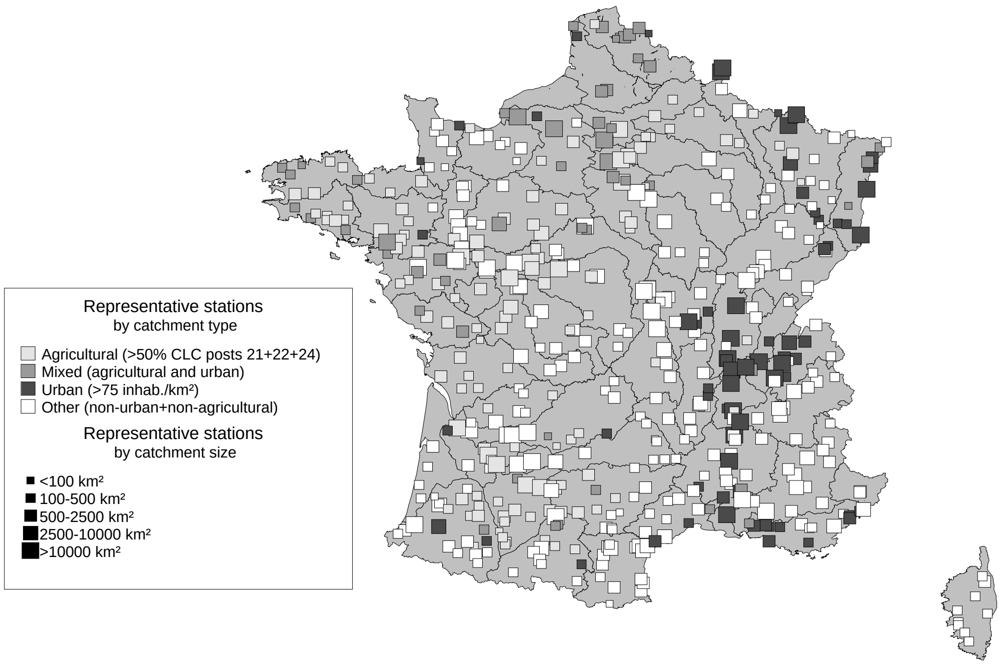
Figure 20. Individual river catchments classified according to (cumulated) pressure by agriculture



Source: IFEN and IOWater

From this database, it is possible to assess the representativeness of the current monitoring stations and to extract by ex-post stratification a subset that constitutes a sample relevant for the issue that is surveyed. In the case of the monitoring of phosphorus in water, the sample, which is considered representative for the European level, is shown in figure 21.

Figure 21. Proposal for a subset of water pollution monitoring stations, statistically representative at the European level



Source: IFEN and IOWater

5.3.3. Aggregation

More information is not synonymous with more detailed data. In many cases, producing useful information means aggregating and analysing, in one way or another, large amounts of data.

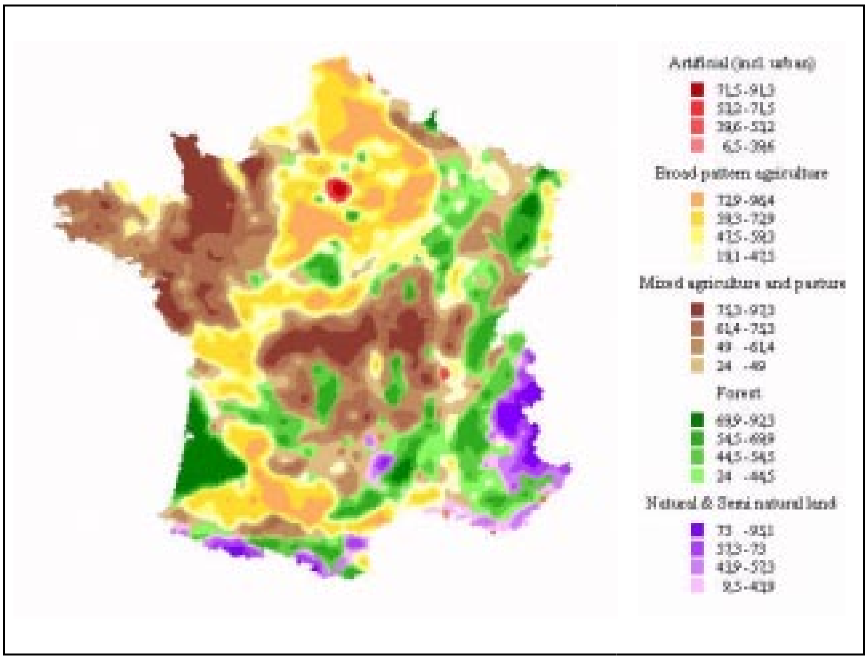
Geographical generalisation is one way of producing this kind of aggregated information. However, some difficulty lies in the fact that geographical generalisation implies that the smaller units disappear in the process for the benefit of the large units. Consequently, the statistical values differ according to the level of generalisation of your map.

An alternative methodology is smoothing of the detailed data. Various smoothing techniques are available. Recently, IFEN implemented on the CORINE Land Cover database a methodology developed for demographic statistics and 'urban temperatures' (this smoothing methodology is called 'Bi-Weight' and has been developed by Grasland, CNRS-PARIS and Chataignon, INSEE, 1998). This methodology has been implemented in France on the CLC database, the result being CORILIS, 'lissage' meaning 'smoothing' in French. The purpose is to assess the weight of human settlements on their surrounding region. In this perspective, it is important to consider the cumulative weight of each settlement and of neighbouring ones. Of course, for the latter, the closer they are, the more they contribute to the weight. In practice, the reference territory is split into geometrical cells (squares or hexagons) to which a value is given (e.g. for the population) cumulating what is inside each reference cell and what is in the surrounding cells, divided by the square of the distance between the centres. The computation is realised for all cells.

The CORILIS methodology provides a simplified vision of the territory and illuminates the dominant characteristics. In figure 22 (Lacaze, Ifen, 1999), CLC is used in a very aggregated way (five classes, see legend). France is split in 50 000 hexagons, each cell being given a colour according to the class which has the highest value at the end of the calculation. Of course, this value can express a high absolute majority or just a relative majority. In fact, when expressed in percentage, the value means the probability to meet the class in the cell. In the example below, each class has been divided in quartiles, coloured in dark (highest values) to light (lowest values). What can be easily seen on the map are the regions where each class is dominant and the transitions between classes.

Due to the way the smoothed values are calculated, nothing disappears. Consequently, the total for the country remains the same, whatever procedure is chosen. For example, one can work on detailed classes and aggregate them in a second step or apply the methodology on very aggregated classes: the national total remains identical. Of course, it is also possible to work class by class, by pairs of class (e.g. urban vs. forests), by ratio of classes, etc.

Figure 22. New perspectives for mapping, a methodology for smoothing detailed data



Source: IFEN, CNRS-PARIS, INSEE

5.4. Integration of environmental and economic data: accounting and modelling

Environmental accounting and modelling aim at describing the interactions within the environment and between the environment and the economy. To some extent, environmental accounts are already a model, very simple and of a general nature. The aim of the accounts is to check the consistency and quality of data from various sources, to organise them in a systematic way and to calculate a first set of indicators (costs, results, availability of a resource etc). To some extent, the accounts also help in organising the statistics for modelling purposes.

5.4.1. Accounting for land cover and land use

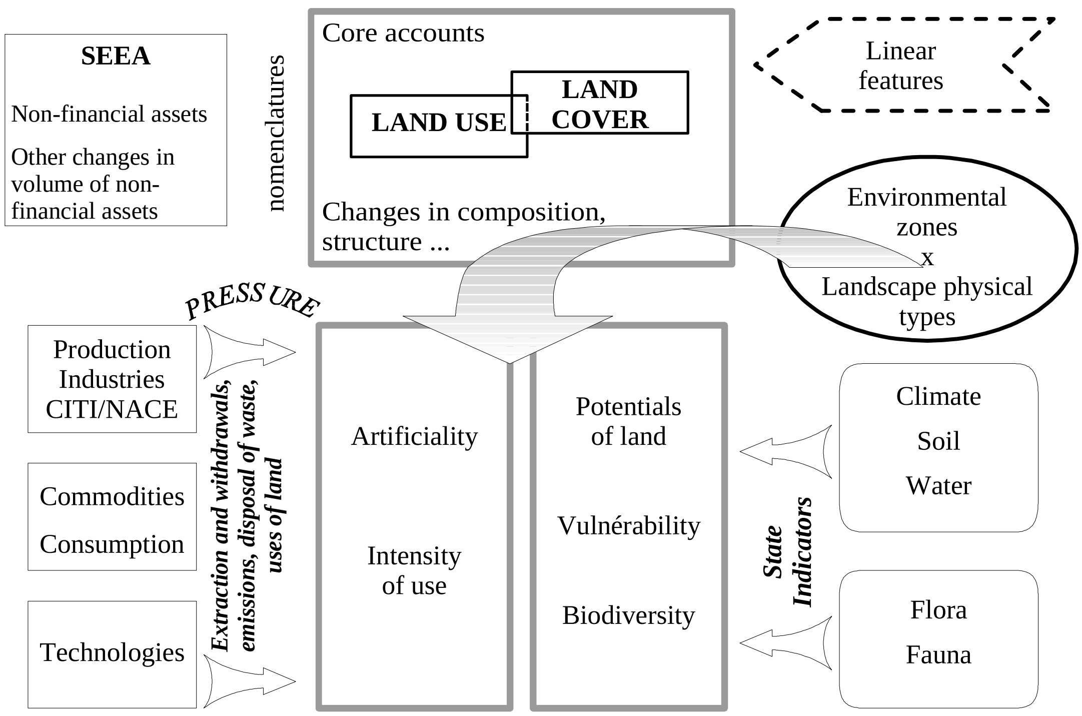
In the continuation of the work initiated by the UN-ECE, Eurostat is leading a working group on land accounting since 1998. It is therefore too early to describe precisely what the land accounts will look like. However, some key points can be noted.

Firstly, land cover (what is seen from the sky) has to be clearly distinguished from land use (what people do). The accounts of the habitats (the use of land by Nature) have to be distinguished as well. For land cover, the CLC inventory is accepted as the basic source in Europe. Land use is a more complex issue and no obvious answer is available. In particular, the current classifications of land uses avoid the key issue of the possible multiple use of land. They miss therefore the description of the conflicts resulting from these multiple uses. The classification of habitats will be based on the classifications defined by the biologists; these classifications can be linked with the land cover types, at least an aggregated level.

It is also agreed that land use should be put in relation to the economic accounts through appropriate tables. The input-output tables and the NAMEA model (developed by the Central Bureau of Statistics of the Netherlands) seem to provide a relevant solution to land accounting.

Another area of agreement is that a distinction has to be made between core accounts, whose production could be recommended for all the countries and supplementary accounts developed for specific policy issues. This position is based on the approach proposed by the UNECE task force[18]. It can be summarised in the following scheme:

Figure 23. Land accounting following the UN-ECE approach



Source: IFEN

[18] UNECE/Conference of European Statisticians Task Force: *Physical environmental accounting: land use/land cover; nutrients and the environment*. Etudes et travaux, IFEN, Orléans, France, 1995.

5.4.2. Environmental modelling

Physical modelling is essential in the development of environmental information systems. Basically, the most important purpose of physical modelling is not the production of forecasts or outlooks. These can only be developed in the context of a broader system analysis, integrating socio-economic factors and scenarios and relating to what is called analytical modelling. Indeed, physical modelling is important for the understanding of the interactions, in particular in the DPSIR assessment framework adopted by EEA. A major difficulty is that the equations of the local models (even simplified) cannot be fed with current statistics, which are either too aggregated or collected in a non-appropriate framework. Modelling is obviously the only way of assessing the excess quantities of nitrogen and obviously, the calculation has to be done river basin by river basin, taking into account the agriculture land in each river catchment area.

Unfortunately, the current statistics on crops and on sales of fertilisers are not available with the appropriate breakdown. They are collected in an administrative framework whereas data is required for physical units. The difficulty can be partly solved with CLC and the HYDROSOL model. For example, a comparative study of the flows of nitrogen in the Loire and Elbe basins, realised by IFEN, Beture and a group of German research institutes, WRc and Gisat for the Joint Research Centre[19].

Analytical economy-environment modelling
This is a new development in economic modelling to take into account of the environmental constraints as well as the most sophisticated way of producing information for sustainable development policies. Questions that are currently answered by such a modelling are:

- What will be the changes in the agricultural practices of farmers generated by (i) a change in the price system, (ii) a change in the subsidies system?
- What will be the consequences of the changes in the use of land by farmers on the natural habitats and on the water resource?
- What will be the cost of complying with such or such environmental standard? What are the consequences for the National Income?

The first two sets of questions lead to an analytical modelling based on a general scheme such as the one presented in the LUCC Science/Research Plan[20].

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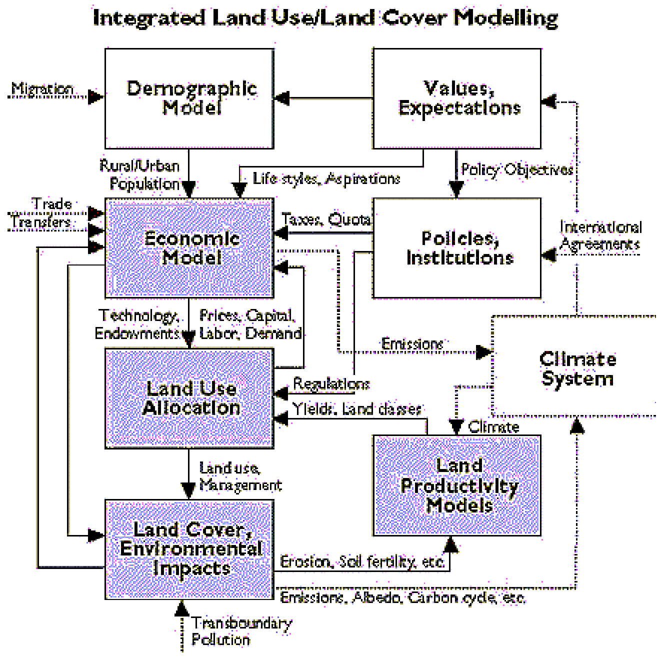
[19] *CORINE LAND COVER as a basis layer to non point sources emissions assessment/ Agriculture emissions comparison between the Loire (F) and the Elbe (D, CZ) basins* by IFEN, Beture and WRc et alii, Report for the JRC of the European Commission, February 1999.

[20] B.L. Turner II, David Skole, Steven Sanderson, Gunther Fischer, Louise Fresco and Rik Leemans, *Land-Use and Land-Cover Change (LUCC) Science/Research Plan*, IGBP Report No. 35 and HDP Report No. 7, ICSU and ISSC, Stockholm and Geneva, 1995 – also on: http://www.icc.es/lucc/scienceplan/scienceplan.html

Figure 24. Analytical economy-environment modelling with CLC – the LUCC approach



Source: IGBP/LUCC

The last type of questioning is typically covered by the GREENSTAMP[21] project supported by the CEC-DG Research. Some aspects of the GREENSTAMP approach deal with national (sectoral) statistics, others require geographical breakdowns for which land cover information is important.

5.4.3. Integration of the social dimension

Obviously, the relationship between people and their environment is better understood when the geographical dimension is integrated in the analysis of the environmental risks and behaviour. Several examples have been given in this report, namely:

- Exposure to the noise around the Toulouse-Blagnac airport;
- Exposure to the noise in the corridors around the Trans-European transport Network;
- Exposure to air pollution;
- Population living in an area with risks of flood;
- Access of the public to forests;
- Population involved in the areas designated for Nature protection;
- Real distribution of the population of Europe.

5.5. The issue of time

Because there is only one version of the CLC, most applications, with the notable exception of LACOAST, are of a static nature. Therefore, the possibility of describing time series is limited. This will change with the updating of CLC planned for the year 2000. This updating is not only launched in order to have fresher data, but even more so for identifying the changes in land cover. As such, changes in land cover and their location are very important information. The

[21] GREENSTAMP: *Greening Statistics for Analytical Modelling Purposes.*

analysis of the changes will lead to new, powerful and easy to understand indicators.

Although of major importance, the updating of the CLC is not the answer to every problem. The scale of CLC (1:100 000) and the size of the smallest mapping unit (25 ha) restrict the sensitivity of the tool. The updating over an average period of 10 years is also a limitation. In some cases, particularly in areas changing at a high pace or in areas under stress (e.g. coastal zones, urban zones, protected zones) it may be necessary to have a more detailed inventory in order to capture changes of a smaller magnitude and, as well, to have more frequent updating.

As already well illustrated by the LACOAST project, the CLC database has proved to be a very successful tool for examining changes (in this case between 1975 and 1990) of the land cover in the European coastal zones (see above). This project should be expanded to all Europe for at least two reasons. First, it is well known that there is some risk in interpreting changes with only two points in time. If one of the points is very specific due to, for instance, an unusual climatic event, a mistake may be made. With three points in time, the risk of misinterpretation is reduced. A second reason is that knowledge of the trends in the past is important for understanding what is presently happening.

6. Conclusions

The present report focuses on the state of development of spatial and territorial indicators based on land cover as contribution to the environmental indicator based reporting. The report summarises the joint efforts during 1999-2000 of the European Topic Centre on Land Cover (ETC/LC) and the PHARE Topic Link for Land Cover (PTL/LC) in this area.

With the present publication a number of concrete spatial and territorial indicators are proposed and developed based on available data sources and using a different approach by introducing environmental reporting units as the basis for the calculation and representation of the information. The indicators are created by means of spatial analysis of different information layers using GIS (Geographic Information System).

The aim of this approach was to better illustrate the regional diversity of the natural environment and assess the state, pressures and impact on the environment. Consequently, the reporting units proposed in this study are natural regions, e.g. watersheds, biogeographic regions or artificial (mostly administrative) regions.

The specificity of the spatial and territorial indicators obtained is that they address the environmental information in terms relevant for the regions. For policy makers, on the other hand, it is useful to monitor how the regions are doing with respect to achieving policy aims, to know if the regions are keeping on target, or if they are lagging behind, and based on this information be able to take the necessary actions.

The present report is a first attempt in the direction of territorial indicators and is only opening a new chapter of investigation which requires consolidation and further development. Therefore the work on spatial and territorial indicators should continue and be extended to new areas, such as:

- carbon sinks;
- soil degradation;
- non-point emissions to water;
- critical loads and biodiversity;
- land abandonment by agriculture;
- direct and indirect costs of abatement of pollution and pressure on landscape.

Moreover the final goal of the work will be to set up a consistent core set of territorial indicators able to regularly feed the reporting cycle at European level. This approach will be continued by EEA through the work of the new ETC on Terrestrial Environment, in collaboration with other relevant European organisations active in this field.

First results are made available on NATLAN (Nature and Land Cover information package). Spatial and territorial indicators will be fully integrated in the EEA data service (European Environmental Reference Centre).