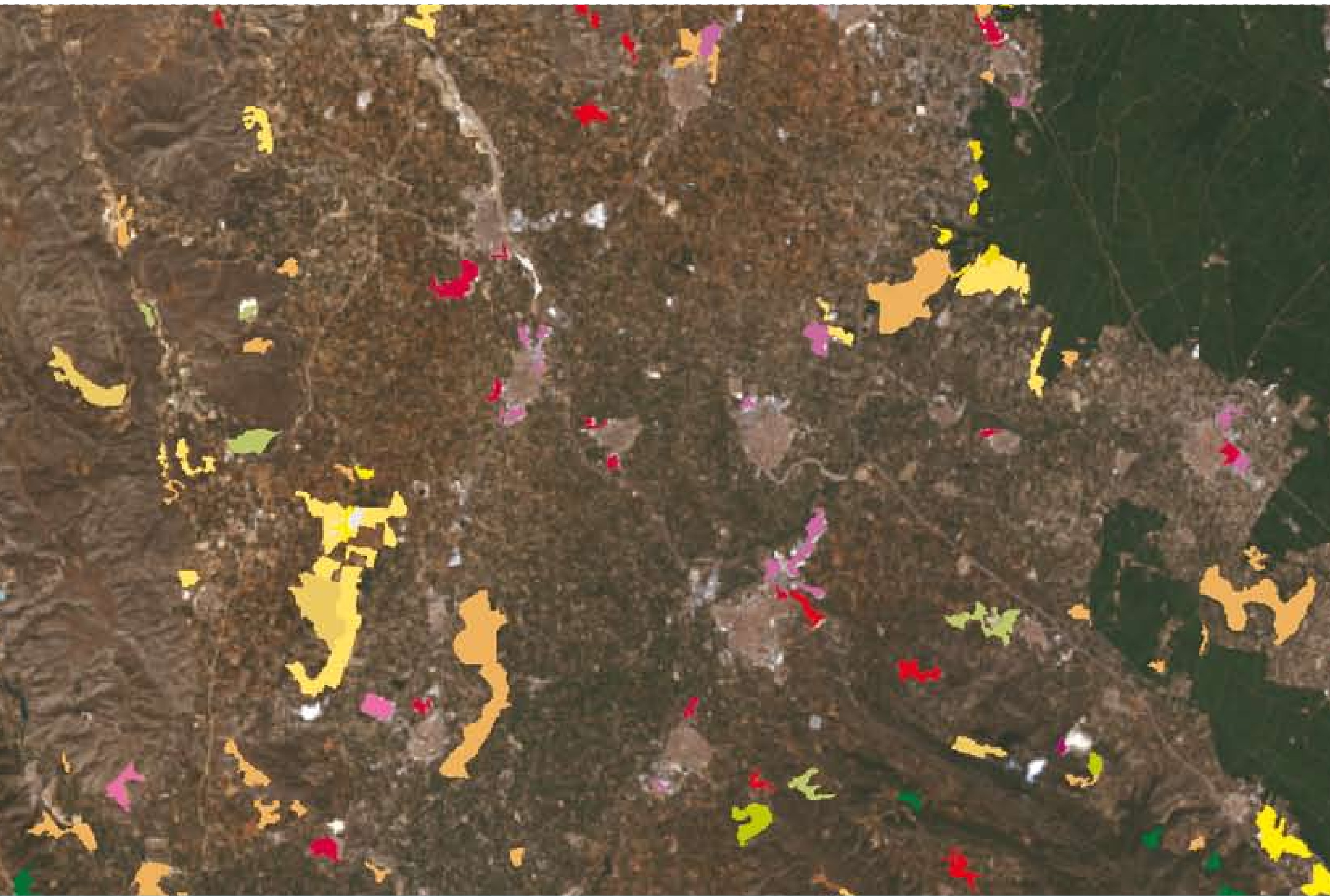
EEA Report | No 11/2006

Land accounts for Europe 1990–2000

Towards integrated land and ecosystem accounting

ISSN 1725-9177



European Environment Agency

EEA Report | No 11/2006

Land accounts for Europe 1990–2000

Towards integrated land and ecosystem accounting

European Environment Agency

Cover design: EEA
Cover photo © Landsat/Image2000/JRC (South of Valencia, Spain)
Left photo © European Environment Agency; Source: Jean-Louis Weber
Right photo © European Environment Agency; Source: Jean-Louis Weber
Layout: EEA

Information about the European Union is available on the Internet. It can be accessed through the Europa server (www.europa.eu).

Luxembourg: Office for Official Publications of the European Communities, 2006

ISBN 92-9167-888-0
ISSN 1725-9177

EMAS
Verified environmental management
REG.NO. DK-000244

European Environment Agency
Kongens Nytorv 6
1050 Copenhagen K
Denmark
Tel.: +45 33 36 71 00
Fax: +45 33 36 71 99
Web: eea.europa.eu
Enquiries: eea.europa.eu/enquiries

Contents

Part III: Methodologies

Part IV: Conclusions

Acknowledgements

This report was prepared by Roy Haines-Young (University of Nottingham) and Jean-Louis Weber (European Environment Agency) with contributions from Ferran Páramo, Françoise Breton, Óscar Gómez Prieto and Tomáš Soukup (EEA/European Topic Centre on Terrestrial Environment). The authors would also like to acknowledge the input of ideas by many others through the various expert meetings at which these materials have been presented.

1 Introduction and background

1.1 The land as a resource for sustainability

An understanding of the implications of changes in land cover and land use is a fundamental part of planning for sustainable development. On the one hand the transformation of land cover and land use by human action can affect the integrity of natural resource systems and the output of ecosystem goods and services. On the other, by careful planning, the development of new patterns of land cover and use can enhance the well-being of people (Millennium Ecosystem Assessment, 2005).

The need to consider the coupling of social and ecological systems through the study of land use change has been identified as an urgent priority by a number of organisations. The recently announced Global Land Project (GLP, 2005), for example, which is a joint initiative promoted by the International Geosphere-Biosphere Programme (IGBP) and the International Human Dimensions Programme on Global Environmental Change (IHDP), takes as its starting point the proposition that it is possible that there is a limit or threshold at which the Earth System (which includes all its biophysical, economic, technological and societal elements) can no longer absorb the impact of human activity. According to the GLP, this represents the sustainability limit. The sponsors observe, however, that on the basis of current knowledge, we cannot say where such a limit lies, and propose that the Global Land Project should investigate the problem from a land-systems perspective.

Within the European Union the importance of a land-systems perspective has also been widely recognised. The Cardiff Process, for example, which was initiated by European heads of state in 1998 required environmental considerations to be fully integrated into all decision-making, in order to streamline and improve the efficiency of the policy process. The importance of a landscape and land cover concerns have also been emphasised through the European Landscape Convention (Council of Europe, 2004). The results of such thinking are also reflected in the evolution of agricultural policy within the Union — a policy which now includes measures designed to benefit the rural landscape and the environment as well as promote and support an efficient farming industry.

The scale and scope of the integration of environmental issues into decision-making within the EU is also illustrated by the requirements of the European Water Framework Directive (WFD) and the European Habitats Directive. The effect of both directives will be a profound change in the way in which water and habitat resources are managed in the Member States. In order to achieve a number of demanding performance objectives, it will require a more integrated approach to the management of land than has been used in the past. The WFD, for example, aims to:

- enhance the status and prevent further deterioration of aquatic ecosystems and associated wetlands. There is a requirement for nearly all inland and coastal waters to achieve 'good status' by 2015;
- promote the sustainable use of water;
- reduce pollution of water, especially by priority and priority hazardous substances;
- lessen the effects of floods and droughts;
- rationalise and update existing water legislation, and introduce a coordinated approach to water management based on the concept of integrated river basin planning.

Such aims will only be realised if there is access to robust information about both the patterns of land cover and land use at different spatial scales as well as the way in which resources linked to land are changing over time. Such needs are also emphasised by the requirements of the Habitats Directive. Through the Natura 2000 process, the Directive seeks to ensure that Europe's key nature conservation areas are not only managed in a more systematic way but that their integrity is protected and enhanced by improving such aspects as habitat connectivity and the buffering of impacts from surrounding land use activities.

As emphasised by the recent proposal for a directive to establish an infrastructure for spatial information (INSPIRE) in the Community, initiatives such as those described above require flexible and timely access to a range of environmental data at broad European scales. Such development will build on the foundation already provided by ESPON ([1]) (the European Spatial Planning Observation Network); a research programme sponsored by the European Commission in support of its regional policies. The recent work undertaken by the European Environment Agency (EEA) on environmental accounting can therefore be seen as one part of this evolving information resource. This document describes the achievements made in relation to the development of asset accounts for land, and the opportunities that exist for the development of a range of decision support tools aimed at sustainable development goals.

1.2 Environmental accounts: the context

The need to develop and apply systems of economic-environmental accounting has been widely recognised by the international community. In the 1990s, for example, Agenda 21 highlighted the need for reform of national systems of economic accounting. The intention was to ensure that the value of environmental services and resources as well as the impacts of economic activities are expressed clearly:

A first step towards the integration of sustainability into economic management is the establishment of better measurement of the crucial role of the environment as a source of natural capital and as a sink for by-products generated during the production of man-made capital and other human activities. As sustainable development encompasses social, economic and environmental dimensions, it is also important that national accounting procedures are not restricted to measuring the production of goods and services that are conventionally remunerated… A programme to develop national systems of integrated environmental and economic accounting in all countries is proposed (United Nations Conference on Environment and Development 1992, Chapter 8).

As a result, subsequent work has sought to develop different ways of taking the environment into account.

A key stimulus to recent work by the EEA has been that of the London Group of the United Nations Statistical Division (London Group, 2006). It aims to provide an annual forum for leading countries and international organisations to exchange practical and conceptual expertise with respect to the development of environmental accounts linked to the System of National Accounts (SNA). Their goal has been to play a leading role in defining international standards in the theory and practice of environmental accounting. A recent milestone was the publication of the revision of the United Nations Handbook of National Accounting — Integrated Environmental and Economic Accounting in 2003 (SEEA, 2003). The latter seeks to describe a common framework for economic and environmental information that will allow an analysis of both the contribution that the environment makes to the economy and the impact of the economy on the environment. The framework has been developed to meet the needs of policy makers by showing how indicators and descriptive statistics can be used to monitor the interaction between the economy and the environment. Moreover, it provides a set of tools that can be used in the context of sustainable development for strategic planning and policy analysis.

The integrated economic and environmental accounts described in the SEEA2003 handbook are regarded as satellite accounts that sit alongside those of the SNA. In other words, as the accounts are linked to the latter via classifications and accounting rules, they are not a mere sub-set of tables. Additional components are presented in order to capture dimensions presently external to the core SNA, especially physical variables. The SEEA essentially consists of four types of accounts, namely those describing:

- the physical flows of materials and energy. These can be used to assess the extent to which more sustainable patterns of consumption and production are being achieved by decoupling economic growth from impact or dependency on natural resource systems;
- the environmental transactions relevant to the good management of the environment, such as expenditures made by businesses, governments and households to protect the environment, environmental taxes or permits;
- the stock and change of environmental assets (broadly represented by natural resources, land and ecosystems) measured either in physical or monetary terms;
- the depletion and degradation of natural capital in relation to the aggregates used by SNA.

([1]) http://www.espon.eu/ (accessed 30.09.2006).

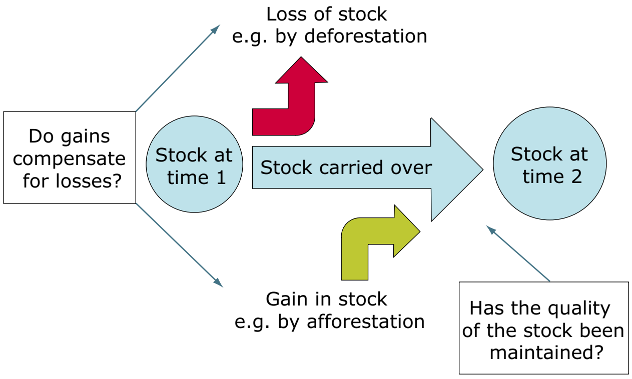
This report will focus specifically on the contribution that the EEA has made to the development of environmental accounting through its work related to the third type of account, namely asset accounts for land cover and land use.

1.3 Environmental accounts for land cover and land use

Land accounts, like those for other types of environmental assets, seek to describe how resource stocks change over time in a consistent and systematic way. By doing this, the implications of those changes can better be understood. The cover of land is not, however, simply an attribute or quality of land, but a concrete set of natural and anthropogenic features that largely results from its use. A given land cover can be modified, degraded or destroyed (consumed) and a new type generated. As such, the consumption and formation of land cover is very similar to the transformation of capital goods in the economy. Since land cannot, in general terms, be created or destroyed (with the notable exceptions such as coastal erosion and accretion), land cover change can generally be characterised in terms of different types of flows between land cover types. A key focus of land cover accounts is, then, the understanding of the way in which the stocks of different land covers and uses are transformed over time (Figure 1.1).

Figure 1.1 illustrates the conceptual model that underpins the asset accounts for land that are presented in this study. If changes in land cover and use are monitored over time, we can envisage an opening balance which represents the physical areas of different land cover types from the outset (time 1). These land cover elements are transformed by the process of land cover change to produce the closing balance at time 2. The gains and losses (flows) are the transfers of land area between the land use types.

Figure 1.1 Flow accounts for land cover and the relationship between the concepts of stocks and flows and fundamental questions about sustainable development



Despite its simplicity, the conceptual model described in Figure 1.1 is a powerful one because it provides a framework in which we can ask some fundamental questions about land use and sustainability (Haines-Young, 1999). For example, in terms of the changing stock levels of a given land cover type, we may ask whether the gains in stock compensate for any of the losses that were experienced over the accounting period. Such questions about compensation are fundamental to the issues associated with strong and weak notions of sustainability. Alternatively, we can ask whether the quality of the stock carried over from time 1 to time 2 has been maintained in terms of the benefits it provides to people or the support it offers to wider ecosystem functions. The maintenance of the integrity of stocks of natural capital is also fundamental to planning for sustainability.

Asset accounts in general are relevant to the measurement of progress towards the goal of sustainable development. If human well-being is to be maintained, then either the capacity of natural resource systems to furnish these needs must be retained, or the economy must find a substitute for the natural capital which is capable of delivering an equivalent input. Asset accounts are also relevant to the intra- and intergenerational equity issues related to sustainable development, since they can be used to track changes in the stock and quality of natural capital over time.

As Figure 1.1 illustrates, land accounts can potentially be used to help explore key issues related to questions about sustainable development. In fact, the SEEA handbook highlights five specific advantages that asset accounts for land have in such contexts, namely that they can provide:

- a comprehensive picture of land cover and land use for a nation from which information about trends can be derived and indicators of change constructed;
- a way of integrating diverse data sources on land cover and land use with other types of information, such as on population, economic activity, water balances, species or fertilizer use;
- a way of standardising classifications of land cover, land use and the causes (driving forces) of changes in land cover and land use;

- a framework in which changes in land use, land cover, habitats and biodiversity can be linked to the driving forces that may transform them;
- a system with sufficient flexibility to be applied at national, regional, watershed or landscape type level.

The connection that asset accounts for land have with habitats and biodiversity is a particularly important one. As the SEEA handbook emphasises, exploration of this interface could be achieved through the development of so-called ecosystem accounts. As the work undertaken under the auspices of the Millennium Ecosystem Assessment has shown, many aspects of human well-being depend not on individual species or elements of the natural environment, but on the goods and services generated by whole ecosystems (Millennium Ecosystem Assessment, 2005). Thus, an understanding of the ecosystem functions that give rise to these goods and services and the impact of human activities on the integrity of ecosystems is also a fundamental part of planning for sustainable development.

As is recognised by the SEEA handbook, methodologies for the construction of ecosystem accounts are still at an early stage of development. It is suggested that they will evolve in parallel with our understanding of ecosystems and the services they provide (SEEA, 2003, p. 33). Part of this work will depend on the construction of a robust framework for the underlying asset of land. *This study can therefore be seen as contributing to the developments required to leverage the design of SEEA to a much broader front* ([2]). In this report we focus specifically on land accounts. However, the final section will examine what opportunities they provide for developing the creation of ecosystem accounts on the European scale.

1.4 Aims and structure

This report provides an overview and discussion of some of the key results that have emerged from the construction of environmental accounts for land and ecosystems. The materials are presented in such a way that those interested can gain a critical insight into what has been achieved. The methodologies used by the EEA are fully transparent. Such scrutiny will demonstrate that the approach to land accounting used is robust and can provide a sound and flexible foundation on which to build future analysis and policy applications.

The report is organised into four parts. Chapters 1 and 2 provide an introduction to the context of the work and an overview of the land accounts at the European scale. Part II (Chapters 3–5) describes some of the results in more detail, and focuses particularly on how the accounts can be used to gain an insight into the processes of land cover change on a range of spatial scales across the EEA member countries. The purpose of presenting these materials at the outset is to emphasise the practical value of organising land cover information in an accounting framework. These materials will help the reader to evaluate the extent to which environmental accounts as currently formulated at European scales can provide the kind of evidence base that policy-makers presently require.

The third part of this report (Chapters 6–8) looks at the methodologies, data resources and analytical techniques in more detail. This part explains more fully the nature of the information and the methods used to process them. In addition, the rationale behind the ways in which the data have been presented is given. As a result, the reader should be able to gain both an understanding of the soundness of the methodologies that have been used by the EEA to implement the environmental accounting approach, and the steps taken to assure their quality. The aim in Part III is not to provide a detailed accounting manual, but a clear understanding of how key results have been achieved, what tools have been developed, what assumptions lie behind their use, and finally what opportunities the data provide for further analysis. A technical account of the database tools developed is provided in Annex A, which also describes how they can be accessed by users to support their own work.

Part IV concludes with a discussion of what has been achieved and how the accounting model might be developed in the future. In particular, the area of developing both targeted accounts and those dealing with ecosystems and their associated goods and services are debated.

([2]) At its June 2006 meeting in New York, the London Group established a sub-group on land and ecosystem accounting and asked the EEA to coordinate its activities.

2 Land cover change at the European scale 1990–2000

2.1 Introduction

The construction of land cover accounts is independent of any particular source of data. A land cover account is fundamentally a conceptual framework that offers a way to analyse the changes associated with land in a robust and systematic way so that key patterns and trends can be identified. Although the accounting model must be discussed in more detail, it is, however, useful to first demonstrate what can be achieved by the approach through a specific application. Thus, the next four chapters describe some of the insights that have been gained from the analysis of one particularly important data set that is available for Europe, namely Corine land cover (CLC) ([3]). A detailed description of the accounting methodologies can be found in Part III of this report.

Corine land cover data have been derived from the analysis of remotely sensed satellite imagery. The information is particularly useful for the purposes of constructing a land cover account. It can be used to estimate the stock of each of the major land cover types that we find in Europe and the way they changed between 1990 and 2000. For the purposes of this publication, 'Europe' is taken to be the 24 countries (see Figure 2.1) that are members or collaborating partners of the European environmental information and observation network (Eionet) coordinated by EEA. Data from the Corine land cover programme forms the basis of this study and are available for these two dates (see Appendix 3).

This chapter describes how the information derived from CLC can be set out in an accounting framework, so that the approach used to present other results in this part of the report can be better understood. A detailed discussion of the technical issues that surround the use of CLC is deferred until later.

2.2 Stock and change accounts

The asset accounts for land that have been developed aim to describe the geographical patterns of land cover types across Europe, the way they are changing over time and what types of processes are bringing about the various transformations. The foundation of the approach has been provided by the development of standardised terminology to describe both the cover types themselves and the types of change that can be seen. Table 2.1 shows how the approach has worked at the European scale.

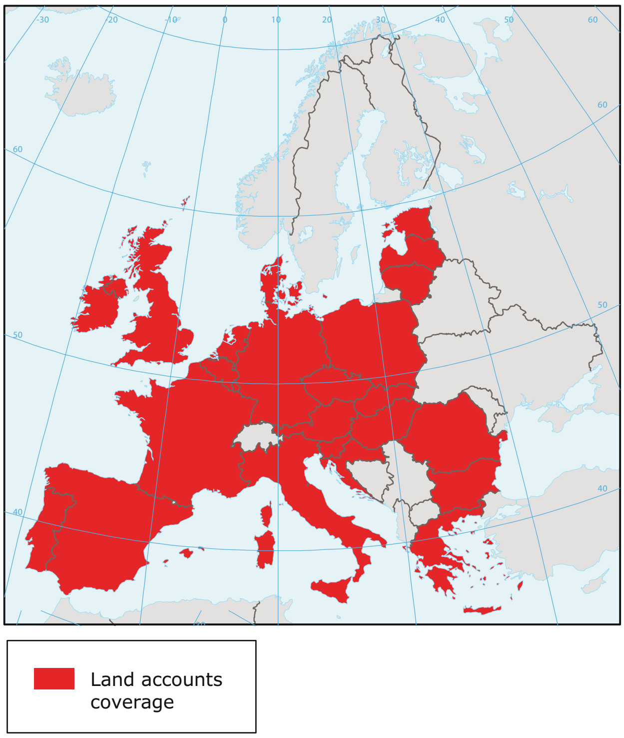
The columns of the table show how the stock of each of the main land cover types that we find across Europe has changed between 1990 and 2000. All of the information is held in a single accounting database from which different types of tabular, graphical and map views can be generated. We will initially consider output such as those shown in Table 2.1, because these best illustrate the nature of the underlying accounting model used by the EEA.

Since the land area of the EEA member countries is fixed, the total land area (shown in the right hand column of Table 2.1) has remained the same over the period 1990–2000. However, the allocation of land between the different cover types has changed. The classification of the types of land cover used in Table 2.1 is a general one with a limited number of classes. The data show that the extent of built-up or 'artificial' areas has increased as a result of urban development, while the area of other types such as semi-natural vegetation has decreased. Between 1990 and 2000 we can see that the urban area of the EEA member countries showed a net increase of about 8 700 km^2 or 5.4 %, while the total area of semi-natural vegetation showed a net decline of about 4 800 km^2 or 1.8 %.

Table 2.1 can be considered as an account, because it shows how the changes in land cover stock have

([3]) Corine is a standardised land cover inventory derived from satellite imagery for two median dates (1990 and 2000) for 24 countries. Seven other countries have only produced a 2000 map, while five additional ones have started a Corine programme. Corine is planned to be updated for all of Europe in 2006, and so the scope of land accounting will be broadened to 35 countries. Appendix 3 gives the current status of Corine mapping.

Figure 2.1 Coverage of the land cover accounts 1990–2000



In the account shown in Table 2.1, the gains and losses are described in terms of the processes of formation and consumption for each land cover class. In the case of forested land, for example, consumption and formation represent the opposing processes of deforestation and afforestation as well as the internal processes of felling and replanting that are part of the forest management cycle. For artificial surfaces (i.e. built-up or developed areas), formation represents the processes of urban development, while consumption or loss might be due to the reclamation of previously developed land and its restoration to agricultural land or forest.

The CLC data on the consumption and formation of each cover type were obtained by using the imagery to record how individual land cover parcels change from one type to another over the period of study. Figure 2.2 shows an example of the type of data used for the region of Valencia, Spain. As shown in Table 2.1, we can begin to see how the net changes observed between 1990 and 2000 came about for each of the cover types. The table shows net changes both as a percentage of the initial stock of each type, and as a percentage of the total land area. An estimate of turnover is also given, expressed as the percentage of the initial stock that has been gained or lost during the period.

The indicator for turnover is particularly interesting in the context of questions about sustainable development, because it helps us to understand

come about. It does this by setting out the gains and losses to the stocks of each cover type. By doing this, we can clearly see how the various flows produce the net change over the accounting period.

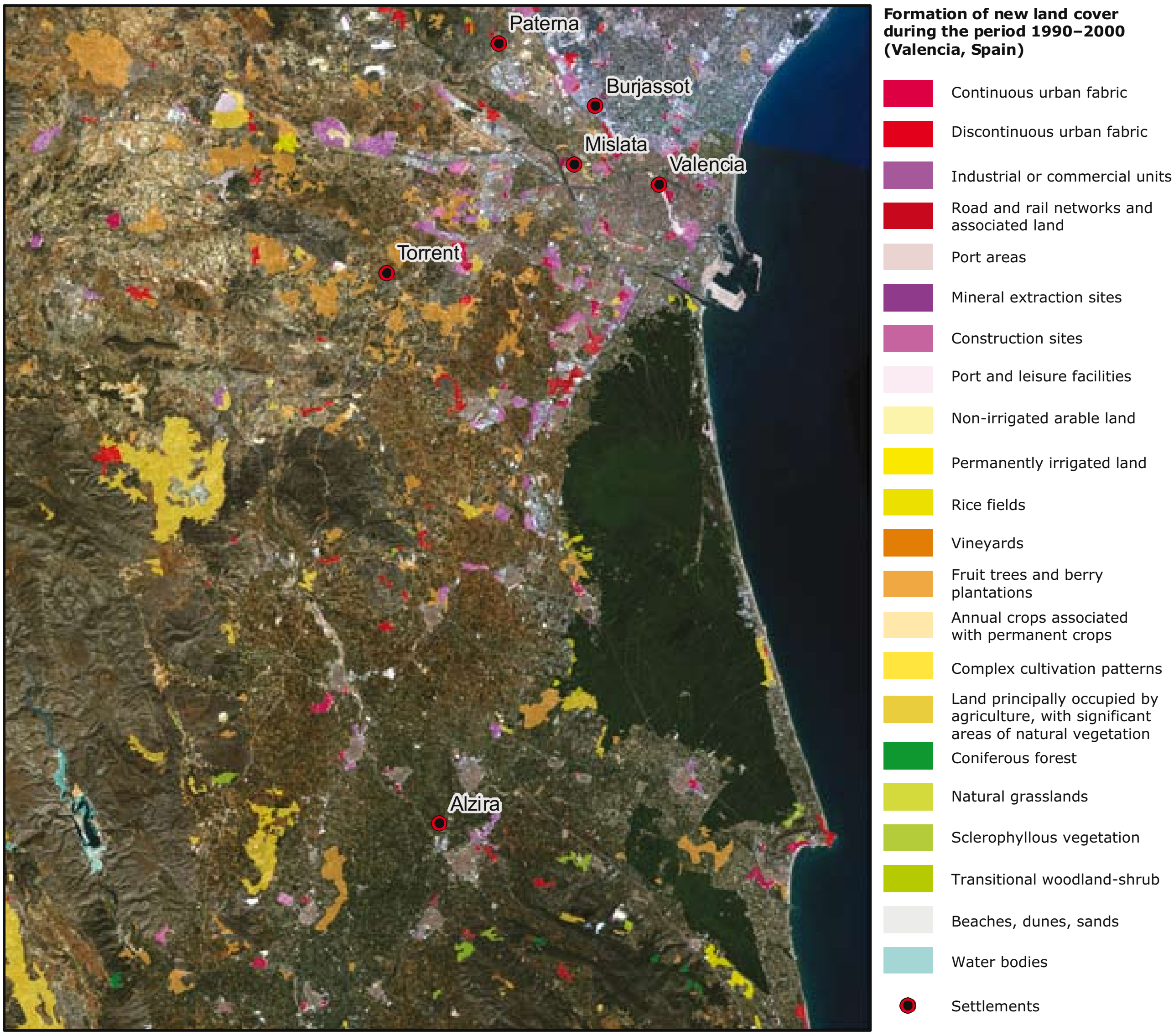
Table 2.1 A stock and change account for European land cover, 24 countries, 1990–2000

	Artificial areas	Arable land and permanent crops	Pastures and mosaics	Forested land	Semi-natural vegetation	Open spaces/bare soils	Wetlands	Water bodies	Total km²
Land cover 1990	161 860	1 174 325	820 109	1 030 635	264 932	52 593	46 915	45 854	3 597 223
Consumption of initial land cover	1 843	24 608	17 607	39 899	9 018	2 304	1 413	381	97 074
Formation of new land cover	10 556	18 144	15 333	45 343	4 177	1 858	383	1 280	97 074
Net formation of land cover (formation − consumption)	8 712	− 6 463	− 2 275	5 444	− 4 842	− 446	− 1030	899	0
Net formation as % of initial year	5.4	− 0.6	− 0.3	0.5	− 1.8	− 0.8	− 2.2	2.0	
Total turnover of land cover (consumption + formation)	12 399	42 752	32 940	85 242	13 195	4 162	1 796	1 661	194 148
Total turnover as % of initial year	7.7	3.6	4.0	8.3	5.0	7.9	3.8	3.6	5.4
No land cover change	160 016	1 149 717	802 502	990 736	255 914	50 289	45 502	45 473	3 500 149
No land cover change as % of initial year	98.9	97.9	97.9	96.1	96.6	95.6	97.0	99.2	97.3
Land cover 2000	170 572	1 167 861	817 835	1 036 079	260 090	52 147	45 885	46 754	3 597 223

what proportion of the original stock is carried over from the start of the accounting period to the end. As a result, we can see how much of the initial resource has been maintained. A key issue to consider in relation to sustainable land management is whether the consumption or loss of a given land cover type is compensated for by the formation of new areas of the same type. A new plantation of young trees, for example, may not make up for the loss of ancient forest in simple area terms. Therefore, the overall quality of the woodland stock may deteriorate even though there may not be a net loss of woodland area. High turnover may also reflect lack of stability in an ecological system and therefore suggest that a land-related asset may be vulnerable.

Table 2.1 shows that there was a small net decline in area of semi-natural vegetation between 1990 and 2000. However, this outcome was the result of an approximate balance between the losses (i.e. consumption of semi-natural by transformation to other types) and the gains (i.e. formation of new semi-natural stock from other types). In fact, a much larger proportion of this cover type was

Figure 2.2 Formation of new land cover in the region of Valencia, Spain



Note: Coloured areas on the image show where land cover change occurred between 1990 and 2000. The image shows the situation in 2000, and highlights the areas where new types of land cover have been formed (see legend). Land cover across the other parts of the satellite image have been classified as unchanged according to the CLC methodology, which maps change only for parcels that exceed 5 hectares. The unchanging areas are not shown and so the satellite image 'shows through'.

Source: Image 2000 and CLC2000 change database.

involved in some kind of change than the figure for net change would suggest. Approximately 5 % of the initial stock turned over, and only 96.6 % of the original stock remained at the end of the accounting period. If policy advisors need to determine whether the goals of sustainable development are being achieved, then such statistics can become an important indicator. In the case of semi-natural habitats, for example, one might argue that only if the formation of new semi-natural areas compensated in some way for losses or consumption by other uses, could this important element of our natural capital be said to have remained intact.

Questions about the turnover of land, and particularly the implications that it might have for other resources associated with land, such as biodiversity, are often extremely important issues that need to be explored in a policy context. From the perspective of conservation of biodiversity, the total amount of turnover is as important as the net change. In periods of fast change, driven for example by economic development or by climate change, the analysis of turnover would reveal information about the degradation of habitats that might previously have been stable and as a result would have been able to support a wide range of species.

Land cover accounts, such as the one illustrated here, can also be used to help policy advisors frame the questions that need to be asked in relation to the consequences of land cover change. We will return to this issue later in the report, and consider how land accounts can potentially provide a framework for more comprehensive ecosystem accounts. For the moment, however, it is sufficient to note the benefits that the accounting approach can offer for the implications of land cover change for sustainable development.

2.3 Flow accounts

One of the important elements of detail that is missing from the stock and change account shown in Table 2.1 is information about the actual processes that have resulted in the flows between the different stocks of land cover. To understand some of the consequences of land cover change, and particularly their implications for sustainable development, we often need to find out how land is being transferred or exchanged between the different cover categories. This can be achieved by constructing a flow account like the one shown in Table 2.2.

The flow account presents the losses of initial land cover for each land cover type — labelled consumption and the creation of new areas — labelled formation. Consumption is shown at the top of the table. When the area of consumption is added to the area that has not changed over the accounting period, we produce an estimate of the initial 1990 stock of land cover for each of the types. The bottom part of the table shows the formation flows. If formation and the stock that shows no change are added together, then this gives the amount of the final stock in 2000. In Table 2.2, the changes are listed according to the processes by which the various types of change have occurred. These define the various land cover flows.

Once again, as with the stock and change account shown in Table 2.1, overall consumption balances with the formation. However, from the flow account shown in Table 2.2, we begin to see what types of changes were taking place and how important they were. Consider, for example, the formation of new artificial areas (i.e. built-up, urban areas) by the process of residential urban sprawl. The flow account shows that between 1990 and 2000, urban residential sprawl added 4 149 km^2 to artificial surfaces. This is the figure that appears at the intersection of the row for the flow, *Urban and residential sprawl,* in the bottom half of the table and the column for artificial surfaces. What types of land cover did this process of residential sprawl replace? We can find this out by looking at the block of data for consumption of land.

In the top half of the account shown in Table 2.2, we can look along the row for urban residential sprawl to see the origin of the land that was converted to artificial surfaces. Using this flow account, it is apparent that for the EEA member counties for which data are available, the formation of new artificial areas through development was largely at the expense of agricultural land. Of the new artificial areas, approximately 1 924 km^2 (47 %) came from arable land and permanent crops, while 1 867 km^2 (45 %) came from pastures and mosaics. Similarly, we can see that approximately 5 039 km^2 of new agricultural land was added to the 1990 stock by the process of conversion (flow LCF5), mainly from land that was previously forested (1 796 km^2) or covered with semi-natural habitats (1 734 km^2).

It is essential that policy advisors have a good understanding of the types of processes that are bringing about land cover change if they are to understand the implications of these changes and design policy measures to help shape future trends.

Flow accounts, such as the one shown in Table 2.2 can therefore be a valuable decision-support tool.

Figure 2.3 illustrates some standard indicators that can be produced from land accounts ([4]). They give an insight into the overall European landscape and the main processes that are bringing about change. They show, for example, that over half of Europe's land cover is agricultural in character, while about one third consists of forest and semi-natural areas of higher nature conservation value. The account generally shows that urban sprawl appears to be the main driver of change. Urban areas have expanded largely at the expense of agricultural land (mainly

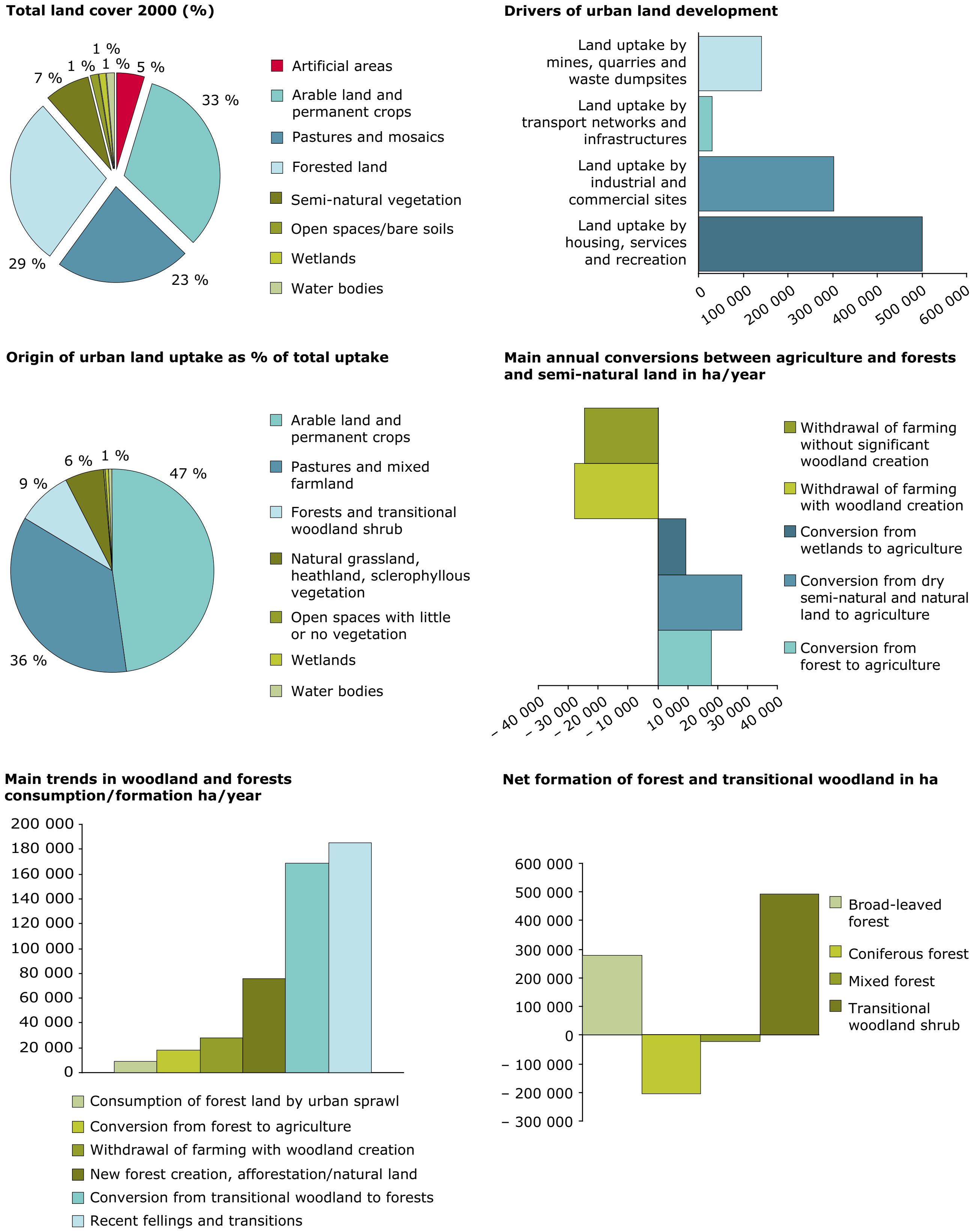
Table 2.2 A flow account describing processes of land cover change in 24 countries in Europe, 1990–2000

	Corine land cover types	1	2A	2B	3A	3B	3C	4	5	
Land cover flows		Artificial areas	Arable land and permanent crops	Pastures and mosaics	Forested land	Semi-natural vegetation	Open spaces/ bare soils	Wetlands	Water bodies	Total, km²
LCF1	Urban land management	737	15	19	0	8	0	0		780
LCF2	Urban residential sprawl		1 924	1 867	200	145	8	3	2	4 149
LCF3	Sprawl of economic sites and infrastructures	77	2 728	1 595	665	451	35	22	53	5 627
LCF4	Agriculture internal conversions		17 252	10 062						27 314
LCF5	Conversion from other land cover to agriculture	273		935	1 796	1 734	155	96	50	5 039
LCF6	Withdrawal of farming		2 393	2 860						5 253
LCF7	Forests creation and management	254			35 803	5 166	1 048	1 063	3	43 337
LCF8	Water bodies creation and management	191	252	253	117	190	17		21	1 042
LCF9	Changes due to natural and multiple causes	311	44	15	1317	1323	1 041	229	252	4 534
Total consumption of 1990 land cover, km²		**1 843**	**24 608**	**17 607**	**39 899**	**9018**	**2 304**	**1 413**	**381**	**97 074**
No change		160 016	1 149 717	802 502	990 736	255 914	50 289	45 502	45 473	3 500 149
Total land cover 1990, km²		**161 860**	**117 4325**	**820 109**	**1 030 635**	**264 932**	**52 593**	**46 915**	**45 854**	**3 597 223**
LCF1	Urban land management	780								780
LCF2	Urban residential sprawl	4 149								4 149
LCF3	Sprawl of economic sites and infrastructures	5 627								5 627
LCF4	Agriculture internal conversions		15 695	11 619						27 314
LCF5	Conversion from other land cover to agriculture		2 450	2 590						5 039
LCF6	Withdrawal of farming			1 124	2 792	1 244	23	70	0	5 253
LCF7	Forests creation and management				42 547	766	24			43 337
LCF8	Water bodies creation and management						21		1021	1 042
LCF9	Land cover due to natural and multiple causes				4	2 167	1 790	313	260	4 534
Total formation of 2000 land cover, km²		**10 556**	**18 144**	**15 333**	**45 343**	**4 177**	**1 858**	**383**	**1280**	**97 074**
No change		160 016	1149717	802 502	990 736	255 914	50 289	45 502	45 473	3500149
Total land cover 2000, km²		**170 572**	**1 167 861**	**817 835**	**1 036 079**	**260 090**	**52 147**	**45 885**	**46 754**	**3 597 223**

Note: The definition of each Land Cover Flows (LCF) and their relationship to the detailed Corine land cover changes are explained in Chapter 7 and Appendix 1 of this report.

([4]) A set of pre-produced maps and graphs can be downloaded from Land Cover Accounts (LEAC) section which presents the analysis of the Corine land cover changes database from the EEA website at http://dataservice.eea.europa.eu/dataservice/metadetails.asp?id=884 (accessed 14.09.2006).

Figure 2.3 Indicators of land cover change in Europe derived from land cover accounts, 24 countries, 1990–2000



arable and permanent crops). Agriculture has also shown exchanges of land with forests and semi-natural areas, which have tended to balance each other. There has, however, been a marked increase in woodland cover, especially in terms of broadleaved standing forests. The data also show the extent of internal changes within the forest sector resulting from the felling and replanting activities associated with the normal process of forest management.

2.4 Exploring the detail

The stock and flow accounts that have been presented in this chapter are highly generalised in that they deal with a large part of the land area of Europe. It has been useful to present them as a way of explaining how data can be structured and reported in an accounting framework, and how the analysis of flows can bring a deeper level of understanding of the processes of land cover change. However, while the data are interesting in their own right, given the diversity of landscapes that we find across the continent we clearly need to look into the data in more detail to develop a full picture of the dynamics of land cover and land use.

Environmental assessments are essentially integrative exercises, and they need to be able to detect and describe potential conflicts or impacts as they relate to real issues that occur on the ground. Interactions between different land uses and potential impacts may or may not happen as the result of land cover change. If the assets accounts are to be interpreted correctly, it is important to identify the extent to which this is actually occurring. Thus, the data we use for such assessments needs to flexible so that we can tailor the analysis to meet the specific user needs. The advantage of the accounting approach developed is that the level of detail at which the data can be presented can be increased, either thematically or by looking at patterns geographically.

2.4.1 Adding thematic detail

Table 2.3 presents a more detailed view of the main land cover flows. It can be used to better understand the significance of the changes shown in the general accounts for Europe shown in Table 2.2. This table illustrates how greater thematic detail can be included in the presentation of the accounts by looking at the different sub-categories used to describe the flows for formation and consumption. For example, in Table 2.2, LCF2, the 'urban residential sprawl' category is a very general one. Thus, in Table 2.3, the data have been disaggregated thematically, to show the proportions of dense and diffuse urban sprawl (LCF21 vs LCF22). Clearly most of the change appears to be of the diffuse kind. This may have particular implications, say, in terms of commuting and transport impacts. The table also shows that diffuse urban sprawl mainly takes land from the agricultural sector.

The greater thematic detail shown in Table 2.3 also enables the internal dynamics within the agricultural sector to be examined. The main conversions have been from arable land to set aside, fallow land and pasture and vice-versa. The additional detail given in Table 2.3 also shows that the withdrawal of farming (LCF6) mainly results in woodland creation (LCF61).

2.4.2 Adding geographical detail

The information shown in Table 2.3 can be presented in further geographical detail by disaggregating the data by countries and/or the various administrative regions in Europe that are used for official statistical purposes. Examples of how this can be done are given in Chapters 3, 4 and 5. More detailed thematic accounts are presented for artificial surfaces, agriculture and forests and semi-natural areas for the different administrative tiers in Europe, represented by the system of NUTS ([5]) regions (see also Section 2.5).

In addition to conventional geographical frameworks such as administrative regions, it is important to note that the flexible structure of the account database also enables the information to be cast into other types of scientifically or policy-relevant frameworks. An example of one such framework is the biogeographical regions of Europe. The latter have been defined for the implementation of the Habitats Directive and the Natura 2000 network. These regions aim to identify coherent areas which show common characteristics of habitats and species. The directive specifies objectives of nature conservation by zones, which have thus become an important framework for policy development. Information about land cover stock and change within them is therefore very important. Table 2.4 provides a view of European land accounts broken down by bio-geographic region.

([5]) NUTS: Nomenclature des Unités Territoriales Statistiques, in use at Eurostat.

Table 2.3 A detailed flow account describing patterns of land cover change in Europe, 24 countries, 1990–2000

Corine land cover types	1	2A	2B	3A	3B	3C	4	5	
Land cover flows	Artificial areas	Arable land and permanent crops	Pastures and mosaics	Forested land	Semi-natural vegetation	Open spaces/bare soils	Wetlands	Water bodies	Total, km²
LCF11 Urban development/infilling	153								153
LCF12 Recycling of developed urban land	575								575
LCF13 Development of green urban areas	9	15	19	0	8	0	0		52
LCF1 Urban land management	**737**	**15**	**19**	**0**	**8**	**0**	**0**		**780**
LCF21 Urban dense residential sprawl		96	59	2	13	2	0	0	173
LCF22 Urban diffuse residential sprawl		1 828	1 809	198	132	6	3	1	3 976
LCF2 Urban residential sprawl		**1 924**	**1 867**	**200**	**145**	**8**	**3**	**2**	**4 149**
LCF31 Sprawl of industrial and commercial sites		1 234	692	136	94	5	10	2	2 174
LCF32 Sprawl of transport networks		109	66	33	15	1	0	0	224
LCF33 Sprawl of harbours		2	3	0	4	1	2	25	37
LCF34 Sprawl of airports		32	8	7	5		0		52
LCF35 Sprawl of mines and quarrying areas		547	263	287	176	13	4	9	1 299
LCF36 Sprawl of dumpsites		40	21	25	9	0	0	6	102
LCF37 Construction		374	251	101	103	9	2	8	848
LCF38 Sprawl of sport and leisure facilities	77	390	290	77	44	6	4	2	891
LCF3 Sprawl of economic sites and infrastructures	**77**	**2 728**	**1 595**	**665**	**451**	**35**	**22**	**53**	**5 627**
LCF41 Extension of set aside fallow land and pasture		9 496	722						10 218
LCF42 Internal conversions between annual crops		4 049							4 049
LCF43 Internal conversions between permanent crops		146							146
LCF44 Conversion from permanent crops to arable land		1 879							1 879
LCF45 Conversion from arable land to permanent crops		1 645							1 645
LCF46 Conversion from pasture to arable and permanent crops			9 330						9 330
LCF47 Extension of agro-forestry		38	10						48
LCF4 Agriculture internal conversions		**17 252**	**10 062**						**27 314**
LCF51 Conversion from forest to agriculture				1 796					1 796
LCF52 Conversion from semi-natural land to agriculture			935		1 734	155			2 824
LCF53 Conversion from wetlands to agriculture							96	50	146
LCF54 Conversion from developed areas to agriculture	273								273
LCF5 Conversion from other land cover to agriculture	**273**		**935**	**1 796**	**1 734**	**155**	**96**	**50**	**5 039**
LCF61 Withdrawal of farming with woodland creation		1 015	1 777						2 792
LCF62 Withdrawal of farming without significant woodland creation		1 378	1 083						2 461
LCF6 Withdrawal of farming		**2 393**	**2 860**						**5 253**
LCF71 Conversion from transitional woodland to forest				16903					16 903
LCF72 Forest creation, afforestation	254				5 166	1 048	1 063	3	7 533
LCF73 Forests internal conversions				341					341
LCF74 Recent fellings, new plantation and other transition				18 559					18 559
LCF7 Forests creation and management	**254**			**35 803**	**5 66**	**1 048**	**1 063**	**3**	**43 337**
LCF8 Water bodies creation and management	**191**	**252**	**253**	**117**	**190**	**17**		**21**	**1 042**
LCF9 Changes due to natural and multiple causes	**311**	**44**	**15**	**1 317**	**1 323**	**1 041**	**229**	**252**	**4 534**
Total consumption of 1990 land cover, km²	**1 843**	**24 608**	**1 7607**	**39 899**	**9 018**	**2 304**	**1413**	**381**	**97 074**
No change	160 016	1 149 717	802 502	990 736	255 914	50 289	45 502	45 473	3 500 149
Total land cover 1990, km²	**161 860**	**1 174 325**	**820 109**	**1 030 635**	**264 932**	**52 593**	**46 915**	**45 854**	**3 597 223**
LCF11 Urban development/infilling	153								153
LCF12 Recycling of developed urban land	575								575
LCF13 Development of green urban areas	52								52
LCF1 Urban land management	**780**								**780**
LCF21 Urban dense residential sprawl	172								172
LCF22 Urban diffuse residential sprawl	3 976								3 976
LCF2 Urban residential sprawl	**4 149**								**4 149**
LCF31 Sprawl of industrial and commercial sites	2 174								2 174
LCF32 Sprawl of transport networks	224								224
LCF33 Sprawl of harbours	37								37
LCF34 Sprawl of airports	52								52
LCF35 Sprawl of mines and quarrying areas	1 299								1 299
LCF36 Sprawl of dumpsites	102								102
LCF37 Construction	848								848
LCF38 Sprawl of sport and leisure facilities	891								891
LCF3 Sprawl of economic sites and infrastructures	**5 627**								**5 627**
LCF41 Extension of set aside fallow land and pasture			10 218						10 218
LCF42 Internal conversions between annual crops		4 049							4 049
LCF43 Internal conversions between permanent crops		146							146
LCF44 Conversion from permanent crops to arable land		1 317	562						1 879
LCF45 Conversion from arable land to permanent crops		1 645							1 645
LCF46 Conversion from pasture to arable and permanent crops		8 538	792						9 330
LCF47 Extension of agro-forestry			48						48
LCF4 Agriculture internal conversions		**15 695**	**11 619**						**27 314**
LCF51 Conversion from forest to agriculture		466	1 330						1 796
LCF52 Conversion from semi-natural land to agriculture		1 800	1 024						2 824
LCF53 Conversion from wetlands to agriculture		64	82						146
LCF54 Conversion from developed areas to agriculture		120	153						273
LCF5 Conversion from other land cover to agriculture		**2 450**	**2 590**						**5 039**
LCF61 Withdrawal of farming with woodland creation				2 792					2 792
LCF62 Withdrawal of farming without significant woodland creation			1124		1244	23	70	0	2 461
LCF6 Withdrawal of farming			**1124**	**2 792**	**1244**	**23**	**70**	**0**	**5 253**
LCF71 Conversion from transitional woodland to forest				16 903					16 903
LCF72 Forest creation, afforestation				7 533					7 533
LCF73 Forests internal conversions				341					341
LCF74 Recent fellings, new plantation and other transition				17 769	766	24			18 559
LCF7 Forests creation and management				**42 547**	**766**	**24**			**43 337**
LCF8 Water bodies creation and management						**21**		**1 021**	**1 042**
LCF9 Land cover due to natural and multiple causes				**4**	**2 167**	**1 790**	**313**	**260**	**4 534**
Total formation of 2000 land cover, km²	**10 556**	**18 144**	**15 333**	**45 343**	**4 177**	**1 858**	**383**	**1 280**	**97 074**
No change	160 016	1 149 717	802 502	990 736	255 914	50 289	45 502	45 473	3 500 149
Total land cover 2000, km²	**170 572**	**1 167 861**	**817 835**	**1 036 079**	**260 090**	**52 147**	**45 885**	**46 754**	**3 597 223**

Table 2.4 Summary land cover stocks accounts of European biogeographical regions, 24 countries, 1990–2000

Corine land cover types	1	2A	2B	3A	3B	3C	4	5	
	Artificial areas	Arable land and permanent crops	Pastures and mosaics	Forested land	Semi-natural vegetation	Open spaces/ bare soils	Wetlands	Water bodies	Total, km²
Alpine									
Land cover 1990, km²	6 593	12 028	37 164	156 311	31 132	24 086	241	1 862	269 417
Consumption of 1990 land cover, km²	27	264	599	2 611	153	124	13	3	3 793
Formation of 2000 land cover, km²	161	109	416	2 928	30	114	1	34	3 793
Net formation of land cover (formation–consumption)	135	– 155	– 184	317	– 123	– 10	– 12	31	
Net formation as % of initial year	2.0	– 1.3	– 0.5	0.2	– 0.4	0.0	– 4.8	1.7	
Land cover 2000, km²	6 728	11 873	36 981	156 627	31 009	24 076	229	1 894	269 417
Atlantic									
Land cover 1990, km²	50 844	236 979	268 871	121 774	66 889	7 717	31 305	11 874	796 253
Consumption of 1990 land cover, km²	582	2 999	5 822	9 359	1 706	203	1 208	180	22 060
Formation of 2000 land cover, km²	3 722	3 275	2 159	11 843	363	141	237	320	22 060
Net formation of land cover (formation–consumption)	3 139	275	– 3 663	2 484	– 1 344	– 63	– 970	140	
Net formation as % of initial year	6.2	0.1	– 1.4	2.0	– 2.0	– 0.8	– 3.1	1.2	
Land cover 2000, km²	53 983	237 254	265 208	124 258	65 546	7 655	30 334	12 014	796 253
Boreal									
Land cover 1990, km²	3 179	30 933	39 449	70 778	634	160	3 873	4 067	153 072
Consumption of 1990 land cover, km²	13	1 023	1 630	2 081	7	1	5	1	4 761
Formation of 2000 land cover, km²	39	1 357	1 273	2 072		5	10	5	4 761
Net formation of land cover (formation–consumption)	26	334	– 357	– 9	– 7	4	5	4	
Net formation as % of initial year	0.8	1.1	– 0.9	0.0	– 1.2	2.6	0.1	0.1	
Land cover 2000, km²	3 205	31 267	39 093	70 768	626	164	3 878	4 071	153 072
Continental									
Land cover 1990, km²	71 067	497 006	291 292	398 659	10 431	1 718	4 417	16 775	1 291 366
Consumption of 1990 land cover, km²	842	8 678	4 005	8 912	525	277	126	57	23 423
Formation of 2000 land cover, km²	3 101	2 894	6 736	9 810	239	250	59	333	23 423
Net formation of land cover (formation–consumption)	2 258	– 5 783	2 731	898	– 286	– 27	– 67	276	
Net formation as % of initial year	3.2	– 1.2	0.9	0.2	– 2.7	– 1.6	– 1.5	1.6	
Land cover 2000, km²	73 326	491 223	294 023	399 557	10 145	1 691	4 350	17 051	1 291 366
Macaronesian									
Land cover 1990, km²	313	1 388	312	890	3 604	929	1	1	7 437
Consumption of 1990 land cover, km²	8	27	1	2	22	3			63
Formation of 2000 land cover, km²	34	26	0	0	2	0			63
Net formation of land cover (formation–consumption)	26	– 1	0	– 2	– 20	– 3			
Net formation as % of initial year	8.4	– 0.1	– 0.2	– 0.2	– 0.6	– 0.3			
Land cover 2000, km²	339	1 387	311	888	3 584	926	1	1	7 437
Mediterranean									
Land cover 1990, km²	19 103	288 500	159 977	250 106	149 118	17 745	2 883	6 922	894 353
Consumption of 1990 land cover, km²	275	9 805	4 524	14 219	6 558	1 689	29	119	37 218
Formation of 2000 land cover, km²	3 317	9 052	3 875	15 580	3 520	1 347	46	482	37 218
Net formation of land cover (formation–consumption)	3 042	– 752	– 649	1 360	– 3 039	– 343	17	363	
Net formation as % of initial year	15.9	– 0.3	– 0.4	0.5	– 2.0	– 1.9	0.6	5.2	
Land cover 2000, km²	22 145	287 748	159 328	251 466	146 079	17 402	2 899	7 285	894 353
Pannonian									
Land cover 1990, km²	8 759	81 066	20 315	29 311	2 661	167	2 834	3 103	148 215
Consumption of 1990 land cover, km²	90	1 450	987	2 593	42	7	25	19	5 214
Formation of 2000 land cover, km²	162	1 105	813	2 981	23	2	28	100	5 214
Net formation of land cover (formation–consumption)	72	– 345	– 174	388	– 19	– 5	4	81	
Net formation as % of initial year	0.8	– 0.4	– 0.9	1.3	– 0.7	– 3.2	0.1	2.6	
Land cover 2000, km²	8 830	80 721	20 141	29 698	2 641	162	2 838	3 184	148 215
Steppic									
Land cover 1990, km²	2 001	26 425	2 730	2 808	464	71	1 362	1 250	37 110
Consumption of 1990 land cover, km²	5	362	41	122	4	0	7	1	543
Formation of 2000 land cover, km²	19	326	61	129		0	1	6	543
Net formation of land cover (formation–consumption)	14	– 36	21	7	– 4	0	– 6	4	
Net formation as % of initial year	0.7	– 0.1	0.8	0.3	– 0.8	– 0.6	– 0.4	0.3	
Land cover 2000, km²	2 015	26 389	2 750	2 816	460	70	1 356	1 254	37 110

Note: The biogeographical regions are unevenly covered by land accounts 1990–2000. Considering only countries participating in the Corine project, which does not cover all EECCA countries, important gaps are within the Boreal region (Finland, Sweden and Norway), the Alpine region (Norway, Sweden, Switzerland), Mediterranean, Anatolian and Black Sea regions (Turkey). The map of Pan-European biogeographical regions can be viewed at http://dataservice.eea.europa.eu/atlas/viewdata/viewpub.asp?id=221 (accessed 14.09.2006).

An important feature of the data shown in Table 2.4 is the high rates of urban development in the Mediterranean biogeographic region. Here, the stock of artificial areas has expanded by approximately 16 % of their initial value over the period 1990–2000. In addition, it can be seen that there is a general increase in forest cover, a decrease of semi-natural vegetation, and marked losses of wetlands in the Alpine (– 4.8 %) and the Atlantic (– 3.1 %) regions.

Other key European policies will clearly require different geographical views of the account data. For example, an important ongoing policy concern is the sensitive regions of Europe, which include the coasts and mountain regions. In the former, integrated coastal zone management is a major objective, while in the latter, the allocation of structural funds to overcome disadvantage and to protect natural resources is an important issue. In the same way that the accounts can be broken down for biogeographical regions, the flexibility of the underlying database allows these other types of thematic account to be developed (Tables 2.5 and 2.6).

The account for Europe's coastal areas shown in Table 2.5 has been generated by extracting the stock and change information from the underlying database for the 10 km coastal strip. Details of how this is done will be provided in the methodological chapters that follow in Part III. At this stage it is sufficient to note the important changes that are

Table 2.5 Land cover accounts for Europe's coastal zones, 1990–2000, based on a 10 km strip for 19 countries

	Corine land cover types	1	2A	2B	3A	3B	3C	4	5	
Land cover flows		Artificial areas	Arable land and permanent crops	Pastures and mosaics	Forested land	Semi-natural vegetation	Open spaces/bare soils	Wetlands	Water bodies	Total, km²
LCF1	Urban land management	185	4	10	0	2	0	0		200
LCF2	Urban residential sprawl		325	483	81	55	6	2	1	953
LCF3	Sprawl of economic sites and infrastructures	18	359	318	138	149	16	11	33	1 043
LCF4	Agriculture internal conversions		1 115	1 458						2 573
LCF5	Conversion from other land cover to agriculture	29		101	182	169	78	18	4	581
LCF6	Withdrawal of farming		188	347						535
LCF7	Forests creation and management	5			3 433	849	86	342		4 715
LCF8	Water bodies creation and management	3	6	9	3	3			2	25
LCF9	Changes due to natural and multiple causes	31	11	3	106	344	177	132	147	953
Total consumption of 1990 land cover, km²		**272**	**2 008**	**2 728**	**3 943**	**1 571**	**364**	**505**	**187**	**11 577**
No change		26 043	96 147	91 898	60 597	57 485	7 703	23 847	10 724	374 443
Total land cover 1990		**26 314**	**98 154**	**94 626**	**64 540**	**59 056**	**8 067**	**24 352**	**10 911**	**386 020**
LCF1	Urban land management	200								200
LCF2	Urban residential sprawl	953								953
LCF3	Sprawl of economic sites and infrastructures	1 043								1 043
LCF4	Agriculture internal conversions		1 813	760						2 573
LCF5	Conversion from other land cover to agriculture		297	284						581
LCF6	Withdrawal of farming			108	225	186	1	15	0	535
LCF7	Forests creation and management				4 617	96	1			4 715
LCF8	Water bodies creation and management						2		23	25
LCF9	Land cover due to natural and multiple causes				0	391	263	191	107	953
Total formation of 2000 land cover, km²		**2 197**	**2 109**	**1 152**	**4 842**	**674**	**267**	**206**	**130**	**11 577**
No change		26 043	96 147	91 898	60 597	57 485	7 703	23 847	10 724	374 443
Total land cover 2000		**28 239**	**98 256**	**93 050**	**65 439**	**58 159**	**7 970**	**24 052**	**10 854**	**386 020**

occurring. The marked expansion of urban land is evident, with artificial surfaces increasing by area equivalent to approximately 8 % of their 1990 stock. The increase was mainly at the expense of agricultural land, where internally there appears to have been a net transfer of land from pasture to arable and permanent crops. The area of semi-natural land and wetlands appears to have declined, while forests have expanded.

The account for Europe's mountain areas (Table 2.6) has been prepared by extracting the information from the accounting database for areas above 1000 m in altitude ([6]). As might be expected, the stock of artificial surfaces is proportionally lower than in the coastal areas, and the change between 1990 and 2000 is less marked (about 7 %). The dominance of forests is, however, evident. Cover has expanded by nearly 3 % of the 1990 area. Much of the increase has resulted from the withdrawal of farming, which mainly appears to be associated with land that was formerly either pasture or, more significantly, semi-natural land.

2.5 Accounting and spatial analysis — beyond conventional representation of regional statistics

2.5.1 *Regional statistics*

The example accounts presented in the last section illustrate how the level of detail used for the presentation of the statistics can be expanded so that the geographical context in which change has occurred can be better understood. The importance of exploring accounts through such detailed spatial analysis cannot be underestimated. Indeed, such

Table 2.6 Land cover accounts of Europe's mountains, 19 countries, 1990–2000

	Corine land cover types	1	2A	2B	3A	3B	3C	4	5	
Land cover flows		Artificial areas	Arable land and permanent crops	Pastures and mosaics	Forested land	Semi-natural vegetation	Open spaces/bare soils	Wetlands	Water bodies	Total, km²
LCF1	Urban land management	19								19
LCF2	Urban residential sprawl		47	126	18	29				219
LCF3	Sprawl of economic sites and infrastructures	2	69	88	84	79	4		1	327
LCF4	Agriculture internal conversions		1 642	358						2 000
LCF5	Conversion from other land cover to agriculture	16		169	327	454	7	1	7	980
LCF6	Withdrawal of farming		260	586						847
LCF7	Forests creation and management	17			9 206	1 877	478	2	0	11 580
LCF8	Water bodies creation and management	7	7	29	18	30	6		2	101
LCF9	Changes due to natural and multiple causes	10	1	3	732	379	442	4	4	1 574
Total consumption of 1990 land cover, km²		**71**	**2 027**	**1 360**	**10 384**	**2 848**	**936**	**7**	**14**	**17 647**
No change		7 845	55 674	104 430	354 604	112 541	37 502	1 027	1 882	675 504
Total land cover 1990		**7 916**	**57 701**	**105 789**	**364 989**	**115 389**	**38 438**	**1 034**	**1 895**	**693 151**
LCF1	Urban land management	19								19
LCF2	Urban residential sprawl	219								219
LCF3	Sprawl of economic sites and infrastructures	327								327
LCF4	Agriculture internal conversions		608	1 392						2 000
LCF5	Conversion from other land cover to agriculture		406	574						980
LCF6	Withdrawal of farming			218	443	182	5			847
LCF7	Forests creation and management				11 194	376	10			11 580
LCF8	Water bodies creation and management						2		98	101
LCF9	Land cover due to natural and multiple causes					712	852	3	8	1 574
Total formation of 2000 land cover, km²		**565**	**1 014**	**2 184**	**11 637**	**1 270**	**868**	**3**	**106**	**17 647**
No change		7 845	55 674	104 430	354 604	112 541	37 502	1 027	1 882	675 504
Total land cover 2000		**8 410**	**56 688**	**106 614**	**366 241**	**113 811**	**38 370**	**1 030**	**1 988**	**693 151**

([6]) The full definition of mountains used is land above 1 000 m, or land between 500 m and 1 000 m where the average slope is > 2 % calculated using a digital elevation model at 1 km x 1 km resolution (Table 8.2).

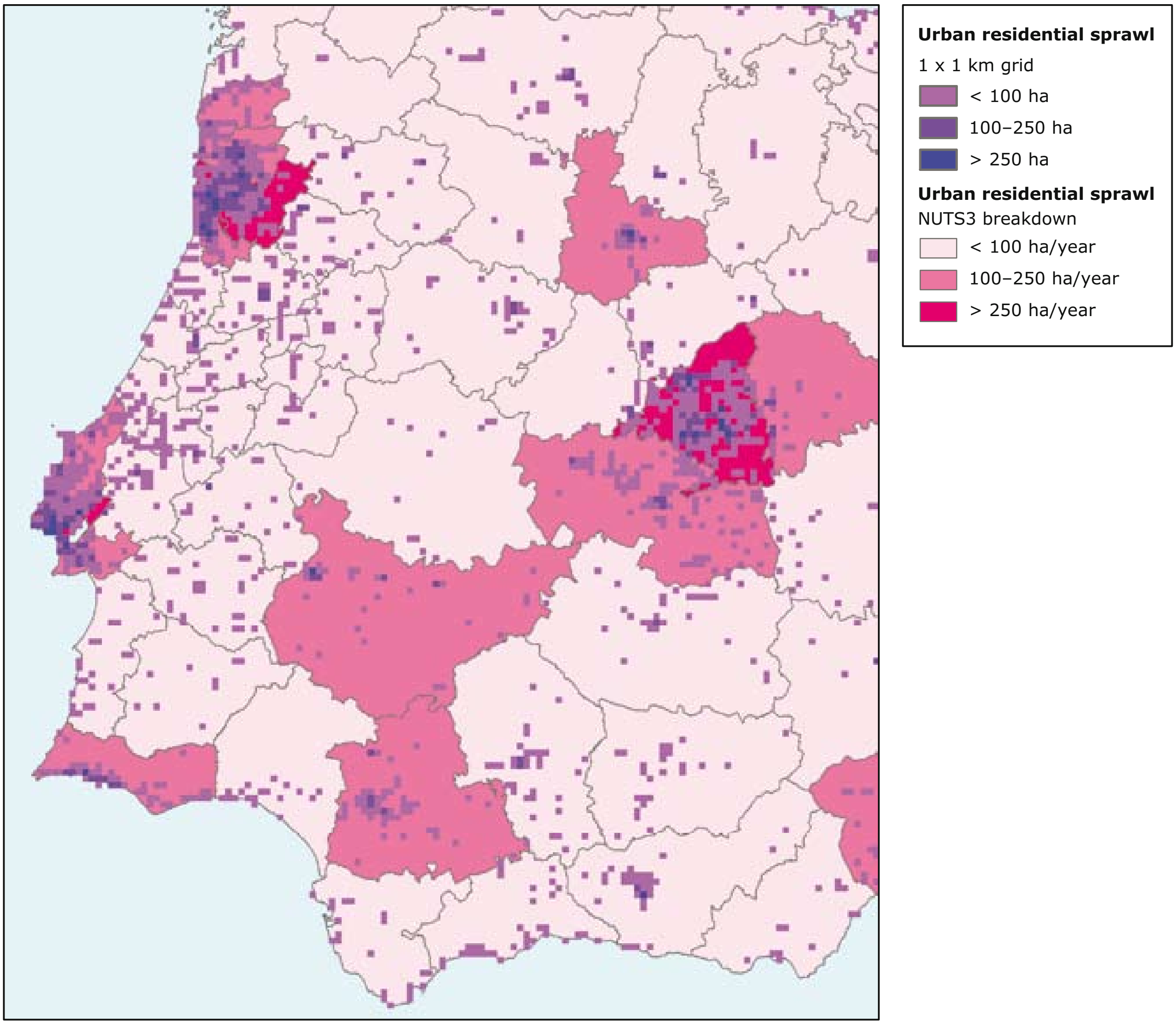
work can bring an additional dimension to the more conventional interpretation of regional statistics based on pre-existing zonings or administrative regions.

Regional statistics that use established administrative or biophysical frameworks have the advantage that they generally match the reporting units commonly used by policy makers. Statistically, however, they have several important limitations:

- The first one is known as the Modifiable Area Unit Problem (MAUP). This arises where the observed phenomenon is unevenly dispersed over an area, so that when spatial units of varying size are used to generate summary statistics, changes in scale can lead to quite different or even contradictory results in regional distributions or rankings.
- Where statistics are presented for regional units, they represent only the average conditions or patterns across an area. As a result, they may be difficult to interpret, especially if average values are low. Indeed, important local changes or hot spots can be overlooked by using this approach since they are indistinguishable from low diffuse change.

These issues are illustrated in Figure 2.4, which also shows how the disaggregated land account data

Figure 2.4 Comparison of urban residential sprawl spatial distribution, by administrative regions and by grid-cells



Note: Map showing values for urban residential sprawl 1990–2000 (LCF2) computed according to a regional breakdown based on administrative units (NUTS 3) and an accounting grid at 1 km x 1 km resolution for southern Portugal and southwest Spain. Only those cells of the accounting grid that show urban residential sprawl are shown. The legend indicating the extent of residential urban sprawl in each unit is common to the two ways of mapping the land cover flow.

can be used to help policy customers interpret the general patterns shown in the more conventional regional breakdowns. The map gives information on the magnitude of the land cover flow 'urban residential sprawl' (LCF2), displayed for the European NUTS 3 regions in southern Portugal and south west Spain. The same data are also displayed using a 1 km x 1 km grid. The finer scale grid mapping gives a much clearer picture of the detail that underlies the patterns of change than can be obtained from the display of values by NUTS regions. For example, the concentration of development along the coasts of Portugal and Spain is much more marked than the representation by NUTS regions would suggest.

The structure of the land account database is described in detail in Part III. At this stage it is sufficient to note that in terms of building account and reporting statistics, the approach developed is based on a spatially explicit, fine resolution grid structure. This holds records for each 1 km x 1 km cell across the whole area of Europe for which data are available (see Section 8.2). This structure allows a range of different analytical and reporting units to be constructed, and important patterns examined in detail by comparing and contrasting different types of output.

2.5.2 *Stocks and flows*

In the presentation of the accounts thus far, stock and flows have been treated somewhat separately. In order to indicate the potential which the accounting approach has for environmental assessment, we conclude by showing the types of insight that can be gained from looking at the two components in relation to each other.

When the land cover flows are displayed at a fine-scale resolution using one of the grids that are available for Europe, they can be considered as representing an e*x post* observation of the effects of environmental pressures or environmental improvements. On the other hand, the stocks give an e*x ante* view of the resource base and the influences they have on the surrounding landscape. By looking at these two aspects together, therefore, a rich analytical framework can be constructed. Figure 2.5 illustrates the kinds of analysis that are now possible using the accounting database. It shows the locations where urban sprawl has been detected using Corine data, and the location of wetlands for the region around Venice, Italy.

In Figure 2.5, the wetlands are mapped according to the Corine nomenclature, and urban agglomerations of more than 50 000 inhabitants are also shown. The magnitude of urban sprawl (defined as the sum of LCF2 and LCF3) has been mapped using a 1 km x 1 km grid to display the data. Several important features are evident. For example, despite possible threats from sea-level rise and the ecological problem of eutrophication in the lagoon arising from agricultural runoff, the development of urban areas and associated infrastructures has continued throughout the province of Venice. The development is occurring both in and around cities such as Mestre and Padua and the wider countryside, and is often in close proximity to the wetland areas.

2.5.3 *The importance of neighbourhood*

The case study presented in Figure 2.5 illustrates the importance of understanding the neighbourhood of stocks and flows. For example, urban sprawl on the periphery of a large agglomeration does not have the same effect as development in more pristine natural or semi-natural environments or rural landscape of new settlements for tourism. The accounting database enables these types of spatial analysis to be made so that the context in which change is occurring can be explored and the likely impacts understood and documented more fully.

Neighbourhood effects can be analysed in various ways. As part of their work on land accounts, the EEA has made use of a set of spatial smoothing tools available as the result of the CORILIS initiative. These tools (see Chapter 8) use the gridded structure of the account data to measure the potential or influence of a given land cover type in the area around the place where it is found, using a weighting distance function. The approach is based on the assumption that the influence of a given land parcel on its surroundings declines with increasing distance from it. Thus, the methods can be used to produce scaled maps. Cell values typically range from 0 to 100 and show the degree of influence that the distribution of a stock of a given cover type has on its neighbourhood.

For example, applying the technique to a gridded map showing urban land cover would result in large agglomerations and their surroundings having high values. This could be interpreted as indicating a strong urban influence or high urban temperature ([7]) (Figure 2.6). Such maps can be used to indicate the existence of a pressure independently of any new development occurring. A cluster of small cities

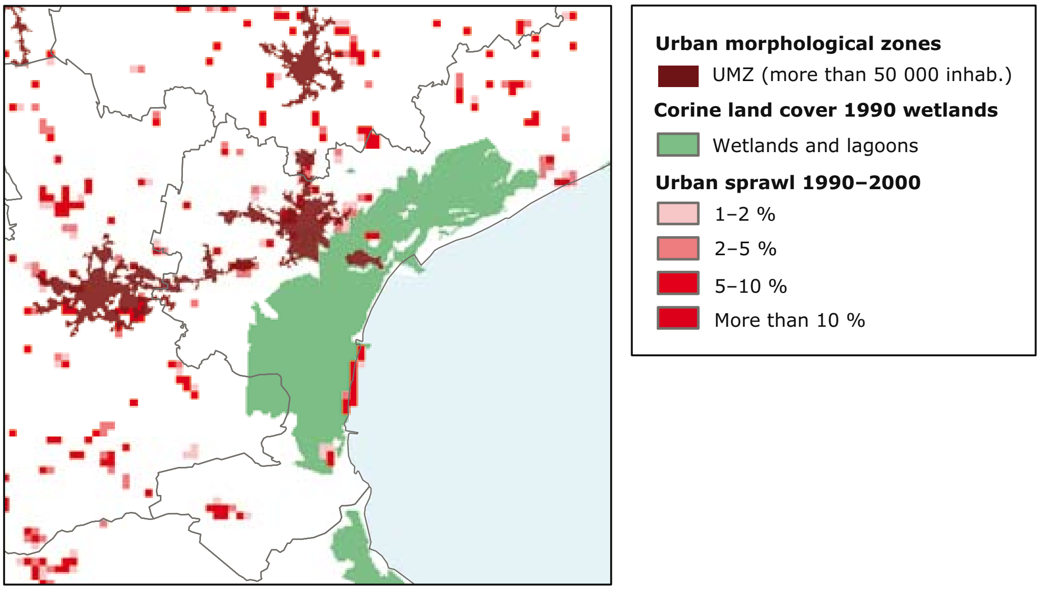
([7]) The expression of urban temperature is borrowed from demographers who use the concept in relation to population statistics to describe the influence of agglomerated as well as more dispersed populations.

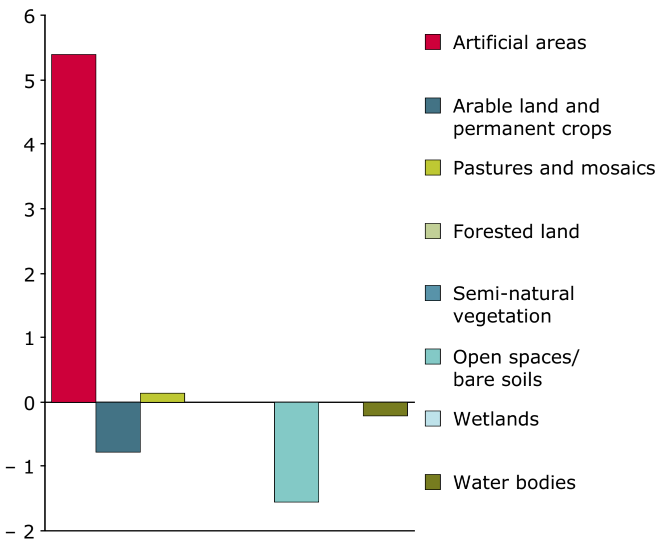
in close proximity would have a large aggregate influence, while a more isolated settlement would have less.

Similar calculations of influence or potential can be made for agriculture, forests and natural land, and each of the 43 inland classes produced by the Corine land cover mapping. These can be combined in various ways to produce maps of, for example, the Green Background, i.e. the areas where there is a high concentration of agriculture (pastures), forests, semi-natural, wetland and water (Figure 2.7). The Green Background provides an overview of the contexts in which natural habitats are found ([8]) and configuration of the major European ecological networks.

The CORILIS approach to spatial smoothing has enabled the EEA to construct maps of dominant land cover types for the cells of the 1 km x 1 km

Figure 2.5 Urban sprawl 1990–2000 in the province of Venice using a 1 km x 1 km grid





Note: A 1 km x 1 km grid has been used to display the land cover change data in the area around Venice. Such data are useful for making sustainability assessments. The mapping suggests that while some sprawl is taking place around the cities of Padova and Mestre, it is also extensive in the wider countryside, and particularly in the proximity of wetlands.

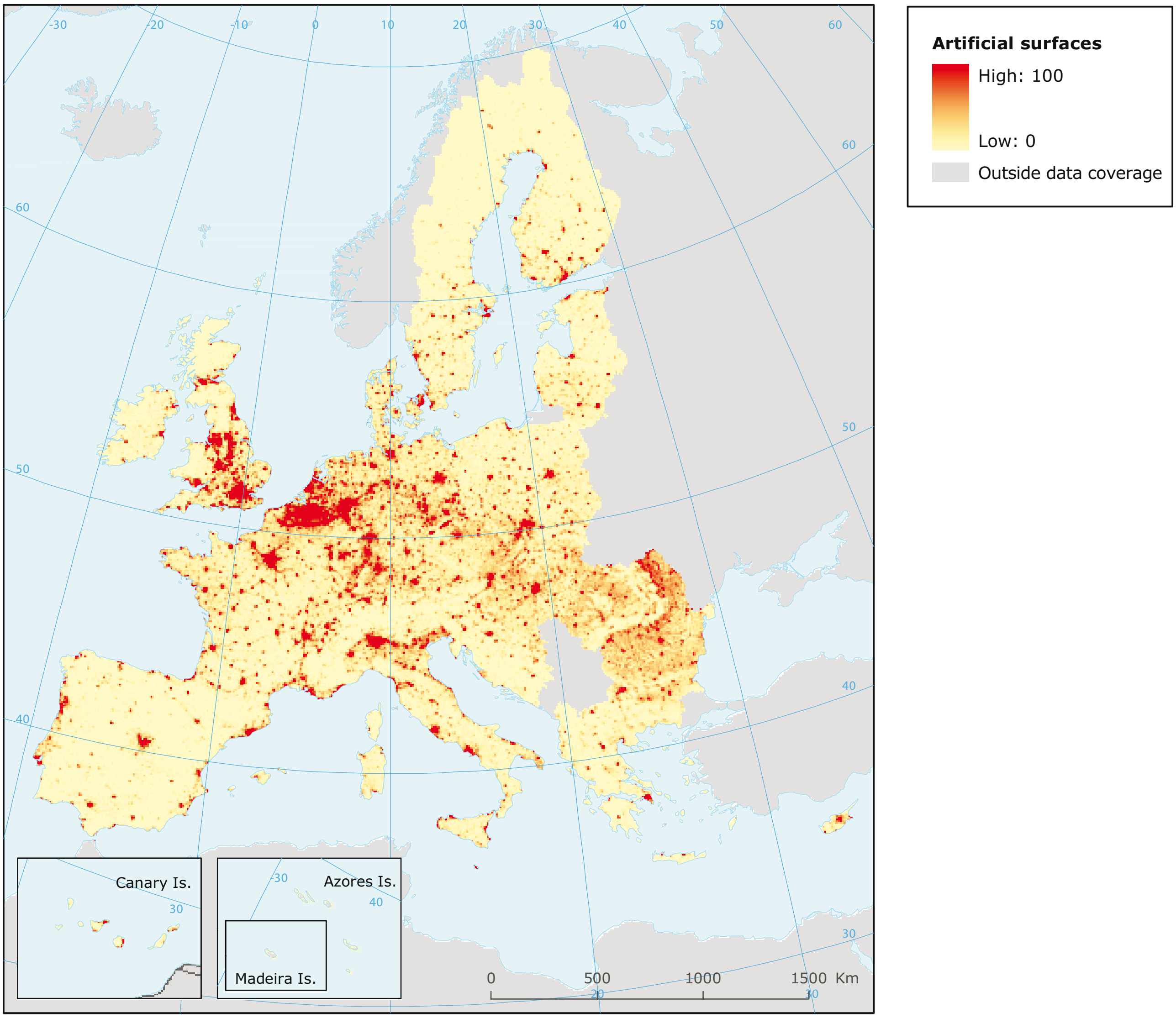
([8]) The other main component of the natural infrastructure being rivers.

accounting grid that has been set up for Europe. It can then use these data to identify dominant landscape types based on the combination of dominant cover types occurring within them, and elevation (low and high coast, lowland/inland, upland and mountain) (see Figure 2.8). Full details of the way this map has been produced are given in Chapter 8. This map has been designed to highlight the influence of the cities which occupy relatively smaller areas than agriculture or forestry but nevertheless have significantly large influences on the surrounding landscape.

In the same way that the land accounts can be presented for biogeographic regions, they can also be broken down using these dominant landscape types. For example, Figure 2.9 shows an expansion of the account for coastal areas in which the data have been split both by dominant landscape type and sea basin.

Figure 2.9 shows that for the European coastal zone, urban development mainly took place in areas already dominated by urban land use. However, in the Mediterranean, up to 25 % of the stock of new artificial areas was created in places which had a more dispersed urban character. The Mediterranean region also showed high rates of conversion in relation to agricultural land. There was an internal transfer of land from pasture to arable, and a conversion of semi-natural land to agriculture.

Figure 2.6 Urban temperatures of Europe computed from Corine land cover



Note: The map of urban temperatures or urban potential is based on the application of CORILIS spatial smoothing techniques. The smoothing radius used can be changed. In this example it was set at 10 km to give a vision and measure of the influence of cities and towns on their neighbourhood, according to their size and their spatial distribution. The scale used is the % area covered by artificial surfaces within a 10 km radius (see Section 8.3.1). Such maps can be used as a pressure indicator. Smoothing techniques such as this, based on population census data, have also been used by demographers to map urban temperatures.

Altogether, these data suggest that semi-natural and natural landscapes are under the highest pressure from development and agriculture conversions.

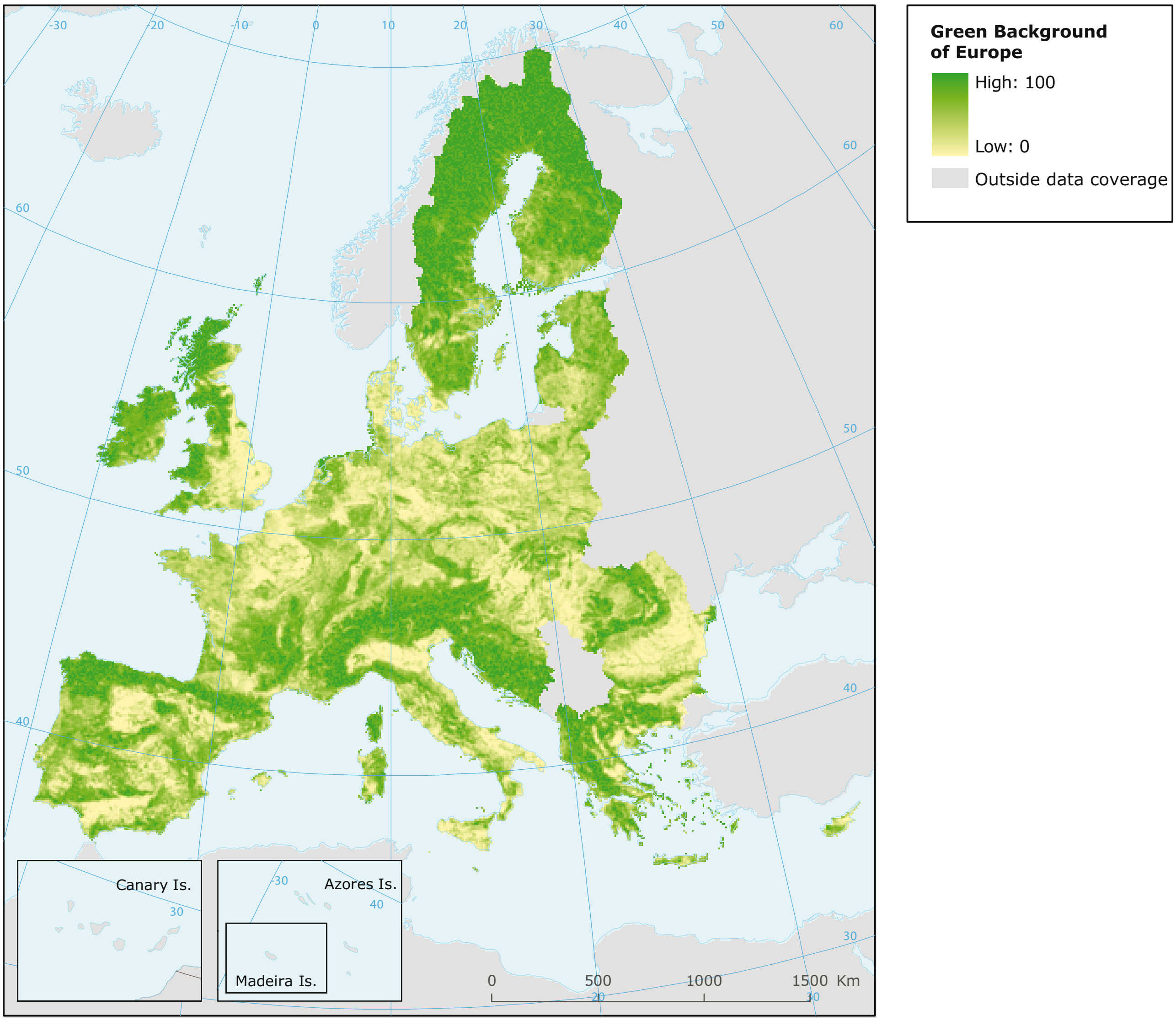
2.6 The importance of time

The accounts described in this chapter have focused on a single time step, mainly because of limited data availability. The importance of building up a longer temporal perspective should not be underestimated, however. This can be illustrated by reference to work that has used Corine land cover information for 1975, alongside the most recent data. This work was undertaken as part of:

- the PHARE programme which looked at land cover change in the countries that that joined the EU in the 1990s (Czech Republic, Hungary, Romania and Slovakia), and the LaCoast (JRC);
- EUROSION (European Commission) projects which focused on the European coastal zone, as represented by the 10 km strip on the land-side of the shoreline.

The longer time series available for the Czech Republic, Hungary, Romania and Slovakia (Figure 2.10 and Table 2.7) show more clearly the effects of the economic transition period that these countries experienced than do the accounts constructed from the 1990–2000 series alone.

Figure 2.7 The Green Background of Europe



Note: The map combines the stock estimates for pastures, mosaic agriculture, forests, dry semi-natural and natural land, wetlands and water bodies. The smoothing radius of 10 km has been used to calculate the extent (%) of these cover types within 10 km of each point (see Section 8.3.1). The resulting density of green surfaces has been mapped as a continuum from high to low.

Although forest cover has been maintained, there appears to have been some slowing of development in the latter period. A decline in agriculture can also be observed in the second period compared to the increase in the first. The loss of wetlands (549 km²) in the period 1975–1990 mainly relates to drainage in the Danube delta, where up to 516 km² of wetlands were converted to agriculture in the region of Tulcea

Figure 2.8 The dominant landscape types of Europe

Note: The map of dominant landscape types was produced from a spatial modelling technique based on CLC2000 and CORILIS mapping. It uses a 10 km smoothing radius applied to five aggregated CLC classes, namely urban/artificial, intensive agriculture, pastures/mosaics, forests and semi-natural/natural land. The dominant character has been assigned according to the rankings of the CORILIS values in each cell. In the example shown the dominant class has been assigned on the basis of the largest value of the mean + standard deviation, calculated at the level of biogeographic regions of Europe (details of the methodology are given in Section 8.3.3). The 'composite landscape' class shows those areas where the algorithm used could not identify any dominant type.

in Romania. The process of conversion to agriculture stopped in 1990 with the designation of the delta as a biosphere reserve by UNESCO. Water bodies have also developed as a consequence of changes in policy.

The data used in Table 2.7 was produced by adjusting and revising the 1975 data using the 1990 information. In the same way the 2000 series was used to adjust the 1990 data set. This procedure has ensured that change has been identified independently and that errors did not compromise the stock data. However, given the lower quality of the 1975 imagery, the higher level of uncertainty in these data should be considered when drawing any specific conclusions.

Similar accounts for the 1975–1990–2000 period can be produced for European coasts, using the results of the LaCoast Project and the EUROSION research programme. Urban sprawl — the main land cover change issue in the coastal area — has been analysed for each coastal sector for the two time periods (Table 2.8). These data have also been summarised in Figure 2.11. Figure 2.11 highlights the contrast between sectors or countries where the high sprawl of the first period has been mitigated in the latter and where the 1990–2000 period shows a

Figure 2.9 Analysis of coastal areas by dominant landscape types

Sprawl of artificial areas 1990–2000 on Europen coasts, by dominant land cover types, km²

Conversion from other land cover to agriculture 1990–2000 on Europen coasts, by dominant land cover types, km²

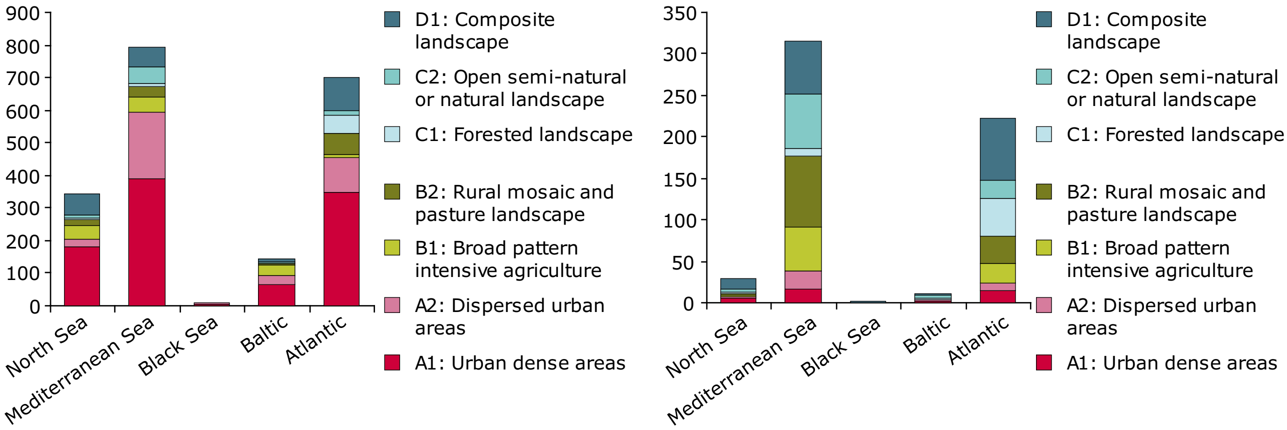


Figure 2.10 Land cover change in the Czech Republic, Hungary, Romania and Slovakia, 1975–2000

Net formation of land cover 1975–2000, total for Czech Republic, Hungary, Romania and Slovakia

Land cover turnover 1975–2000, total for Czech Republic, Hungary, Romania and Slovakia

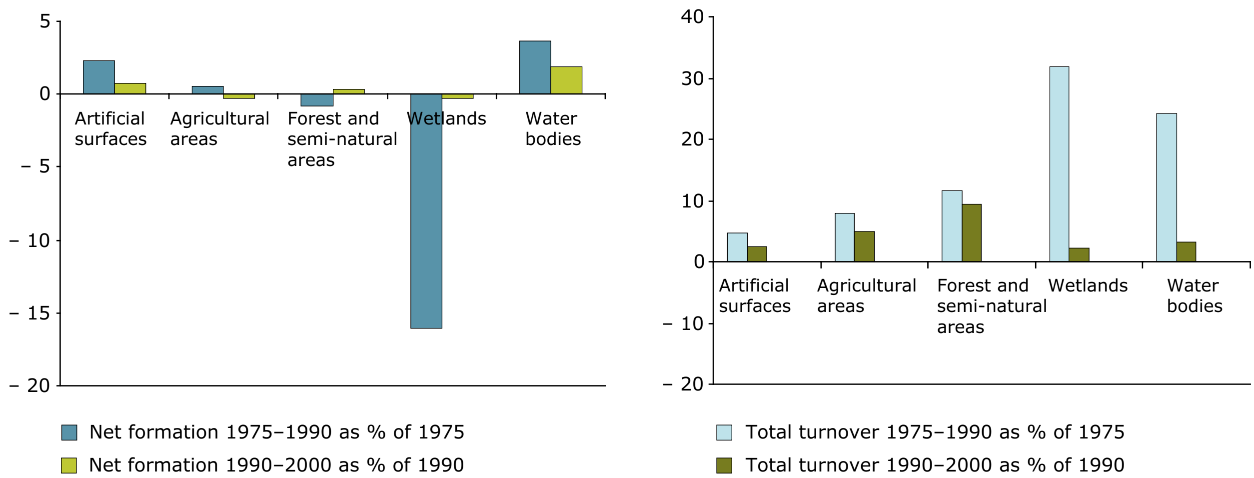


Table 2.7 Land cover accounts for the Czech Republic, Hungary, Romania and Slovakia, 1975–1990–2000

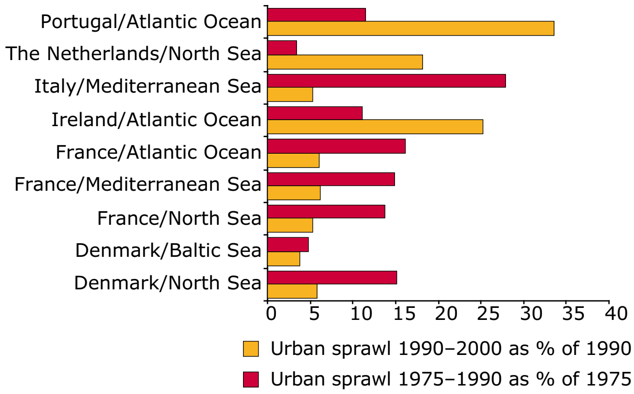
Land cover flows	1 Artificial surfaces	2 Agricultural areas	3 Forest and semi-natural areas	4 Wetlands	5 Water bodies	Total km²
1975–1990 (old)						
LCF1 Urban land management	85	1	1		0	88
LCF2 Urban residential sprawl		183	60	2	7	252
LCF3 Sprawl of economic sites and infrastructures	2	292	209	7	33	543
LCF4 Agriculture internal conversions		5 968				5 968
LCF5 Conversion from other land cover to agriculture	120		2 590	549	184	3 444
LCF6 Withdrawal of farming		2 776				2 776
LCF7 Forests creation and management	59		6 953	121	69	7 202
LCF8 Water bodies creation and management	19	193	175		35	422
LCF9 Changes due to natural and multiple causes	28	62	260	318	214	882
Consumption of 1975 land cover	**313**	**9 474**	**10 249**	**997**	**544**	**21 577**
No change	24 876	249 448	155 275	3 168	4 726	437 492
Total 1975, km²	**25 189**	**258 922**	**165 524**	**4 165**	**5 270**	**459 070**
LCF1 Urban land management	88					88
LCF2 Urban residential sprawl	252					252
LCF3 Sprawl of economic sites and infrastructures	543					543
LCF4 Agriculture internal conversions		5 968				5 968
LCF5 Conversion from other land cover to agriculture		3 444				3 444
LCF6 Withdrawal of farming		1 330	1 425	21		2 776
LCF7 Forests creation and management			7 202			7 202
LCF8 Water bodies creation and management			35		386	422
LCF9 Changes due to natural and multiple causes			224	308	350	882
Formation of 1990 land cover	**883**	**10 742**	**8 887**	**328**	**737**	**21 577**
No change	24 876	249 448	155 275	3 168	4 726	437 492
Total old CLC 1990, km²	**25 759**	**260 189**	**164 162**	**3 497**	**5 462**	**459 070**
1990 (new)–2000						
LCF1 Urban land management	64	1				65
LCF2 Urban residential sprawl		112	1	0	0	114
LCF3 Sprawl of economic sites and infrastructures	8	198	42	1	1	249
LCF4 Agriculture internal conversions		5 687				5 687
LCF5 Conversion from other land cover to agriculture	39	235	44	18	13	349
LCF6 Withdrawal of farming		917				917
LCF7 Forests creation and management	48		6 686	1	0	6 736
LCF8 Water bodies creation and management	29	54	11			94
LCF9 Changes due to natural and multiple causes	34	4	25	40	30	132
Consumption of 1990 land cover	**222**	**7 206**	**6 809**	**61**	**43**	**14 3432**
No change	27 400	261 535	144 656	4 982	6 331	444 904
Total new CLC 1990	**27 622**	**268 742**	**151 466**	**5 043**	**6 374**	**459 247**
LCF1 Urban land management	65					65
LCF2 Urban residential sprawl	114					114
LCF3 Sprawl of economic sites and infrastructures	249					249
LCF4 Agriculture internal conversions		5 687				5 687
LCF5 Conversion from other land cover to agriculture		349				349
LCF6 Withdrawal of farming		333	574	10		917
LCF7 Forests creation and management			6 736			6 736
LCF8 Water bodies creation and management					94	94
LCF9 Changes due to natural and multiple causes			26	39	68	132
Formation of 2000 land cover	**428**	**6 369**	**7 335**	**49**	**162**	**14 343**
No change	27 400	261 535	144 656	4 982	6 331	444 904
Total CLC 2000, km²	**27 828**	**267 905**	**151 992**	**5 031**	**6 492**	**459 247**
Adjustment (new CLC 1990 minus old CLC 1990=, total, km²	**1 863**	**8 552**	**-12 696**	**1 546**	**912**	**177**
% of old CLC 1990 of which	**7**	**3**	**-8**	**44.**	**17**	**0**
CZ	10	– 2	2	14	0	0
HU	– 4	– 5	14	51	5	0
RO	12	10	– 17	44	5	– 1
SK	1	– 1	1	23	0	– 3
Land cover change summary indicators — 1975–1990						
Net formation of land cover (formation – consumption) 1975–1990	570	1 267	– 1 362	– 668	193	
Net formation 1975–1990 as % of 1975	2.3	0.5	– 0.8	– 16.0	3.7	
Total turnover of land cover (consumption + formation) 1975–1990	1 196	20 216	19 136	1 325	1 281	43 155
Total turnover 1975–1990 as % of 1975	4.7	7.8	11.6	31.8	24.3	9.4
Land cover change summary indicators — 1990–2000						
Net formation of land cover (formation-consumption) 1990–2000	205	– 837	526	– 13	118	
Net formation 1990–2000 as % of 1990	0.7	– 0.3	0.3	– 0.2	1.9	
Total turnover of land cover (consumption + formation) 1990–2000	650	13 576	14 145	110	205	28 685
Total turnover 1990–2000 as % of 1990	2.4	5.1	9.3	2.2	3.2	6.2

faster increase. Once again the value of constructing accounts over several time periods can be seen.

2.7 Conclusions

The accounting database that has been constructed using Corine land cover data is highly flexible, and its full value will only be realised when other users begin to explore the data for themselves. The data and associated tools are primarily intended as an aid to problem solving, and their value reflects both the insights that they can bring and the innovative techniques that have been used in their construction. In presenting the materials in this chapter, the aim has been to give an overview of the methodologies so that potential users can see how they might use the accounting tools both to reproduce the analysis for themselves and go on to design new types of output. In order to assist this process, the next chapters develop and build on the framework introduced here. They explore the account data in more detail by focusing on three key topic areas, namely the changes in land cover and land use associated with the development of the built environment, changes in the agricultural landscape, and changes in the status of forest and semi-natural habitats. The further exploration of these themes will also provide the opportunity to describe how the analysis of land cover account data has been refined and developed through the work at the EEA.

Figure 2.11 Urban sprawl, 1975–1990–2000



Note: Urban sprawl is shown as a % change based on the initial urban area for each coastal sector.

Source: LaCoast 1975–1990 (JRC/IES) and LEAC 24 — 1990–2000 (EEA).

Table 2.8 Urban sprawl 1975–2000 in the coastal zone, for selected coastal sectors

	Denmark/North Sea	Denmark/Baltic Sea	France/North Sea	France/Mediterranean Sea	France/Atlantic Ocean	Ireland/Atlantic Ocean	Italy/Mediterranean Sea	The Netherlands/North Sea	Portugal/Atlantic Ocean
Artificial surfaces 1975	174	1 761	937	896	929	426	2 650	608	647
Total urban sprawl 1975–1990 (LCF2 + LCF3)	27	85	129	134	150	47	740	21	74
Urban sprawl 1975–1990 as % of 1975	15.2	4.8	13.8	14.9	16.2	11.1	27.9	3.4	11.4
Artificial surfaces 1990	292	2 038	1265	1212	1 327	617	3 789	634	904
Total urban sprawl 1990–2000 (LCF2 + LCF3)	17	77	67	75	80	156	200	115	303
Urban sprawl 1990–2000 as % of 1990	5.8	3.8	5.3	6.2	6.0	25.2	5.3	18.2	33.5
Artificial surfaces 2000	307	2 113	1 324	1 285	1 403	780	3 988	739	1 206

Note: The coastal zone is defined as the area within 10 km of the coastline.

Source: LaCoast 1975–1990 (JRC/IES) and LEAC 24 — 1990–2000 (EEA).

3 Patterns of urbanisation in Europe 1990–2000

3.1 Introduction

The asset accounts for Europe presented in the previous chapter are very general in character and show land cover stock, change and flows in only a highly aggregated way. Clearly many policy applications would require the information to be broken down, so that particular themes or regions can be considered in detail. The advantage of the accounting approach is that it is sufficiently flexible to enable disaggregation to be carried out easily. The application of 'accounting principles' also ensures a systematic process of disaggregation. Thus, there is consistency in the estimates of stocks and flows at the different levels of detail.

This chapter shows how the land account data for Europe can be explored in more detail by exploiting its hierarchical structure to break down data either thematically or geographically. The techniques and approaches for disaggregation that we describe are general ones which can be used to explore any aspect of the account data. In this chapter, our focus will be on the processes of urban development. It will show the kinds of insights these approaches can bring to this important policy area.

3.2 Developing a thematic view

The first way in which the general land cover accounts for Europe can be broken down is thematically, by using a much more detailed set of land cover types to present the accounts information.

A hierarchical approach has been used to classify the Corine land cover information that forms the basis of the accounts shown in Table 2.1 and 2.2. In these tables the data have been presented using the most general set of cover classes, or level 1. Two other hierarchical levels are available that split the eight broad units at level 1 down successively into 15 and 44 sub-classes. These are known as levels 2 and 3. Since the EEA has also classified the flows between classes in a hierarchical way, with three nested levels for the change categories, the information displayed in Tables 2.1 and 2.2 can be expanded to show how the land resource is changing in much greater depth.

When the land cover stock, change and flow data (shown in Tables 2.1 and 2.2) are displayed at levels 2 and 3, the tables can become very large. Therefore, they are best viewed using one of the database tools that have been provided (see Annex A). However, since it is important to illustrate what advantages the hierarchical approach can bring, an extract has been taken from a more detailed account for Europe which shows the stock and change for artificial surfaces at level 2 (Table 3.1).

Table 3.1 shows that within the general category of artificial surfaces, the residential and industrial categories exhibit the largest expansion. Moreover, most of the land 'consumed' through such development came from one of the agricultural categories as represented by the cover types classified as arable and permanent crops or pastures and mosaics.

In some countries, such as the United Kingdom, the recycling of previously developed land, or 'brownfield development', is used as a sustainability indicator (Defra, 2006). The account shown in Table 3.2 shows how a similar indicator could be constructed at the European scale; approximately 2.5 % of the new artificial surfaces created between 1990 and 2000 were derived by 'recycling' of developed land (Table 3.2). As it stands these data have been used to construct one of the core indicators used by the EEA, namely the uptake of land by urban development (CSI014) (Figure 3.1).

3.3 Developing a geographical view

Clearly, more detailed stock, change and flow accounts can be developed by refining the thematic classification of land cover types as illustrated in Table 3.1. A second important way of expanding the view that they provide is by disaggregating them geographically. This allows the spatial patterns of stock and change to be better understood. The data analysis tools enable the Corine data to be

Table 3.1 Detailed flow accounts for artificial surfaces in Europe, 24 countries, 1990–2000

Land cover flows	A	B	C	D	E	F	G	H	I	J
Corine land cover types	Stock 1990, km²	LCF1 Urban land management	LCF2 Urban residential sprawl	LCF3 Sprawl of economic sites and infrastructures	LCF5 Conversion from other land cover to agriculture	LCF7 Forests creation and management	LCF8 Water bodies creation and management	LCF9 Changes of Land Cover due to natural and multiple causes	Total flows, km²	Stock 2000, km²
111 Continuous urban fabric	5 785	5		0	3				8	
112 Discontinuous urban fabric	118 867	103		2	4	3		1	113	
121 Industrial or commercial units	16 208	12		1	5	2		2	21	
122 Road and rail networks and associated land	1 372	1				0			1	
123 Port areas	905	0		0	0			1	2	
124 Airports	2 590	14			2	1		0	18	
131 Mineral extraction sites	5 151	57		8	155	181	138	229	768	
132 Dump sites	971	24		11	50	43	1	25	154	
133 Construction sites	995	470		50	54	23	51	52	700	
141 Green urban areas	2 434	35		3		0	0		39	
142 Sport and leisure facilities	6 582	16			2	0	1		19	
1 Artificial areas total	**161 860**	**737**		**77**	**273**	**254**	**191**	**311**	**1 843**	
2A Arable land and permanent crops	(*)	**15**	**1 923**	**2 728**					**4 666**	
2B Pastures and mosaics	(*)	**19**	**1 867**	**1 595**					**3 482**	
3A Forested land	(*)	**0**	**200**	**665**					**865**	
3B Semi-natural vegetation	(*)	**8**	**145**	**451**					**605**	
3C Open spaces/bare soils	(*)	**0**	**8**	**35**					**43**	
4 Wetlands	(*)	**0**	**3**	**22**					**25**	
5 Water bodies	(*)		**2**	**53**					**55**	
Stock and consumption of land cover 1990, km²	**161 860**	**780**	**4 149**	**5627**	**273**	**254**	**191**	**311**	**11 584**	
111 Continuous urban fabric		43	172						216	5 993
112 Discontinuous urban fabric		237	3 976						4 214	122 967
121 Industrial or commercial units		248		2 174					2 422	18 609
122 Road and rail networks and associated land		75		224					299	1 670
123 Port areas		27		37					65	968
124 Airports		15		52					67	2 639
131 Mineral extraction sites		11		1 299					1 311	5 694
132 Dump sites		45		102					147	964
133 Construction sites		26		848					874	1 169
141 Green urban areas		52							52	2 447
142 Sport and leisure facilities				891					891	7 453
1 Artificial areas total		**780**	**4 149**	**5 627**					**10 556**	**170 572**
Stock and formation of 2000 land cover, km²		**780**	**4 149**	**5 627**					**10 556**	**170 572**

(*) Data exist but are not relevant to artificial areas.

Table 3.1 Detailed flow accounts for artificial surfaces in Europe, 24 countries, 1990–2000 (cont.)

Indicators

Corine land cover types	Land take by urban developement 1990–2000 (LCF13+LCF2+LCF3, Formation) km²	Land take by urban developement 1990–2000 (LCF13+LCF2+LCF3, Formation) as % of 1990	Net change in artificial land cover (= Stock 2000 minus 1990 or Formation minus Consumption)	Net change in artificial land cover as % of 1990	Land take by urban developement 1990–2000 (LCF13+LCF2+LCF3, Consumption) km²
111 Continuous urban fabric	216	3.7	208	4	(*)
112 Discontinuous urban fabric	4 214	3.5	4 100	3	(*)
141 Green urban areas	52	2.1	13	1	(*)
142 Sport and leisure facilities	891	13.5	871	13	(*)
Housing, services and recreation (CLC111,112,141,142)	5 371	4.0	5 192	3.9	(*)
121 Industrial or commercial araes	2 422	14.9	2 401	15	(*)
133 Construction sites	874	87.9	174	18	(*)
Industrial or commercial sites (CLC121, 133)	3 296	19.2	2 575	15.0	(*)
122 Road and rail networks and associated land	299	21.8	298	21.7	(*)
123 Port areas	65	7.2	63	6.9	(*)
124 Airports	67	2.6	49	1.9	(*)
Transport infrastructure (CLC122,123,124)	431	8.9	409	8.4	(*)
131 Mineral extraction sites	1 311	8.4	543	10.5	(*)
132 Dump sites	147	135.0	– 7	– 0.7	(*)
Mines, quarries and dumpsites (CLC131, 132)	1 457	0.9	536	8.7	(*)
minus recycling of artificial land (including constructions)	– 815				(*)
1 Artificial areas total	**9 741**	**6.0**	**8 712**	**5.4**	(*)
2A Arable land and permanent crops	(*)	(*)	(*)	(*)	**4 666**
2B Pastures and mosaics	(*)	(*)	(*)	(*)	**3 482**
3A Forested land	(*)	(*)	(*)	(*)	**865**
3B Semi-natural vegetation	(*)	(*)	(*)	(*)	**605**
3C Open spaces/bare soils	(*)	(*)	(*)	(*)	**43**
4 Wetlands	(*)	(*)	(*)	(*)	**25**
5 Water bodies	(*)	(*)	(*)	(*)	**55**
Total	**9 741**	**6.0**	**8 712**	**5.4**	**9 741**

(*) Data exist but are not relevant to artificial areas.

Table 3.2 Recycling of developed land 1990–2000, 24 countries — detail

Corine land cover \ Land cover flows	LCF11 Urban development/infilling	LCF12 Recycling of developed urban land	LCF13 Development of green urban areas	LCF1 Urban land management — total	LCF38 Sprawl of sport and leisure facilities	LCF3 Sprawl of economic sites and infrastructures — total	Internal conversions in artificial areas — (LCF1+LCF3)
111 Continuous urban fabric		476		476	23	23	499
112 Discontinuous urban fabric	10 221		75	10 296	206	206	10 502
121 Industrial or commercial units		1 160	30	1 190	145	145	1 335
122 Road and rail networks and associated land		93		93			93
123 Port areas		16	2	18	48	48	66
124 Airports		1 359	85	1 444			1 444
131 Mineral extraction sites		5 715	34	5 749	793	793	6 542
132 Dump sites		2 080	308	2 388	1 146	1 146	3 534
133 Construction sites		46 596	361	46 957	5 026	5 026	51 983
141 Green urban areas	3 490			3 490	334	334	3 824
142 Sport and leisure facilities	1 632		8	1 640			1 640
A Artificial areas total	**15 343**	**57 495**	**903**	**73 741**	**7 721**	**7 721**	**81 462**
B Artificial areas total without 133 construction sites	**15 343**	**10 899**	**542**	**26 784**	**2 695**	**2 695**	**29 479**
C Total land consumption by artificial development 1990–2000							**1 158 449**
Percentage of land recycling (B/C) as LCF1 Urban development/infilling							**2.3**
Percentage of land recycling (B/C) as Total LCF1+LCF3							**2.5**

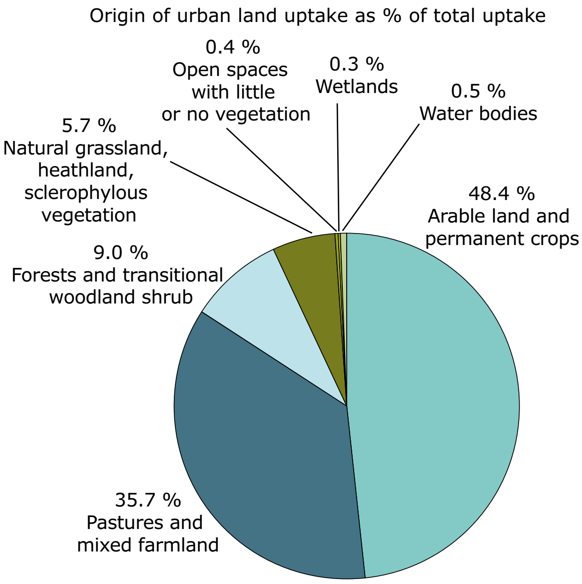
examined both at the continental scale, and for the different administrative tiers within Europe and major geographical regions, such a river and sea catchments, altitude zone, major landscape types and biogeographical regions.

The advantages of breaking account data down using some kind of geographical framework can be illustrated by reference to the hierarchical system of administrative units that exists for Europe — the so-called NUTS regions ([9]). As with the analysis of account data using greater thematic detail, when stock, change and flow accounts are disaggregated geographically, the tables can become very large. These are also best displayed using one of the database tools provided by the EEA. One particularly efficient way to see patterns, however, is to extract key information and display it in map form (Figure 3.2).

Figure 3.2 shows how account data for the expansion of artificial surfaces can be extracted from the accounting database and displayed spatially for different levels in the NUTS hierarchy. When using NUTS regions there are a number of technical issues that need to be considered. These will be discussed in Chapter 8. However, setting these qualifications aside, such maps are clearly able to show which

([9]) The NUTS boundaries data set (Nomenclature des Unités Territoriales Statistiques) shows sub-national administrative areas within the European Community (EC). Every EC Member State has different levels of administrative subdivisions. The national area is designated as NUTS 0, and the successively smaller regional and sub-regional administrative units are assigned to NUTS 1, NUTS 2 and NUTS 3. Former NUTS 4 (counties) and NUTS 5 (municipalities) are now coded as LAU 1 and LAU 2 (Land Administrative Units) respectively. http://ec.europa.eu/comm/eurostat/ramon/nuts/home_regions_en.html (accessed 23.09.2006).

Figure 3.1 Land-take by artificial development (EEA core indicators, CSI014)



Source: EEA, 2005.

regions are most dynamic in terms of development pressure, and which are more stable.

The maps shown in Figure 3.2 were created using the software tools provided by the ESPON HyperAtlas, 2006. As a cross-reference, the data on urban sprawl between 1990 and 2000 are shown alongside information on the distribution of population across the NUTS regions in 1999. Since the size of administrative regions in the NUTS hierarchy varies between countries, a mixture of NUTS 2 and NUTS 3 have been used to display the data. This ensures as even a distribution of spatial units as possible. At the top of Figure 3.2, both population and the extent of land cover change are shown in absolute terms as proportional circles. Below this, the data are displayed on a unit area basis to take account of the size of each NUTS region. Thus, population is displayed as the number of people per km^2, while the land cover change data are shown the area of urban sprawl in the NUTS region per km^2.

Figure 3.2 shows that there is a cluster of NUTS regions showing a high rate of sprawl extending from central and southern England through Belgium and the Netherlands into Germany. The Mediterranean coast, especially in Spain also stands out as an area with a high rate of change. The contrast between the more dynamic parts of northern Italy and the more slowly developing south is also apparent. These regions often coincide with those areas showing the highest population densities. However, there are some areas, such as parts of Ireland and the east of Germany, where the rates of urban sprawl is high but population densities are low. An advantage of using HyperAtlas is that the deviation of each spatial unit from European and national averages can easily be calculated and mapped (see lower part of Figure 3.2). The positive deviations from the European average for both population and sprawl appear to emphasise the dominance of the central block of NUTS regions extending from the southern part of the United Kingdom into Belgium, the Netherlands, Denmark, Germany and northern France. The positive deviations from the national averages tend to emphasise both the individual capital cities and their environments, and a number of border and coastal areas.

The geographical disaggregation of the account data by administrative region is just one way of gaining an insight into the spatial patterns of stock and change at different scales within Europe. The accounting database developed by the EEA not only allows data to be reported by major river and sea catchments, major landscape types, altitude zones and proximity to coast, it also reports in highly 'customisable' ways, using a gridded structure ([10]). A 1 km^2 grid for the whole of Europe can now be used to hold the account data. This offers the possibility to report land cover stock and change flows in very flexible ways, because users can assemble from regions of their choice the individual records held in each 1 km^2. The technical issues that underlie this approach will be discussed in Part III. This chapter concludes by looking at the accounts information for artificial surfaces in more detail. It highlights the importance of such data for policy development and appraisal.

3.4 Land cover accounts as a policy tool

The European Commission has argued that current approaches to spatial planning need to be improved. The 1999 European Spatial Development Perspective (ESDP) emphasised that present patterns of development across Europe are highly concentrated. Marked variations of economic wealth and prosperity exist. For the future it was argued that there should be many geographically prosperous regions evenly

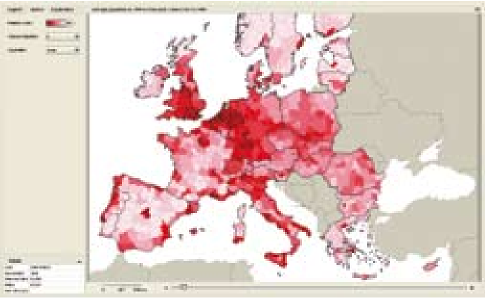
([10]) Those interested can access the database using the tools available through the EEA data service. For more advanced applications, the basic Corine land cover data can be downloaded in their original vector or raster formats (100 m and 250 m resolution), together with land cover flows in raster format (100 m). The standard 1 km² grid and the associated database are also available from the EEA.

Figure 3.2 Spatial patterns of land cover change for regions in Europe. Sprawl of artificial surfaces by NUTS 2/3 and population regional distribution

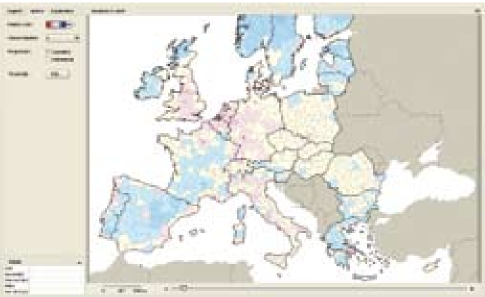
Population 1999

Distribution of population in 1999 by NUTS 2/3 region shown as proportional circles

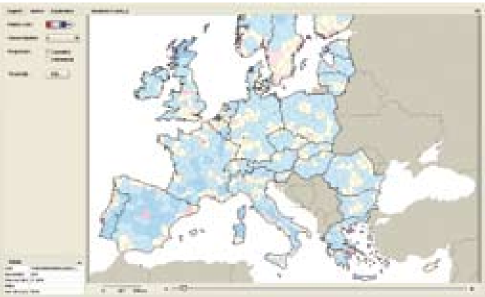
Population density in 1999 by NUTS 2/3 region; population is now expressed on a unit area basis



Deviation of population density from the European average by NUTS 2/3 region



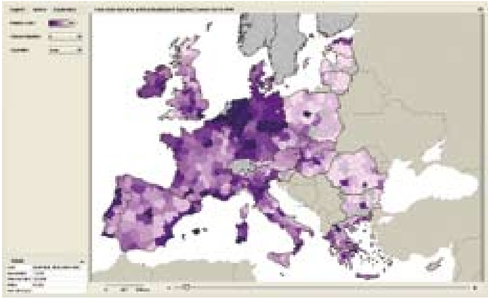
Deviation of population density from individual country averages by NUTS 2/3 region



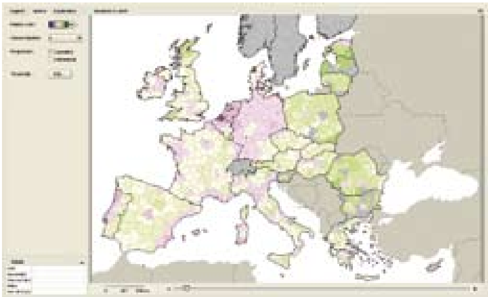
Urban/artificial sprawl 1990–2000

Intensity of urban sprawl, 1990–2000 by NUTS 2/3 region, shown as proportional circles

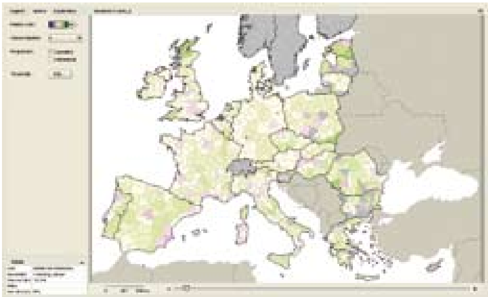
Intensity of urban sprawl, 1990–2000, by NUTS 2/3 region; sprawl is now expressed on a unit area basis



Deviation of intensity of urban sprawl from the European average by NUTS 2/3 region



Deviation of intensity of urban sprawl from individual country averages by NUTS 2/3 region



Source: ESPON, HyperAtlas, 2006 ([11]).

([11]) The HyperAtlas software was developed within ESPON 3.1 Project (Integrated Tools for European Spatial Development) and is a shared property of ESPON Programme (www.espon.eu) and the Hypercarte Research Project. The Hypercarte Research Project groups the LSR-IMAG laboratory (UMR 5526), the ID-IMAG laboratory (UMR 5132), the Géographie-Cités laboratory (UMR 8504), and RIATE (UMS 2414) and their respective supervision research institutes: CNRS, INRIA, Université de Paris 1, Université de Paris 7, and Université Joseph Fourier. Hypercarte Project Website: http://www-lsr.imag.fr/Hypercarte/ (accessed 02.10 2006).

spread across Europe, and that stronger 'territorial cohesion' could be achieved by 'polycentric' spatial development. Thus, the ESDP aimed to put in place mechanisms to:

- strengthen the partnership between urban and rural areas. This will create a new urban-rural relationship to address issues related to household growth and urban sprawl, and the need to promote new economic opportunities through such concepts as 'gateway' cities;
- promote integrated transport and communication initiatives. This will support the polycentric development of the EU territory, so that there is gradual progress towards parity of access to infrastructure and knowledge. As a result, issues arising from patterns of migration, unemployment and significant variations in GDP per head across the EU could be better addressed;
- ensure the wise management of the natural and cultural heritage. This will help conserve regional identities and cultural diversity in the face of globalisation and climate change.

There is also an aim to ensure that both generally and specifically the development of transport infrastructures, agriculture and other aspects of rural policy has no adverse impacts on the environment, in terms of the integrity of the Natura 2000 ecological network, either at national or local scales.

If such aims are to be realised, then the availability of relevant and timely spatial information describing patterns of land use and its change over time is clearly essential. Thus, the Commission has initiated two further initiatives to ensure that such data infrastructures are developed, namely:

- INSPIRE (INfrastructure for SPatial InfoRmation in Europe). This will put in place mechanisms for ensuring the availability of relevant, harmonised and high quality geographic information for decision support within the EU; and,
- GMES (Global Monitoring for Environment and Security). This will aim to enhance EU's capabilities of acquiring and integrating high-quality environmental data from space, with other geographic and socio-economic information to support policy-making on different spatial scales.

Such initiatives as GMES will ensure that data become available to update the types of land cover account considered in this document. The outcomes of INSPIRE will mean that the data resources created by organisations like the EEA through its land cover accounting work will become more widely available for decision support. The analysis and presentation of data through the land accounting framework is one way to achieve the aims of INSPIRE.

For example, Table 3.3 shows the magnitude of the flows into the different types of artificial surface between 1990 and 2000 for each of the EEA member countries. Although all the data come from Corine land cover mapping for two dates, the time span considered varies from one country to another. Thus, to help make more meaningful comparisons, the annual rate has been calculated country by country from the period actually observed. The complete stocks and flows account is only presented country by country or aggregated at the European level ([12]) of for large zones or sets of countries. These data are just an extract from the full account that can be built and only show the formation of the different types of artificial surface. To bring out the detailed difference between countries, we have displayed the land cover flow data at level 3, the highest level of detail at which change is recorded and classified.

A review of Table 3.3 suggests that there are marked differences between countries which are most easily seen if the data on annual land take related to the development of artificial surfaces are expressed as a proportion of the 1990 developed area (Figure 3.3). In addition, there are differences in terms of the proportions of the flows into the artificial land cover class resulting from urban land management, urban residential sprawl and the sprawl of economic sites and infrastructures (Figure 3.4).

Figure 3.3 suggests that Ireland, the Netherlands Portugal and Spain and show the highest percentage increase in artificial surfaces when this is expressed as a percentage of the 1990 developed area. In the case of Ireland this partly reflects the relatively small urban area that existed in 1990, and the rapid economic growth that the country has experienced since that time.

In Figure 3.4 the balance between the urban land management flow and the flows for sprawl of residential and economic sites gives an indication of the intensity of recycling of previously developed land. The highest rates of 'recycling' suggest for some of the newer Member States (Slovenia, Lithuania,

([12]) The Corine initiative started as an experimental programme in the mid-1980s and was expanded and formalised with the inclusion of the Accession Countries in the first half of the 1990s. This has meant that the time period for mapping change may vary between countries, although most comply with the 'theoretical' decade, 1990–2000. The variation in start and end date between countries means that the average time period between the two Corine inventories is in fact a little more than ten years.

Czech Republic and Poland) some redevelopment of existing industrial and mining structures. This was a significant process between 1990 and 2000, although the absolute areas involved are small.

Those countries where residential sprawl represented a high proportion (greater than approximately 50 %) of the total area of development and redevelopment were: Italy, Luxembourg, Portugal, Estonia, Croatia, and Slovakia. In Latvia, Bulgaria, Greece, Hungary, Austria, Denmark, Belgium and Poland most of the development and redevelopment was taken up by the sprawl of industrial and economic sites. Elsewhere the balance between these two types of flow was more even during the period 1990–2000.

In the smaller countries, the absolute areas involved are small, and there is obviously a danger of generalising from limited data. However, it does appear that development can be significant locally. In Luxembourg, for example, the increase of artificial areas is the most important land cover change overall. The changes are mainly concentrated around the existing urban centres of the country

Table 3.3 Formation of artificial surfaces by EEA member country estimated for the period 1990–2000 (mean annual values, hectares)

	LCF11 Urban development/infilling	LCF12 Recycling of developed urban land	LCF13 Development of green urban areas	**LCF1 Urban land management — total**	LCF21 Urban dense residential sprawl	LCF22 Urban diffuse residential sprawl	**LCF2 Urban residential sprawl — total**	LCF31 Sprawl of industrial and commercial sites	LCF32 Sprawl of transport networks	LCF33 Sprawl of harbours	LCF34 Sprawl of airports	LCF35 Sprawl of mines and quarrying areas	LCF36 Sprawl of dumpsites	LCF37 Construction	LCF38 Sprawl of sport and leisure facilities	**LCF3 Sprawl of economic sites and infrastructures — total**	**Total total of artificial development and redevelopment, hectares per year**	Mean annual land take by artificial development and redevelopment as % of the initial accounting year
AT Austria	8	18	2	**28**		218	**218**	85	9		23	160	3	11	308	**599**	**845**	0.2
BE Belgium	91	156	2	**249**		567	**567**	860	128	42	13	162	13	106	71	**1 395**	**2 211**	0.4
BG Bulgaria						19	**19**	13				284	41			**338**	**357**	0.1
CZ Czech Republic	9	522	6	**537**		517	**517**	217	50		2	298	191	106	124	**988**	**2 042**	0.4
DE Germany	379	608	38	**1 025**		9 865	**9 865**	5 285	58	14	174	2 811	177	654	1 953	**11 126**	**22 016**	0.8
DK Denmark	10	12	7	**29**		419	**419**	266	8	25		207	7	25	393	**931**	**1 379**	0.5
EE Estonia	3	8	5	**16**		232	**232**	14		1	6	127	14	25		**187**	**435**	0.5
ES Spain	155	828	120	**1 103**	1 146	3 620	**4 766**	2 827	224	111	68	1 627	128	1 763	808	**7 556**	**13 425**	2.0
FR France	206	871	19	**1 096**	1	5 452	**5 453**	3 426	729	22	93	2 229	91	1 356	1 117	**9 063**	**15 612**	0.6
GR Greece	3	203		**206**		502	**502**	731	304	24	12	1 070	35	901	63	**3 140**	**3 848**	1.5
HR Croatia						246	**246**	41	44		6	31	15	86		**223**	**469**	0.3
HU Hungary	6	57	11	**74**		186	**186**	292	173		8	271	94	193	118	**1 149**	**1 409**	0.3
IE Ireland	72	98	89	**259**		1 569	**1 569**	201	129	6	11	263		270	702	**1 582**	**3 410**	3.3
IT Italy	9	153	6	**168**	47	5 022	**5 069**	2 388	81	18	13	525	20	256	186	**3 487**	**8 724**	0.6
LT Lithuania	1	142		**143**		30	**30**	29			3	75	1	6		**114**	**287**	0.1
LU Luxembourg	1	4	3	**8**		96	**96**	19	5		2	11	5	3	21	**66**	**170**	0.8
LV Latvia								1				22				**23**	**23**	0.0
NL Netherlands	106	615	101	**822**		2 889	**2 889**	1 455	31	28	12	97	33	680	787	**3 123**	**6 834**	1.8
PL Poland	62	582	11	**655**		530	**530**	290	55		6	991	104	506	30	**1 982**	**3 167**	0.3
PT Portugal	133	135	9	**277**	36	2 679	**2 715**	865	103	12	21	498	9	292	247	**2 047**	**5 039**	2.9
RO Romania	2	124		**126**		379	**379**	204				385	4	94	26	**713**	**1218**	0.1
SI Slovenia		75		**75**		5	**5**	9	18			3		26		**56**	**136**	0.3
SK Slovakia	7	65		**72**		377	**377**	92	18			37	26	99	41	**313**	**762**	0.3
UK United Kingdom	156	242	3	**401**		1 441	**1 441**	468	28	20	10	481	37	173	1 131	**2 348**	**4 190**	0.2
Total, hectares/ year	1 419	5 518	432	**7 369**	1 230	36 860	**38 090**	20 078	2 195	323	483	12 665	1 048	7 631	8 126	**52 549**	**98 017**	0.6

— the capital and the old industrial southwest. The expansion partly reflects the efforts made to attract new inhabitants from neighbouring countries.

In the larger countries there is a good deal of spatial variation in patterns of urbanisation. These are best considered in detail by mapping the account data using a gridded approach (Figure 3.5). This map shows the areas where expansion due to residential sprawl is most significant, and when the extent of urban sprawl is calculated for each of the 1 km x 1 km cells that make up Europe in the accounting grid. In Figure 3.5, the change is displayed against the Green Background discussed in Chapter 2.

In Italy, urban sprawl due to the expansion of residential and commercial sites is particularly evident in the northern part of country around Rome and on Sardinia. In Portugal, the developments in the Algarve are also especially significant. In Spain, there are concentrations around Madrid and along the Mediterranean coast. The Mediterranean coastal region also stands out in France as an area of marked development, along with the areas around Paris. The greatest concentration of urban sprawl occurs in Belgium, the Netherlands and Denmark, which form part of a major development axis that also extends across into the United Kingdom. The Netherlands stands out as one of the member countries where more than half of the total land cover change observed was associated with urban sprawl. The concentration of development in Ireland, especially around Dublin is also evident.

In Germany, the land cover accounts also suggest that urban sprawl represented a major land cover change during the period 1990–2000, increasing the urban area by approximately 6 % over the period. While most urbanisation seems to have occurred within already densely populated areas and around the major settlements in the west and south, the effects of unification are evident. High rates of change are also

Figure 3.3 Mean annual artificial surface land-take by country, 1990–2000

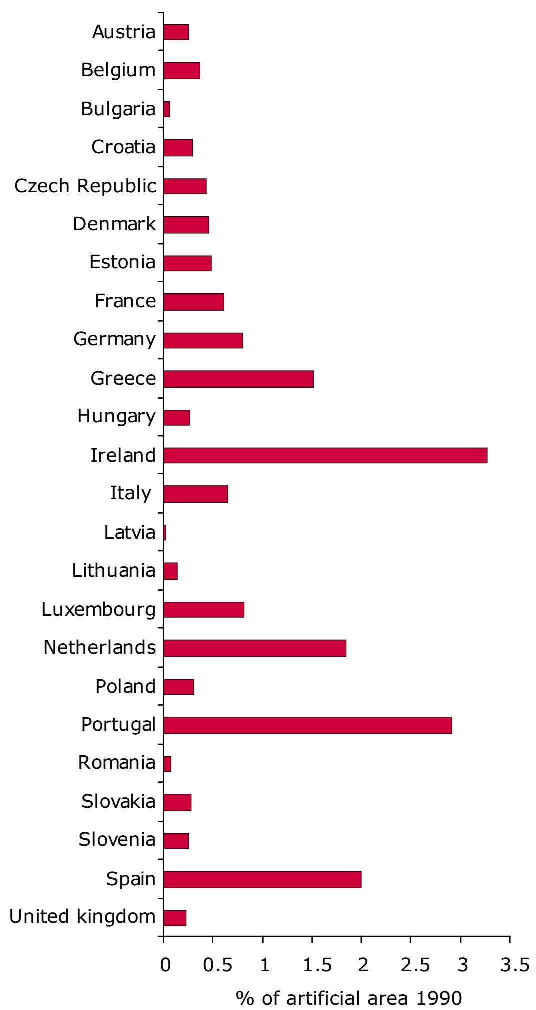
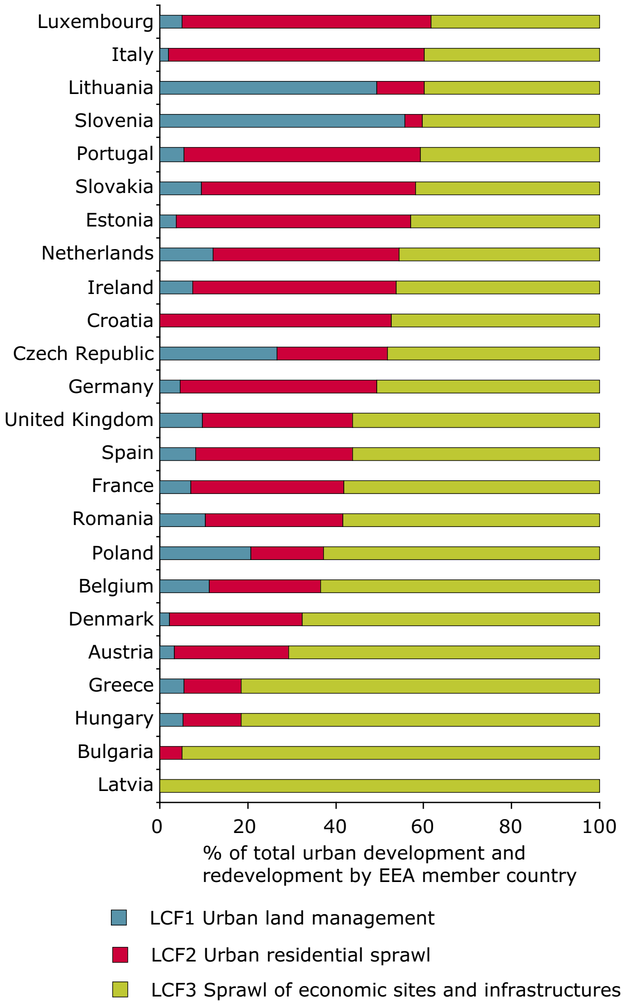


Figure 3.4 Balance between flows making up development and redevelopment

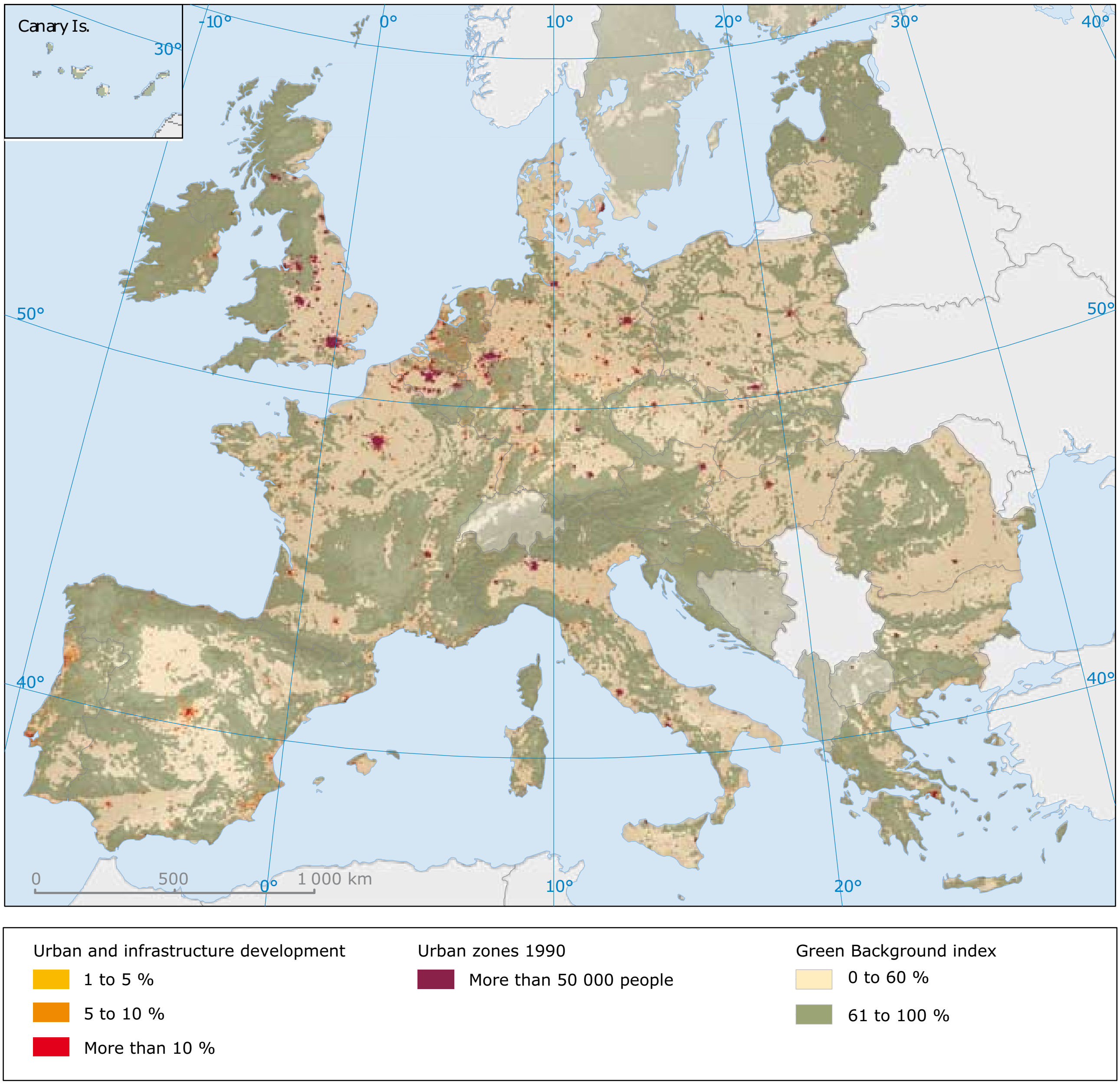


seen in the east. Although it is probably too early to detect the influence of accession elsewhere in Europe, concentrations of development are evident in the Czech Republic, along the border with Germany, and in Slovakia and Hungary, both around the existing centres and along the border with Austria.

3.5 Exploring the processes of land cover change

The type of analysis presented in this chapter provides only an initial introduction into what can be achieved using mapping techniques to display land cover account data. Our focus has been on the process of urbanisation. We have shown how the information assembled by the EEA in its environmental accounting work can be explored in more depth both by adding thematic detail to the classification of stocks and flows, and by breaking down the information geographically. In the chapters that follow, other examples are provided to show the range of analyses that can be attempted.

Figure 3.5 Patterns of urban sprawl across Europe, 24 countries, 1990–2000, 1 km x 1 km grid



Note: Urban sprawl by grid cells is overlaid to a background map of the 'green' character of the European landscape. The methods used to construct the Green Background are described in Chapter 8, Section 8.3.2.

4 Patterns of agricultural change in Europe 1990–2000

4.1 Introduction

Agriculture is the most important land cover type in Europe in terms of the proportion of the total land area occupied. It covers approximately 55 % of the land surface, compared to 37 % for forest and semi-natural and 5 % for urban. Thus, an understanding of the changes that take place within the areas dominated by farming is important if we are to understand what is happening to the landscapes across the continent. An analysis of the transformations of land use associated with farming is also important from a policy perspective. In recent years there has been significant reform in EU's common agricultural policy (CAP), involving a shift from a production focus to one that emphasises the need for a broader approach to rural development as well as the maintenance and restoration of environmental quality. The implications of these and the other transformations triggered by the enlargement of the EU mean that the analysis of changes of agricultural land cover is an important part of planning for sustainable development.

The 'Cardiff Process', initiated by the European Council in 1998, set in place the requirement that the environmental impacts of all the major policy proposals of the European Commission should be subject to an appraisal. In the context of agriculture, the need to integrate environmental concerns into agricultural policy has led to a number of developments. These have included the IRENA ([13]) initiative, which has sought to develop a comprehensive set of indicators describing the environmental performance of farming across Europe. Amongst the suite of indicators proposed is a subset that deals with land use issues, and the way agricultural land use changes over time. This chapter will describe in more detail how the accounting approach offers a flexible framework for the development of policy-relevant indicators related to agricultural land use.

4.2 The agricultural account for Europe

Table 4.1 shows an 'agricultural account' for Europe. Its structure is the same as that used in Chapters 2 and 3, except that the information has been expanded around the agricultural theme. Thus, the flows within the 'agricultural sector' and between agriculture and the other major types of land cover are shown in more detail. Clearly, such a table hides much of the diversity that exists at national and regional levels. In order to give a picture of these underlying patterns, the information has been supplemented with other maps and graphs.

4.2.1 The loss of agricultural land through development

Figure 4.1 gives an insight into the spatial patterns of change that can be picked out from the accounts derived from the CLC land cover change data. Once again this map is based on a hybrid set of NUTS regions to make comparisons between the different European countries more reliable. Since the loss of agricultural land is mainly to urban, it is not surprising that those administrative regions showing the greatest rate of loss are also those close to the major centres of population. Thus, the map of the annual rate of loss of agricultural land to urban is broadly similar to that shown in Figure 3.1 — for the sprawl of artificial surfaces. There is a marked axis of change extending from the south central part of the United Kingdom through Belgium, the Netherlands and into Germany. There are also concentrations of change around Paris, along the southwest Atlantic coast of France, in coastal areas of Portugal around Lisbon and in the Algarve, along the Mediterranean coast of Spain, and in northern Italy.

An indicator based on a measure of the amount of agricultural land uptake by urban and infrastructure development (including water body creation for hydraulic purposes) has been proposed

([13]) IRENA = Indicator reporting on the integration of environmental concerns into agricultural policy; see EEA (2006a).

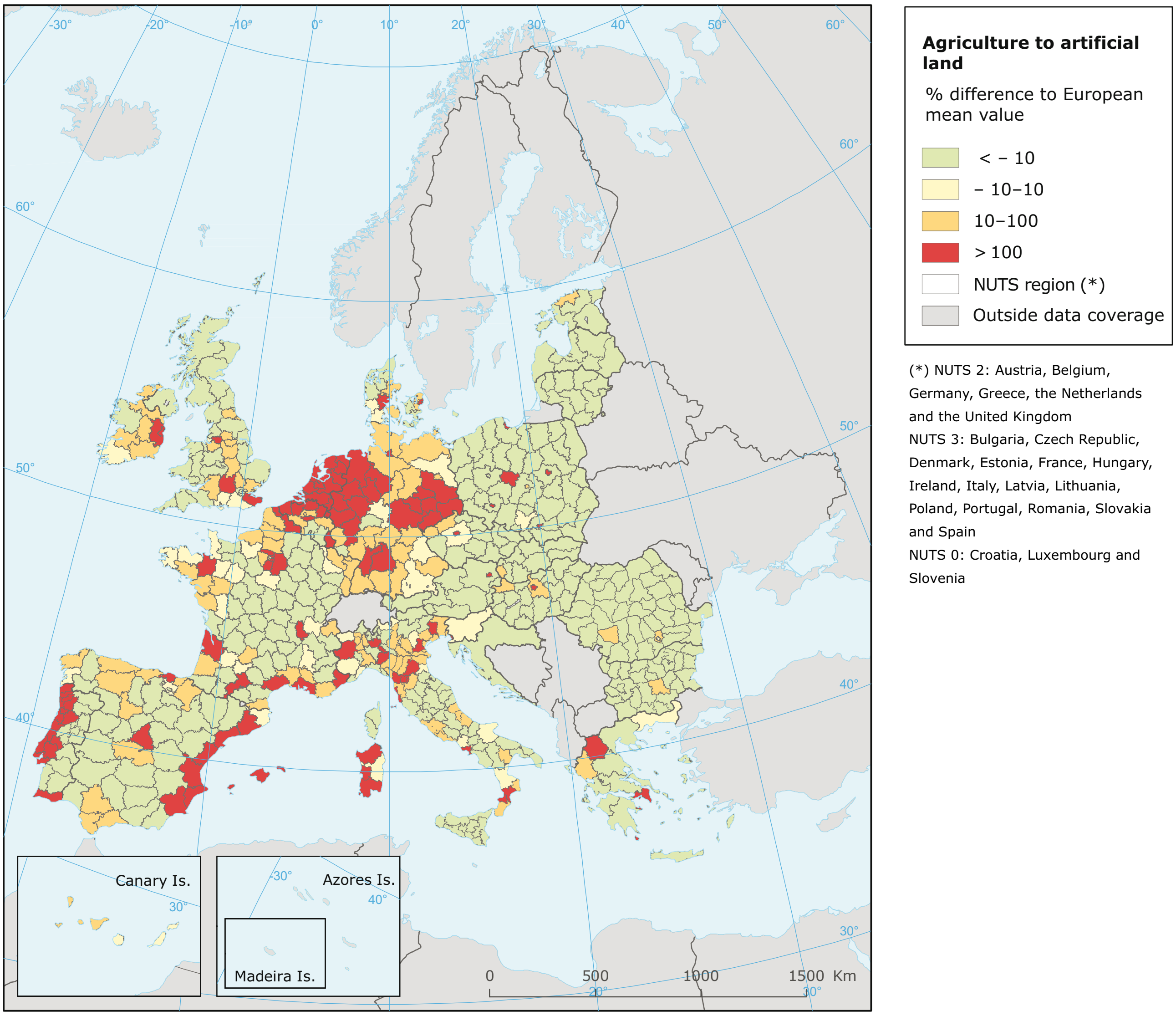
as one of the IRENA set of land use indicators (IRENA 12). Figure 4.1 effectively maps this for the period 1990–2000, across the European Countries for which CLC data are available.

This overall conclusion that the agricultural sector is the most important contributor of land to artificial development needs to be qualified for some areas. In the coastal areas of the Atlantic and the Mediterranean, for example, where rapid development has occurred, the loss of farmland due to urban sprawl seems to be partly compensated by conversion of forests and semi-natural land to agriculture. Using Table 4.2 the 'Net consumption of agriculture land cover' (i.e. land take by urban minus conversions of land cover to agriculture) may be compared to the 'Total consumption of forest and semi-natural land by urban and agriculture' extension. The data show that while agriculture appears to contribute more than 60 % of the land taken up by urban/artificial development, forest and semi-natural land are probably the main source.

4.2.2 *Changes in the structure of farming*

The second major feature of the agricultural account (shown in Table 4.1) is the significant amount of 'internal' conversions between the different land cover types within the agricultural sector. The key flows to consider in Table 4.1b are the extension of pasture, set aside and fallow land (LCF41), and the counter-flow represented by the conversion from pasture to arable and permanent crops (LCF46). It is important to consider these kinds of changes

Figure 4.1 Loss of land from agriculture to artificial surfaces by NUTS regions



(*) NUTS 2: Austria, Belgium, Germany, Greece, the Netherlands and the United Kingdom
NUTS 3: Bulgaria, Czech Republic, Denmark, Estonia, France, Hungary, Ireland, Italy, Latvia, Lithuania, Poland, Portugal, Romania, Slovakia and Spain
NUTS 0: Croatia, Luxembourg and Slovenia

Source: Data: EEA; NUTS boundaries: Eurogeographics.

Table 4.1 The 'agricultural account' for Europe, 24 countries, 1990–2000

Table 4.1a Overall balance

Land cover flows / Corine land cover types	Stock 1990, km²	LCF1 Urban land management	LCF2 Urban residential sprawl	LCF3 Sprawl of economic sites and infrastructures	LCF4 Agriculture internal conversions total	LCF5 Conversion from other land cover to agriculture	LCF6 Withdrawal of farming	LCF8 Water bodies creation and management total	LCF9 Changes of land cover due to natural and multiple causes	Total flows, km²	Stock 2000, km²
1 Artificial areas	**161 860**					**273**			**311**	**584**	
211 Non-irrigated arable land	1 027 807	12	1 538	2 417	13 493		2 121	225	39	19 844	
212 Permanently irrigated land	28 180	1	66	101	790		34	7	5	1 004	
213 Rice fields	5 688		2	2	619		8	0		631	
221 Vineyards	39 067		45	42	926		59	2		1 074	
222 Fruit trees and berry plantations	24 656		92	84	948		58	1	1	1 184	
223 Olive groves	39 007		54	48	225		82	13	0	424	
241 Annual crops associated with permanent crops	9 919	2	127	34	252		31	3		448	
2A Arable land and permanent crops total	**1 174 325**	**15**	**1 923**	**2 728**	**17 252**		**2 393**	**252**	**44**	**24 608**	
231 Pastures	367 361	15	625	668	7 412		924	114	6	9 764	
242 Complex cultivation patterns	244 214	4	952	639	2 543		317	43	3	4 500	
243 Agriculture mosaics with natural vegetation	177 077	1	278	274	10	935	1 261	58	5	2 822	
244 Agro-forestry areas	31 457		12	14	97		358	38	1	521	
2B Pastures and mosaics total	**820 109**	**19**	**1 867**	**1 595**	**10 062**	**935**	**2 860**	**253**	**15**	**17 607**	
3A Forested land	**1 030 635**					**1 796**			**1 317**	**3 113**	
3B Semi-natural vegetation	**264 932**					**1 734**			**1 323**	**3 058**	
3C Open spaces/bare soils	**52 593**					**155**			**1 041**	**1 196**	
4 Wetlands	**46 915**					**96**			**229**	**325**	
5 Water bodies	**45 854**					**50**			**252**	**302**	
Stock and consumption of land cover 1990, km²	**3 597 223**	**34**	**3 791**	**4 323**	**27 314**	**5 039**	**5 253**	**506**	**4 534**	**50 794**	
1 Artificial areas											**170 572**
211 Non-irrigated arable land					8 987	1 464				10 451	1 018 414
212 Permanently irrigated land					3 631	383				4 014	31 191
213 Rice fields					520	27				547	5 604
221 Vineyards					760	122				882	38 874
222 Fruit trees and berry plantations					956	281				1 237	24 709
223 Olive groves					784	141				925	39 509
241 Annual crops associated with permanent crops					56	32				88	9 560
2A Arable land and permanent crops total					**15 695**	**2 450**				**18 144**	**1 167 861**
231 Pastures					7 832	486				8 318	365 916
242 Complex cultivation patterns					3 740	419				4 160	243 873
243 Agriculture mosaics with natural vegetation						780	1 124			1 904	176 159
244 Agro-forestry areas					48	904				952	31 887
2B Pastures and mosaics total					**11 619**	**2 590**	**1 124**			**15 333**	**817 835**
3A Forested land							**2 792**		**4**	**2 796**	**1 036 079**
3B Semi-natural vegetation							**1 244**		**2 167**	**3 411**	**260 090**
3C Open spaces/bare soils							**23**		**1 790**	**1 813**	**52 147**
4 Wetlands							**70**		**313**	**383**	**45 885**
5 Water bodies							**0**		**260**	**260**	**46 754**
Stock and formation of land cover 2000, km²					**27 314**	**5 039**	**5 253**		**4 534**	**42 140**	**3 597 223**

Table 4.1 The 'agricultural account' for Europe, 24 countries, 1990–2000 (cont.)

Table 4.1b Internal conversions of agriculture land cover

Land cover flows	LCF4 Agriculture internal conversions							
Corine land cover types	LCF41 Extension of set aside fallow land and pasture	LCF42 Internal conversions between annual crops	LCF43 Internal conversions between permanent crops	LCF44 Conversion from permanent crops to arable land	LCF45 Conversion from arable land to permanent crops	LCF46 Conversion from pasture to arable and permanent crops	LCF47 Extension of agro-forestry	LCF4 Agriculture internal conversions total
1 Artificial areas								
211 Non-irrigated arable land	9 049	3 021			1 389		35	13 493
212 Permanently irrigated land	170	438			180		1	790
213 Rice fields	27	590			2			619
221 Vineyards	49		85	791			1	926
222 Fruit trees and berry plantations	43		24	881				948
223 Olive groves	1		37	187			0	225
241 Annual crops associated with permanent crops	157			21	74			252
2A Arable land and permanent crops total	**9 496**	**4 049**	**146**	**1 879**	**1 645**		**38**	**17 252**
231 Pastures						7 412		7 412
242 Complex cultivation patterns	722					1 821	0	2 543
243 Agriculture mosaics with natural vegetation							10	10
244 Agro-forestry areas						97		97
2B Pastures and mosaics total	**722**					**9 330**	**10**	**10 062**
Total consumption of 1990 land cover, km²	10 218	4 049	146	1 879	1 645	9 330	48	**27 314**
1 Artificial areas								
211 Non-irrigated arable land		565		1 172		7 251		8 987
212 Permanently irrigated land		2 986		126		519		3 631
213 Rice fields		498		1		21		520
221 Vineyards			42		451	267		760
222 Fruit trees and berry plantations			62		566	328		956
223 Olive groves			42		599	143		784
241 Annual crops associated with permanent crops				18	30	9		56
2A Arable land and permanent crops total		**4 049**	**146**	**1 317**	**1 645**	**8 538**		**15 695**
231 Pastures	7 832							7 832
242 Complex cultivation patterns	2 387			562		792		3 740
243 Agriculture mosaics with natural vegetation								
244 Agro-forestry areas							48	48
2B Pastures and mosaics total	**10 218**			**562**		**792**	**48**	**11 619**
Total formation of 2000 land cover, km²	10 218	4 049	146	1 879	1 645	9 330	48	**27 314**

are because they may reflect some of the ways that the industry responds to economic and social conditions. Overall, Table 4.1 shows that there has been a conversion of arable and permanent crops to pasture of 9 330 km² over the period 1990–2000. This process has been more than compensated for by the conversion of cropland to pastures, fallow land and set aside (10 278 km²). It is important to note, however, that compensatory flows did not occur in the same place, and indeed often not in the same regions. Once again, there are large differences between countries and regions within Europe which need to be considered by expanding the level of detail at which these data are presented.

Figure 4.2 shows the differences between countries in terms of the magnitude and direction of transfers between pasture and arable and permanent crops.

Table 4.1 The 'agricultural account' for Europe, 24 countries, 1990–2000 (cont.)

Table 4.1c Indicators

Corine land cover types	Net change in agriculture land cover (Stock 2000 — Stock 1990)	Agricultural land uptake by urban and other land use (IRENA12 — LCF1 to 3 and LCF8)	Net uptake of forests and semi-natural land by agriculture (IRENA24a — LCF5 minus LCF6)	Net conversions from pasture to arable land (IRENA24b — LCF46 minus LCF41)	Total agriculture internal land cover conversions (LCF4)	Net agriculture internal conversions (LCF4/2000 minus LCF4/1990)
1 Artificial areas						
211 Non-irrigated arable land	– 9 393	4 191	– 2 121	– 9 049	13 493	– 4 506
212 Permanently irrigated land	3 010	176	– 34	– 170	790	2 842
213 Rice fields	– 84	4	– 8	– 27	619	– 99
221 Vineyards	– 193	89	– 59	– 49	926	– 166
222 Fruit trees and berry plantations	53	178	– 58	– 43	948	8
223 Olive groves	502	116	– 82	– 1	225	559
241 Annual crops associated with permanent crops	– 359	165	– 31	– 157	252	– 195
2A Arable land and permanent crops total	**– 6 463**	**4 918**	**– 2 393**	**– 9 496**	**17 252**	**– 1 557**
231 Pastures	– 1 446	1 422	– 924	7 412	7 412	420
242 Complex cultivation patterns	– 341	1 637	– 317	1 098	2 543	1 197
243 Agriculture mosaics with natural vegetation	– 918	612	– 325		10	– 10
244 Agro-forestry areas	430	65	– 358	97	97	– 50
2B Pastures and mosaics total	**– 2 275**	**3 735**	**– 1 925**	**8 608**	**10 062**	**1 557**
3A Forested land			**1 796**			
3B Semi-natural vegetation			**1 734**			
3C Open spaces/bare soils			**155**			
4 Wetlands			**96**			
5 Water bodies			**50**			
Stock and consumption of land cover 1990, km²	**– 8 738**	**8 654**	**– 4 318**	**– 888**	**27 314**	**0**

The figures show the net transfer for the period 1990–2000 normalised by the country area. Positive values indicate a net flow from pasture to arable, and negative values the opposite trend. In order to capture some of the spatial patterns in the dynamics of this measure, a map has also been provided. The exchange of land between arable and pasture is one of the land cover indicators suggested by the IRENA initiative (IRENA 24b), and is proposed as a way of looking at the balance between the processes of agricultural intensification and extensification. Thus, the account database allows us to map this indicator across the area of Europe for which CLC change data are available. It is evident that there are considerable differences in the balance between these two land cover categories.

In Estonia, Ireland, Lithuania, the Netherlands and, for example, there was a net transfer of agricultural land from pasture into arable land. In Ireland, the change was particularly evident, and was partly driven by the expansion of forage crop production that was associated with changing animal husbandry practices, particularly in the early part of the 1990s. Increasingly, animals wintered indoors and this required increased amounts of silage. The same change may also explain the transfer between pasture and arable seen in the Netherlands. The inset map shown in Figure 4.2 presents the same data but at a more geographically disaggregated scale. It uses the hybrid NUTS regions described in Chapter 3. In France, while at the national scale there appears to be only a small transfer of pasture to arable in statistical terms, we can see that the transfer is particularly marked in the Paris basin and in the valley of the Garonne. Similarly, in Poland, the transfer mainly occurs in the polder areas on the delta of the Vistula river. The same local trends can be observed in some regions of Greece, Hungary and Romania.

By contrast, elsewhere in Europe it is apparent that there has been a net conversion of arable into pasture. These trends are particularly evident in the Czech Republic and Germany, which together account for more than half of the increase in set-aside, fallow land and pasture. In the Czech Republic the change was the direct result of government policy which provided farmers with incentives to maintain pasture.

4.2.3 *Agriculture at the margins*

The loss of pasture and arable land at the urban interface deals with the dynamics of the agricultural landscape at one of its 'margins'. The other margin that we have to consider is that with forest and semi-natural land. It is here that new farmed areas can be created, or areas previously used for farming abandoned. In any set of asset accounts for land that seeks to capture the effect of human activities on our natural capital, the dynamics of the interface between agriculture and our forested and semi-natural landscapes is a particularly important one to consider. The importance of looking at these processes has also been emphasised by the IRENA initiative, which suggested that such a measure should be included in its suite of land cover indicators (i.e. IRENA 24a).

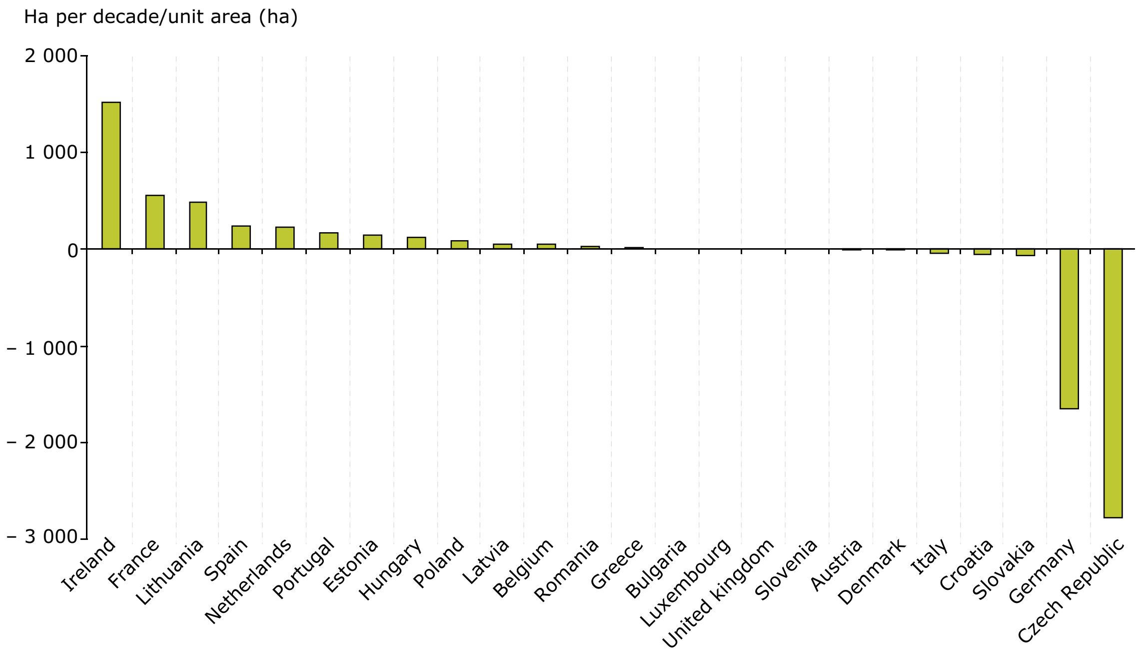
Figure 4.3 shows the net exchanges between agriculture and forest and semi-natural land; expressed on an annual basis for the countries for which CLC change data are available for the period 1990–2000. The key flows that need to be considered are the:

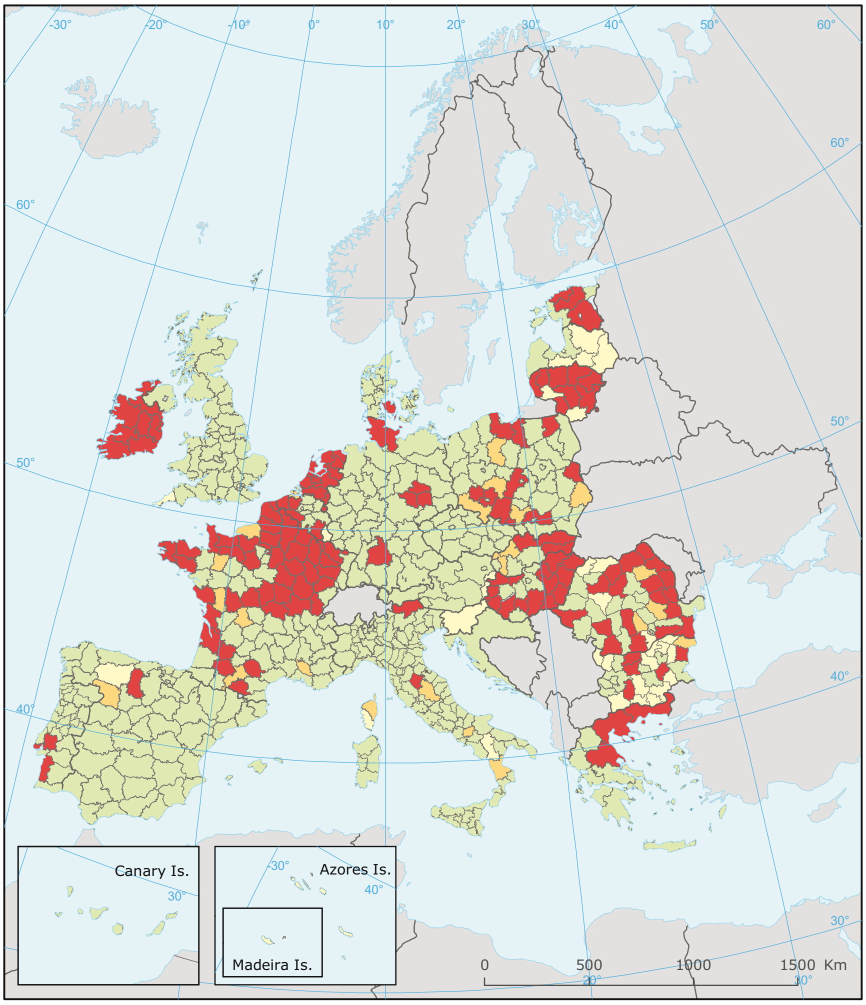
- conversions from forest to agriculture (LCF51);
- conversions from dry semi-natural and natural land to agriculture (LCF52);
- conversions from wetlands to agriculture (LCF53);
- withdrawal of farming with woodland creation (LCF61);

Table 4.2 Estimation to urban/artificial development of the relative direct and indirect contribution of agriculture and forests + semi-natural land, European coast (10 km), 19 countries, 1990–2000

Regional sea basins		Land take by urban developement 1990–2000 (LCF13+LCF2+LCF3, Consumption) km²	LCF5 Conversion from other land cover to agriculture	Net consumption of agriculture land cover	Total consumption of forest and semi-natural land by urban and agriculture
	2 Agricultural areas	30 583	96		
	3 Forest and semi-natural areas	2 965	1 121		
	4 Wetlands	276	98		
	5 Water bodies	566	16		
1 North Sea total		**34 390**	**1 331**	**29 252**	**5 042**
	2 Agricultural areas	54 389	4 150		
	3 Forest and semi-natural areas	22 550	26 502		
	4 Wetlands	336	359		
	5 Water bodies	1 768	350		
2 Mediterranean Sea total		**79 043**	**31 361**	**23 028**	**51 865**
	2 Agricultural areas	950	116		
	3 Forest and semi-natural areas	37	8		
	4 Wetlands	49	47		
	5 Water bodies				
3 Black Sea total		**1 036**	**171**	**779**	**141**
	2 Agricultural areas	13 387	183		
	3 Forest and semi-natural areas	874	425		
	4 Wetlands	142	171		
	5 Water bodies	272			
4 Baltic Sea total		**14 675**	**779**	**12 608**	**1 884**
	2 Agricultural areas	50 610	5 528		
	3 Forest and semi-natural areas	18 333	14 881		
	4 Wetlands	501	1 115		
	5 Water bodies	790			
5 Atlantic Ocean total		**70 234**	**21 524**	**29 086**	**35 620**

Figure 4.2 The transfers of land between pasture and arable cover types across Europe: net conversion from pasture to arable land and permanent crops, 24 countries, 1990–2000, ha per year





Pasture to arable land

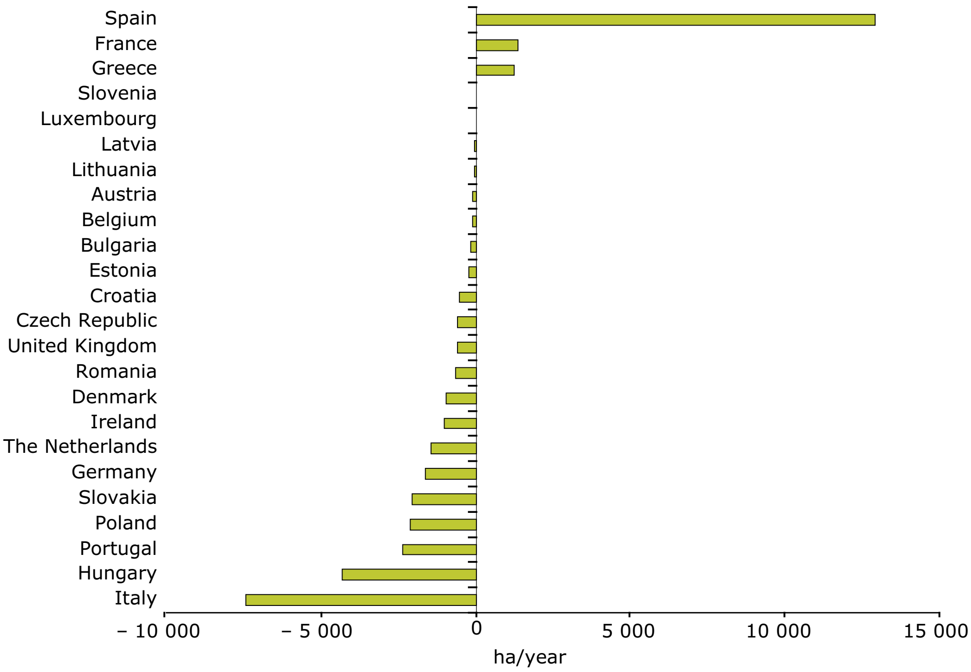
% difference to European mean value

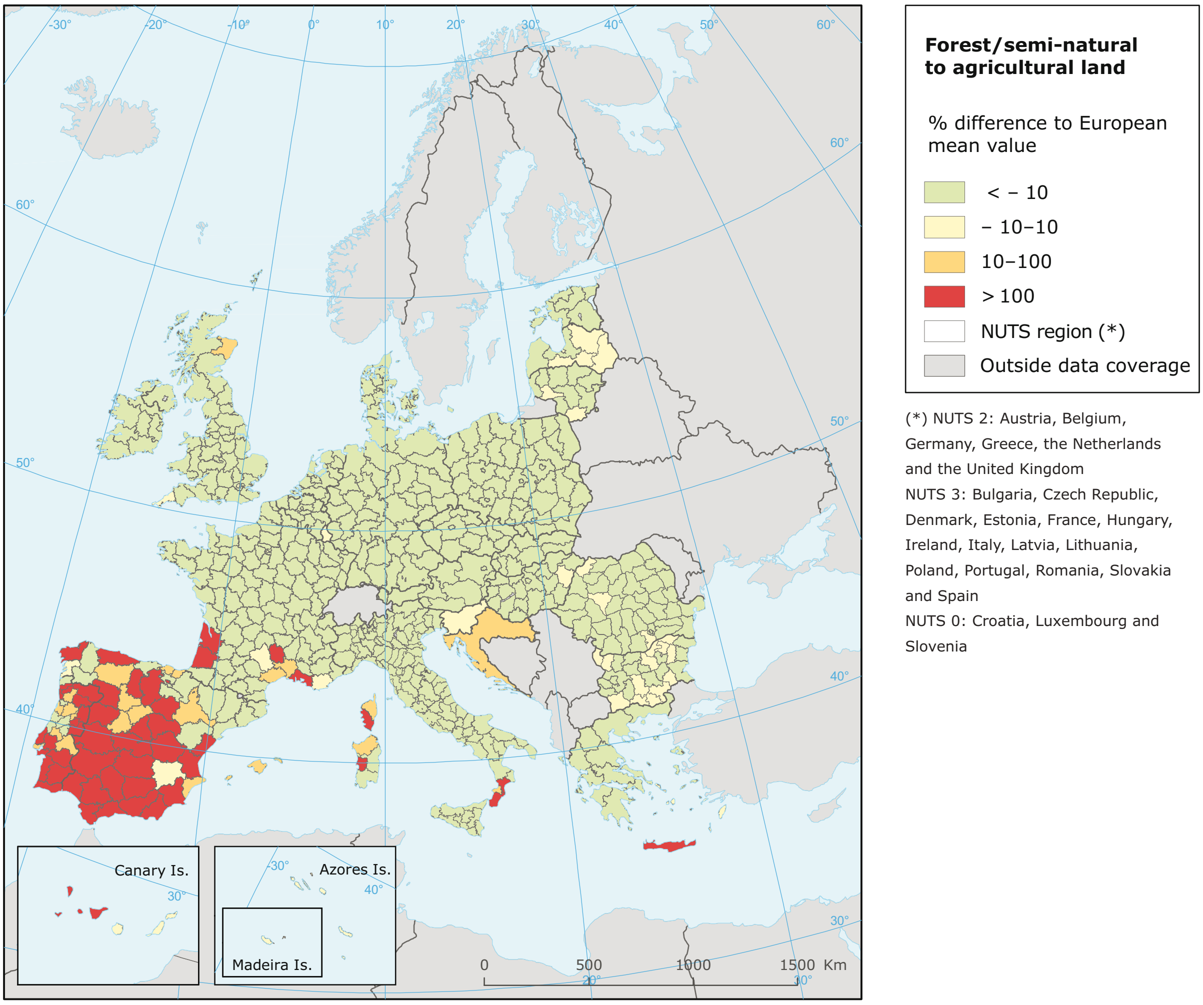
- < – 10
- – 10–10
- 10–100
- > 100
- NUTS region (*)
- Outside data coverage

(*) NUTS 2: Austria, Belgium, Germany, Greece, the Netherlands and the United Kingdom
NUTS 3: Bulgaria, Czech Republic, Denmark, Estonia, France, Hungary, Ireland, Italy, Latvia, Lithuania, Poland, Portugal, Romania, Slovakia and Spain
NUTS 0: Croatia, Luxembourg and Slovenia

Source: Data: EEA; NUTS boundaries: Eurogeographics.

Figure 4.3 The transfers of land between agriculture and forest and semi-natural cover types across Europe





(*) NUTS 2: Austria, Belgium, Germany, Greece, the Netherlands and the United Kingdom
NUTS 3: Bulgaria, Czech Republic, Denmark, Estonia, France, Hungary, Ireland, Italy, Latvia, Lithuania, Poland, Portugal, Romania, Slovakia and Spain
NUTS 0: Croatia, Luxembourg and Slovenia

Source: Data: EEA; NUTS boundaries: Eurogeographics.

- conversions from wetlands to agriculture (LCF53);
- withdrawal of farming with woodland creation (LCF61);
- withdrawal of farming without significant woodland creation (LCF62).

Table 4.1c — Indicators — suggests that on the basis of the sum of these flows there has been a net loss of agriculture to forests and semi-natural of approximately 487 km^2 between 1990 and 2000. In Figure 4.3 we can see the considerable differences between countries. Positive values show the expansion of agriculture and negative values retreat. For example, at the country level conversion of forest and semi-natural marginal land to agriculture appears to be taking place in Spain and Greece. This process is in part due to the limited areas of good agricultural land and the loss of the best areas through urbanisation. In other places, however, it represents the expansion of more intensive industrialised agricultural practices which include the expansion of irrigated horticultural crops in the Mediterranean region.

Elsewhere in Europe, we can see clear patterns of land abandonment or the withdrawal of farming in marginal areas. Such trends can be observed in many of the mountain regions of Europe, and in Hungary, Slovakia, Portugal and Italy as well as in some parts of Germany, where arable land has been transformed to forest through the process of natural regeneration. In part the process has been triggered by the uneconomic nature of farming in more marginal areas. In Slovakia, however, it was also triggered partly by the fact that land was returned to its former owners who did not necessarily have an interest in farming. The marked transfer of agricultural land to forest and semi-natural cover observed in the Netherlands and Denmark probably reflects national policies in both these countries. In the Netherlands, policy measures had encouraged the protection and recreation of nature protection areas. In Denmark, many new forested areas were created mainly to protect groundwater aquifers from agricultural pollution.

4.3 Understanding complexity

This review of the land account data for agriculture that has been created from CLC change information has, of necessity, been presented at a fairly general level. Nevertheless, the examples show that it is possible to disaggregate the data either thematically or geographically to discover the detail that lies within the database, and to construct a series of policy-relevant indicators that can be used to gain an overview of key trends and processes.

It must be acknowledged, however, that more refined types of analysis are needed to fully understand the complex nature of the changes that agricultural land cover can exhibit. As we have seen, the different countries of Europe and the regions within them can show quite different combinations of trends, so that overall interpretation is often highly specific to particular localities. Even from this general analysis it is clear that no simple patterns of intensification and extensification across Europe are evident. Thus, in countries such as Ireland, Hungary, the Netherlands and Portugal, we have seen both the transfer of pasture into arable and the expansion of woodland and semi-natural at the expense of agricultural land. Such counter trends may suggest a degree of polarisation in the agricultural landscape. By contrast other countries, such as the Czech Republic, Germany and Slovakia show both increases in pasture at the expense of arable and loss agricultural land to forest and semi-natural. This possibly implies a more uniform trend towards more extensive forms of land cover.

It is likely that only by mapping the account data at a range of spatial scales will it be possible to fully understand the implications of land cover change. Later we will describe some of the mapping tools which can be used to refine the analysis and reporting of land account data in detail. However, to complete this more general introduction to the accounting database we conclude by turning our attention to forests and semi-natural habitats.

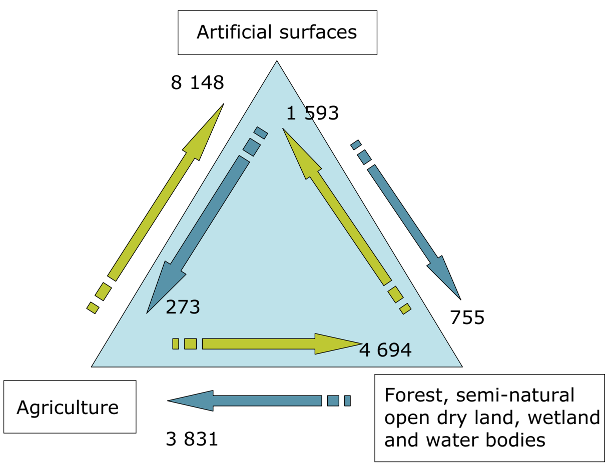
5 Patterns of change in forests and semi-natural habitats 1990–2000

5.1 Introduction

One way to visualise the dynamics of land cover in Europe at the most general level is in terms of the 'three-cornered' relationship between artificial surfaces, agriculture and forests and semi-natural habitats (Figure 5.1). As we have seen, between 1990 and 2000 development largely occurred at the expense of agricultural land. In turn, the total stock of agricultural land has declined as a result of the net transfer to artificial surfaces and forest and semi-natural elements. Although there has been a net flow into artificial, on balance the overall stock of forest and semi-natural habitats was maintained.

For completeness we have included the information on wetlands, water bodies, and open and bare surfaces in this chapter alongside forest and semi-natural habitats in order to estimate the flows and stocks shown in Figure 5.1. The picture shown is over-simplified and so in this chapter we also explore the patterns in more detail to better understand the impact of land cover change on those cover types with potentially the highest

Figure 5.1 The dynamics of major land cover types in Europe, 1990–2000



Note: All figures are in km² and are the total flows for the decade 1990–2000. The dark arrows indicate the dominant direction of flow.

conservation value. The relative proportions of the different elements are shown in Figure 5.2. The accounts suggest that although, collectively, the total stock of all these types has increased slightly, their individual dynamics is often quite different.

5.2 Dominant landscape types

The earlier chapters of this report emphasised the importance of mapping the account data as a way of exploring the detail that they hold. The approach illustrated was based on the system of administrative units (NUTS regions) for Europe. Clearly there are other types of spatial framework that can be used. For example, the gridded structure that is used to hold the CLC land account data can be used to look at the dominance and combination of the major land cover types in each 1 km² cell across Europe. This information allows us to identify, for example, the major landscape types that occur across Europe, and all those areas where forest and semi-natural cover types dominate (see Chapter 2). The 'green background' map (Figure 2.7), for example, was used as a way to potentially identify where landscape of higher nature-conservation value might be found. The dominant landscape types can also be used to disaggregate the account data to explore how the dynamics of land cover varies spatially (see Chapter 2, Figure 2.8).

Figure 5.3 shows the net formation of the major land cover types in each of the major landscapes, as a percentage of the 1990 stock. A number of features are evident. As might be expected given the discussion in the earlier chapters, agricultural land (both arable and pasture) shows loss in the dense and dispersed urban landscapes. In the latter, the loss of open space and bare soils is especially marked, possibly reflecting the way these areas are being in-filled through development. The increase in arable and loss of pasture mainly appears to be occurring in the composite rural landscapes. By contrast, the loss of arable and expansion of pasture is more marked in the areas dominated by forests and where no dominant land cover exists.

The stock of forests is either stable or increasing across all the dominant landscape types of Europe. The greatest percentage change is observed in the open semi-natural landscapes. By contrast, for semi-natural habitats, these show loss across all landscapes except the composite rural type. Even where they dominate, their stock has declined by nearly 2 %. This is possibly the result of forest expansion, although in this landscape type the expansion of artificial areas is also marked. Wetlands and open bare spaces and soils appear mostly to decline in all landscape types except that of dense urban, while the area of water bodies has increased throughout.

The factors that have driven these changes are complex, and possibly quite specific to particular areas. Some insight may, however, be gained, by looking at the land accounts for the forest and semi-natural separately.

Figure 5.2 The extent of forests, semi-natural areas, wetland and water bodies in Europe, 2000

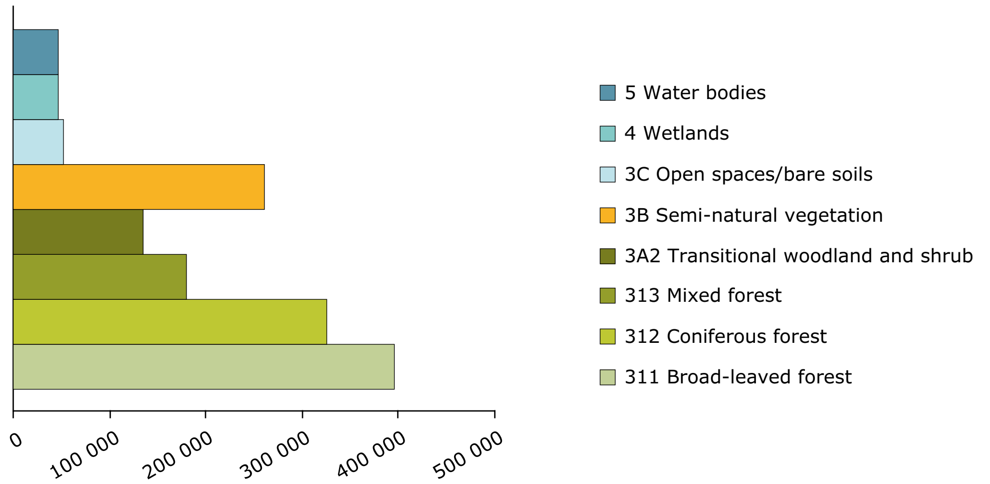
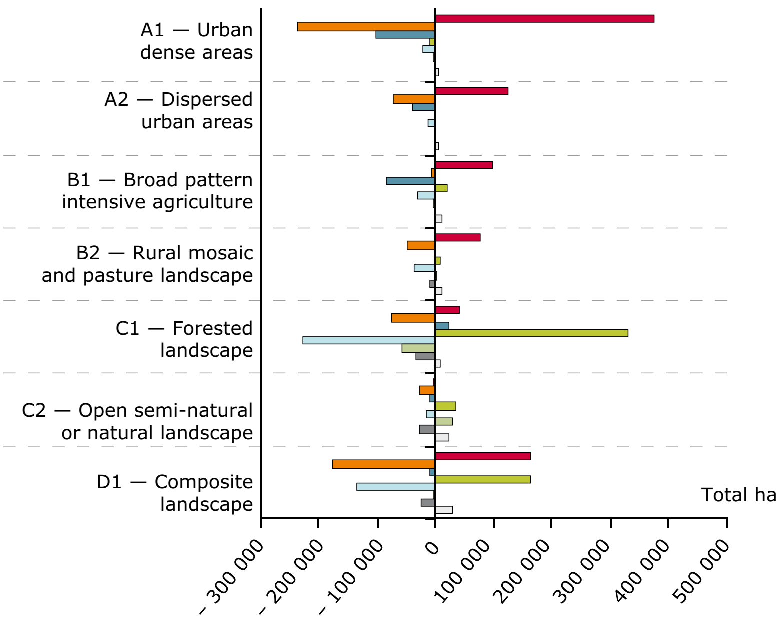


Figure 5.3 Net formation of land cover across the dominant landscape types



5.3 The account for forest

The forest account for those countries for which CLC data change are available for the period 1990–2000 is shown in Table 5.1. Forest is made up of two major elements, standing forests and transitional woodland and shrub. Standing forest, which itself can be split into broadleaved, coniferous and mixed woodlands, is the larger of the two. Its area far exceeds that of any of the other types considered in this chapter (Figure 5.4). Between 1990 and 2000 the land accounts suggest that the extent of this element increased by about 0.1 %. Much of the stock is, however, commercial forest, and so, as one might expect, there has been a good deal of turnover (about 5 %) due to the normal cycle of felling and replanting. Overall, about 98 % of the original stock of standing forest was carried over to 2000 from 1990.

Transitional woodland and shrub is the second, smaller component of forest. Of the two components, however, it appears to be much more dynamic. Between 1990 and 2000, its cover increased by nearly 4 %. But since the magnitude of flows for consumption and formation were as large as those for standing forest, there was a significant turnover of initial stock of this resource. The land accounts show that about 34 % of the initial cover of transitional and shrub woodlands turned over, and only 85 % of the 1990 stock was carried over to 2000.

The more volatile character of transitional woodland and shrub compared to standing forest probably reflects its 'successional' status. Thus, there are significant transfers from this cover type to standing forest over the accounting period, and significant additions through the processes of afforestation and agricultural abandonment. Table 5.1 shows that most of the new woodland creation was achieved through the transitional woodland and shrub category, and that about 25 % of the new stock was created by withdrawal of farming. It is also interesting to note that in terms of its susceptibility of conversion to agriculture or artificial surfaces, the transitional woodland and shrub class was also the most vulnerable. Table 5.1 shows that nearly 55 % of the consumption of forest by agriculture and sprawl of artificial surfaces was from this cover type.

There are of course considerable differences between countries and regions in terms of the dynamics of forest cover. For example, there has been major afforestation in Ireland, Portugal, Spain and the United Kingdom. In Italy, withdrawal of farming and afforestation in the Alps and Apennines has been triggered by the abandonment of pastures and the decline of farming on terraces. Where new forests replace land that was previously farmed, the change may be beneficial, especially if it provides an alternative source of income to farmers in areas where agriculture is no longer profitable. However, in some areas it appears that the expansion of woodland has occurred at the expense of semi-natural habitats. In Ireland, for example, there has been some afforestation of blanket peat-bog, although this practice has now declined. These kinds of processes may partly explain the dynamics of forest and semi-natural habitats identified in Figure 5.3.

Figure 5.4 Consumption and formation of forested land

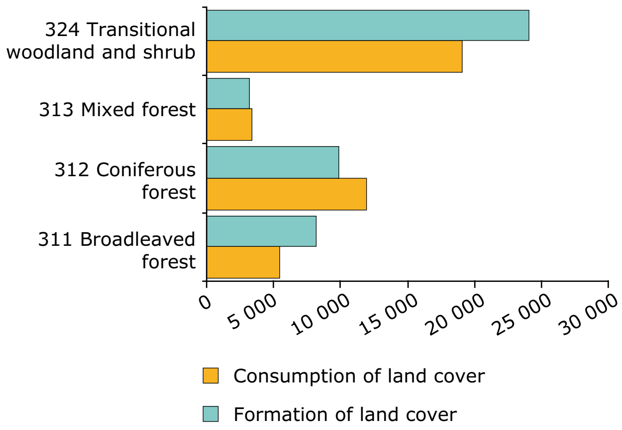
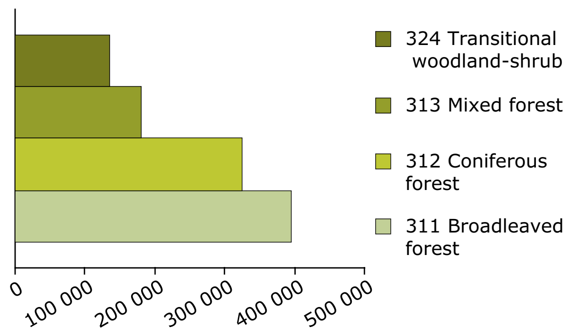


Figure 5.5 The stocks of forest types in Europe 1990–2000



5.4 The account for open semi-natural and wetland

Table 5.2 and Figure 5.6 shows the European account for semi-natural habitats for the period 1990–2000. In contrast to forests, whose stock increased between 1990 and 2000, the loss of semi-natural exceeded formation and so there was a small overall decline of about 0.1 %. In terms of consumption and formation

Table 5.1 The detailed forest account for Europe, 1990–2000

	311 Broad-leaved forest	312 Coniferous forest	313 Mixed forest	S/total 31 Standing forests	324 Transitional woodland-shrub	Total Forested Land
Forested land, stock 1990, hectares	**39 217 609**	**32 755 535**	**18 032 376**	**90 005 520**	**13 057 930**	**103 063 450**
LCF13 Development of green urban areas		32		32		32
LCF21 Urban dense residential sprawl	32	82	22	136	72	208
LCF22 Urban diffuse residential sprawl	2 786	7 001	3 852	13 639	6 174	19 813
LCF31 Sprawl of industrial and commercial sites	2 769	4 282	3 456	10 507	3 080	13 587
LCF32 Sprawl of transport networks	1 095	882	512	2 489	764	3 253
LCF33 Sprawl of harbours	14			14	12	26
LCF34 Sprawl of airports	165	313	68	546	152	698
LCF35 Sprawl of mines and quarrying areas	8 525	9 086	3 689	21 300	7 355	28 655
LCF36 Sprawl of dump sites	618	281	342	1 241	1 275	2 516
LCF37 Construction	2 651	3 246	1 663	7 560	2 500	10 060
LCF38 Sprawl of sport and leisure facilities	1 559	3 430	947	5 936	1 738	7 674
LCF1+LCF2+LCF3 Total conversion from forest to artificial land cover	**20 214**	**28 603**	**14 551**	**63 368**	**23 122**	**86 490**
LCF511 Intensive conversion from forest to agriculture	12 599	7 708	4 316	24 623	21 962	46 585
LCF512 Diffuse conversion from forest to agriculture	23 030	10 581	5 054	38 665	94 338	133 003
LCF51 Conversion from forest to agriculture	**35 629**	**18 289**	**9 370**	**63 288**	**116 300**	**179 588**
LCF71 Conversion from transitional woodland to forest (consumption)					1 690 300	1 690 300
LCF73 Forests internal conversions (consumption)	9 906	11 854	12 374	34 134		34 134
LCF74 Recent fellings, new plantation and other transition (consumption)	461 000	1 099 445	295 441	1 855 886		1 855 886
LCF7 Forest creation and management	**470 906**	**1 111 299**	**307 815**	**1 890 020**	**1 690 300**	**3 580 320**
LCF8 Water bodies creation and management	**5 951**	**1 250**	**927**	**8 128**	**3 590**	**11 718**
LCF911 Semi-natural creation					54 867	54 867
LCF913 Extension of water courses	492	15	5	512	142	654
LCF92 Forests and shrubs fires	8 731	35 479	5 381	49 591	25 345	74 936
LCF93 Coastal erosion					19	19
LCF99 Other changes and unknown	571	565	136	1 272		1 272
LCF9 Change due to natural or multiple causes	**9 794**	**36 059**	**5 522**	**51 375**	**80 373**	**131 748**
Total consumption of forested land 1990	**542 494**	**1 195 500**	**338 185**	**2 076 179**	**1 913 685**	**3 989 864**
LCF61 Withdrawal of farming with woodland creation	**70 163**	**36 499**	**12 651**	**119 313**	**159 917**	**279 230**
LCF71 Conversion from transitional woodland to forest (formation)	669 039	761 644	259 617	1 690 300		1 690 300
LCF72 Forest creation, afforestation	70 590	185 246	27 913	283 749	469 583	753 332
LCF73 Forests internal conversions (formation)	10 648	8 331	15 155	34 134		34 134
LCF74 Recent fellings, new plantation and other transition (formation)					1 776 888	1 776 888
LCF7 Forest creation and management	**750 277**	**955 221**	**302 685**	**2 008 183**	**2 246 471**	**4 254 654**
LCF99 Other changes and unknown					**405**	**405**
Total formation of forested land 2000	**820 440**	**991 720**	**315 336**	**2 127 496**	**2 406 793**	**4 534 289**
Forested land, stock 2000, hectares	**39 495 555**	**32 551 755**	**18 009 527**	**90 056 837**	**13 551 038**	**103 607 875**
Net formation of forest and woodland (formation – consumption)	277 946	– 203 780	– 22 849	51 317	493 108	544 425
Net formation of forest and woodland as % of 1990	0.7	– 0.6	– 0.1	0.1	3.8	0.5
Forested land 2000 as % of LEAC24 territory	11.0	9.0	5.0	25.0	3.8	28.8

(Figure 5.7), the largest losses to semi-natural were through forest creation, which accounted for about 66 % of the loss. Loss to forestry also accounted for about 60 % of the consumption of wetlands. It is interesting to note that urban sprawl represented about 7 % of the loss to semi-natural, whereas conversion to agriculture consumed only about 2 %. The main contributor to the stock of semi-natural habitats was the abandonment of farmland that did not result in woodland creation. This flow accounted for about 22 % of the new stock formed. Fire, through the creation of burnt areas, contributed about another 21 % to semi-natural cover.

5.5 Spatial analysis of stocks and flows

The data for change in the extent of forest and semi-natural areas provide a base-line against which future spatial planning policy and the impacts of development and agriculture on key natural resource systems can be assessed. Although these data are useful in identifying broad trends, insights into the processes active on the ground can probably only be gained through more detailed spatial analysis. The accounting grid on which these data are held allows such analyses to be made.

Table 5.2 The account for open dry semi-natural land and wetlands in Europe, 1990–2000

	321	322	323	33	411	412	421	422	423	5	
	321 Natural grasslands	322 Moors and heathland	323 Sclerophyllous vegetation	3C Open spaces/ bare soils	411 Inland marshes	412 Peat bogs	421 Salt marshes	422 Salines	423 Intertidal flats	5 Water bodies	Total, km²
Semi-natural land, stock 1990, km²	110 492	57 750	96 690	52 593	10 839	22 085	2 921	710	10 359	45 854	410 294
LCF1 Urban land management	6	1	1	0			0				9
LCF2 Urban residential sprawl	81	11	53	8	1	0	1	0	0	2	158
LCF3 Sprawl of economic sites and infrastructures	202	72	178	35	6	9	5	1	2	53	562
LCF4 Agriculture internal conversions											
LCF5 Conversion from other land cover to agriculture	852	104	779	155	57	35	3	0		50	2 035
LCF6 Withdrawal of farming											
LCF7 Forests creation and management	1 959	1 218	1 989	1 048	43	1 015	5			3	7 279
LCF8 Water bodies creation and management	97	16	77	17						21	228
LCF9 Changes due to natural and multiple causes	415	187	721	1 041	91	6	12		121	252	2 846
Consumption of land cover 1990	**3 612**	**1 608**	**3 799**	**2 304**	**198**	**1 065**	**26**	**1**	**122**	**381**	**13 117**
LCF1 Urban land management											
LCF2 Urban residential sprawl											
LCF3 Sprawl of economic sites and infrastructures											
LCF4 Agriculture internal conversions											
LCF5 Conversion from other land cover to agriculture											
LCF6 Withdrawal of farming	594	48	602	23	56	7	7			0	1 337
LCF7 Forests creation and management	178	66	522	24							790
LCF8 Water bodies creation and management				21						1 021	1 042
LCF9 Changes due to natural and multiple causes	798	246	1123	1790	123	18	14	16	143	260	4 530
Formation of land cover 2000	**1 571**	**359**	**2 247**	**1 858**	**179**	**25**	**21**	**16**	**143**	**1 280**	**7 698**
Semi-natural land, stock 2000, km²	108 451	56 501	95 138	52 147	10 821	21 044	2 916	725	10 380	46 754	404 876
Net formation of semi-natural land (formation − consumption)	1 571	359	2 247	1 858	179	25	21	16	143	1 280	7 698
Net formation of forest and woodland as % of 1990	1.4	0.6	2.3	3.5	1.7	0.1	0.7	2.2	1.4	2.8	1.9
Semi-natural land 2000 as % of LEAC24 territory	3.0	1.6	2.6	1.4	0.3	0.6	0.1	0.0	0.3	1.3	11.3

As we have seen the dominant land cover types in each 1 km² can be used to classify the major landscape types of Europe. Other techniques, such as those provided by the CORILIS initiative, can also be used to present these data in ways that do not tie them to administrative boundaries. Figure 5.8 is an example of how 'urban temperatures' can be mapped by looking at the spatial concentrations of artificial surfaces at different spatial scales. These can be used to look at the juxtaposition of urban areas with sites of high nature conservation value

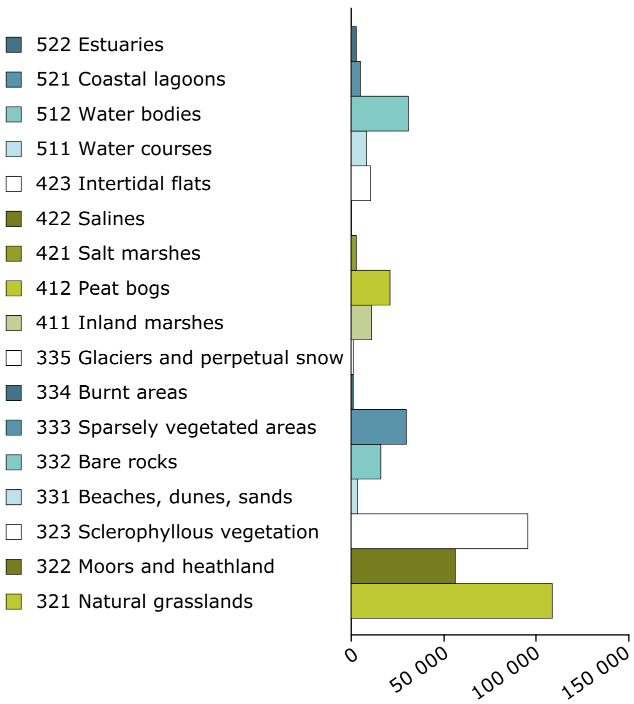
The CORILIS methodology has been developed in France jointly by the Hypercarte Research Group, INSEE and IFEN (see Grasland *et al.* 2000). It has been designed as a tool that can be used to map the spatial 'intensities' or 'potentials' across a region. The approach can be applied to any grid-based data, such as CLC. It operates by a process of smoothing, which modifies the values in each cell of the grid according to its neighbourhood. The original value in each cell is replaced by a weighted mean derived from the values of the neighbours divided by the square of the distance between the centres of the corresponding cells. The approach was first applied to demographic data, but was extended to be used with Corine land cover data, a development which gave rise to the name 'CORILIS' ([14]).

A more detailed description of the CORILIS approach will be provided in Part III of this report. At this stage it is more useful to gain some familiarity with the kinds of output that can be generated and its potential use in relation to the analysis and presentation of land cover account data. Figure 5.8 shows an example of the types of output that the CORILIS methodology can produce. The European scale map has been constructed by calculating the density of artificial surfaces as recorded on the CLC map for 1990 and 2000, within circular radius of 5, 10 and 20 km for every 1 km² cell in the European grid. Figure 5.8a maps the variations in urban density and the gradients of urban influence in a region. As the inset (Figure 5.8b) shows, the approach can be useful as a backdrop upon which other types of process of resource can be considered.

In order to illustrate the types of analysis that are possible using the CORILIS approach, Figure 5.8b shows an extract for a smaller area around Paris. In this map 'urban temperature' (influence) has been calculated using a 5 km search radius. This map has been overlaid with information on the location of 1 km² cells that show evidence of urban sprawl during the period 1990–2000. It can be seen that while much of it is concentrated in and around existing urban centres, the spread of development along the major route corridors is serving to infill and connect up existing settlements so that the extent of urban influence is spreading. Clearly the implications and impacts of such change may be many and varied. For those interested in the implications for the conservation of key nature conservation sites, these data can be extremely useful if they are looked at alongside the locations of say, the Europe's network of Natura 2000 sites. These sites have also been included in the inset map shown in Figure 5.8b, from which we can begin to identify sites, such as the one south east of Paris, which may be vulnerable to the effects of urban expansion.

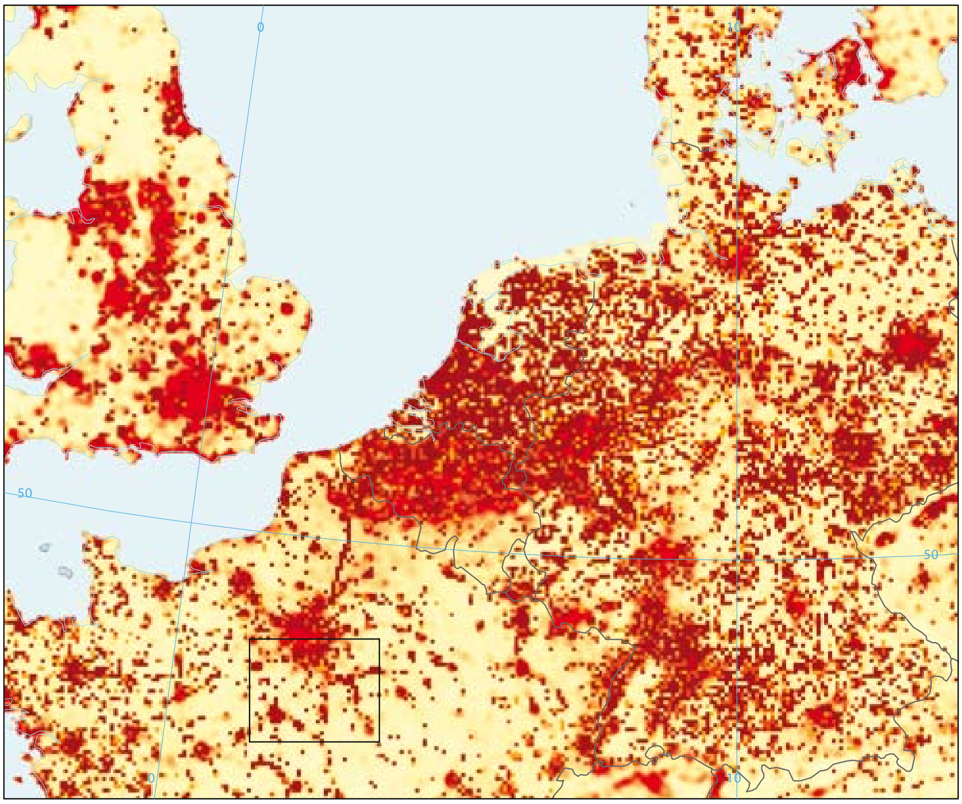
At a regional scale such maps can be used as part of the evaluations that might be needed when policies are subject to, for example Sustainability Impact Assessment. At the national or European scale, ultimately such data can be used to construct a specific or customised asset account showing the number and types of Natura 2000 sites subject to different degrees of urban influence, and thus the proportion of the habitat resource at potential risk. The changing urban temperature of nature conservation sites might be one way of recording

Figure 5.6 The magnitude of semi-natural vegetation, open bare surfaces, wetland and water bodies

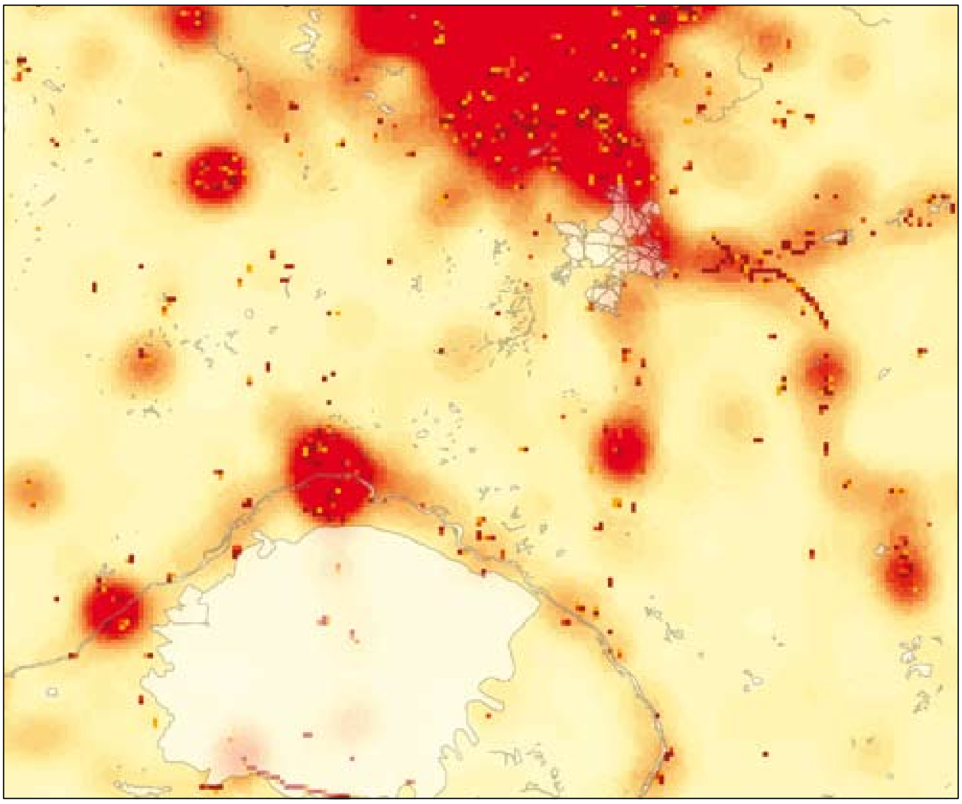


([14]) CORILIS = 'Corine' + 'LISsage' ('smoothing' in French).

Figure 5.8 CORILIS map of urban temperatures, and locations of major increases



A map of urban influence or 'urban temperatures' constructed using the CORILIS methodology which has been used to calculate the density of artificial surfaces recorded on CLC 1990, within a 10 km radius of each point.



A map showing the area around Paris in more detail, this time using a 5 km search radius to calculate 'urban temperature'. The map has been overlaid with the location of 1 km cells in which urban sprawl occurred between 1990 and 2000, and the location of Natura 2000 sites (white polygons).

Artificial surfaces

High: 100

Low: 0

Urban sprawl 1990–2000

1–5 %

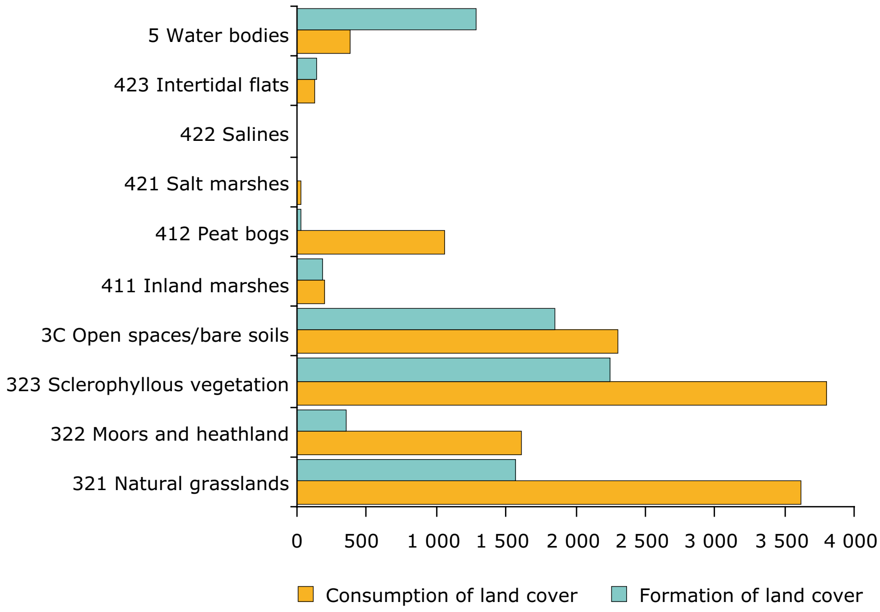
5–10 %

> 10 %

Natura 2000 sites

Note: The map gives a picture of contrasts between urban development attracted by cities and landscapes with low urban temperature. Both importance and location can be visualised.

Figure 5.7 Consumption and formation of dry semi-natural land and wetland



the number and types of Natura 2000 sites subject to different degrees of urban influence, and thus the proportion of the habitat resource at potential risk. The changing urban temperature of nature conservation sites might be one way of recording pressure on environmental quality and an indicator that can be used to track the condition of key elements of our natural capital over time.

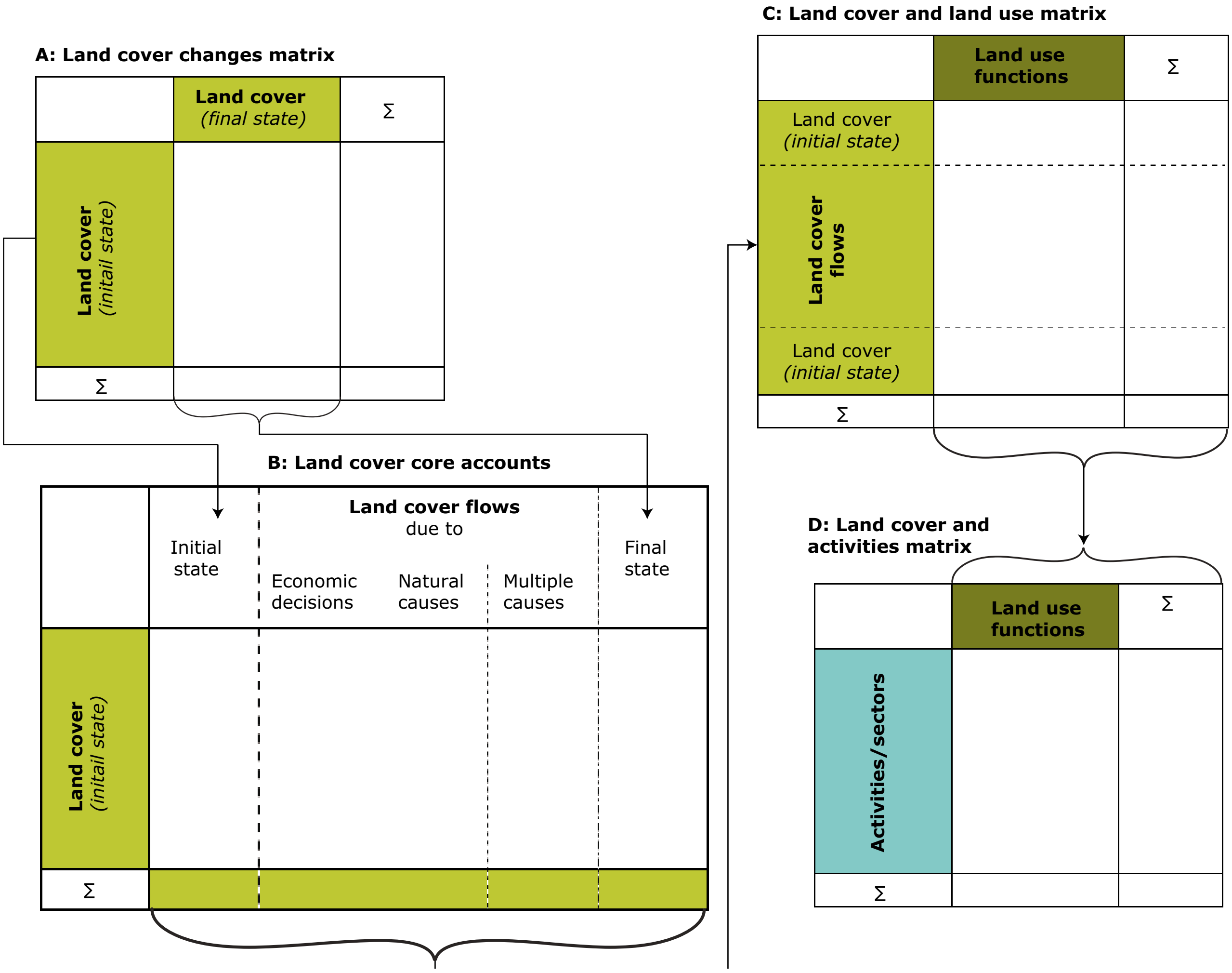
6 The structure of land cover accounts

6.1 The accounting model

The concept of a stock and flow account for land cover was introduced in Chapter 1 of this report. Chapters 2 to 5 provided a range of examples to illustrate how the idea can be applied. This chapter describes in more detail the general conceptual model that underpins the approach.

The aim of developing land accounts, like those for other types of environmental asset, is to describe how resource stocks change over time in a consistent and systematic way so that the implications of change can be better understood. Land is unlike most other natural resources, however, because over periods relevant to most policies it cannot be created or destroyed ([15]). Rather, it is mostly the potentials and capabilities of land that are transformed through human action. This is expressed by the different uses which particular types of land cover can support. A key concern of land cover accounts is the need to understand the way in which the stocks

Figure 6.1 The structure of land cover and land use accounts



([15]) The local importance of coastal reclamation and erosion are, however, acknowledged.

of different land covers and uses are transformed over time.

The approach adopted by the EEA follows that recommended in the SEEA2003 handbook (SEEA, 2003). The methods grew out of work carried out in the mid-1990s by a UNECE task force on physical environmental accounts (see UNECE, 1995, Parker *et al.* 1996, and Haines-Young, 1996), which sought to describe the relationship between the stock of land and the associated uses as a set of linked tables (Figure 6.1).

The basis of the SEEA approach is to represent the transformation of land cover over time as a transition matrix which describes the transfers into and out of the different cover categories between two time periods (Figure 6.1(A)). Because such matrices are difficult to read, these data can be presented more usefully in the form of the flow account shown in Figure 6.1(B). These are the types of account illustrated in Parts I and II of this report, which were populated by Corine land cover change data for the period 1990–2000.

The schema shown in Figure 6.1 highlights a fundamental distinction that has to be made in the development of asset accounts for land, namely that between 'cover' and 'use'. Land cover reflects the biophysical characteristics of the earth's surface and would include categories such as built-up areas, grassland, forests, rivers and lakes. Land use, on the other hand, describes the purposes or economic activities (functions) associated with a given piece of land. Typical categories for land use are dwelling (housing), industrial use, transport, agriculture, forestry, recreational use and nature protection (see McConnell, 2000).

The accounts developed for land essentially deal with cover, because the cover data from Corine are derived from the interpretation of remotely sensed imagery which mostly depends on information about the biophysical characteristics of the earth's surface. Land use is often a more complex dimension to describe than land cover, because a single land cover type can fulfil many purposes. Indeed in many parts of the world, multi-functional land use is the norm. Thus, there may be a 'one-to-many' relationship between cover and use.

The approach described in Figure 6.1 shows how the flow accounts for cover can be extended to cope with the complex relationship that exists between land cover and use. Thus, in Figure 6.1(C) the stocks and flows of cover can be associated (crossed) with a set of land use functions in the form of a matrix, which can then be linked to information about the activity sectors in the economy that give rise to particular types of land use (Figure 6.1(D)).

At this stage it has not been possible to extend the land cover accounts developed by the EEA to fully make the link through land use to the activity sectors that characterise the European economy. In practice, however, a clear distinction between cover and use is often difficult to maintain in any classification system for cover, and so some types of link can be made implicitly. Thus, in the classification system used for Corine land cover, we see that some categories, especially those dealing with agriculture, have labels that clearly refer to some associated use. As a result, we have been able to partially explain the types of change that we have seen in terms of for example the withdrawal of farming or land abandonment in areas where the economics of agriculture are marginal. Nevertheless, the clear and explicit linkage between land cover and the economy through the concept of use remains an ultimate goal of the work undertaken here, and it is an issue to which we shall return in the discussion of the directions for future work.

6.2 Physical vs. monetary accounts

There is an ongoing debate concerning the ways in which the impact of the economy on the environment can best be represented. For many this involves putting monetary values on environmental goods and services and expressing impacts in terms of changes in marginal value. Others have argued that such monetisation is not needed in every case. The physical accounting approach is, for example, promoted in the SEEA framework not only on the grounds that it is difficult to assign monetary values to many environmental assets, but also because in any case monetisation is often unnecessary. Sustainability assessments are, for example, frequently based on judgments about whether stocks of a given set of resources are being maintained, and there is no reason why all forms of natural capital have to be represented by the same unit of measure.

The work builds on the proposition of the SEEA framework that while the development of monetary values for land resources might be desirable, physical accounts can be useful in their own right. Thus, the account presented seeks only to describe stocks and flows in physical rather than monetary units. In land cover accounts the units of measurement are generally those of area. In the accounts presented here, stocks are represented in km^2; the flows, especially the annual estimates, are given in ha/yr.

This approach is therefore consistent with that used more generally to develop asset accounts for other types of natural resource where volume, weight and length units have also been used to describe stock and change. Land accounts that include discrete objects, such as ponds, wells or wind turbines, can also be devised using simple feature counts.

Thus, while a key aim of the land accounts model might be to link changes in cover to economic activity through ideas about land use, the assignment of value to the land resources is not essential. Rather, establishing the link to the various economic sectors is possibly more important because it allows the drivers of land cover change to be better understood.

6.3 Satellite, basic and supplementary accounts

The underlying philosophy of the accounting model shown in Figure 6.1 is that it should provide a platform on which a range of other types of analysis can be built. Two aspects need to be considered to see what directions this work might take.

The first feature of the model that needs to be noted is that since it deals with resource flows in physical, rather than monetary terms, the data cannot be easily integrated into the standard national accounts as they are presently constructed. Rather, according to the SEEA terminology, they are best regarded as a set of external 'satellite accounts' that can be used to provide insights into processes or to assist decision-making. Although the environmental accounts are primarily expressed in physical units, it is clear that they can nevertheless be aligned with monetary valuations to build a 'hybrid' set of accounts, which can inform economic discussions.

In the case of the schema for land accounts shown in Figure 6.1, for example, the connection with the various activity sectors achieved by the identification of the land use functions can be used to help reflect how variations in economic output in different parts of the economy drive the processes of land use change. Other types of hybrid account could also be built to describe the different levels of defensive or protective expenditures arising out of decisions to encourage, prevent or mitigate certain types of land cover transformation. The integration of different data streams and types is an important benefit arising from the construction of asset accounts for land.

The second key feature of the model presented in Figure 6.1 is that the structure described relates only to what the SEEA terminology describes as the basic accounts for land cover. In the same way that these accounts can be developed to make a link to monetary value, they can be used to explore other characteristics of land cover, particularly those relating to the more qualitative attributes. Thus, a series of supplementary accounts could be built, describing for example the biodiversity or nature conservation value of a given set of land cover units, or the proportions of different stocks under different types of management or ownership. These supplementary accounts can be particularly useful in answering some of the key questions that arise in the context of sustainability where we need to consider not only the maintenance of the stock of a given resource, but also its quality as measured, for example by its capacity to continue to deliver benefits to society.

6.4 Scope and prospect

The accounting model presented in Figure 6.1 shows what form a fully developed set of basic land accounts would take. The implementation of such a set of accounts is clearly a major undertaking, and the work of the EEA is only the first step towards such an aim. As Parts I and II of this report have shown, the focus of recent efforts has mainly been to create consistent accounts for stocks and flows for the EEA member countries, rather than to create accounts linking cover to economic sectors via land use, or to develop supplementary accounts for themes such as biodiversity or whole ecosystems. Nevertheless, while these tasks need to be completed, it is appropriate to review what has already been achieved in order to provide a platform for future work.

An assessment of the robustness of the land accounting approach depends on the coherence of the conceptual models that underpin the work. Since the methodology used follows that recommended by the SEEA handbook, the approach of the EEA can justifiably be said to represent best practice. In order to make a final judgment, however, other aspects of the work must also be considered, not least the soundness of the data resources, and the systems used to classify stocks and flows of land cover and use at European scales. We now turn to these issues in the next three chapters of this report.

7 Representing stocks and flows using Corine land cover

7.1 Introduction

It could be said that the main problem of implementing environmental accounts for land cover lies not in their conceptual design but in assembly of a set of sufficiently robust data that can be used to populate the various tables. As the SEEA handbook notes, a precondition for policy relevant and scientifically sound land accounts is the availability of a good database.

Parts I and II of this report described some of the key results that have been obtained using the Corine land cover change data for the period 1990–2000. These chapters also highlighted the relevance of the analysis to policy. In order to demonstrate the robustness of these results, we must now turn to the details of the data sets themselves and the key analytical issues that relate to them.

7.2 The Corine database

The Corine (Coordination of information on the environment) initiative of the European Commission, which began in the mid 1980s, aimed to create the first database and geographical reference system for the European environment. Various projects were launched under the initiative, such as CORINAIR, Corine water, Corine biotopes, Corine soil erosion, and Corine coastal erosion. Corine land cover was undertaken to make available comparable information on land cover and land cover changes at the European scale ([16]).

The first published Corine land cover map (CLC1990) provided information on the stock of land cover for the 'median year' 1990 ([17]). It was derived from a mosaic of photo-interpreted Landsat and SPOT satellite images spanning the years 1986 to 1995. The mapping, which was undertaken at the scale of 1/100 000, used a standardised approach and a purpose-built classification that could be applied across Europe. The minimum mapping unit for individual cover parcels was 25 ha. Although the database was assembled on a country by country basis, a central coordination team provided training to national photo-interpreters and quality control of the products. The information is therefore consistent across the whole of the continent. The work was completed initially for the then EU Member States and accession countries. However, 1990 coverage has now been extended to cover over 30 European countries.

As a result of the success of the first Corine land cover map it was recognised that there was a need to update the inventory to explore the pattern and extent of land cover change at the Pan-European scale. Following a formal proposal by the European Commission, the project to create Corine land cover 2000 (CLC2000) was initiated ([18]) The work drew on the results of IMAGE2000, a satellite imaging programme undertaken by the Joint Research Centre (JRC) of the European Commission and EEA. The work was steered by EEA with the support of the JRC, the Directorates of Environment, Regional Policy and Agriculture of the Commission, and the member countries of the EEA. To date, 34 countries and more than 100 organisations have been involved in the production and dissemination of the CLC2000 data, and there is now the prospect that there will be a further update in 2006, within the context of the GMES (Global Monitoring for Environment and Security) initiative.

The update of CLC2000 drew on the experience gained in the creation of the first Corine land cover map, and this allowed inconsistencies and geometric errors in the earlier mapping to be identified and resolved. Data on land cover change between CLC1990 and CLC2000 were therefore not derived from the simple subtraction/addition of CLC1990 map from that produced for 2000, but rather from the direct comparison of satellite images. Thus, the CLC2000 product effectively updated the extent

([16]) http://terrestrial.eionet.europa.eu/CLC2000/docs/publications/Corinescreen.pdf (accessed 30.09.2006).
([17]) http://dataservice.eea.europa.eu/dataservice/metadetails.asp?id=309 (accessed 30.09.2006).
([18]) http://dataservice.eea.europa.eu/dataservice/available.asp?type=azlist&letter=C (accessed 30.09.2006).

of parcels mapped in the first phase independently. Using this method, it has been shown that the minimum mapping unit for change detection could be set at 5 ha ([19]).

As a result of the Corine revision process, the user now has three data products available: CLC1990-revised, CLC change 1990–2000 and CLC2000. For its land accounts work, EEA therefore had available a good integrated database of stocks and changes, both geometrically and thematically for 24 member countries ([20]).

Although not so complete, the CLC1975 database is also worth mentioning. It has been constructed for two subsets of Europe:

- the four countries which were set to join the EU in the 1990s and which participated in the PHARE programme, namely the Czech Republic, Hungary, Romania and Slovakia; ,
- the European coastal zone represented by the 10 km strip in the land-side of the shoreline. This was developed through two different programmes, LaCoast (by JRC) and EUROSION (sponsored by the European Commission).

These data which were mapped using the level 2 CLC nomenclature, needed to be adapted for the purposes of integration with the more recent Corine data. However, it appeared that there was very little loss of information and so it was possible to prepare land cover accounts with a 1975 baseline. An insight into some of the results obtained has been presented in Chapter 2 of this report.

7.3 The classification of stocks and flows using Corine

The system used to classify Corine land cover has at the most detailed level 44 classes. The full list is provided in Appendix 1 ([21]). These detailed classes have been aggregated, so that more general reporting can be achieved, by arranging them into three hierarchical levels. Thus for the purposes of building land cover accounts, the 44 detailed cover types recognised at level 3 have been grouped into five broad classes at level 1, and 15 intermediate classes at level 2.

To build the accounts, the EEA has used a hybrid between levels 1 and 2 (see Table 7.1a), with eight broad classes so that patterns of change can be described more clearly. The agriculture class is split into two sub-classes, namely arable and permanent crops and pasture and heterogeneous farmland. Forests are also classified using two classes, standing forest and transitional woodland and shrub. The latter mainly maps areas that have been recently felled or new plantations, and so by treating them as part of a more general class of forested land, normal forest rotations are not confused with the losses or gains of woodland that come about through deforestation or afforestation.

In order to evaluate the adequacy of the classification approach used for the construction of land cover accounts, it is important to note that the nomenclature has attempted to make the optimal use of the so-called high resolution satellite images provided by satellite platforms such as Landsat, Spot, and IRS. It is based on the distinction between artificial, agricultural and natural land surfaces, and is generally consistent with the principles of the Land Cover Classification System (LCCS) developed by FAO and UNEP ([22]), which is a scale independent system for classification.

There are, however, some differences between the Corine system and the nomenclature suggested under LCCS. For example, the Corine system makes a more detailed distinction within the artificial and agricultural classes. This is appropriate in the European context, because of the complex nature of the landscapes that we find here, with their intimate mixture of natural and man-made surfaces. It also reflects the need to use Corine to look at both land cover change and the associated drivers, which are mainly linked to urban development and the conversion of land into and out of agriculture. This particular focus makes the Corine nomenclature slightly different from other LCCS mainstream applications which generally provide more detail on forests and natural vegetation types. However, the approaches are not fundamentally contradictory.

In looking at the differences between the Corine and LCCS approaches, it has also been argued that the LCCS framework concerns itself more strictly with land cover, while the Corine classes tend to conflate

([19]) http://dataservice.eea.europa.eu/dataservice/metadetails.asp?id=759 (accessed 30.09.2006).
([20]) Twenty-two countries have the three integrated layers; two countries have only the 2000 and the change layers. In addition, five countries are covered with the 2000 layer only. Iceland, Norway and Turkey are currently being processed (2006).
([21]) Detailed handbooks are also available at: http://reports.eea.europa.eu/COR0-landcover/en, http://reports.eea.europa.eu/tech40add/en and for update methodologies, http://reports.eea.europa.eu/technical_report_2002_89/en (all accessed 30.09.2006).
([22]) For example, the Global land cover 2000 map by JRC, the IGBP Global land cover characterisation or the various legends used in the AfriCover FAO programme.

land cover and land use. However, this argument should be treated with caution, because it should be noted that in making a classification based primarily on image data, the Corine system inherently uses the biophysical characteristics of the land for assigning parcels to categories. The classification approach used to generate the Corine data is not based on the classification of individual image pixels, but rather is one that segments images and identifies units that represent the basic elements of landscape systems. These elements can be interpreted simultaneously in terms of their cover and use. Thus, although the mapping classes may be strongly correlated with particular uses, it does not follow that the final product cannot be regarded as a land cover map. Thus, once again we suggest that the approach used to classify the land cover for the asset accounts is consistent with the general LCCS approach.

The availability of the Corine land cover classification has also provided a framework that can be used to identify the types of change recorded through the Corine updating process. The 1892 possible transitions identified by the intersection of the 44 land cover classes at Corine level 3 have been grouped using a hierarchical approach, which at the most general level allocates flows to eight broad types (Table 7.1a). These broad types include such processes as urban sprawl, the conversion of land to agriculture and forest creation (afforestation) (Table 7.1b). The full classification of types of land cover changes or flows that has been used in the construction of asset accounts for land is given in Appendix 2.

7.4 The limitations of the Corine database

Despite the undoubted value of CLC data for the construction of land cover accounts, there are some technical limitations associated with these data that should be noted in order to evaluate the quality of the outputs that have been derived from them. The issues mainly concern the spatial and temporal resolution of the remotely sensed data.

7.4.1 Spatial resolution

The scale used for the basic Corine mapping is of the order of 1:100 000. Although this level of spatial resolution is sufficiently detailed for assessments at the European scale it is relatively coarse for local mapping. Thus, CLC is not adequate for most local applications such as urban planning, forest management or risk assessment, which would require data at scales approaching 1:50 000 or

Table 7.1 The aggregated classification of land cover stocks and flows based on Corine data

(a) Broad land cover classes used to classify Corine land cover data for land accounts

Broad cover type	Code
Artificial surfaces	CLC 1
Arable land and permanent crops	CLC 2.1+2.2+2.4.1
Pastures and mosaic farmland	CLC 2.3+2.4.2+24.3+2.4.4
Forests and transitional woodland shrub	CLC 3.1+3.2.4
Natural grassland, heathland, sclerophylous vegetation	CLC 3.2.1+3.2.2+3.2.3
Open space with little or no vegetation	CLC 3.3
Wetlands	CLC 4
Water bodies	CLC 5

(b) The classification of the major types of land cover flow using Corine data

Major type of cover change	Code
Urban land management	LCF1
Urban residential sprawl	LCF2
Extension of economic sites and infrastructures	LCF3
Agriculture internal conversions	LCF4
Conversion from forested and natural land to agriculture	LCF5
Withdrawal of farming	LCF6
Forests creation and management	LCF7
Water body creation and management	LCF8
Changes of land cover due to natural and multiple causes	LCF9

Note: Detailed classifications are presented in Appendices 1 and 2.

1:10 000. Nevertheless, CLC can be usefully overlaid with these maps to provide information about the neighbourhood of these zones so that change in the environmental context can be understood. An example of this kind of approach has been provided in Chapter 5, where the Natura 2000 sites were plotted on an underlying map of urban temperatures and locations where urban sprawl had been detected.

A second aspect of the limitations associated with the spatial resolution of the Corine data concerns the size of the minimum mapping unit, which was set at 25 ha, with a minimum width of 100 meters. For the detection of change, the minimum mapping unit was set at 5 ha. The consequence of a large minimum mapping unit for stock was that many classes are heterogeneous. Thus, the Corine classification includes a number of mixed classes such as 'discontinuous urban fabric' and 'land principally occupied by agriculture with significant areas of natural vegetation'. It should be noted, however, that they are not 'residuals' of the interpretation of other classes but are explicitly defined as typical and distinctive land systems. Therefore, heterogeneity *per se* is not a fundamental limitation of the Corine classes, although it may make interpretation more challenging and change more difficult to detect. This is the case for small changes which are not an extension of existing units; they are not considered as representing change until they collectively lead to a change of cover classification in a block 25ˆha or more in size.

In a recent study undertaken for the EEA, the thematic accuracy of Corine 2000 was tested against an independent land cover data set derived from the LUCAS project (EEA, 2006b). The aim was to determine whether the 85 % classification accuracy specified in the technical requirements for the product was met. The structure of the two data sets meant that only 22 of the 44 Corine classes could be evaluated. For the classes tested the study showed that notwithstanding the limitations associated with the coarse spatial resolution of the data that were noted above, the overall reliability was of the order of 87 %. The highest class-level reliability (> 95 %) was observed for rivers, lakes, industrial and commercial units and discontinuous urban fabric. Arable land and coniferous forest, two of the most widespread CLC classes, were estimated to have a reliability of between 90 % and 95 %. Two other agricultural classes also enjoyed a high level of reliability: agro-forestry and permanently irrigated land ([23]). The lowest class-level reliability, which was below 70 %, was found for the sparse vegetation class, which highlights the difficulties in interpreting this category.

This kind of analysis is useful but can only be regarded as indicative because the observation units used in the two studies are not the same. The LUCAS study used plots, for example, while CLC employed geographical units. Moreover, the LUCAS data is not without observational error. Thus the results cannot be regarded as definitive. As a consequence, other cross-checks have also been undertaken, such as the comparison of estimates with the land use accounts of Germany ([24]) (Table 7.2), which was derived from a regular cadastral survey, and the TERRUTI annual agriculture survey in France ([25]). The latter used the same approach as LUCAS.

Both sets of analysis suggest the same conclusions, namely that the main limitations of the CLC data are:

- insufficient detection of small change, in particular that associated with urban development which tended to be underestimated;
- underestimation of the extent of land occupied by transport networks, with the exception of parts of motorways, and railways and rivers. As a result there may be a bias in the estimates of stock and change mainly for artificial surfaces. The limitation arises from the spatial resolution of the underlying data and the need to avoid the over-interpretation of the images. Data on roads, railways and rivers are best derived from other sources.

7.4.2 *Temporal resolution*

In addition to the issues associated with CLC arising from its spatial resolution, users should also

([23]) However, temporary irrigation is not part of the Corine legend. This is due to the methodology which is based on a single satellite image per year, the observation being in the case of temporary irrigation completely dependent on the acquisition date of the satellite image. This gap is considered to be bridged by using medium spatial resolution satellite images which can be supplied with a high temporal resolution, in principle daily and in practice every fortnight or month.

([24]) DeStatis, the Federal Statistical Office of Germany displays economic-environmental accounts on its website. Land use accounts are detailed by economic branches. http://www.destatis.de/basis/e/umw/ugrtab7.htm (accessed 30.09.2006).

([25]) IFEN, the French environmental institute, Données de l'environnement n°101, 2005, http://www.ifen.fr/publications/DE/PDF/de101.pdf (accessed 30.09.2006).

be aware of limitations arising from the temporal resolution of the data sets.

A principal issue is that for the first mapping phase, 1990 can only be regarded as the median date for the map and associated data, having been assembled from imagery collected mostly between 1986 and 1995. Thus the time-span between the first and second phase of Corine land cover mapping varies on a country-by-country basis; it can be as much as 14 years in some cases (e.g. Austria and Portugal), or as little as five years in others (e.g. Lithuania and Slovenia). Appendix 3 provides full details on the variation of period of mapping between countries.

Clearly users can avoid the problems imposed by the temporal resolution of the data by only using the information as calculated for analysis at national and sub-national levels. However, if comparisons are required between countries, the user must rely upon estimated rates of change. These rates of change can be expressed on an annual basis or used to estimate likely change in stock over a decade. However, in making comparisons between countries, the interpretation of the factors that drive these changes must be based on an understanding of the processes at work during the period actually used to calculate the rates. Thus some of the effects of changes in land holding and management for the recent accession of countries may not yet be detectable, because the time period used to estimate rates of change have been too short and/or the transformations in land cover only began late in the accounting period.

7.5 Fitness for purpose

All environmental data sets have biases and errors associated with them, and CLC is no exception. These issues should not, however, prevent these data being used in a wide range of policy applications, provided that people are aware of these limitations and take them into account. All interpretations must therefore be presented with appropriate qualifications.

In the case of CLC data, the major qualifications that need to be set out in relation to the overall estimates are that compared to other methods, and in particular agriculture surveys, CLC is good at describing the same broad stock categories and trends in a relative sense, but is probably less precise about the absolute values involved. This is particularly so in the case of small land cover objects and small changes. However, CLC data does successfully capture information for a range of features that are important for policy customers, and can provide estimates of change down to a resolution of to 5 ha. The gridded nature of the data allows users to gain a much better picture of

Table 7.2 Comparison of LEAC and national land use accounts for Germany (km²)

LEAC				DESTATIS land use accounts			
Corine land cover		**1990**	**2000**	**Type of use**	**1993**	**1997**	**2001**
11	Urban fabric	21 492	22 443	Building and adjacent open area	20 733	21 937	23 081
121	Industrial or commercial units	2 490	3 069	Plant area excl. exploitation area	550	620	732
14	Artificial, non-agricultural vegetated areas	1 205	1 394	Recreation area	2 255	2374	2 659
122	Road and rail networks and associated land	165	173	Traffic area	16 441	16786	17 118
123	Port areas	119	120	thereunder:			
124	Airports	467	474	Road, path, square	14 815	15 005	15 264
13	Mine, dump and construction sites	1 447	1 299	Area of other use	7 630	7 497	7 219
				thereunder:			
				Cemetery	327	335	350
				Wasteland	2 452		2 666
1	Artificial surfaces total	27 384	28 972	Built-up and traffic area	40 305	42 052	43 939
2	Agricultural areas	216 073	214 016	Agricultural area	195 112	193 075	191 028
3	Forest and semi natural areas	108 844	109 148	Forest/wood	104 536	104 908	105 314
4	Wetlands	4 349	4 374				
5	Water bodies	5 142	5 281	Sheet of water	7 837	7 940	8 085
Total		**361 791**	**361 791**	**Area, total**	**356 970**	**357 030**	**357 031**

Source: EEA and DeStatis, 2006.

the spatial distribution of stocks and flows than is possible from other types of survey, which use larger administrative units as a framework for analysis and reporting.

Ultimately, conclusions about data quality can only be made by looking at whether the information fits the purpose. The aims and objectives of the analysis provide the context in which the advantage and disadvantages of different data sets have to be assessed. Table 7.3 provides a comparison of CLC with other types of survey.

As Table 7.3 illustrates, there are a number of 'trade-offs' that have to be considered when users look at different data sets as a source of information for their particular application. The CLC object-based classification approach has advantages over more conventional 'per-pixel' image classifications in that it provides data with much better geometric characteristics. The data relates to 'real' land cover objects, rather than isolated pixels or pixel blocks that only approximately relate to the underlying structure of the land cover mosaic. Both approaches, however, give data with potentially much higher spatial resolution than sample-based surveys, which generally only produce statistical estimates for larger spatial units such as administrative regions.

The advantages of sample-based and cadastral surveys, however, is that the precision of measurements is often higher compared to Corine, so that absolute values may be more reliable. In the case of cadastral systems, the temporal resolution may be much higher than that of image-based approaches, since data are often updated continuously. The problem with all image-based change detection is that the magnitude of the change relative to the 'noise' in the data needs to be considered.

Thus CLC data, and the accounts that have been built upon them, are best used for applications that require a good understanding of the relative proportions and trends of major land cover types at high spatial resolutions. The data are possibly less useful when absolute estimates of stock or change need to be made, say for the purposes of calculating area-based payments to farmers. It can be concluded therefore that the land account data are particularly valuable for the type of broad strategic or regional assessments now increasingly required for the design and assessment of policies for sustainable development.

Table 7.3 Advantages and limitations of different land cover survey methodologies

Method	Corine land cover employing object-based classifications	Pixels-based classifications of imagery	Area- or point-based sample surveys	Cadastral surveys
Observation	Physiognomy of geographical units (objects)	Radiometry of pixels	Field observation of 'points' or their neighbourhood, or of area units	Registration of parcels
Accuracy	Complex entities containing many pixels and mixed classes, but these can be classified meaningfully according to their dominant character; small objects and change ignored	Dependent on dimensions of image pixels; properties of mixed classes difficult to handle; small objects and change uncertain	Potentially high, but proportional to the sampling rate	Potentially high, but often not related to general land cover units, but rather to individual legal parcels (such as a house with its garden)
Spatial resolution	High, with good representation of spatial geometry at a given scale, and exhaustive coverage	High, with limited geometrical information about land parcels, but exhaustive coverage	Low, with estimates represented only by statistical totals for reporting units	High (when access to cadastre database)
Temporal resolution	Depends on image frequency and magnitude of changes relative to accuracy of mapping	Depends on image frequency and magnitude of changes relative to accuracy of mapping	Depends on sampling frequency	High, because data are continuously updated

8 Recording patterns of change: construction of the LEAC database

8.1 Introduction

The SEEA handbook stresses the importance of using geo-referenced or spatial data to build land cover accounts. It is argued that information which can be linked to a geographical coordinate system is more flexible and versatile in its use because it can be aggregated in different ways to provide information about different spatial units. In Part II of this report we described some of the ways in which account data can be mapped, using the system of administrative units in Europe and the idea of dominant landscape types. This chapter provides information on how geo-referencing was achieved and how it can be exploited both for analytical and reporting purposes.

8.2 The accounting grid

Although the image data used to produce CLC1990 and CLC2000 were fully geo-referenced and co-registered so that change could be mapped accurately, further processing was necessary to create the Land and Ecosystem Account database (LEAC) that has become the foundation of the work undertaken by the EEA. Basically, this involved the creation of a system of spatial grids, starting from the 100 m x 100 m CLC raster files which have then been assimilated statistically into successively larger grids at 1 km x 1 km, 5 km x 5 km and 10 km x 10 km resolution. Statistical assimilation differs from cartographic generalisation in the sense that the former preserves the original values while the latter incorporates the small objects into the larger ones.

The 1 km x 1 km accounting grid for the whole of Europe, which can be used to store, analyse and report stock and change data in efficient and flexible ways plays a central role in LEAC. Such reference grids have, in fact, been widely used in GIS applications as a means of integrating different data sources and types ([26]). The grid developed for the purposes of the LEAC study was shaped by the recommendations of a workshop on European reference grids which was part of the INSPIRE initiative ([27]). It consists of approximately 4.5 million 1 km x 1 km cells, each of which can hold a data record in the LEAC database.

It is particularly important to understand how the information on land cover stock and change were recorded using the accounting grid, because this has a fundamental influence on the way in which the information can be used. The approach is summarised in Figure 8.1. The basic Corine mapping consists of a vector data set which contains the boundaries of the various interpreted land cover parcels for the two survey dates. From these data, two raster maps have been created at 100 m and 250 m resolution. The LEAC database was constructed from the 100 m rasters for the two CLC maps from 1990 and 2000, because these showed a good match to the original vector coverage. At the local level, LEAC can be compiled with the 100 m x 100 m grid if necessary. According to the specific resolution of various socio-economic and ecological data sets and the choice of sampling and/or data modelling strategies, the 1 km x 1 km, 5 km x 5 km or 10 km x 10 km grids can also be used ([28]) .

For each cell in the accounting grid, the records on land cover stock and change were constructed by superimposing the 1 km x 1 km cells onto the underlying raster, and calculating the extent of each

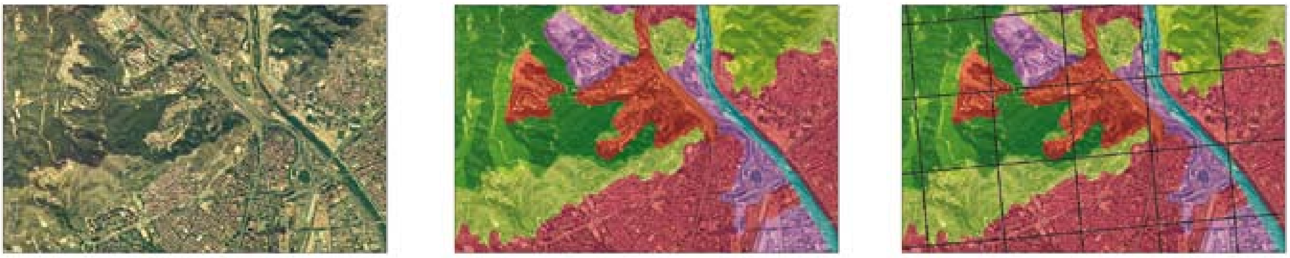
([26]) The European reference standard grid can be produced with any GIS software package. However, in order to be able to overlay CLC and LEAC data as well as other derived data sets, the EEA strongly recommends the use of the grid which can be downloaded from its website. This will avoid possible problems resulting from different geoid parameters employed by the various software packages for the same 'theoretical' projection system. http://dataservice.eea.europa.eu/dataservice/metadetails.asp?id=760 (accessed 30.09.2006).

([27]) INSPIRE (Infrastructure for Spatial Information in Europe) is an initiative launched by the European Commission and developed in collaboration with Member States and accession countries. It aims at making available relevant, harmonised and quality geographic information to support formulation, implementation, monitoring and evaluation of Community policies with a territorial dimension or impact.

([28]) In fact, whatever the size of the grid cell, it contains a complete land cover account.

Figure 8.1 The creation of the LEAC database records

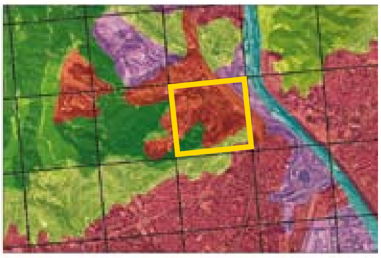
(a) The approach used to generate the LEAC record for stock



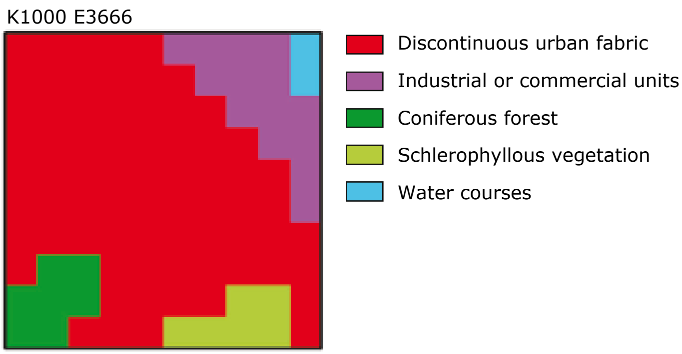
Step 1: The raw image data are interpreted for a land cover map

Step 2: Interpreted CLC map for 1990 and 2000

Step 3: Superimposition of the 1 km x 1 km accounting grid

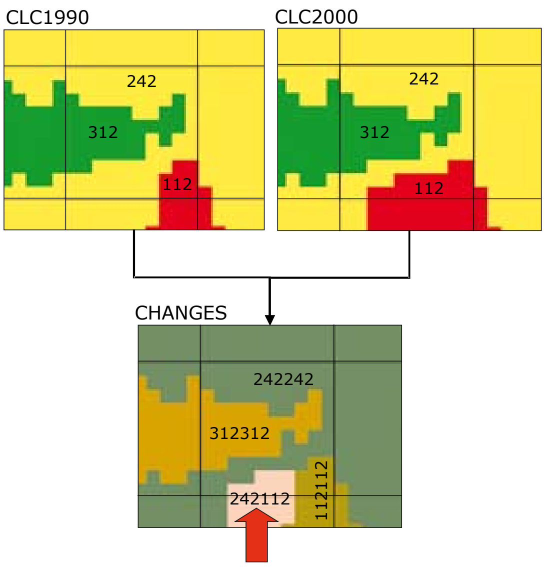


Step 4: Location of an individual record for the LEAC database



Step 5: The underlying 100 m raster used for stock calculation for the selected record

(b) Calculation and representation of stock and change in the LEAC database



CHANGES Matrix

	112	242	312
112	8		
242	8	51	
312			33

LEAC_DATA Table

GRIDCODE	CHANGE	AREA
K1000E3968N3163	112112	8
K1000E3968N3163	242112	8
K1000E3968N3163	242242	51
K1000E3968N3163	312312	33

cover type and the change observed between the two Corine images. The five stage process illustrated in Figure 8.1a goes from the original image data, through classification to the identification of an individual grid cell in the accounting grid. As Figure 8.1b shows, the calculation of stock and change reflects the actual data contained in each cell, and no further generalisation is involved in the calculation of the resulting statistics. The records are formed by identifying the relationships between cover elements at Corine level 3 between the two image dates via a small transition matrix. This can then be used to code up the changes for the particular cell. Given the 100 m resolution of the raster data, each cell in the original image represents an area of 1 hectare.

In the example given in Figure 8.1b, we can see that the 1 km x 1 km grid cell generates four records in the final LEAC database table. In each case the change code is a six figure string, formed from the three digit codes for the original and final covers. Thus for 'discontinuous urban fabric' (CLC level 3 code 112), eight hectares remain the same over the accounting period (coded as 112112 in the LEAC table), while a further eight hectares were formed by the consumption of land that was previously assigned to 'complex cultivation patterns' (CLC level 3 code 242). This change is coded as 242112 in the LEAC table. In the example given, the other records shown in the LEAC Table record the amount of land assigned to complex cultivation patterns that was carried over between the two image dates, and the extent of coniferous forests (CLC level 3 code 312) converted into this type of agricultural land cover.

The particular advantage of the approach used to create the LEAC database records is that they can be grouped for analytical or reporting purposes, and the results remain consistent across the different scales. The key feature to note is that although the accounting grid may have a resolution of 1 km x 1 km, the 100 m resolution of the underlying CLC data and thus the properties of the underlying Corine vector data are retained by the approach.

8.3 Geographical frameworks

Each of the records held in the LEAC database is fully spatially referenced via the underlying accounting grid. However, to increase the flexibility of the database for analysis and reporting, the location of the cell relative to other geographical frameworks has also been included in the database record.

In Parts I and II of this report we saw how the underlying patterns of change could be represented by displaying the account data in map form using the various administrative tiers of Europe represented by the so-called NUTS regions (see, for example, Chapter 3, Section 3.3). Such maps can be generated very easily from the LEAC database because each of the cells has been assigned to one of the spatial units that make up the various administrative tiers at the different levels in the NUTS hierarchy.

Table 8.1 lists all the so-called land analytical and reporting units (LARU) that have been coded into the LEAC database. In addition to the system of NUTS regions, records have also been assigned to the major geo-physical regions of Europe, such as river basins or sea catchments, the major bio-geographical and the dominant landscape types. In the future coding for ecological zones, describing potential vegetation patterns in Europe will be added. Finally cells have been assigned to altitudinal ranges using a digital elevation model for Europe, or various buffer regions involving, for example distance from coast. To assign a LARU code to a cell the maximum area criterion was used along with a standard method for rasterisation of the underlying geographical framework. Although rasterisation led to some generalisation of the boundaries of the various spatial units, the locational inaccuracies were relatively minor, and were considered to be outweighed by the benefits that the grid-based approach brought for analytical and reporting purposes ([29]).

The sources of the different data sets used to create the LARU structure is given in Annex A of this report. Many of the geographical frameworks are standard, and need no further description here. Instead we will focus on those that were developed or adapted specifically by the EEA and its partners.

8.3.1 *The mapping of potentials and influence via CORILIS*

The CORILIS methodology was introduced in Chapters 2 and 5, where it was largely used to look at the urban influence (or temperature). Such contextual information is often essential for the spatial analysis of stocks of land cover units and

([29]) In this case, only one LARU value is assigned to each grid cell using a 'Maximum area' criterion. This process produces a slight generalisation of borders but it allows updating LARU values easily and combining layers with different specific geographic patterns.

their transformation over time, because it can help identify some of the key drivers of change.

Clearly such contextual information can take many forms, since it is possible to derive such information from a range of social, cultural, economic, historical, legal, geological and climatic sources. The accounts work shows that it is also possible to construct contextual information for land cover data itself by looking at the neighbourhood of land cover elements at a range of spatial scales. A natural area, for example, will be influenced differently by the settlements within the local area, and the character of the surrounding agricultural land. The magnitude of the influence is likely to be dependent on its distance to these features and their size. It is precisely these aspects of spatial context that are captured in the methodology provided by the CORILIS approach.

The purpose of the CORILIS project (see also Section 5.5) was to develop a set of tools for the calculation of 'intensities' or 'potentials' of a given land cover theme at each point across a defined territory. The basis of the approach is a Gaussian statistical function, called BiWeight, which is used to scale this information according to the distances between points. The application of the CORILIS methodology to Corine land cover data results in index values (ranging from 0 to 1) that represents the presence of a given CLC class within a neighbourhood, as represented by the size of the radius used for the spatial smoothing. The size of the radius is specified by the user. The CORILIS methodology was originally developed to calculate weights across hexagonal units. However, in later tests undertaken, it was found that these could be replaced by regular square grids, so that the tools could be applied to the land cover stock data held on the LEAC accounting grid.

The advantages of the CORILIS approach to cartographic generalisation over more traditional methods is that it avoids the problem of eliminating small values and inflating large ones. As a result, for the generalised map, the proportions of 'smoothed values' for land cover stocks, for example calculated across a region is the same as

Table 8.1 The land analytical and reporting units coded into the LEAC database

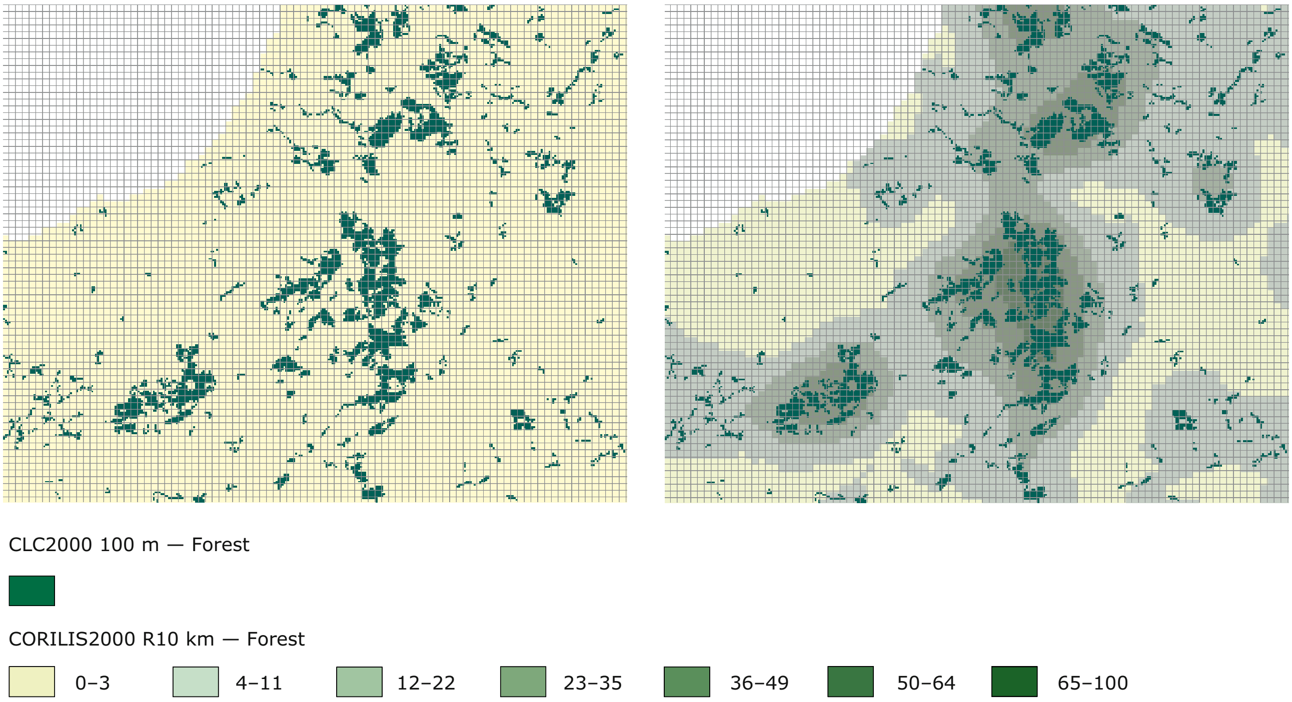
Administrative units
NUTS 0 (countries)
NUTS 1
NUTS 2
NUTS 3
Geographic regions
Sea catchments (according to international conventions on sea)
Coastal zones
Mountain areas
Urban morphological zones
Bio-geographic regions (according to Natura 2000)
Land covers units (Corine land cover)
Land cover intensity in neighbourhoods (CORILIS modifiable layers)
Dominant land cover and landscape type areas (LEAC/DLT modifiable layers)

Note: Other zonings are currently being considered, including river basins (according to CCM2), ecological regions, and landscape types.

Table 8.2 Definition of altitude classes used in LEAC

Lowland:	all land below 200 m; lowland can be subdivided between coastal zone (10 km strip from the coastline) and low inland.
Upland:	all land above 200 m and lower than 500 m, as well as up to 1 000 m when the average slope in the 1 km² grid cells is < 2 % (i.e. a plateaux surface).
Mountain:	all land above higher than 1 000 m as well as land between 500 m and 1 000 m, when the average slope in a 3 km x 3 km grid cells is > 2 %.

Figure 8.2 Application of the CORILIS methodology to CLC data for forests in Ireland using a 10 km smoothing radius over the 1 km x 1 km accounting grid



the estimate derived from the initial, 'unsmoothed' data. However, the underlying geographic patterns are more easily seen using the CORILIS approach.

An example of the type of output derived from applying the CORILIS algorithms to the map of dominant land cover for forest in part of Ireland is shown in Figure 8.2. The example highlights the effect of the smoothing algorithm. Such data can be used individually to look at the relationship between LEAC records and particular themes, such as forest proximity, or combined in various ways to develop additional types of contextual information. Two particularly important additional data layers that have been created in the land accounting work by EEA are the so-called Green Background index, and the map of Dominant landscape types.

8.3.2 The Green Background index

The Green Background (Figure 8.3) is a type of index map which shows 'ecological potential'. It is based on the spatial distribution of pasture, agriculture mosaics, forests and other semi-natural or natural land. As noted earlier, a smoothing algorithm has been applied to each point on a land cover map, so that the area of a given type within a fixed radius can be calculated. The smoothing radius can be varied by the user; outputs are available from the EEA for each of the input layers for smoothing radii of 5 km, 10 km or 20 km. The Green Background index shown in Figure 8.3a was produced by adding the smoothed, CORILIS layers derived from land cover maps for the following combined Corine classes:

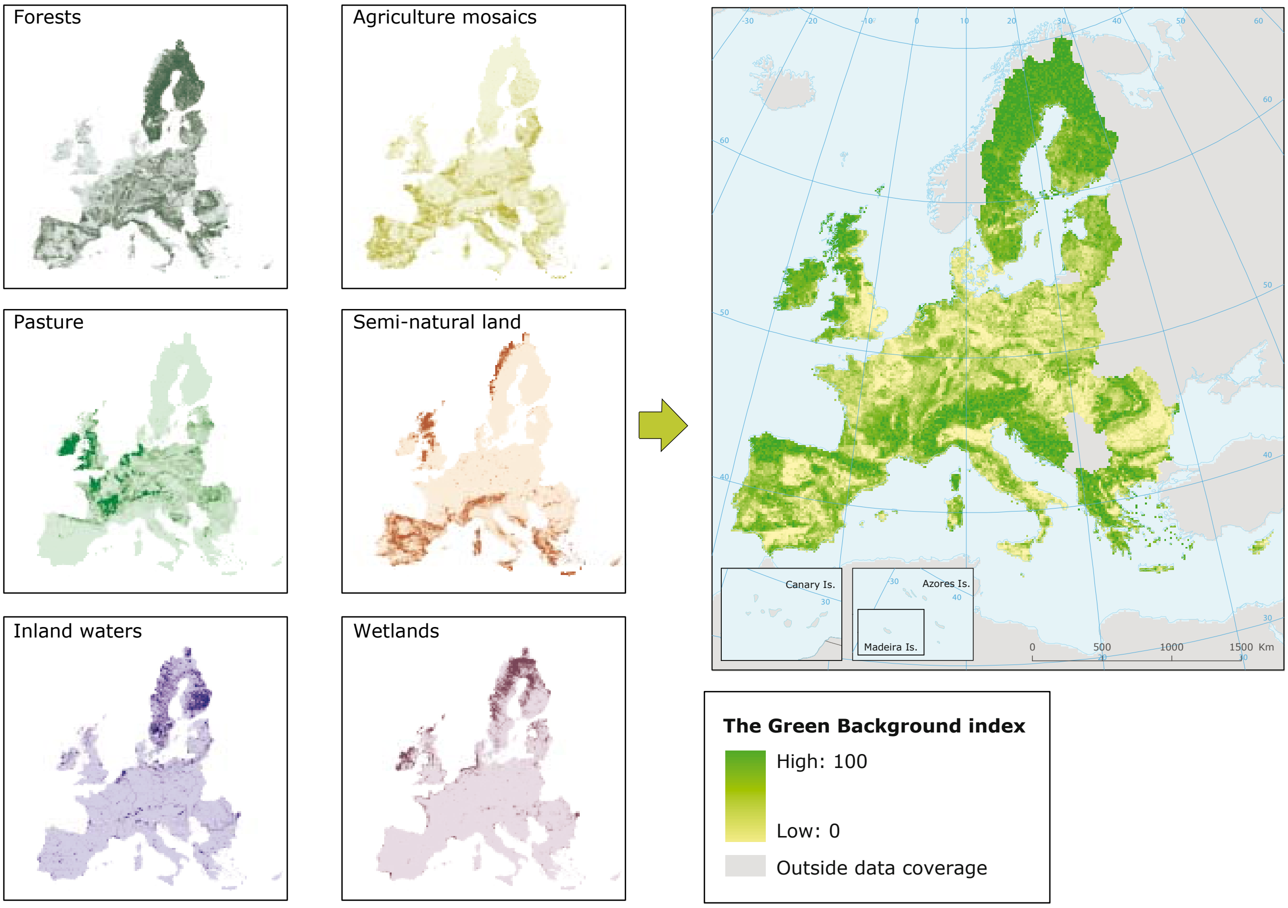
- 2b Pastures and mosaic farmland
- 3a Forests and transitional woodland shrub
- 3b Natural grassland, moors, heathland and sclerophylous vegetation
- 3c Open spaces with little or no vegetation
- 4 Wetlands
- 5 Water bodies.

The index is displayed as a continuum of values from 0 to 100 (Figure 2.7).

For mapping, the output can be modified in a number of ways. For example, different thresholds can be used to indicate the areas of highest ecological potential. In Figure 8.3b, a minimum threshold value of 65 % for the presence of green areas has been set, largely for empirical reasons. In Figure 2.7, the Green Background was represented as a continuous surface. The threshold value of 65 % has been tested for regions where broad scale maps of ecological networks are available. This value was found to be a suitable cut-off for gaining a good overview at European scales.

Figure 8.3 Green Background index derived from the combination of CORILIS layers

(a) Creation of the LEAC Green Background from CORILIS layers for pasture, agriculture mosaics, forests, other semi-natural land, wetlands and inland waters



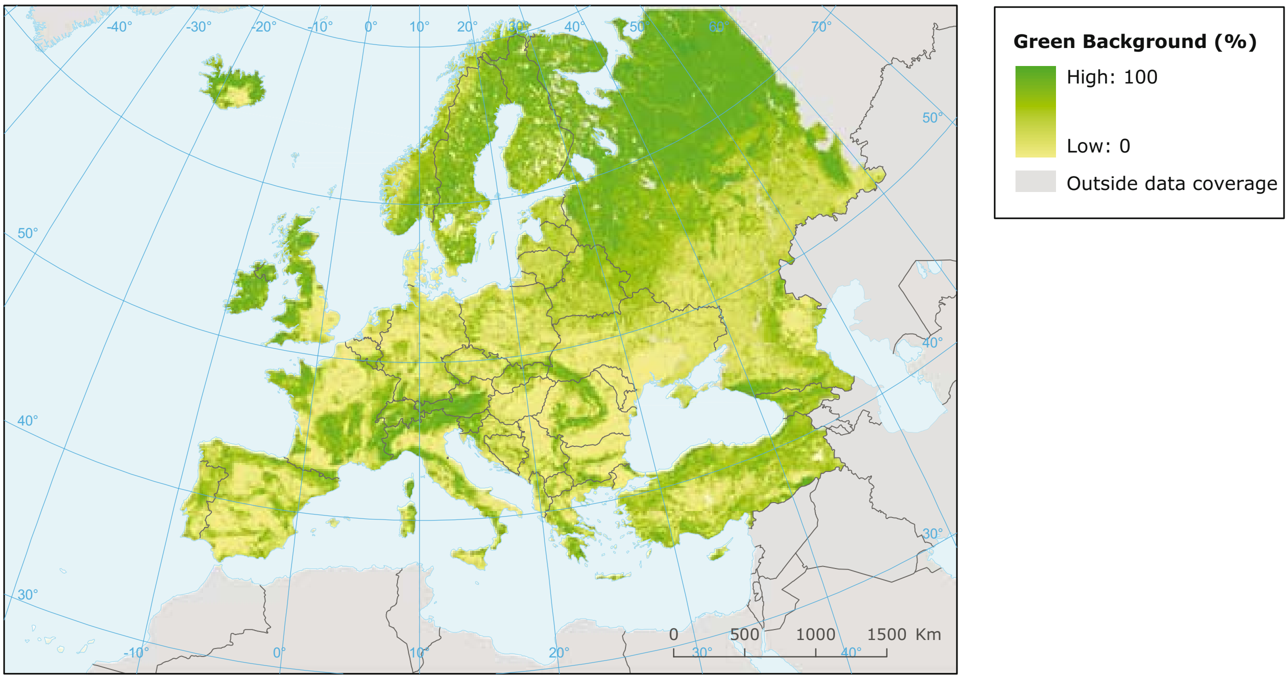
(b) The Green Background for three different smoothing radii (example with 65 % threshold)

Note: The Green Background map is a modifiable map, both in terms of smoothing radii and minimum intensity. The use of the CORILIS components shows the make-up of a given region or location with the Green Background index. This gives a possibility to modify the selection of the thematic CORILIS layers.

For studies focused at regional or local scales, the mapping thresholds and/or the smoothing radii can be varied to take account of specific conditions or specific issues (Figure 8.3b). When studying the connectivity of habitats for butterflies, for example, one may prefer using the 5 km radius; a similar study involving large mammals may require a radius of 20 km. The mixture of cover types used to calculate the extent of 'green surfaces' can also be varied. For example, pasture can be dropped from the calculation in a regional study if locally it is managed intensively.

The CORILIS methodology is a generic one, and so mapping of potential can be undertaken using a variety of data sources. Figure 8.4 shows a

Figure 8.4 Green Background index for Pan-Europe, computed from GLC2000 v.2



Source: JRC/IES and EEA/ETCTE.

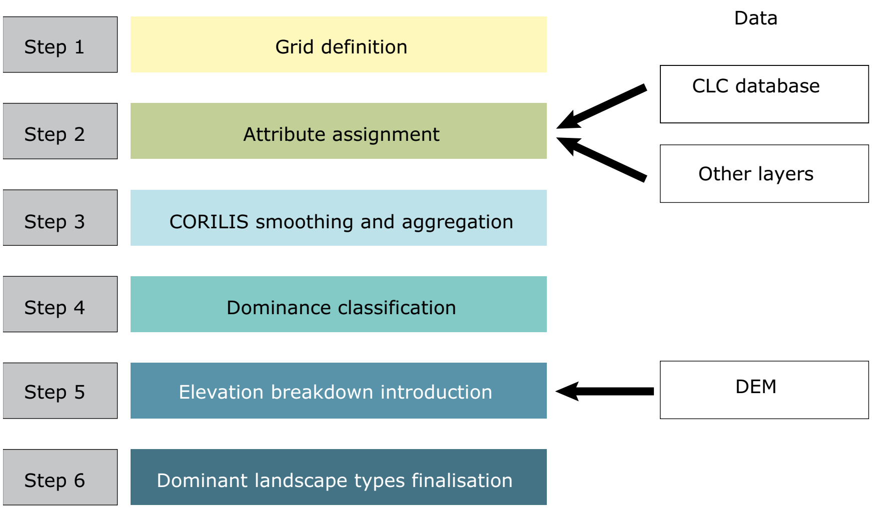
Table 8.3 Dominant landscape types (summary)

A1 Urban dense areas	
A2 Dispersed urban areas	
B1 Broad pattern intensive agriculture	
B2 Rural mosaic and pasture landscape	
	B21 Lowland rural mosaic and pasture landscape
	B22 Upland rural mosaic and pasture landscape
	B23 Mountain rural mosaic and pasture landscape
C1 Forested landscape	
	C11 Lowland forested landscape
	C12 Upland forested landscape
	C13 Mountain forested landscape
C2 Open semi-natural or natural landscape	
	C21 Lowland open semi-natural or natural landscape
	C22 Upland open semi-natural or natural landscape
	C23 Mountain open semi-natural or natural landscape
D1 Composite landscape	
	D11 Lowland composite landscape
	D12 Upland composite landscape
	D13 Mountain composite landscape

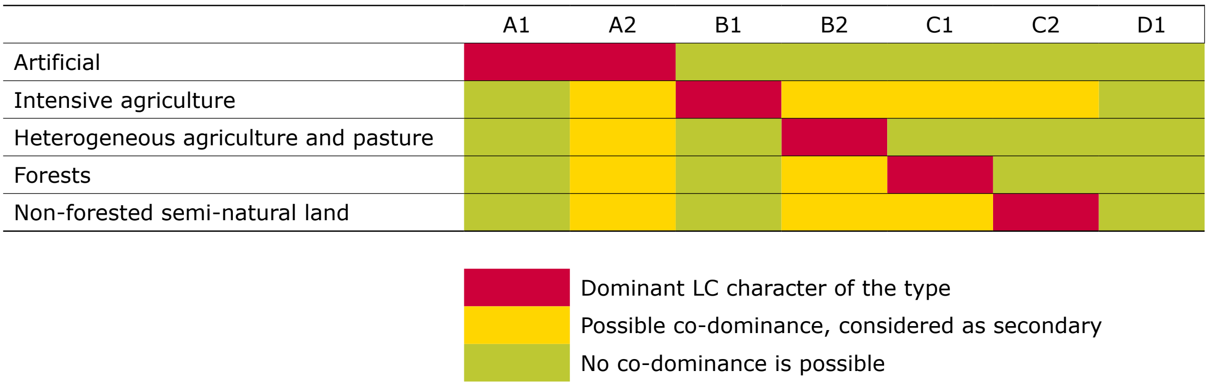
Note: The definition of altitude classes used for LEAC is given in Table 8.2.

Figure 8.5 Methodology for the identification of dominant landscape type

(A) Key data processing steps



(B) Definition of dominant land cover types and their relationship to the broad Corine land cover classes



Note: Key: A1 = Urban dense areas; A2 = Dispersed urban areas; B1 = Broad pattern intensive agriculture; B2 = Rural mosaic and pasture landscape; C1 = Forested landscape; C2 = Open semi-natural or natural landscape; D1 = Composite landscape.

Pan-European map of the Green Background index computed from the Global land cover 2000 v. 2 map that has recently been produced by the Joint Research Centre from SPOT4-Vegetation images ([30]).

8.3.3 Dominant landscape types

The concept of dominant landscape types and the way in which they have been mapped is a further innovative aspect of the work. The approach, which is summarised in Figure 8.5a, is based on a six step process that involves combining the results of applying the CORILIS smoothing algorithms to the underlying CLC cover data for the seven major cover types, and intersecting the results with a set of discrete relief classes derived from a digital elevation model.

For each cell in the grid, the dominant land cover is calculated; this is done by comparing the CORILIS layers to find the one that shows the highest probability of occurrence for a given land cover type. The cells of the accounting grid are then allocated to one of the resulting landscape classes according the dominant and subdominant types present. In this way seven major landscape types and their subtypes were identified, using the criteria shown in Table 8.3. Three standard versions are available

([30]) Joint Research Centre, Institute for Environment and Sustainability, Global Environment Monitoring unit; http://www-gvm.jrc.it/glc2000/ (accessed 30.09.2006).

based on smoothing radii of 5, 10 and 20 km ([31]). The map of dominant landscape types has already been presented in Chapter 2, Figure 2.8.

8.4 The analytical and reporting framework

The aim of this chapter has been to describe the way in which the LEAC database has been constructed to support the analytical and reporting frameworks needed for the construction and use of land accounts. The focus of this work has been to develop the specific database that has been built using Corine land cover change data to ensure that it is sufficiently robust to support potential applications, and to create a set of more generic techniques that can assist environmental accounting more generally. In fact, the intention of the work has been to create a platform upon which other applications can be built by combining the information derived from CLC with other data sources. The prospects for developing the approach in this way will be considered in Chapter 9 of the report.

([31]) The database of dominant landscape types at 5 km is currently used for data analysis.

9 Targeting the analysis: from land cover to land use and ecosystem

*By examining all uses of land in an integrated manner, it makes it possible to minimize conflicts, to make the most efficient trade-offs and to link social and economic development with environmental protection and enhancement, thus helping to achieve the objectives of sustainable development (*Agenda 21, Chapter 10).

9.1 Introduction

As the SEEA handbook emphasises, a particular advantage of land cover accounting is the opportunity it offers to build sets of thematic or targeted accounts that can be used to supplement discussions about the impact of human activities on natural capital, and the benefits that natural resources provide to society. In this final chapter we take stock of what has been achieved through the work of the EEA and consider some of the ways in which this may be further developed so that the long-term objectives suggested for land cover accounting can be achieved.

Although analysing land cover change is an important activity, the exercise essentially yields a set of e*x post* observations. In other words, we potentially have good information after the event but may have to cope with the fact that the knowledge comes too late — especially if irreversible changes have occurred. In order to develop a more strategic approach to the assessment of environmental change, it may instead be possible to explore the spatial and temporal patterns that relate to the different processes that transform land cover, so that future sensitivities might be recognised and areas that might be vulnerable to particular combinations of different drivers of change identified. The approach to land use and ecosystem accounting that has been developed shows how this might be achieved.

The design of the land account database, which is referenced to a fine-scale resolution spatial grid, facilitates the detailed analysis of the spatial interactions between processes of land cover change and the underlying resource stocks. The analysis of land cover flows that has been presented here has been based on an analysis of the information provided by CLC for just two time periods. In this sense they provide a first broad-brush view of the major types of transformation that can be detected. As is illustrated by the analysis of CLC data back to 1975 for the European coasts and four countries of central and eastern Europe (see Chapter 2), a better understanding of dynamics is possible if longer time series are established. As information accumulates over time about the histories of the different land use/cover parcels, new and more refined classifications of flows can be developed by grouping the different types of trajectory. The refinement of our understanding and the representation of land cover flows represent major challenges for the future. The work presented here provides a platform on which this kind of work can be undertaken.

What is most needed is a commitment to invest in reprocessing land cover images in the archives (back to 1975, as it has been carried out for the coastal zone and four countries) and historical maps of earlier periods to provide a longer time frame for analysis of past trends. Time series regarding CO_2 emissions commonly start with the 19th century and the industrialisation process. The present potentials of landscapes for sustaining ecosystems are earmarked by the same driver and its consequences in terms of urban concentration, change in agriculture patterns and development of transport networks. The 'industrialisation of agriculture' after the Second World War was another major turning point for European landscapes and natural habitats. The effects of the first generation of European agriculture and cohesion policies are still to be assessed in full. 'Backcasting' the past, using historical data, statistics and maps is important for understanding the origins of our present situation as much as for analysing possible futures. Spatial integration of time series provides a stronger basis for developing scenarios, training forecasting models and carrying out other *ex ante* analysis such as 'nowcasting'.

The development of an approach that can provide an integrated view of the processes that initiate land cover change and the structure of the underlying land cover mosaic is an additional important achievement of the land accounting work. Information about the sorts of processes that have created individual land parcels, or which are acting on or around them, can be used to refine the various types of resource inventory, socio-economic statistics and monitoring protocols that are so important in the context of policy development and appraisal. It can in particular help in defining sampling strategies for in situ monitoring in relation to satellite earth observation in a cost effective way, as requested under the GMES initiative. The work presented here illustrates how a much richer understanding of the spatial and temporal contexts in which resource stocks are set can be achieved by applying the accounting model.

Clearly the integrated view of land cover stock and change can be developed further by extending the range of information used to create the accounts. Land use, which is commonly observed via the proxy of land cover, needs to be assessed across all its dimensions. The task will involve the description of areas or spatial units in terms of their economic and social functions, such as those associated with residential, industrial or commercial activities, farming or forestry, recreational or conservation. The reciprocal links between land use and land cover, or more generally between land use function and land cover, therefore need to be better understood if fully integrated accounts are to be developed. This also represents a major challenge for future work.

In terms of setting priorities for the future, one particular application area that stands out as important is the development of integrated land and ecosystem accounts. The construction of these accounts would extend the notion of land use functions to include those related to ecological processes, and would represent an essential starting point for the type of assessments called for by Agenda 21. Indeed, the importance of developing an ecosystem approach is underlined by the recent publication Millennium Ecosystem Assessment, which seeks to emphasise the importance of understanding the links between the ecosystem goods and services that are vital for the well-being of people, and the underlying processes that generate them. The paradigm of 'Biodiversity with Man in the Middle' is one that is now actively being promoted and applied (Global Biodiversity Outlook, 2006).

Ecosystem assessments involve consideration of a wide range of issues. While it would seem that the accounting approach may lead to some simplifications, it offers one way in which an integrated assessment can be achieved. The key issues that have to be considered are:

- the operation of patterns and processes across multiple interacting spatial and temporal scales, from local habitats to broad landscape systems and networks, and from short to long time periods;
- the extent to which ecosystem integrity and resilience can be characterised in terms of the limits and thresholds associated with the output of individual ecosystem goods, or their combined output in a multi-functional context.

In the remaining parts of this chapter we explore how accounts involving the classification of land use functions can be developed so that both issues of human use can be understood and the impacts of human action on ecosystems can be better appreciated. Since most of the EEAs recent work has been focused on the concept of ecosystem accounts, we begin the discussion here. The chapter will conclude with a short review of the links between land accounts, land use functions, ecosystem services, natural capital and wider social and economic issues.

9.2 The land and ecosystem accounting framework

9.2.1 Ecosystem goods and services

The concept of ecosystem goods and services provides a valuable framework for the construction of integrated land and ecosystem accounts that can potentially link issues across environmental, economic and social dimensions. Although the idea has been discussed actively since the early 1990s, its importance has only begun to be more widely appreciated, following the publication of the Millennium Ecosystem Assessment (MEA) (Millennium Ecosystem Assessment, 2005). This was the result of an international initiative that drew on contributions of over 1 300 researchers over a five-year period. The MEA has shown that the concept of ecosystem goods and services is central to current debates about nature-society relations and in particular to the way the environment is assessed and valued.

The view that ecosystems can generate goods and services grew out of the idea that ecosystems and the biological diversity contained within them can provide a stream of benefits to people. Within the MEA framework, four major categories are identified, namely:

- supporting functions, such as nutrient cycling, soil formation and primary production;
- provisioning functions, such as the production of food and fibre;
- regulation functions, covering the role that ecosystems have in controlling climate, disease, flooding and water supply;
- cultural functions, which include spiritual, aesthetic, educational and scientific roles that ecosystems can fulfil.

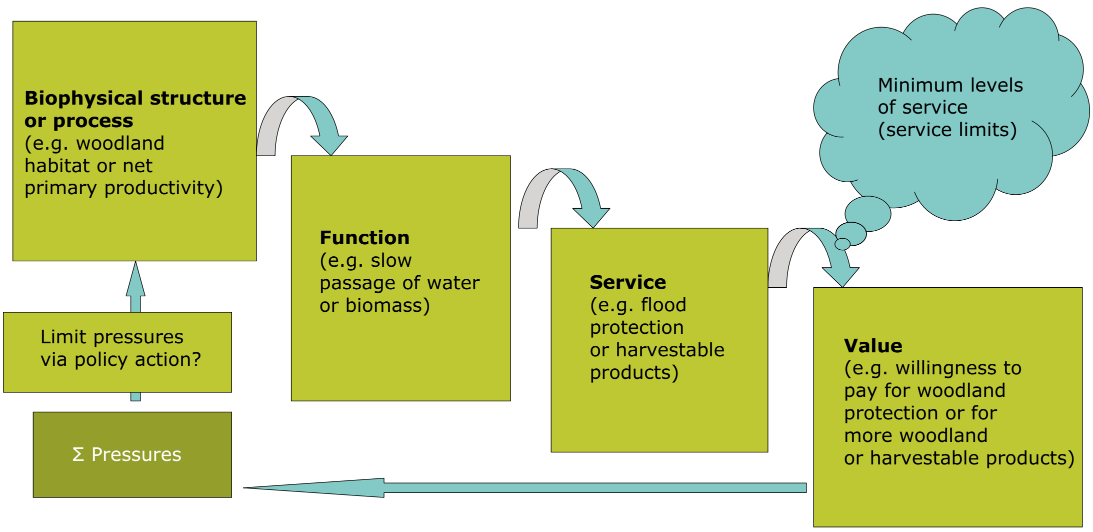
Figure 9.1 summarises the essential logic that underlies the idea that the biophysical structures or processes associated with ecosystems can give rise to sets of functions that may provide services that are valued by people. Thus, a biophysical structure, such as woodland cover, may have the functional ability to slow the passage of precipitation through a river basin, and this function may in turn give rise to the service of flood protection to which people might ascribe a value. Alternatively, a process, such as primary productivity, may provide biomass that can be harvested, and those products may also be of value to society. In both situations, depending on the values assigned and the minimum levels of service required and the risks of continued supply that might be perceived, society may take a view of how particular or cumulative pressures that impact on the biophysical system should be modified.

The MEA is an important step forward, and among its strengths are the consistency of its approach, its interdisciplinary character, and the template it offers for refining the analysis at global, regional and local spatial scales. Its major weakness is the fact that it is incomplete, because at a conceptual level our understanding of the ways in which services link to processes is often only partial, and because important data and analysis are lacking. Key data deficiencies relate to the condition of ecosystems themselves and the values that people place upon their services. Analytical insufficiency includes the absence of an explicit connection with the UN integrated system of economic and environmental accounting (SEEA, 2003), the natural gateway to the UN system of national accounts, on which large range of economic decisions are based. Clearly the construction of land and ecosystem accounts could be one way in which these deficiencies can be overcome.

Indeed it could be argued that only by approaching the analysis of ecosystem functions in terms of the services they offer to people is it likely that the goal of developing integrated environmental and economic accounts, as set out in the SEEA handbook, could be achieved. This ambition forms the basis of EEA's ongoing work within this important topic area.

From an EEA perspective, the assessment of ecosystem services is considered in land accounting terms as an outcome of the analysis of land use function. Through the construction land and ecosystem accounts the aim is to develop tools that will allow the status of a range of non-marketed services to be assessed using monetary and non-monetary (physical) measures. Their

Figure 9.1 The relationship between biophysical systems, functions, services and values



Source: Defra, 2006b.

contribution can then be added to, or considered alongside, the conventional measurements of marketed goods and government services supplied for final consumption. In this way, environmental degradation will not simply be seen as a reduction in the products delivered by the market (and the government, using market factors), but also as the destruction of non-accounted services that are essential for human well-being, even though they are not priced by the economy.

9.2.2 *The resilience of coupled social-ecological systems and the 'ecosystem distress syndrome'*

While, quite rightly the concept of ecosystem services puts emphasis on the importance of natural systems to people, we must not lose sight of the need to look at the state of the natural capital that delivers them. This task covers a range of issues, including:

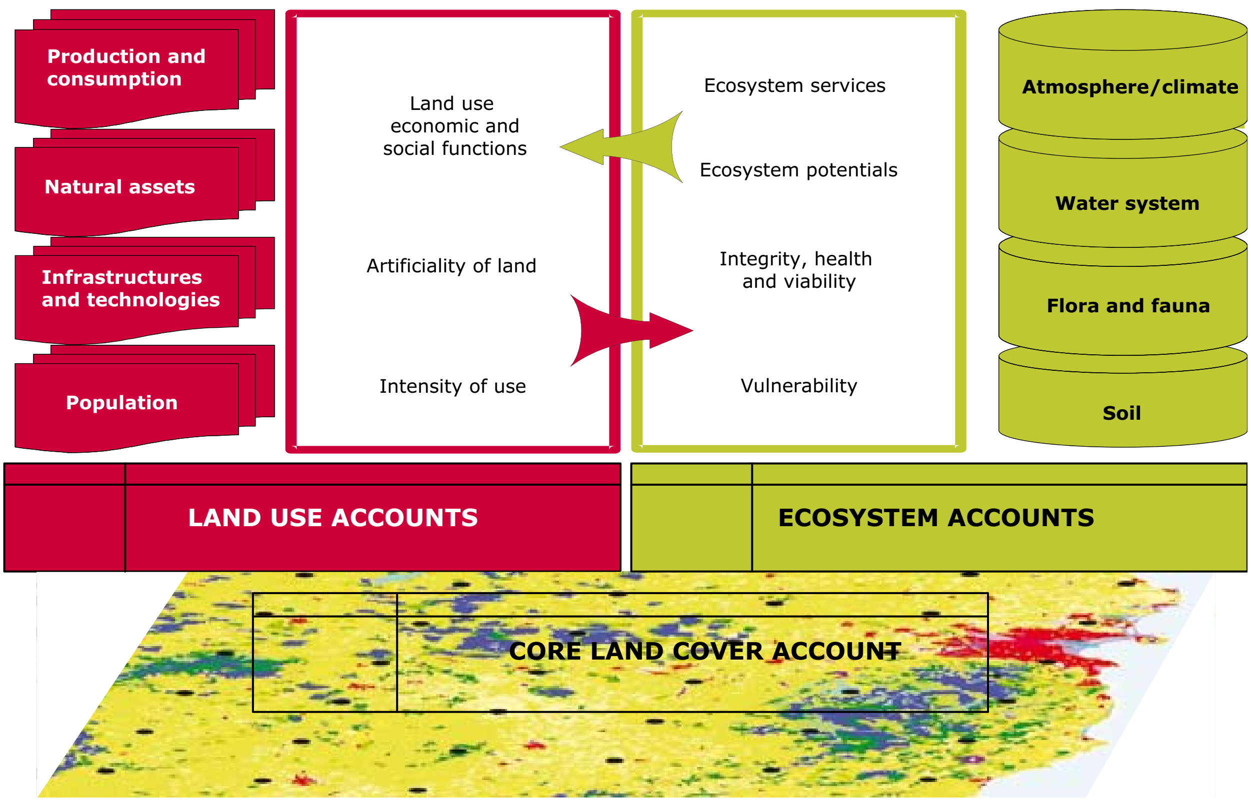
- the mass and energy balances associated with ecosystems, such as those relating to C, N, P, water, and composite materials such as biomass, soil, timber, species, that collectively constitute the ecosystems and which ultimately deliver products directly or indirectly to market.
- the sustainability of flows and stocks of the different resources associated with ecosystems.

An analysis of the efficiency of energy and materials use is one of the key objectives set out in SEEA2003, so that different economic sectors can be better connected to the natural processes on which they are based. More generally, the scope of the land and ecosystem accounts should also include ideas about how the overall integrity of these systems can be measured (Figure 9.2).

The 'ecosystem distress syndrome' (EDS) is one way in which an assessment of the overall status of an ecosystem might be made. It proposes a check-list of symptoms, analogous to the steps in medical diagnosis, through which 'ecosystem distress' can be determined (Rapport, 1999). These include:

- disruptions in the nutrient cycling;
- change in species composition, for example from specialist to generalist species;
- degradation of substrates (e.g. fragmentation, soil erosion);

Figure 9.2 Ecosystem and land use accounting based on land cover



- capacity of supporting healthy communities;
- dependence on human input (management, irrigation, fertilizers, subsidies, etc.).

By limiting the observation to a set of symptoms of ecosystem distress, this framework would support a practical strategy for the implementation of ecosystem accounts to be developed and used to assess the state and trends of our natural capital base. The system would potentially operate by constructing a set of supplementary accounts linked to those for land cover that describe the ecosystem characteristics or qualities associated with each stock class.

9.2.3 Harmonised and flexible use of multiple system units and data

The development of integrated land and ecosystem accounts will also require a much richer understanding of the properties of land cover mosaics than is currently necessary for creating land accounts. A range of different classification frameworks will be required, including those which focus on:

- ecosystem types, such as wetlands, grassland, forests, rivers, agri-systems, urban systems defined in the first instance using combinations of CLC data elements, so that they are relevant to specific analytical or policy requirements.
- geo-systems, eco-complexes or landscape units such as ecological networks, urban systems (starting with UMZ), rural systems, landscape types, which describe the multi-scalar mosaic nature of many ecosystems;
- geographical zones fixed *a priori*, such as biogeographical zones, coastal zones, mountain areas, river basins, protected areas, administrative zones which allow information to be reported in ways that are relevant in scientific and policy terms.

Through the land accounts work already undertaken and described in this report, it is clear that many of these analytical elements are already in place. The immediate challenge therefore is to test the concepts more fully through a range of pilot applications.

In developing ecosystem accounts, the emphasis of description will shift from the straightforward assessment of land cover stocks and flows, to include an analysis of the more qualitative characteristics of different types of land cover. As the introductory discussion in Chapter 1 emphasised, to frame policies for sustainable development, we need to know how much of a resource is available, how the stocks are changing and whether the quality of the resource stock that is being carried over is being maintained.

An illustration of the type of account that might be developed is given in Table 9.1, which uses data from the assessment of the conservation status of sites of special scientific interest in England. Many of these sites are part of the Natura 2000 network, and so a key policy concern is to determine the extent of the resource that can be considered to be in a favourable condition. The proportions of each habitat type found to be in the different status categories in 2003 are therefore shown. The key points to note about this example are that in keeping with similar sites throughout Europe, many of these areas are protected, and so it is unlikely that the physical stock of these habitats will change significantly over short time periods. This has indeed been the case in England. However, constant stock does not mean that the resource is being maintained. Their conservation significance is as much determined by their ecological quality, which ultimately determines their capacity to support biodiversity and supply a range of ecosystem services. Currently for many habitat types these qualities are or have been impacted by external drivers such as diffuse pollution and over grazing. The extent to which policy instruments and wider management strategies can restore the qualities of these systems could be assessed by the construction of a suitably structured set of land and ecosystem accounts.

This example illustrates how integrated land and ecosystem accounts can be built, namely by using the stock framework provided by the land accounts as a framework in which a range of other qualitative ecological information about biodiversity of ecological properties or process can be assigned. Such an approach could, for example be used to look at carbon sequestration, changes in biodiversity or species groups, or even the allocation of payments through agri-environmental schemes. Figure 9.3 illustrates how an assessment of small landscape units (SLUs) not detectable by Corine could be assessed using other data, and these statistics assigned to broader land- or geo-complexes, that could be used in a wider set of environmental accounts.

The implementation of land and ecosystem accounts is therefore likely to require access to a wide range of data beyond that available from CLC. These will include:

- access to local statistics, including those for human populations (e.g. health, life expectancy, income), agriculture, transport, energy;
- the ability to disaggregate statistics to the scale of various systems (e.g. population, use of agriculture inputs by river basin);
- the ability to generate statistics on land and ecosystem status at scales that are relevant to the socio-bio-physical units employed in decision-making (UMZ, agri-environmental regions, ecological networks and regions, protected areas, coastal areas, dominant landscape types);
- the inclusion of linear elements such as rivers, ecotones, roads, and small point and linear objects (so-called small landscape units);

Table 9.1 Example account describing the conservation status of sites of special scientific interest in England, 2003

Habitat type	Stock, ha (2003)	Conservation status (% stock in each status category, areas < 1 % not shown)						
		Favourable	Destroyed	Part destroyed	Unfavourable declining	Unfavourable — no change	Unfavourable recovering	Unknown
Acid grassland — lowland	**16 235**	58			4	11	27	
Acid grassland — upland	**25 714**	31			29	31	10	
Arable and horticulture	**14 125**	97				2	1	
Bogs	**185 739**	15			18	49	18	
Boundary and linear features	**9**	81			10		9	
Bracken	**2**	100						
Broadleaved, mixed and yew woodland — lowland	**78 093**	42			11	22	25	
Broadleaved, mixed and yew woodland — upland	**14 768**	50			7	24	20	
Built up areas and gardens	**67**	64	29		1	6		
Calcareous grassland — lowland	**41 293**	53			15	6	25	
Calcareous grassland — upland	**13 915**	17			40	28	15	
Coastal lagoons	**1 026**	61		6	17	9	7	
Coniferous woodland	**23 773**	90			1	7	1	2
Dwarf shrub heath — lowland	**38 245**	29			15	17	38	
Dwarf shrub heath — upland	**172 488**	18			17	50	16	
Earth heritage	**22 296**	87		1	1	2	1	6
Fen, marsh and swamp	**29 238**	42			17	19	22	
Improved grassland	**968**	78			5	12	5	
Inland rock	**8 698**	33			15	31	21	
Littoral rock	**600**	92			1	7		
Littoral sediment	**32 613**	66		1	21	8	4	
Montane habitats	**1 360**	1			27	72		
Neutral grassland — lowland	**47 396**	52			11	24	13	
Neutral grassland — upland	**2 644**	58			3	28	11	
Rivers and streams	**8 624**	27			3	67	2	
Standing open water and canals	**20 916**	56			9	22	12	
Supralittoral rock	**4 707**	82			6	8	4	
Supralittoral sediment	**12 219**	47			11	17	25	
Grand total	**817 772**	36			15	32	17	

Source: This table is derived from data supplied by English Nature in 2003 as part of the Countryside Quality Counts project, and should be treated as illustrative rather than definitive. Monitoring is ongoing and information on the current status of Sites of Special Scientific Interest (SSSIs) in England can be obtained through Natural England http://www.naturalengland.org.uk/ (accessed 14.11.2006).

- the integration of data from earth observation platforms beyond that simply relating to land cover such as meteorological information and estimates of net primary production of ecosystems;
- the ability to combine heterogeneous data sources, data collected using different sampling strategies, probabilistic data and those constructed using methods based on fuzzy logics.

Such data are being collected at global and regional levels, independently of the needs of environmental accounting, to monitor the effects of climate change. Clearly, they can be re-used and improved to enable their integration into a core set of social and economic statistics. The extension of the land accounts using such data is now the focus on ongoing work within the EEA.

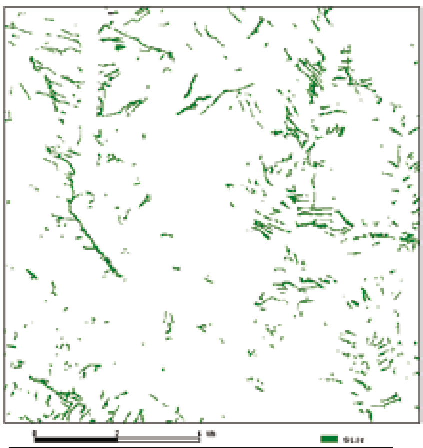
9.4 Land use and the classification of land functions

As Chapter 6 has shown, the relationship between land cover and use is complex because not only may several uses can be associated with a given land cover type, but the mixture of uses may also vary from place to place and over time. Conceptually, the connections are most conveniently explored by means of a matrix expressing the relationship between the elements of cover and use. In practice, however, it is often difficult to clearly differentiate between cover and use, because land classifications often appear to conflate cover and use categories because of the terms they use. The classification of cover developed to handle Corine data is no exception.

Despite the problems of differentiating cover and use, one of the features of the accounting approach is the importance that it attaches to the systematic classification of the elements that make up the various tables. In Chapter 2 we saw how the major cover types and flows between the various classes that could be recognised at the European scale. Table 9.2 shows the major use or functional categories identified for the accounting work and how their relationship to the broad Corine land cover stocks and flows might be handled. Clearly, each of the general use classes shown in Table 9.2 can be subdivided in order to expand the level of detail contained in the accounts. The use categories shown in Table 9.2 is a continuation of the pioneering statistical classification of land use published by the UN Economic Commission for Europe (UN/ECE, 1989).

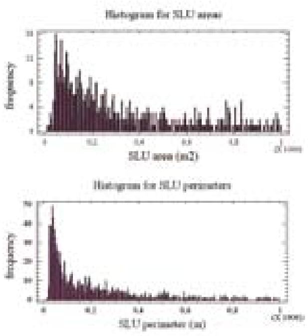
One important property of the establishment of a classification of land use functions is that it facilities the types of cross-cutting analysis required for

Figure 9.3 Assessment of small landscape units (SLUs) (not monitored by Corine)



Type	Number	%
Point	451	37.0
Line	672	55.2
Areal	95	7.8
Total	1 218	

Number of SLUs	1218
Area total (ha)	200.6
Area min. (ha)	0.001
Area max. (ha)	7.7
Area median (ha)	0.049
Perimeter total (m)	273676
Perimeter median (m)	113



Note: Small landscape features such as hedgerows, small ponds or woods are essential for assessing the state of ecosystems. Even though CLC may not detect any change, their disappearance reveals a degradation of ecosystem quality. On this example in the Czech Republic, small linear and point features are observed from very high-resolution satellite images (Ikonos). Field sampling is another solution for collecting this information.

Source: ETCTE/Gisat, 2006.

policy evaluation and potentially allows rapid comparisons between domains. This is in fact the principle that lies behind the development of the satellite accounts suggested as an important element of the standard system of national accounts by the United Nations.

Table 9.2 Land use functions of rural areas

Supply and use of land cover resource by land use functions		LUF1 Residential, incl. services	LUF2 Commercial	LUF3 Transport	LUF4 Industrial production	LUF5 Energy production	LUF6 Mining and quarrying	LUF7 Waste dumping	LUF8 Water management	LUF9 Farming, food production	LUF10 Forestry	LUF11 Recreation and Tourism	LUF12 Nature conservation	LUF13 Other uses	Adjustment for multiple uses	Total
Initial surface																
1	Artificial surfaces															
2A	Arable land and permanent crops															
2B	Pastures and mosaic farmland															
3A	Forests and transitional woodland shrub															
3B	Natural grassland, heathland, sclerophylous vegetation															
3C	Open space with little or no vegetation															
4	Wetlands															
5	Water bodies															
A — Total initial surface ~ 1990																
Net formation of land cover by Use																
lcf1	Urban land management															
lcf2	Urban sprawl															
lcf3	Extension of economic sites and infrastructures															
lcf4	Agricultural rotation and intensification															
lcf5	Conversion of land to agriculture															
lcf6	Forests creation and management															
lcf7	Water body creation and management															
lcf8	Changes of land cover due to natural and multiple causes															
B — Total net formation of land cover																
Net extension of use without formation of cover																
1	Artificial surfaces															
2A	Arable land and permanent crops															
2B	Pastures and mosaic farmland															
3A	Forests and transitional woodland shrub															
3B	Natural grassland, heathland, sclerophylous vegetation															
3C	Open space with little or no vegetation															
4	Wetlands															
5	Water bodies															
C — Total net extension of use without formation of cover																
Final surface																
1	Artificial surfaces															
2A	Arable land and permanent crops															
2B	Pastures and mosaic farmland															
3A	Forests and transitional woodland shrub															
3B	Natural grassland, heathland, sclerophylous vegetation															
3C	Open space with little or no vegetation															
4	Wetlands															
5	Water bodies															
D — Total final surface ~2000 (D = A + B + C)																

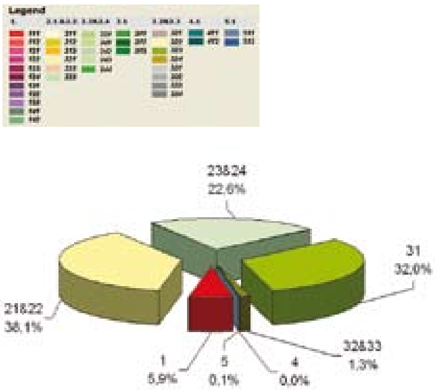
Once the relationships between cover and use can be established, the accounting tools described in this report can potentially be used to produce more clearly differentiated maps of land cover and land use, so that the patterns of change can be more fully explored. Figure 9.4 provides an example from recent work undertaken in the Czech Republic, which has attempted to show how agricultural census data can be linked to land cover information to produce a more full differentiated mapping of land use.

Other ongoing work initiated by the EEA has sought to develop other forms of targeted or supplementary accounts by linking the CLC data to Europe-wide databases for:

- Transport infrastructure (e.g. TELEATLAS, the Eurostat Regio database, and European Transport policy Information System, ETIS);
- Population (e.g. Eurostat Regio database, Eurostat SIRE);
- Agriculture (e.g. Structure of agricultural holdings/FSS, Eurofarm).

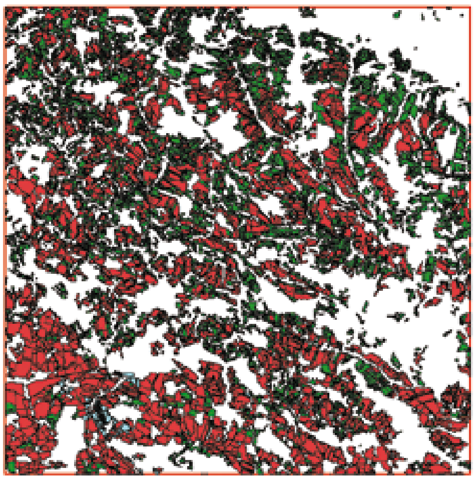
In addition, data on more specific themes, such as tourism, is being developed.

Figure 9.4 Assimilation of CLC and agriculture statistics for land use accounting in the Czech Republic



		Area (ha)
[illegible]	[illegible]	[illegible]
Agricultural areas		
Arable land & Permanent crops	21&22	34317,61
Pastures & Heterogeneous areas	23&24	20369,21
Forest & Semi-natural areas		
Forests	31	28797,03
Shrubs & Semi-natural areas	32&33	1172,22
Wetlands	4	0,00
Water bodies	5	59,48

Left is a map of a small area in the Czech Republic which shows the spatial distribution of Corine land cover types at level 3. By linking the information to agricultural statistics, a more detailed picture of land use can be established, which is shown below.



R: arable land
S: orchards
T: pastures and medows
L: forest (?)
O: others (e.g. green houses)

Extensive 1	Area ha	Percentage %	No. fields
R	23982	56	2686
T	18116	43	6233
S	372	1	145
O	2	0.004	1
L	16	0.039	24
SUM	42487		9089

In this map the CLC polygons have been reclassified according to the use of categories employed in the agricultural census, so that a more differentiated picture of the land cover/landscape mosaic in this area can be provided. Moreover, the potential impacts of changes in market conditions for the land cover elements in this area might be more completely understood by using this data.

Source: ETCTE/Gisat 2006.

Beyond their immediate informative interest, the development of targeted land use accounts can also be seen as a step towards the characterisation and quantification of ecosystem services. Not all ecosystem functions deliver services which are equivalent to those resulting from production. In order to support efficient decision-making, the definition of ecosystem services must enable realistic comparisons and trade offs with produced outputs to be made. Such products are ultimately accounted by the SNA as end or final consumption ([32]). Final consumption can be on an individual basis, by private households or collectively, when services are provided to the community as a whole by government or private non-profit organisations ([33]). The way forward for streamlining the construction of accounts for ecosystem services is therefore threefold:

- to work towards consistency with the definitions of individual and collective, marketed and non-marketed household consumption;
- to make an assessment from the perspective of households within ecosystems, in terms of the land use functions from which they benefit;
- to make a measurement of the natural capital that supports the production of ecosystem services.

Such accounts can be constructed using physical measures or developed further to enable full monetary valuation.

9.5 Conclusion

This report began with the assertion that an understanding of the implications of changes in land cover and land use is a fundamental part of planning for sustainable development and ecosystems. Through the materials presented here, we have shown how the development of land accounts can contribute knowledge and understanding in this important area.

It has been argued that land accounts provide a valuable integrating framework for decision-making because they allow a range of ecological, social and economic issues to be considered alongside each other. The work of the EEA on land cover accounts has now established a platform on which such developments can now take place.

Thus, the future construction of integrated land and ecosystem accounts may facilitate a better understanding of how changes in land cover and land use by human action can impact on the integrity of natural resource systems, and hence the output of ecosystem goods and services that are so important for the well-being of people. More generally, by linking land cover dynamics to the wider patterns of social and economic activities through the concept of land use functions, the environmental implications of policies might be better assessed. As a result of the work begun here and through the further development of land accounts, it may finally be possible to design a set of decision support tools that will help achieve the goal expressed in Agenda 21, namely, to find ways of minimising conflicts and of making the efficient trade-offs that link social and economic development with environmental protection and enhancement.

([32]) In strict accounting terms, this equation should additionally include the net formation of capital stocks and the net balance of imports and exports.

([33]) 1993 SNA, IX. THE USE OF INCOME ACCOUNT, UN Statistical Division, http://data.un.org/unsd/sna1993/toctop.asp?L1=9 (accessed 02.10.2006).

Acronyms

CAP	Common agriculture policy
CBD	Convention on biological diversity
CLC	Corine land cover
CORILIS	Corine + lissage (smoothing, in French)
CORINAIR	Corine air
Corine	COoRdination de l'INformation sur l'Environnement
CSI	EEA's core set of indicators
DEFRA	Department for Environment, Food and Rural Affairs (UK)
DESTATIS	German Federal Statistical Office
DLT	Dominant landscape type
DMEER	Digital map of European ecological regions
EC	European Community
EDS	Ecosystem distress syndrome
EEA	European Environment Agency
EIONET	European environmental information and observation network
ESDP	European spatial development perspective
ESPON	European spatial perspective observatory network
ETCTE	European Topic Centre on Terrestrial Environment
EU	European Union
EUROSION	Assessment of European coastal erosion
FSS	Farm structure survey
GBL	Green Background landscape index
GDP	Gross domestic product
GMES	Global monitoring for environment and security
HELCOM	Helsinki Commission — Baltic Marine Environment Protection Commission

IES	Institute of Environment and Sustainability (JRC)
IGBP	International geosphere and biosphere programme
IMAGE2000	European database of satellite images used for CLC2000
INSPIRE	Infrastructure for spatial information in Europe
IRENA	Indicator reporting on the integration of environmental concern into agricultural policy
IRS	Indian remote sensing satellite
JRC	Joint Research Centre
LACOAST	Map of European coastal zone (10 km) 1975 by JRC
LARU	Land analytical and reporting units
LAU	Land administrative units
LCCS	Land cover classification system
LCF	Land cover flow
LEAC	Land and ecosystem accounts
LUCAS	Land use/cover area frame survey
MAP	Mediterranean action plan
NUTS	Nomenclature des unités territoriales statistiques
OSPARCOM	OSPAR Commission for the Protection of the Marine Environment of the North-East Atlantic
PHARE	EU cooperation programme with accession countries of central and eastern Europe in the 1990s
SEEA	Integrated environmental and economic accounting or System of integrated environmental and economic accounting (UN)
SNA	System of national accounts (UN)
TERRUTI	Enquête d'utilisation du territoire (France)
UMZ	Urban morphological zones
UN	United Nations
UNCEEA	United Nations Expert Committee on Environmental and Economic Accounting
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Program
UNESCO	United Nations Education, Science and Culture Organization
UNSD	United Nations Statistical Division

Bibliography

Council of Europe (2000). *The European Landscape Convention*. http://www.coe.int/T/e/Cultural %5FCo %2Doperation/Environment/Landscape/ (accessed 23.09.2006).

Defra (2006a). *Sustainable development indicators in your pocket 2006, UK*. Department for Environment, Food and Rural Affairs. http://www.sustainable-development.gov.uk/progress/index.htm (accessed 23.09.2006).

Defra (2006b). *Defining and Identifying Environmental Limits for Sustainable Development*. Department for Environment, Food and Rural Affairs. http://www2.defra.gov.uk/research/project_data/More.asp?I=NR0102andM=KWSandV=NR0102andSCOPE=0 (accessed 30.09.2006).

EEA (2005). *The European environment — State and outlook 2005,* State of Environment Report No 1/2005 , http://www.eea.europa.eu/Highlights/20051122115248 (accessed 23.09.2006).

EEA (2006a). *Integration of environment into EU agricultural policy — the IRENA indicator-based assessment report*. EEA Report No 2/2006. http://reports.eea.europa.eu/eea_report_2006_2/en (accessed 30.09.2006).

EEA (2006b). *The thematic accuracy of Corine land cover 2000: Assessment using LUCAS (land use/cover area frame statistical survey)*. EEA Technical Report No 7/2006 http://reports.eea.europa.eu/technical_report_2006_7/en (accessed 30.09.2006).

Global Biodiversity Outlook (2006). *Healthy, biodiverse ecosystems provide the goods and services that humans need for their well-being*. Global Biodiversity Outlook 2, released at CBD COP8, Curitiba, March 2006).

GLP (2005). *Science Plan and Implementation Strategy*. IGBP Report No. 53/IHDP Report No. 19. IGBP Secretariat, Stockholm. 64pp. http://www.glp.colostate.edu/report_53.pdf (accessed 14.09.2006).

Grasland C., Mathian H., Vincent J.M., (2000). Multi-scalar analysis and map generalisation of discrete social phenomena: Statistical problems and political consequences, *Statistical Journal of the United Nations ECE*, 17, IOS Press, 1–32.

Haines-Young, R. H. (1999). *Environmental accounts for land cover: their contribution to 'state of the environment' reporting*. Transactions of the Institute of British Geographers 24: 441–456.

London Group (2006). *The London Group on Environmental Accounting*. http://unstats.un.org/unsd/methods/citygroup/londongroup.htm and http://www4.statcan.ca/citygrp/london/london.htm and (accessed 23.09.2006).

McConnell, W.J. and Emilio F., Moran, E.F., 2000. Meeting in the Middle: The Challenge of Meso-Level Integration. An International Workshop October 17–20, 2000 Ispra, Italy. LUCC Report Series No. 5

Millennium Ecosystem Assessment (2005). Millennium Ecosystem Assessment, Ecosystems and Human Well-Being: General Synthesis, Millennium Ecosystem Assessment Series, Island Press, ISBN: 1-59726-040-1. http://millenniumassessment.org//en/Products.Synthesis.aspx (accessed 14.09.2006).

Parker J., Steurer A., Uhel R., and Weber J-L (1996). A general model for land cover and land use accounting — Invited Paper drafted from the report of the UN-ECE Task Force on Physical Environmental Accounting — Special Conference on Environmental Accounting in Theory and Practice, Tokyo, March 5–8, 1996.

Radermacher, W. (1998). 'Land use accounting: pressure indicators for economic activities'. In Uno and Bartelmus 1998.

Rapport D J., and Whitford W.G. (1999). How Ecosystems Respond to Stress — Common properties of arid and aquatic systems in BioScience Volume: 49 Number: 3, Page: 193–203 American Institute of Biological Sciences.

SEEA (2003). Handbook of National Accounting: Integrated Environmental and Economic Accounting 2003. United Nations, European Commission, International Monetary Fund, Organisation for Economic Co-operation and Development, World Bank. http://unstats.un.org/unsd/envAccounting/seea2003.pdf (accessed 14.09.2006).

Stott, A. and Haines-Young, R. (1998). 'Linking land cover, intensity of use and botanical diversity in an accounting framework in the UK'. In Uno and Bartelmus 1998.

UNECE (1989). UNECE Standard Statistical Classification of Land Use. www.unescap.org/stat/envstat/stwes-class-landuse.pdf#search=%22UNECE%20Standard%20Statistical%20Classification%20of%20Land%20Use%22 (accessed 30.09.2006).

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

United Nations Conference on Environment and Development (1992). Agenda 21 http://www.un.org/esa/sustdev/documents/agenda21/english/agenda21toc.htm (accessed 14.09.2006).

Uno, K. and Bartelmus, P. (eds) (1998). Environmental Accounting in Theory and Practice. Dordrecht, Boston and London: Kluwer academic Publishers.

Annex A The LEAC database, access tools and data resources

A.1 Introduction

The general structure of the Land and Ecosystem Accounts (LEAC) database that has been developed by the EEA and its partners has been introduced in Chapter 8. In this annex we present a more complete account of the database in terms of the full data model that underlies it. We also explain how the database can be accessed by those interested in using the data to develop their own applications.

A.2 The LEAC database

The LEAC database holds records for each of the 1 km x 1 km cells in the accounting grid that has been used by the EEA for this study. Metadata describing the grid and details of how to obtain a copy of it are given later in the chapter. In general terms the database itself consists of two main tables and a set of definition tables, such as the so-called flatmatrix table which defines the various flows that can be identified using the CLC change data.

The main data tables in the LEAC database are:

- the **LEAC_DATA** table, which contains Corine land cover change information for the 1990 and 2000 reference dates for each reference grid cell. Each land cover block in the grid cell is coded according to the change it has exhibited over the accounting period, which is represented as a six-figure string made up of the initial and final Corine level 3 cover class to which it has been assigned. The area of the land cover block in hectares is also recorded.

- the **LARU** table contains the land analytical and reporting units codes which have bee assigned to each cell.

The relationship between the two main tables in the LEAC database is shown in Figure A.1a. The link is established between them through a unique identifier for each grid cell held in the field gridcode. The relationship between them is 'one-to-many', because potentially many change records can be assigned to an individual grid cell. Each distinct land cover block that occurs in the grid cell gives rise to a single record in the LEAC table.

The definitions of the values for the analysis and reporting units held in the LARU table are stored in a set of separated tables that can be linked through the LARU code. In the example given in Figure A.1b, the LARU codes shown relate to the various NUTS administrative units, the dominant landscape types, 10 km coastal strip and sea catchment areas in which the cell is located. In the full database the codes cover the much longer list of potential analytical and reporting units shown in Table A.1.

The definitions of the land cover changes that are recorded in the LEAC_Data table are stored in the flatmatrix table. The link is made through the Change_Code field (Figure A.1c).

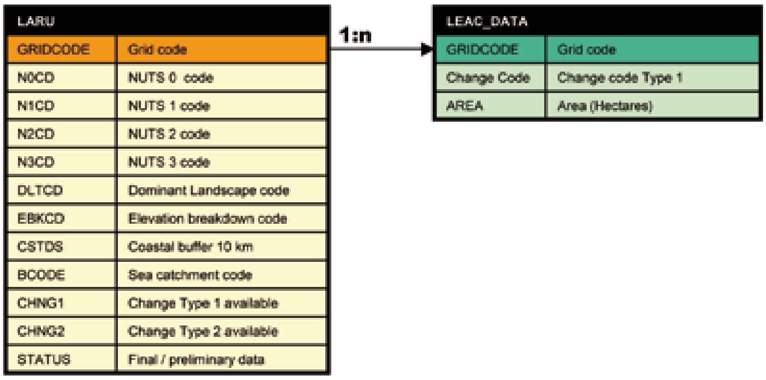
The classification of changes was derived from the cross tabulation of the 44 level 3 Corine land cover classes, which produced 1936 possible pairings of all potential initial and final cover classes. Of these, 44 represented no change (i.e. they were arranged along the leading diagonal of the matrix), and 1 892 represent a potential type of transformation. In order to make the matrix of change easier to handle the changes were aggregated into 50 types of flows, which themselves could be grouped into just nine major categories of change. The latter represented level 1 in the resulting nomenclature of change.

They are:

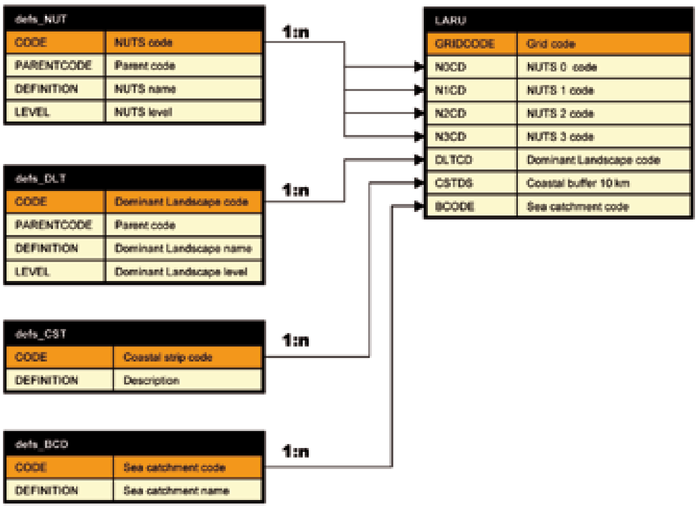
LCF1	Urban land management
LCF2	Urban residential sprawl
LCF3	Sprawl of economic sites and infrastructures
LCF4	Agriculture internal conversions
LCF5	Conversion from forested and natural land to agriculture
LCF6	Withdrawal of farming
LCF7	Forests creation and management
LCF8	Water bodies creation and management
LCF9	Changes of land cover due to natural and multiple causes.

Figure A.1 Structure of the LEAC database

(a) Relationship between the two main tables of the LEAC database



(b) Land analytical and reporting units (LARU) table and definition tables



(c) Definition of land cover changes

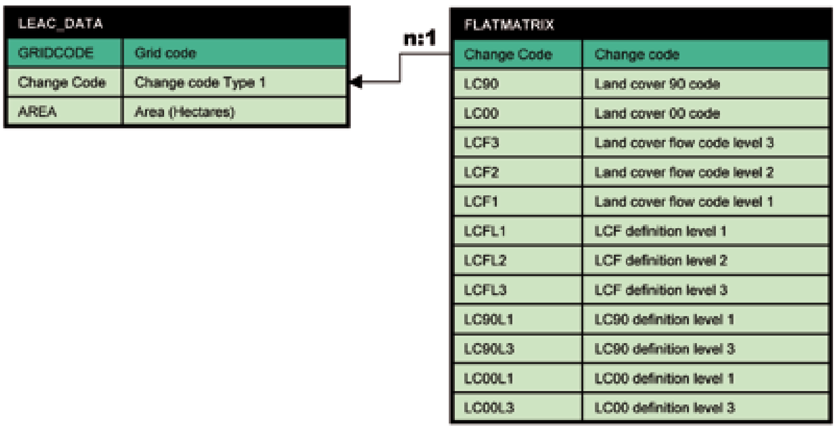


Table A.1 Analytical and reporting units used in the LEAC database

Administrative units	
	NUTS 0 (countries)
	NUTS 1
	NUTS 2
	NUTS 3
	LAU 1 (previously NUTS 4) (*)
	LAU 2 (previously NUTS 5) (*)
Geographic regions and zonings	
	River basins (*)
	Sea catchments
	Coastal zones
	Geographical definition
	10 km standard buffer zone
	Mountain areas
	Elevation breakdown
	Urban morphological Zones
	Designated areas (*)
	Bio-geographic regions
	Ecological regions (*)
	Land cover units (Corine land cover)
	Modifiable zonings
	Land cover intensity neighbourhoods (CORILIS)
	Dominant landscape type areas (LEAC/DLT)
Reference grids	
	1 km x 1 km
	5 km x 5 km
	10 km x 10 km
	100 m x 100 m

(*) not yet available by October 2006

The classification of flows at level 1 have mostly been used as the basis of the examples presented in Part II of this report, and so they need little further description here. Figure A.1c shows the broad structure of the flatmatrix table, divided up according to the major types of flow identified at level 1. Appendix 2 presents the complete classification of land cover flows in the form of a detailed annotated nomenclature and a 44 x 44 class look up table with LCF codes.

A.3 Access to the LEAC data resources

The structure of the LEAC database is simple, but highly flexible, thus enabling the information to be made available in a variety of database formats so that users can make spatial queries without access to more sophisticated GIS tools. In the next sections of this chapter we describe the access tools that the EEA has made available so that users can make their own analyses of the account data.

Up to now the EEA has been the main user of the land account data, and so the results have been published mainly in the form of reports, such as *The European Environment: State and outlook 2005* (EEA, 2005). However, it is clear that the applications developed to date by no means exhaust the types of analysis that is possible using these data. The EEA is keen to make the data available so that their potential can be fully realised. Access to the data resources that have shaped EEA's thinking is also considered essential, in order that its work can be made as open and transparent as possible. Thus EEA sought to develop a set of database tools that would enable potential users to explore the account data for themselves.

Therefore, general access to the EEA LEAC data is now possible through one of three major routes:

- as downloads of the complete database, intended mainly for the more technical user and researchers;
- via on-line extraction of statistics and ready-for-mapping tables, again as a service to technical or scientific users, as well as policy advisors;
- through a set of interactive reporting and analysis tools to support desktop applications.

A.3.1 Data downloads

A.3.1.1 Corine land cover

Corine land cover data sets can be downloaded from EEA's data service at: http://dataservice.eea.europa.eu/dataservice/available.asp?type=azlistandletter=C (accessed 02.10.2006.)

The following files are available:

- Corine land cover (CLC1990) 100 m — version 8/2005;
- Corine land cover (CLC1990) 250 m — version 8/2005;
- Corine land cover 2000 (CLC2000) 100 m — version 8/2005;
- Corine land cover 2000 (CLC2000) 250 m — version 8/2005;
- Corine land cover 2000 vector by country (CLC2000);

- Corine land cover changes (CLC1990–CLC2000) 100 m — version 8/2005;
- Corine land cover changes (CLC1990–CLC2000) vector by country;
- Corine land cover (CLC1990) Switzerland;
- Corine land cover 1975 (CLC1975) and Corine land cover changes (1975–1990) in a 10 km zone around the coast of Europe.

These files are free to users after registration. An extensive description of Corine methodology and products, with examples and an annotated and illustrated nomenclature is available at the website of the EEA topic centre at: http://terrestrial.eionet.europa.eu/CLC2000 (accessed 02.10.2006).

A.3.1.2 Basic accounts for land cover stocks and change

Due to its volume, the LEAC database can only be supplied on request. However extracts can be downloaded from the database using a range of access routes, which enable users to build their own applications via their own spreadsheet, database, geographical information system software. Using systems such as ArcGis, for example, the account data can be displayed in a map form by using the 1 km x 1 km accounting reference grid.

The account data can be accessed from the EEA data service where statistics can be extracted online at land cover accounts (LEAC) based on Corine land cover changes database:
http://dataservice.eea.europa.eu/dataservice/metadetails.asp?id=884 (accessed 02.10.2006).

The underlying data are also available for each of the individual land cover flows and their hierarchical aggregations. The layers are derived from the LEAC database and stored in raster format with a resolution of 1 000 m. The spatial reference system is ETRS LAEA 5 210 and the positions of their cells match the 1 km European standard grid definition.

A.3.1.3 Additional spatial data for land accounting

Several other data sets used for land accounting and spatial analyses are also available through the EEA ([34]), including:

- CORILIS 1990 and CORILIS 2000, with smoothing radii of 5, 10 and 20 km.
- Layers derived from CORILIS such as the composite Green Background landscape map and the map of dominant landscape types (see Chapter 8)
- Other layers derived from Corine land cover:
  - urban morphological zones (the agglomeration of Corine artificial areas distant of less than 200 m, with population estimates) http://dataservice.eea.europa.eu/dataservice/metadetails.asp?id=720 (accessed 02.10.2006);
  - disaggregated Population Density to CLC, 2000 and (for some countries) 1990. This layer is developed by JRC from Eurostat population data. http://dataservice.eea.europa.eu/dataservice/metadetails.asp?id=830 (accessed 02.10.2006);
  - green urban areas within urban morphological zones, down to 1 hectare. http://dataservice.eea.europa.eu/dataservice/metadetails.asp?id=912 (accessed 02.10.2006);
  - the EEA reference grid samples for projection ETRS89-LAEA 52N 10E. http://dataservice.eea.europa.eu/dataservice/metadetails.asp?id=760 (accessed 02.10.2006).

A.3.2 Interactive reporting tools

If users do not wish to download the information, they can nevertheless gain interactive use of the information held at EEA via a range of other routes. For example, users may link to the account data held in the form of an OLAP database at EEA. This is intended for use with MS Excel or ArcGis. With these packages and a computer connected to internet, the EEA server can be queried directly for the production of a wide range of tables. Mapping can be achieved by linking downloaded tables to ArcGis shapefiles. The methods used to establish the links are as follows:

- spreadsheets: The LEAC OLAP database allows users on-line access to Microsoft Excel pivot tables, that can be customised so that users to generate their own reports;
- information on how to connect to the LEAC OLAP database can be found at: http://terrestrial.eionet.europa.eu/LEAC/Databases/Connection (accessed 02.10.2006).

  At present the service gives users access to a set of data cube files for:
  - CLC 2000 — CLC Changes (CLC2000 Minus);

([34]) http://terrestrial.eionet.europa.eu/LEAC/Layers (accessed 02.10.2006).

– CLC 1990 — CLC 2000 (CLC1990 against 2000)

together with data from a set of earlier studies:

– PHARE 1975–1990
– LaCoast 1975–1990
– LaCoast 1975–1990 — Eastern Europe Extension.

- maps: the ARCGIS LEAC OLAP database facility also allows users to link their desktop GIS session directly to the online database so that map output can be prepared. Information on how to connect to the LEAC OLAP ARCGis tool can also be found at: http://terrestrial.eionet.europa.eu/LEAC/Databases/Connection (accessed 02.10.2006).

A.3.3 On-line statistics and maps

For those users with less technical demands, or who do not wish to handle the LEAC data themselves, basic statistics can be extracted on-line from the LEAC and Corine land cover change databases via the EEA data service at: http://dataservice.eea.europa.eu/dataservice/metadetails.asp?id=884 (accessed 02.10.2006).

Statistics can be produced interactively in-screen via a set of pivot tables which can be customised by changing the thematic levels at which CLC data are used or by selecting different analysis and reporting units. The service also provided the opportunity to download pre-formatted maps and graphs.

Figure A.2 illustrates the nature of the interface provided by the data service.

The following pivot tables are available via this service:

- Corine land cover 1990 (by NUTS units)
- Corine land cover 1990 (Europe)
- Corine land cover 2000 (by NUTS units)
- Corine land cover 2000 (Europe)
- Land cover changes 1990–2000 (by country)
- Land cover changes 1990–2000 (Europe)
- Land cover flows (by NUTS units)
- Land cover flows (Europe)

The on-line map service for LEAC is under development. However, it is presently possible to inspect maps on-line with an advanced viewer that allows the mapping of land cover type selected by users and a transparent overlay of data onto the basic satellite images. The service is available at:http://dataservice.eea.europa.eu/clc/(accessed 02.10.2006). This service will eventually be expanded to include the presentation of the LEAC data themselves.

A.4 Source data

In addition to the LEAC database itself, the EEA provides access to the underlying data on which the accounts have been based. This section provides details of the ways in which they have been processed and how they may be downloaded.

Figure A.2 On-line access to land accounts on the EEA web service

All the data sets described below, except those indicated, can be accessed via the EEA data service at: http://dataservice.eea.europa.eu/dataservice/(accessed 02.10.2006).

This site also provides further links to more detailed metadata for each of the resources.

A.4.1 The European reference grid

The generation of the European reference grids which were used for the creation of the LEAC database followed the standards established at the 1ST Workshop on European reference grids ([35]) (Table A.2). They were generated at 1 km resolution, using a modified version of the 'Generate fishnet' tool for ArcMap called 'EEA reference grid fishnet tool for ArcGIS 9'. The 1 km grid has been aggregated to 5 and 10 km in a second step.

All of the grids were based on the ETRS89 Lambert Azimuthal Equal Area projection. The basic metadata relating to the 1 km grid is given in Table 9.2, and Figure 9.3 shows how the 1, 5 and 10 km grids are nested in relation to the underlying Corine land cover data.

Further details of the way in which it the grids were generated can be found at: http://www.eionet.europa.eu/gis (accessed 02.10.2006).

Table A.2 Meta data for the European 1 km x 1 km reference grid

Reference system:	
	Name: ETRS_1989_LAEA_L52_M10
	Datum Name: D_ETRS_1989
	Ellipsoid Name: GRS_1980
	Semi-major axis: 6378137
	Axis units: degrees
	Flattening ratio: 3,35281068118232E-03
	Projection Name: Lambert_Azimuthal_Equal_Area
	Longitude of central meridian: 10
	Latitude of projection origin: 52
	False easting: 4321000 meters
	False northing: 3210000 meters
Methodology:	
	This reference grid is based on ETRS89 Lambert Azimuthal Equal Area projection with parameters: latitude of origin 52° N, longitude of origin 10° E, false northing 3 210 000.0 m, false easting 4 321 000.0 m. Origin of grid is calculated from 0 m N 0 m E of projection. Created using the 'EEA ETRS89_LAEA fishnet tool v1 for ArcGIS 9'. The tool and guidelines are available at http://www.eionet.europa.eu/gis (accessed 02.10.2006)
Geographic box coordinates:	
	West bound longitude: -179,66464054676
	East bound longitude: 179,975298365794
	North bound latitude: 89,7128910377918
	South bound latitude: 18,7981039480947

A.4.2 Corine land cover 1990 and 2000, and Corine land cover change

Two versions of Corine land cover for 1990 and 2000 are available at spatial resolutions of 100 m and 250 m for the 44 land cover classes, with a minimum mapping unit of 25 ha and a positional accuracy of 150 m. The data are projected using the same reference system as that used for the European reference grid (see above). The spatial extent of the data sets is shown in Figure 9.2, and more complete tabular information on temporal coverage is given in Appendix 3.

The coarser resolution version allows users to undertake mapping at European scales, given the large file seizes that result from such extensive coverage. The thematic and geometric data quality of the original 1990 data has been improved basis of the Corine 2000 update.

The Corine land cover change data set has been generated from these two sources, and is available at similar spatial resolutions. Coverage is also indicated in Figure 9.2. The changes between CLC1990 and CLC2000 were not derived from the simple subtraction/addition of CLC1990 map from CLC2000, but rather from the direct comparison of satellite images. Thus, the CLC2000 product effectively updated the extent of parcels mapped in the first phase. Using this method, it has been shown that the minimum mapping unit for change detection could be set at 5 ha. The full classification of flows is given in Appendix 2.

A.4.3 CORILIS 1990 and 2000

As discussed in Chapters 2 and 8, the CORILIS initiative has provided a set of tools to enable spatial smoothing for the generalisation and analysis of land cover data information. The purpose of CORILIS is to calculate intensities or potentials of a given theme in each point of a territory. A detailed description of the approached used is given in Figure 9.4.

([35]) Proceedings and recommendations from 1st Workshop on European reference grids, Ispra, 27–29 October 2003. A. Annoni, European reference grids, volume EUR 21 494 EN European Commission, Joint Research Centre, 2005.

CORILIS products with different smoothing radii (5 km, 10 km and 20 km) have been generated for both the 1990 and 2000 Corine land cover data at levels 1 and 3. The data can be downloaded from: http://dataservice.eea.europa.eu/dataservice/metadetails.asp?id=880 (accessed 02.10.2006) and http://dataservice.eea.europa.eu/dataservice/metadetails.asp?id=881 (accessed 02.10.2006).

These sites also provide detailed information about algorithms used to create the data sets.

A.4.4. Dominant land cover and landscape types

These have been defined using the generalised land cover information derived from the CORILIS products described in Section 9.4.3, which have allowed cells in the European reference grid to be assigned to a dominant and sub-dominant land cover types using the Corine level 1 land cover classification.

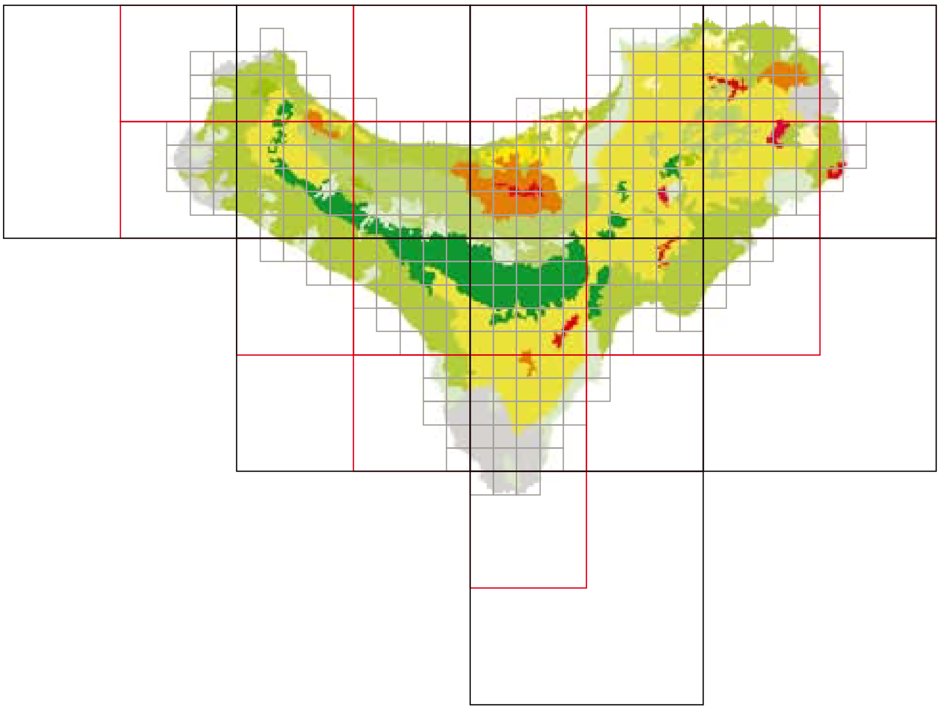
Being a statistical generalisation, CORILIS allows various aggregations and computations. Two standard maps are currently used for spatial analysis: the Green Background landscape (GBL) and the dominant landscape types (DLT). GBL represents the probability of finding pasture, agriculture mosaics, forests and other semi-natural or natural land in a given neighbourhood. DLT maps the dominant character of land cover and, combined with relief, bio-physical landscapes.

Both maps can be changed by altering the underlying parameters and cut-offs, and therefore do not represent a single and definitive zonation. The algorithm used for their calculation can be modified in terms of:

- the choice and weighting of the components CORILIS layers;
- the smoothing radii applied in the CORILIS algorithm (e.g. 5, 10 or 20 km);
- varying the thematic level at which CLC data are used; and
- varying the threshold values (intensity levels) used to distinguish the core areas for the GBL.

Therefore, the background maps can be tuned or modified by the users according to specific conditions, constraints or policy objective. The dominant land cover and landscape maps and the map of the Green Background can be downloaded from: http://terrestrial.eionet.europa.eu/LEAC/Layers (accessed 02.10.2006).

Figure A.3 Illustration of European reference grids for El Hierro (Canary Islands)



Note: Key : 1 x 1 km (grey), 5 x 5 km (red) and 10 x 10 km (black). Corine land cover pixel size is 100 m. The reference system is Lambert Equal Area.

Figure A.4 The CORILIS approach

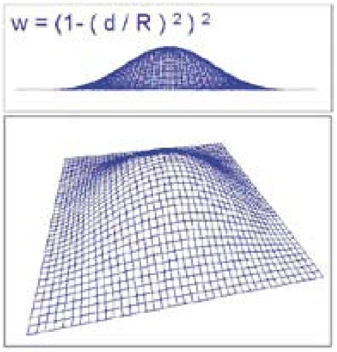
The last version of CORILIS methodology set up at ETC/TE in 2005, uses the newly defined European reference grid and the smoothing toolbox of MatLab 7, a powerful programme used for mathematical calculation. CLC90 and CLC00 layers have been tabulated into the reference grid for computing the proportion in each grid cell of each of the 43 CLC classes (excluding 'Sea and oceans' class). This information was used as an input for the MatLab script.

The spatial smoothing consists on determining for each point of the land the potential information present in its neighbourhood. A Gaussian type statistical function (called BiWeight) is used to weight (w) this information according to the distance from the considered point in kilometres.

The smoothed data are stored in the same format than the input data. This ASCII files can be imported directly to ArcGIS using the ASCIIGRID command. Before using these layers they should be masked with a land/sea layer to eliminate the border effect. Another mandatory step is to define the projection for the new files. The projection should be the same ETRS 1989 LAEA which is currently implemented in ArcGIS and that was used to define the Reference Grid.

Further development

The bottleneck of the smoothing process in MatLab is to read/write data from text files. A possible improvement of the script would allow reading and writing data from/to a database management system such as MS SQL Server. This functionality is implemented in MatLab through the database toolbox. It would lead to reconsider the possibility of smoothing raw data instead of surfaces aggregated to the 1 km² reference grid. This smoothing would work directly on Boolean values for each of the CLC classes and the results would maintain the spatial resolution of the input land cover layers (100 m).



w = (1 – (d/R)2)2
w: weight
d: distance in km
R: smoothing radius

A.4.5 Bio-geographic regions

The bio-geographic regions data set contains the official delineations used for the Habitats Directive (92/43/EEC) and for the EMERALD Network, set up under the Convention on the Conservation of European Wildlife and Natural Habitats (Bern Convention). Modifications adopted by the Bern Convention Standing Committee and approved by habitats Committee 3 April 2005 have also been included.

The version available incorporates digital data by countries, which has the consequence that the polygons and lines in the map have different generalisation levels. The changes in this version are:

- Lithuania: the whole country is in the Boreal region.
- Czech Republic: change in order between Continental and Pannonian regions.
- Slovak Republic: change in border between Alpine and Pannonian regions.

The data are available at: http://dataservice.eea.europa.eu/dataservice/metadetails.asp?id=839 (accessed 02.10.2006).

A.4.6 Regional sea basins

Another geographic unit used to allocate land cover change is the Regional sea boundaries. These boundaries were produced in the context of the Regional Seas Conventions (HELCOM, OSPARCOM and MAP) by grouping river catchments draining to the same regional sea. These units are the Baltic, the North Sea, the Atlantic, the Mediterranean and the Black Sea.

The data are available at: http://terrestrial.eionet.europa.eu/LEAC/Layers (accessed 02.10.2006).

Appendix 1 Corine land cover classification

A: Standard CLC hierarchical classification

1	Artificial surfaces		
	1.1	Urban fabric	
		111	Continuous urban fabric
		112	Discontinuous urban fabric
	1.2	Industrial, commercial and transport units	
		121	Industrial or commercial units
		122	Road and rail networks and associated land
		123	Port areas
		124	Airports
	1.3	Mines, dump and construction sites	
		131	Mineral extraction sites
		132	Dump sites
		133	Construction sites
	1.4	Artificial non-agricultural vegetated areas	
		141	Green urban areas
		142	Sport and leisure facilities
2	Agricultural areas		
	2.1	Arable land	
		211	Non-irrigated arable land
		212	Permanently irrigated land
		213	Rice fields
	2.2	Permanent crops	
		221	Vineyards
		222	Fruit trees and berry plantations
		223	Olive groves
	2.3	Pastures	
		231	Pastures
	2.4	Heterogeneous agricultural areas	
		241	Annual crops associated with permanent crops
		242	Complex cultivation patterns
		243	Agriculture and significant natural vegetation mosaics
		244	Agro-forestry areas
3	Forests and semi-natural areas		
	3.1	Forests	
		311	Broad-leaved forest
		312	Coniferous forest
		313	Mixed forest
	3.2	Shrub and/or herbaceous vegetation associations	
		321	Natural grassland
		322	Moors and heathland
		323	Sclerophyllous vegetation

		324	Transitional woodland shrub
	3.3	Open spaces with little or no vegetation	
		331	Beaches, dunes and sand plains
		332	Bare rock
		333	Sparsely vegetated areas
		334	Burnt areas
		335	Glaciers and perpetual snow
4	Wetlands		
	4.1	Inland wetlands	
		411	Inland marshes
		412	Peatbogs
	4.2	Coastal wetlands	
		421	Salt marshes
		422	Salines
		423	Intertidal flats
5	Water bodies		
	5.1	Inland waters	
		511	Water courses
		512	Water bodies (lakes and reservoirs)
	5.2	Coastal waters	
		521	Coastal lagoons
		522	Estuaries
		523	Sea and ocean

B: Aggregation used for land cover accounts

LEAC groups			CLC classes
1	Artificial surfaces		1.
2A	Arable land and permanent crops		2.1 + 2.2 + 2.4.1
2B	Pastures and mosaic farmland		2.3 + 2.4.2 + 2.4.3 + 2.4.4
	2B1	Pastures	2.3
	2B2	Mosaic farmland	2.4.2 + 2.4.3 + 2.4.4
3A	Forests and transitional woodland shrub		3.1 + 3.2.4
	3A1	Standing forests	3.1
	3A2	Transitional woodland and shrub	3.2.4
3B	Natural grassland, heathland, sclerophylous vegetation		3.2.1 + 3.2.2 + 3.2.3
3C	Open space with little or no vegetation		3.3
4	Wetlands		4.
5	Water bodies		5.

Appendix 2 Classification of land cover flows

A: Definition of land cover flows

LCF1	**Urban land management:** Internal transformation of urban areas	
LCF11		Urban development/infilling: Conversion from discontinuous urban fabric, green urban areas and sport and leisure facilities to dense urban fabric, economic areas and infrastructures
LCF12		Recycling of developed urban land: Internal conversions between residential and/or non-residential land cover types. Construction of urban greenfields is not considered here but as LCF11
LCF13		Development of green urban areas: Extension of green urban areas over developed land as well as, in the periphery of cities, over other types of land uses
LCF2	**Urban residential sprawl:** Land uptake by residential buildings altogether with associated services and urban infrastructure (classified in CLC111 and 112) from non-urban land (extension over sea may happen)	
LCF21		Urban dense residential sprawl: Land uptake by continuous urban fabric (CLC111) from non-urban land
LCF22		Urban diffuse residential sprawl: Land uptake by discontinuous urban fabric (CLC112) from non-urban land
LCF3	**Sprawl of economic sites and infrastructures:** Land uptake by new economic sites and infrastructures (including sport and leisure facilities) from non-urban land (extension over sea may happen)	
LCF31		Sprawl of industrial and commercial sites: Non-urban land uptake by new industrial and commercial sites
LCF32		Sprawl of transport networks: Non-urban land uptake by new transport networks (note that linear features narrower than 100 m are not monitored by CLC)
LCF33		Sprawl of harbours: Development of harbours over non-urban land and sea
LCF34		Sprawl of airports: Development of airports over non-urban land and sea
LCF35		Sprawl of mines and quarrying areas: Non-urban land uptake by mines and quarries
LCF36		Sprawl of dump sites: Non-urban land uptake by waste dump sites
LCF37		Construction: Extension over non-urban land of areas under construction during the period (note: covers mainly construction of economic sites and infrastructures)
LCF38		Sprawl of sport and leisure facilities: Conversion from developed as well as non-urban land to sport and leisure facilities
LCF4	**Agriculture internal conversions:** Conversion between farming types. Rotation between annual crops is not monitored by CLC	
LCF41		Extension of set aside fallow land and pasture: Conversion from crop land to grassland as an agricultural rotation or for cattle husbandry
	LCF411	Uniform extension of set aside fallow land and pasture: Large parcels conversion from crop land to grassland
	LCF412	Diffuse extension of set aside fallow land and pasture: Conversion from crop land to complex cultivation patterns (with grassland) and from mixed agriculture to large pasture parcels
LCF42		Internal conversions between annual crops: Conversions between irrigated and non-irrigated agriculture
	LCF421	Conversion from arable land to permanent irrigation perimeters: Extension of permanent irrigation (incl. rice fields) over arable land
	LCF422	Other internal conversions of arable land: Other conversions between arable land and irrigated perimeters, incl. rice fields
LCF43		Internal conversions between permanent crops: Conversions between vineyards, orchards and/or olive groves
	LCF431	Conversion from olives groves to vineyards and orchards: Conversion from olives groves to vineyards and orchards
	LCF432	Conversion from vineyards and orchards to olive groves: Conversion from vineyards and orchards to olive groves
	LCF433	Other conversions between vineyards and orchards: Other conversions between vineyards and orchards
LCF44		Conversion from permanent crops to arable land: Conversion from vineyards, orchards and olive groves to irrigated and/or non-irrigated arable land
	LCF441	Conversion from permanent crops to permanent irrigation perimeters: Conversion from permanent crops (incl. when associated with arable land — CLC241) to permanent (large) irrigation perimeters and rice fields
	LCF442	Conversion from vineyards and orchards to non-irrigated arable land: Conversion from vineyards and orchards to non-irrigated arable land and from associations of annual and permanent crops to uniform arable land
	LCF443	Conversion from olive groves to non-irrigated arable land: Conversion from olive groves to non-irrigated arable land, incl. conversions to associations of annual and permanent crops (CLC241) and of crops and pasture (CLC242)
	LCF444	Diffuse conversion from permanent crops to arable land: Conversion from vineyards and orchards to associations of annual and permanent crops (CLC241) and of crops and pasture (CLC242: complex cultivation patterns)

LCF45		Conversion from arable land to permanent crops: Plantation of vineyards, orchards and olive groves on arable land
	LCF451	Conversion from arable land to vineyards and orchards: Plantation of vineyards, orchards on arable land
	LCF452	Conversion from arable land to olive groves: Plantation of olive groves on arable land
	LCF453	Diffuse conversion from arable land to permanent crops: Conversion from uniform arable land to associations of permanent crops and annual crops (CLC241)
LCF46		Conversion from pasture to arable and permanent crops: Conversion from pasture to arable and permanent crops
	LCF461	Conversion from pasture to permanent irrigation perimeters: Conversion of uniform pasture areas to permanent irrigation perimeters
	LCF462	Intensive conversion from pasture to non-irrigated arable land and permanent crops: Conversion of uniform pasture areas to non-irrigated annual and permanent crops
	LCF463	Diffuse conversion from pasture to arable and permanent crops: Conversion from complex cultivation patterns including pasture (CLC242) to uniform arable land and permanent crops as well as to associations of the last two (CLC241) and conversion of uniform pasture (CLC231) to complex cultivation patterns
LCF47		Extension of agro-forestry: Conversion of cultivated land and open pasture to agro-forestry systems such as dehesas and montanas (note: conversion from 243 to 244, where natural vegetation is important, is recorded under LCF522)
LCF48		Other conversions from agriculture mosaics to arable land and permanent crops: This land cover class is used only when changes are detected from a Corine land cover matrix combing classification of level2 for the initial year and level 3 for the final year. Agriculture mosaic classes being grouped in CLC24 only, it is not possible to differentiate the processes according to the type of land consumed. It includes in particular the sub-class LCF523, conversions from agriculture-nature mosaics to continuous agriculture, not isolated in this case
	LCF481	Other conversions from agriculture mosaics to permanent crops: Used for CLC level 2 x level 3 only. It includes conversion of agriculture-nature mosaics to arable land (see LCF48)
	LCF482	Other conversions from agriculture mosaics to arable land (including conversion of agriculture-nature mosaics to permanent crops). Used for CLC level 2 x level 3 only. It includes conversion of agriculture-nature mosaics to arable land (see LCF48)
LCF5	**Conversion from forested and natural land to agriculture:** Extension of agriculture land use	
LCF51		Conversion from forest to agriculture: Deforestation for agriculture purpose, including agricultural conversion of transitional woodland shrub
	LCF511	Intensive conversion from forest to agriculture: Deforestation, including agricultural conversion of transitional woodland shrub, for cultivation of annual and permanent crops (incl. in association, CLC241)
	LCF512	Diffuse conversion from forest to agriculture: Conversion from uniform forest to complex cultivation patterns, mosaic agricultural landscape and agro-forestry. Due to possible uncertainties in monitoring extension of pasture vs. recent felling, conversion from forests to pasture land (CLC231) is recorded here
LCF52		Conversion from semi-natural land to agriculture: Conversion from dry semi-natural land (except CLC324, grouped with forests) to agriculture
	LCF521	Intensive conversion from semi-natural land to agriculture: Conversion from dry semi-natural land (except CLC324, grouped with forests) to annual crops, permanent crops and their association
	LCF522	Diffuse conversion from semi-natural land to agriculture: Conversion from dry semi-natural land (except CLC324, grouped with forests) to pasture and mixed agriculture with pasture
	LCF523	Conversions from agriculture-nature mosaics to continuous agriculture: Conversion from CLC243, where natural areas are distinctive feature of the land systems to continuous agriculture. This is an over-estimation from an agriculture perspective but is justified in terms of analysis of ecological potentials of complex land systems
LCF53		Conversion from wetlands to agriculture: Conversion of wetlands to any type of farmland (CLC2)
LCF54		Conversion from developed areas to agriculture: Conversion of urban land to any type of farmland (CLC2)
LCF6	**Withdrawal of farming:** Farmland abandonment and other conversions from agriculture activity in favour of forests or natural land	
LCF61		Withdrawal of farming with woodland creation: Forest and woodland creation (incl. transitional woodland shrub) from all CLC agriculture types. Withdrawal of farming with woodland creation is a broader concept than farmland abandonment with woodland creation, which results more from decline of agriculture than afforestation programmes. Additional information is necessary to identify an abandonment process (type of agriculture, landscape type, socio-economic statistics...)
LCF62		Withdrawal of farming without significant woodland creation: Farmland abandonment in favour of natural or semi-natural landscape (except forests and transitional woodland shrub), as long as they are a possible transition. Some odd cases are provisionally recorded as LCF99 Other changes and unknown
LCF7	**Forests creation and management:** Creation of forests and management of the forest territory by felling and replanting. Due to the CLC cycle of 10 years, only one part of the shrubs are tall enough to be identified as trees. In order to taking stock of all recent plantations, conversions of semi-natural land to CLC324 are conventionally recorded as afforestation (although some natural colonisation may take place). In the case of conversion from farmland, see LCF61	
LCF71		Conversion from transitional woodland to forest: Conversion from transitional woodland to broadleaved, coniferous or mixed forest, taking place when shrubs can be detected as trees
LCF72		Forest creation, afforestation: Forest creation and afforestation take place on all previously non-agricultural landscapes where new forests can be identified. Extension of transitional woodland shrub over non-agricultural land is recorded as afforestation. Conversion from transitional woodland to broadleaved, coniferous or mixed forest are not a creation of forest territory and are therefore registered separately (LCF71)

LCF73		Forests internal conversions: Conversions between broadleaved, coniferous and/or mixed forest (CLC311, 312 and 313)
LCF74		Recent felling and transition: Conversion from broadleaved, coniferous and/or mixed forest to open semi-natural and natural dry land resulting more likely from felling. The main transition is towards CLC324 Transitional woodland shrub, although some other types can be detected. Due to uncertainties, all are provisionally considered as transitional states of forests
LCF8	**Water bodies creation and management:** Creation of dams and reservoirs and possible consequences of the management of the water resource on the water surface area	
LCF81		Water bodies creation: Extension of water surfaces resulting from the creation of dams and reservoirs
LCF82		Water bodies management: Consequences of the management of the water resource on the water surface area of reservoirs
LCF9	**Changes of land cover due to natural and multiple causes:** Changes in land cover resulting from natural phenomena with or without any human influence	
LCF91		Semi-natural creation and rotation: Changes in natural and semi-natural land cover due to natural factors
	LCF911	Semi-natural creation: Natural colonisation of land previously used by human activities. Note that extension of CLC324 is considered as the result of farmland abandonment or direct afforestation
	LCF912	Semi-natural rotation: Rotation between the dry semi-natural and natural land cover types of CLC (except forest and transitional woodland shrub)
	LCF913	Extension of water courses: Results from natural erosion and artificial works. Due to the very incomplete detection of rivers with CLC, the LCF913 flow item has to be used very carefully
LCF92		Forests and shrubs fires: Due to the short cycle of recovery of vegetation from fire, burnt areas (which are well identified on satellite images) cannot be compared in a ten-year interval, except for very aggregated statistics
LCF93		Coastal erosion: Conversion of all land cover types to intertidal flats, estuaries or sea and ocean. The tide level when the satellite image is shot being unknown of the photointerpretors, the coastal erosion flow has to be used very carefully
LCF94		Decrease in permanent snow and glaciers cover: Decrease of permanent snow and glaciers due to climate change to semi-natural and natural land covers, mainly to bare rock, sparsely vegetated areas and water systems
LCF99		Other changes and unknown: In this category are recorded land cover changes that are rare or more likely improbable

B1: Conversions to artificial land (one-to-one changes (CLC classes) to flows of land cover)

Corine land cover 1990	Corine land cover 2000	111 Continuous urban fabric	112 Discontinuous urban fabric	121 Industrial or commercial units	122 Road and rail networks and associated land	123 Port areas	124 Airports	131 Mineral extraction sites	132 Dump sites	133 Construction sites	141 Green urban areas	142 Sport and leisure facilities
111	Continuous urban fabric	NC	LCF12	LCF12	LCF12	LCF12	LCF12	LCF12	LCF12	LCF12	LCF13	LCF38
112	Discontinuous urban fabric	LCF11	NC	LCF11	LCF11	LCF11	LCF11	LCF11	LCF11	LCF11	LCF13	LCF38
121	Industrial or commercial units	LCF12	LCF12	NC	LCF12	LCF12	LCF12	LCF12	LCF12	LCF12	LCF13	LCF38
122	Road and rail networks and associated land	LCF12	LCF12	LCF12	NC	LCF12	LCF12	LCF12	LCF12	LCF12	LCF13	LCF38
123	Port areas	LCF12	LCF12	LCF12	LCF12	NC	LCF12	LCF12	LCF12	LCF12	LCF13	LCF38
124	Airports	LCF12	LCF12	LCF12	LCF12	LCF12	NC	LCF12	LCF12	LCF12	LCF13	LCF38
131	Mineral extraction sites	LCF12	LCF12	LCF12	LCF12	LCF12	LCF12	NC	LCF12	LCF12	LCF13	LCF38
132	Dump sites	LCF12	LCF12	LCF12	LCF12	LCF12	LCF12	LCF12	NC	LCF12	LCF13	LCF38
133	Construction sites	LCF12	LCF12	LCF12	LCF12	LCF12	LCF12	LCF12	LCF12	NC	LCF13	LCF38
141	Green urban areas	LCF11	LCF11	LCF11	LCF11	LCF11	LCF11	LCF11	LCF11	LCF11	NC	LCF38
142	Sport and leisure facilities	LCF11	LCF11	LCF11	LCF11	LCF11	LCF11	LCF11	LCF11	LCF11	LCF13	NC
211	Non-irrigated arable land	LCF21	LCF22	LCF31	LCF32	LCF33	LCF34	LCF35	LCF36	LCF37	LCF13	LCF38
212	Permanently irrigated land	LCF21	LCF22	LCF31	LCF32	LCF33	LCF34	LCF35	LCF36	LCF37	LCF13	LCF38
213	Rice fields	LCF21	LCF22	LCF31	LCF32	LCF33	LCF34	LCF35	LCF36	LCF37	LCF13	LCF38
221	Vineyards	LCF21	LCF22	LCF31	LCF32	LCF33	LCF34	LCF35	LCF36	LCF37	LCF13	LCF38
222	Fruit trees and berry plantations	LCF21	LCF22	LCF31	LCF32	LCF33	LCF34	LCF35	LCF36	LCF37	LCF13	LCF38
223	Olive groves	LCF21	LCF22	LCF31	LCF32	LCF33	LCF34	LCF35	LCF36	LCF37	LCF13	LCF38
231	Pastures	LCF21	LCF22	LCF31	LCF32	LCF33	LCF34	LCF35	LCF36	LCF37	LCF13	LCF38
241	Annual crops associated with permanent crops	LCF21	LCF22	LCF31	LCF32	LCF33	LCF34	LCF35	LCF36	LCF37	LCF13	LCF38
242	Complex cultivation patterns	LCF21	LCF22	LCF31	LCF32	LCF33	LCF34	LCF35	LCF36	LCF37	LCF13	LCF38
243	Agriculture mosaics with significant natural vegetation	LCF21	LCF22	LCF31	LCF32	LCF33	LCF34	LCF35	LCF36	LCF37	LCF13	LCF38
244	Agro-forestry areas	LCF21	LCF22	LCF31	LCF32	LCF33	LCF34	LCF35	LCF36	LCF37	LCF13	LCF38
311	Broad-leaved forest	LCF21	LCF22	LCF31	LCF32	LCF33	LCF34	LCF35	LCF36	LCF37	LCF13	LCF38
312	Coniferous forest	LCF21	LCF22	LCF31	LCF32	LCF33	LCF34	LCF35	LCF36	LCF37	LCF13	LCF38
313	Mixed forest	LCF21	LCF22	LCF31	LCF32	LCF33	LCF34	LCF35	LCF36	LCF37	LCF13	LCF38
321	Natural grassland	LCF21	LCF22	LCF31	LCF32	LCF33	LCF34	LCF35	LCF36	LCF37	LCF13	LCF38
322	Moors and heathland	LCF21	LCF22	LCF31	LCF32	LCF33	LCF34	LCF35	LCF36	LCF37	LCF13	LCF38
323	Sclerophyllous vegetation	LCF21	LCF22	LCF31	LCF32	LCF33	LCF34	LCF35	LCF36	LCF37	LCF13	LCF38
324	Transitional woodland shrub	LCF21	LCF22	LCF31	LCF32	LCF33	LCF34	LCF35	LCF36	LCF37	LCF13	LCF38
331	Beaches, dunes and sand plains	LCF21	LCF22	LCF31	LCF32	LCF33	LCF34	LCF35	LCF36	LCF37	LCF13	LCF38
332	Bare rock	LCF21	LCF22	LCF31	LCF32	LCF33	LCF34	LCF35	LCF36	LCF37	LCF13	LCF38
333	Sparsely vegetated areas	LCF21	LCF22	LCF31	LCF32	LCF33	LCF34	LCF35	LCF36	LCF37	LCF13	LCF38
334	Burnt areas	LCF21	LCF22	LCF31	LCF32	LCF33	LCF34	LCF35	LCF36	LCF37	LCF13	LCF38
335	Glaciers and perpetual snow	LCF99	LCF99	LCF99	LCF99	LCF99	LCF99	LCF99	LCF99	LCF99	LCF99	LCF99
411	Inland marshes	LCF21	LCF22	LCF31	LCF32	LCF33	LCF34	LCF35	LCF36	LCF37	LCF13	LCF38
412	Peatbogs	LCF21	LCF22	LCF31	LCF32	LCF33	LCF34	LCF35	LCF36	LCF37	LCF13	LCF38
421	Salt marshes	LCF21	LCF22	LCF31	LCF32	LCF33	LCF34	LCF35	LCF36	LCF37	LCF13	LCF38
422	Salines	LCF21	LCF22	LCF31	LCF32	LCF33	LCF34	LCF35	LCF36	LCF37	LCF13	LCF38
423	Intertidal flats	LCF21	LCF22	LCF31	LCF32	LCF33	LCF34	LCF35	LCF36	LCF37	LCF13	LCF38
511	Water courses	LCF21	LCF22	LCF31	LCF32	LCF33	LCF34	LCF35	LCF36	LCF37	LCF13	LCF38
512	Water bodies	LCF21	LCF22	LCF31	LCF32	LCF33	LCF34	LCF35	LCF36	LCF37	LCF13	LCF38
521	Coastal lagoons	LCF21	LCF22	LCF31	LCF32	LCF33	LCF34	LCF35	LCF36	LCF37	LCF13	LCF38
522	Estuaries	LCF21	LCF22	LCF31	LCF32	LCF33	LCF34	LCF35	LCF36	LCF37	LCF13	LCF38
523	Sea and ocean	LCF21	LCF22	LCF31	LCF32	LCF33	LCF34	LCF35	LCF36	LCF37	LCF13	LCF38

B2: Conversions to agriculture (one-to-one changes (CLC classes) to flows of land cover)

Corine land cover 1990	Corine land cover 2000	211 Non-irrigated arable land	212 Permanently irrigated land	213 Rice fields	221 Vineyards	222 Fruit trees and berry plantations	223 Olive groves	231 Pastures	241 Annual crops associated with permanent crops	242 Complex cultivation patterns	243 Agriculture mosaics with significant natural vegetation	244 Agro-forestry areas
111	Continuous urban fabric	LCF54	LCF54	LCF54	LCF54	LCF54	LCF54	LCF54	LCF54	LCF54	LCF54	LCF54
112	Discontinuous urban fabric	LCF54	LCF54	LCF54	LCF54	LCF54	LCF54	LCF54	LCF54	LCF54	LCF54	LCF54
121	Industrial or commercial units	LCF54	LCF54	LCF54	LCF54	LCF54	LCF54	LCF54	LCF54	LCF54	LCF54	LCF54
122	Road and rail networks and associated land	LCF54	LCF54	LCF54	LCF54	LCF54	LCF54	LCF54	LCF54	LCF54	LCF54	LCF54
123	Port areas	LCF54	LCF54	LCF54	LCF54	LCF54	LCF54	LCF54	LCF54	LCF54	LCF54	LCF54
124	Airports	LCF54	LCF54	LCF54	LCF54	LCF54	LCF54	LCF54	LCF54	LCF54	LCF54	LCF54
131	Mineral extraction sites	LCF54	LCF54	LCF54	LCF54	LCF54	LCF54	LCF54	LCF54	LCF54	LCF54	LCF54
132	Dump sites	LCF54	LCF54	LCF54	LCF54	LCF54	LCF54	LCF54	LCF54	LCF54	LCF54	LCF54
133	Construction sites	LCF54	LCF54	LCF54	LCF54	LCF54	LCF54	LCF54	LCF54	LCF54	LCF54	LCF54
141	Green urban areas	LCF54	LCF54	LCF54	LCF54	LCF54	LCF54	LCF54	LCF54	LCF54	LCF54	LCF54
142	Sport and leisure facilities	LCF54	LCF54	LCF54	LCF54	LCF54	LCF54	LCF54	LCF54	LCF54	LCF54	LCF54
211	Non-irrigated arable land	NC	LCF421	LCF421	LCF451	LCF451	LCF452	LCF411	LCF453	LCF412	LCF62	LCF47
212	Permanently irrigated land	LCF422	NC	LCF422	LCF451	LCF451	LCF452	LCF411	LCF453	LCF412	LCF62	LCF47
213	Rice fields	LCF422	LCF422	NC	LCF451	LCF451	LCF452	LCF411	LCF453	LCF412	LCF62	LCF47
221	Vineyards	LCF442	LCF441	LCF441	NC	LCF433	LCF432	LCF411	LCF444	LCF444	LCF62	LCF47
222	Fruit trees and berry plantations	LCF442	LCF441	LCF441	LCF433	NC	LCF432	LCF411	LCF444	LCF444	LCF62	LCF47
223	Olive groves	LCF443	LCF441	LCF441	LCF431	LCF431	NC	LCF411	LCF443	LCF443	LCF62	LCF47
231	Pastures	LCF462	LCF461	LCF461	LCF462	LCF462	LCF462	NC	LCF462	LCF463	LCF62	LCF47
241	Annual crops associated with permanent crops	LCF442	LCF441	LCF441	LCF451	LCF451	LCF452	LCF411	NC	LCF412	LCF62	LCF47
242	Complex cultivation patterns	LCF463	LCF463	LCF463	LCF463	LCF463	LCF463	LCF412	LCF463	NC	LCF62	LCF47
243	Agriculture mosaics with significant natural vegetation	LCF523	LCF523	LCF523	LCF523	LCF523	LCF523	LCF523	LCF523	LCF523	NC	LCF47
244	Agro-forestry areas	LCF462	LCF461	LCF461	LCF462	LCF462	LCF462	LCF412	LCF462	LCF463	LCF62	NC
311	Broad-leaved forest	LCF511	LCF511	LCF511	LCF511	LCF511	LCF511	LCF512	LCF511	LCF512	LCF512	LCF512
312	Coniferous forest	LCF511	LCF511	LCF511	LCF511	LCF511	LCF511	LCF512	LCF511	LCF512	LCF512	LCF512
313	Mixed forest	LCF511	LCF511	LCF511	LCF511	LCF511	LCF511	LCF512	LCF511	LCF512	LCF512	LCF512
321	Natural grassland	LCF521	LCF521	LCF521	LCF521	LCF521	LCF521	LCF522	LCF521	LCF522	LCF522	LCF522
322	Moors and heathland	LCF521	LCF521	LCF521	LCF521	LCF521	LCF521	LCF522	LCF521	LCF522	LCF522	LCF522
323	Sclerophyllous vegetation	LCF521	LCF521	LCF521	LCF521	LCF521	LCF521	LCF522	LCF521	LCF522	LCF522	LCF522
324	Transitional woodland shrub	LCF511	LCF511	LCF511	LCF511	LCF511	LCF511	LCF512	LCF511	LCF512	LCF512	LCF512
331	Beaches, dunes and sand plains	LCF521	LCF521	LCF521	LCF521	LCF521	LCF521	LCF522	LCF521	LCF522	LCF522	LCF522
332	Bare rock	LCF521	LCF521	LCF521	LCF521	LCF521	LCF521	LCF522	LCF521	LCF522	LCF522	LCF522
333	Sparsely vegetated areas	LCF521	LCF521	LCF521	LCF521	LCF521	LCF521	LCF522	LCF521	LCF522	LCF522	LCF522
334	Burnt areas	LCF521	LCF521	LCF521	LCF521	LCF521	LCF521	LCF522	LCF521	LCF522	LCF522	LCF522
335	Glaciers and perpetual snow	LCF99	LCF99	LCF99	LCF99	LCF99	LCF99	LCF99	LCF99	LCF99	LCF99	LCF99
411	Inland marshes	LCF53	LCF53	LCF53	LCF53	LCF53	LCF53	LCF53	LCF53	LCF53	LCF53	LCF53
412	Peatbogs	LCF53	LCF53	LCF53	LCF53	LCF53	LCF53	LCF53	LCF53	LCF53	LCF53	LCF53
421	Salt marshes	LCF53	LCF53	LCF53	LCF53	LCF53	LCF53	LCF53	LCF53	LCF53	LCF53	LCF53
422	Salines	LCF53	LCF53	LCF53	LCF53	LCF53	LCF53	LCF53	LCF53	LCF53	LCF53	LCF53
423	Intertidal flats	LCF53	LCF53	LCF53	LCF53	LCF53	LCF53	LCF53	LCF53	LCF53	LCF53	LCF53
511	Water courses	LCF53	LCF53	LCF53	LCF53	LCF53	LCF53	LCF53	LCF53	LCF53	LCF53	LCF53
512	Water bodies	LCF53	LCF53	LCF53	LCF53	LCF53	LCF53	LCF53	LCF53	LCF53	LCF53	LCF53
521	Coastal lagoons	LCF53	LCF53	LCF53	LCF53	LCF53	LCF53	LCF53	LCF53	LCF53	LCF53	LCF53
522	Estuaries	LCF53	LCF53	LCF53	LCF53	LCF53	LCF53	LCF53	LCF53	LCF53	LCF53	LCF53
523	Sea and ocean	LCF53	LCF53	LCF53	LCF53	LCF53	LCF53	LCF53	LCF53	LCF53	LCF53	LCF53

B3: Conversions to forest and dry natural and seminatural land (one-to-one changes (CLC classes) to flows of land cover)

	Corine land cover 2000	311	312	313	321	322	323	324	331	332	333	334	335
Corine land cover 1990		Broad-leaved forest	Coniferous forest	Mixed forest	Natural grassland	Moors and heathland	Sclerophyllous vegetation	Transitional woodland shrub	Beaches, dunes and sand plains	Bare rock	Sparsely vegetated areas	Burnt areas	Glaciers and perpetual snow
111	Continuous urban fabric	LCF72	LCF72	LCF72	LCF911	LCF911	LCF911	LCF72	LCF911	LCF911	LCF911	LCF92	LCF99
112	Discontinuous urban fabric	LCF72	LCF72	LCF72	LCF911	LCF911	LCF911	LCF72	LCF911	LCF911	LCF911	LCF92	LCF99
121	Industrial or commercial units	LCF72	LCF72	LCF72	LCF911	LCF911	LCF911	LCF72	LCF911	LCF911	LCF911	LCF92	LCF99
122	Road and rail networks and associated land	LCF72	LCF72	LCF72	LCF911	LCF911	LCF911	LCF72	LCF911	LCF911	LCF911	LCF92	LCF99
123	Port areas	LCF72	LCF72	LCF72	LCF911	LCF911	LCF911	LCF72	LCF911	LCF911	LCF911	LCF92	LCF99
124	Airports	LCF72	LCF72	LCF72	LCF911	LCF911	LCF911	LCF72	LCF911	LCF911	LCF911	LCF92	LCF99
131	Mineral extraction sites	LCF72	LCF72	LCF72	LCF911	LCF911	LCF911	LCF72	LCF911	LCF911	LCF911	LCF92	LCF99
132	Dump sites	LCF72	LCF72	LCF72	LCF911	LCF911	LCF911	LCF72	LCF911	LCF911	LCF911	LCF92	LCF99
133	Construction sites	LCF72	LCF72	LCF72	LCF911	LCF911	LCF911	LCF72	LCF911	LCF911	LCF911	LCF92	LCF99
141	Green urban areas	LCF72	LCF72	LCF72	LCF911	LCF911	LCF911	LCF72	LCF911	LCF911	LCF911	LCF92	LCF99
142	Sport and leisure facilities	LCF72	LCF72	LCF72	LCF911	LCF911	LCF911	LCF72	LCF911	LCF911	LCF911	LCF92	LCF99
211	Non-irrigated arable land	LCF61	LCF61	LCF61	LCF62	LCF62	LCF62	LCF61	LCF62	LCF62	LCF62	LCF92	LCF99
212	Permanently irrigated land	LCF61	LCF61	LCF61	LCF62	LCF62	LCF62	LCF61	LCF62	LCF62	LCF62	LCF92	LCF99
213	Rice fields	LCF61	LCF61	LCF61	LCF62	LCF62	LCF62	LCF61	LCF62	LCF62	LCF62	LCF92	LCF99
221	Vineyards	LCF61	LCF61	LCF61	LCF62	LCF62	LCF62	LCF61	LCF62	LCF62	LCF62	LCF92	LCF99
222	Fruit trees and berry plantations	LCF61	LCF61	LCF61	LCF62	LCF62	LCF62	LCF61	LCF62	LCF62	LCF62	LCF92	LCF99
223	Olive groves	LCF61	LCF61	LCF61	LCF62	LCF62	LCF62	LCF61	LCF62	LCF62	LCF62	LCF92	LCF99
231	Pastures	LCF61	LCF61	LCF61	LCF62	LCF62	LCF62	LCF61	LCF62	LCF62	LCF62	LCF92	LCF99
241	Annual crops associated with permanent crops	LCF61	LCF61	LCF61	LCF62	LCF62	LCF62	LCF61	LCF62	LCF62	LCF62	LCF92	LCF99
242	Complex cultivation patterns	LCF61	LCF61	LCF61	LCF62	LCF62	LCF62	LCF61	LCF62	LCF62	LCF62	LCF92	LCF99
243	Agriculture mosaics with significant natural vegetation	LCF61	LCF61	LCF61	LCF62	LCF62	LCF62	LCF61	LCF62	LCF62	LCF62	LCF92	LCF99
244	Agro-forestry areas	LCF61	LCF61	LCF61	LCF62	LCF62	LCF62	LCF61	LCF62	LCF62	LCF62	LCF92	LCF99
311	Broad-leaved forest	NC	LCF73	LCF73	LCF74	LCF74	LCF74	LCF74	LCF74	LCF74	LCF74	LCF92	LCF99
312	Coniferous forest	LCF73	NC	LCF73	LCF74	LCF74	LCF74	LCF74	LCF74	LCF74	LCF74	LCF92	LCF99
313	Mixed forest	LCF73	LCF73	NC	LCF74	LCF74	LCF74	LCF74	LCF74	LCF74	LCF74	LCF92	LCF99
321	Natural grassland	LCF72	LCF72	LCF72	NC	LCF912	LCF912	LCF72	LCF912	LCF912	LCF912	LCF92	LCF99
322	Moors and heathland	LCF72	LCF72	LCF72	LCF912	NC	LCF912	LCF72	LCF912	LCF912	LCF912	LCF92	LCF99
323	Sclerophyllous vegetation	LCF72	LCF72	LCF72	LCF912	LCF912	NC	LCF72	LCF912	LCF912	LCF912	LCF92	LCF99
324	Transitional woodland shrub	LCF71	LCF71	LCF71	LCF911	LCF911	LCF911	NC	LCF911	LCF911	LCF911	LCF92	LCF99
331	Beaches, dunes and sand plains	LCF72	LCF72	LCF72	LCF912	LCF912	LCF912	LCF72	NC	LCF912	LCF912	LCF92	LCF99
332	Bare rock	LCF72	LCF72	LCF72	LCF912	LCF912	LCF912	LCF72	LCF912	NC	LCF912	LCF92	LCF912
333	Sparsely vegetated areas	LCF72	LCF72	LCF72	LCF912	LCF912	LCF912	LCF72	LCF912	LCF912	NC	LCF92	LCF912
334	Burnt areas	LCF72	LCF72	LCF72	LCF912	LCF912	LCF912	LCF72	LCF912	LCF912	LCF912	NC	LCF99
335	Glaciers and perpetual snow	LCF99	LCF99	LCF99	LCF94	LCF94	LCF94	LCF94	LCF94	LCF94	LCF94	LCF99	NC
411	Inland marshes	LCF72	LCF72	LCF72	LCF912	LCF912	LCF912	LCF72	LCF99	LCF99	LCF99	LCF99	LCF99
412	Peatbogs	LCF72	LCF72	LCF72	LCF912	LCF912	LCF912	LCF72	LCF99	LCF99	LCF99	LCF92	LCF99
421	Salt marshes	LCF72	LCF72	LCF72	LCF912	LCF912	LCF912	LCF72	LCF99	LCF99	LCF99	LCF99	LCF99
422	Salines	LCF72	LCF72	LCF72	LCF911	LCF911	LCF911	LCF72	LCF911	LCF99	LCF911	LCF99	LCF99
423	Intertidal flats	LCF72	LCF72	LCF72	LCF99	LCF99	LCF99	LCF99	LCF99	LCF93	LCF99	LCF99	LCF99
511	Water courses	LCF72	LCF72	LCF72	LCF99	LCF99	LCF99	LCF99	LCF99	LCF99	LCF99	LCF99	LCF99
512	Water bodies	LCF72	LCF72	LCF72	LCF99	LCF99	LCF99	LCF99	LCF82	LCF82	LCF82	LCF99	LCF99
521	Coastal lagoons	LCF72	LCF72	LCF72	LCF99	LCF99	LCF99	LCF99	LCF99	LCF99	LCF99	LCF99	LCF99
522	Estuaries	LCF72	LCF72	LCF72	LCF99	LCF99	LCF99	LCF99	LCF99	LCF99	LCF99	LCF99	LCF99
523	Sea and ocean	LCF72	LCF72	LCF72	LCF99	LCF99	LCF99	LCF99	LCF99	LCF99	LCF99	LCF99	LCF99

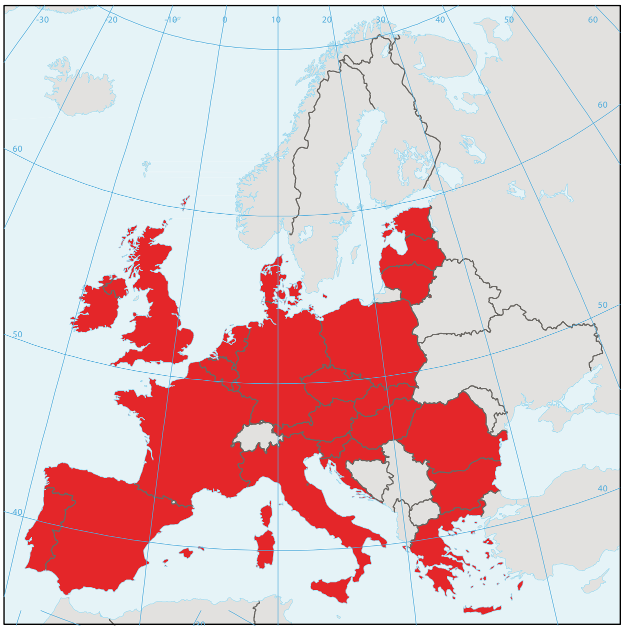
B4: Conversions to wetland and water bodies (one-to-one changes (CLC classes) to flows of land cover)

Corine land cover 1990	Corine land cover 2000	411 Inland marshes	412 Peatbogs	421 Salt marshes	422 Salines	423 Intertidal flats	511 Water courses	512 Water bodies	521 Coastal lagoons	522 Estuaries	523 Sea and ocean
111	Continuous urban fabric	LCF99	LCF99	LCF99	LCF99	LCF93	LCF913	LCF99	LCF99	LCF93	LCF93
112	Discontinuous urban fabric	LCF99	LCF99	LCF99	LCF99	LCF93	LCF913	LCF99	LCF99	LCF93	LCF93
121	Industrial or commercial units	LCF99	LCF99	LCF99	LCF99	LCF93	LCF913	LCF99	LCF99	LCF93	LCF93
122	Road and rail networks and associated land	LCF99	LCF99	LCF99	LCF99	LCF93	LCF913	LCF99	LCF99	LCF93	LCF93
123	Port areas	LCF99	LCF99	LCF99	LCF99	LCF93	LCF913	LCF99	LCF99	LCF93	LCF93
124	Airports	LCF99	LCF99	LCF99	LCF99	LCF93	LCF913	LCF99	LCF99	LCF93	LCF93
131	Mineral extraction sites	LCF99	LCF99	LCF99	LCF99	LCF93	LCF913	LCF81	LCF99	LCF93	LCF93
132	Dump sites	LCF99	LCF99	LCF99	LCF99	LCF93	LCF913	LCF81	LCF99	LCF93	LCF93
133	Construction sites	LCF99	LCF99	LCF99	LCF99	LCF93	LCF913	LCF81	LCF99	LCF93	LCF93
141	Green urban areas	LCF99	LCF99	LCF99	LCF99	LCF93	LCF913	LCF81	LCF99	LCF93	LCF93
142	Sport and leisure facilities	LCF99	LCF99	LCF99	LCF99	LCF93	LCF913	LCF81	LCF99	LCF93	LCF93
211	Non-irrigated arable land	LCF99	LCF99	LCF99	LCF99	LCF93	LCF913	LCF81	LCF99	LCF93	LCF93
212	Permanently irrigated land	LCF99	LCF99	LCF99	LCF99	LCF93	LCF913	LCF81	LCF99	LCF93	LCF93
213	Rice fields	LCF62	LCF62	LCF62	LCF62	LCF93	LCF913	LCF81	LCF62	LCF93	LCF93
221	Vineyards	LCF99	LCF99	LCF99	LCF99	LCF93	LCF913	LCF81	LCF99	LCF93	LCF93
222	Fruit trees and berry plantations	LCF99	LCF99	LCF99	LCF99	LCF93	LCF913	LCF81	LCF99	LCF93	LCF93
223	Olive groves	LCF99	LCF99	LCF99	LCF99	LCF93	LCF913	LCF81	LCF99	LCF93	LCF93
231	Pastures	LCF62	LCF62	LCF62	LCF99	LCF93	LCF913	LCF81	LCF99	LCF93	LCF93
241	Annual crops associated with permanent crops	LCF99	LCF99	LCF99	LCF99	LCF93	LCF913	LCF81	LCF99	LCF93	LCF93
242	Complex cultivation patterns	LCF62	LCF62	LCF62	LCF99	LCF93	LCF913	LCF81	LCF99	LCF93	LCF93
243	Agriculture mosaics with significant natural vegetation	LCF62	LCF62	LCF62	LCF99	LCF93	LCF913	LCF81	LCF99	LCF93	LCF93
244	Agro-forestry areas	LCF62	LCF99	LCF99	LCF99	LCF93	LCF913	LCF81	LCF99	LCF93	LCF93
311	Broad-leaved forest	LCF99	LCF99	LCF99	LCF99	LCF93	LCF913	LCF81	LCF99	LCF93	LCF93
312	Coniferous forest	LCF99	LCF99	LCF99	LCF99	LCF93	LCF913	LCF81	LCF99	LCF93	LCF93
313	Mixed forest	LCF99	LCF99	LCF99	LCF99	LCF93	LCF913	LCF81	LCF99	LCF93	LCF93
321	Natural grassland	LCF912	LCF912	LCF912	LCF99	LCF93	LCF913	LCF81	LCF99	LCF93	LCF93
322	Moors and heathland	LCF912	LCF912	LCF912	LCF99	LCF93	LCF913	LCF81	LCF99	LCF93	LCF93
323	Sclerophyllous vegetation	LCF912	LCF912	LCF912	LCF99	LCF93	LCF913	LCF81	LCF99	LCF93	LCF93
324	Transitional woodland shrub	LCF911	LCF911	LCF911	LCF99	LCF93	LCF913	LCF81	LCF99	LCF93	LCF93
331	Beaches, dunes and sand plains	LCF912	LCF912	LCF912	LCF99	LCF93	LCF913	LCF81	LCF99	LCF93	LCF93
332	Bare rock	LCF99	LCF99	LCF99	LCF99	LCF93	LCF913	LCF81	LCF99	LCF93	LCF93
333	Sparsely vegetated areas	LCF912	LCF912	LCF912	LCF99	LCF93	LCF913	LCF81	LCF99	LCF93	LCF93
334	Burnt areas	LCF912	LCF912	LCF912	LCF99	LCF93	LCF913	LCF81	LCF99	LCF93	LCF93
335	Glaciers and perpetual snow	LCF94	LCF94	LCF94	LCF94	LCF94	LCF94	LCF94	LCF94	LCF94	LCF94
411	Inland marshes	NC	LCF912	LCF912	LCF99	LCF93	LCF913	LCF912	LCF912	LCF93	LCF93
412	Peatbogs	LCF912	NC	LCF912	LCF99	LCF93	LCF913	LCF912	LCF912	LCF93	LCF93
421	Salt marshes	LCF99	LCF912	NC	LCF99	LCF93	LCF913	LCF912	LCF912	LCF93	LCF93
422	Salines	LCF99	LCF99	LCF911	NC	LCF93	LCF913	LCF81	LCF911	LCF93	LCF93
423	Intertidal flats	LCF99	LCF912	LCF912	LCF99	NC	LCF913	LCF99	LCF93	LCF93	LCF93
511	Water courses	LCF912	LCF912	LCF912	LCF99	LCF99	NC	LCF912	LCF912	LCF93	LCF93
512	Water bodies	LCF912	LCF912	LCF912	LCF99	LCF93	LCF99	NC	LCF99	LCF93	LCF93
521	Coastal lagoons	LCF912	LCF912	LCF912	LCF99	LCF93	LCF99	LCF99	NC	LCF93	LCF93
522	Estuaries	LCF912	LCF912	LCF912	LCF99	LCF93	LCF99	LCF99	LCF99	NC	LCF93
523	Sea and ocean	LCF912	LCF912	LCF912	LCF99	LCF99	LCF99	LCF99	LCF912	LCF912	NC

Appendix 3 Time periods for calculation of land cover change using CLC1990 and 2000, by country

Time periods for calculation of land cover change using CLC1990 and 2000, by country codes used in databases

Code and name		Years
AT	Austria	15
BE	Belgium	10
BG	Bulgaria	10
CZ	Czech Republic	8
DE	Germany	10
DK	Denmark	10
EE	Estonia	6
ES	Spain	14
FR	France	10
GR	Greece	10
HR	Croatia	10
HU	Hungary	8
IE	Ireland	10
IT	Italy	10
LT	Lithuania	5
LU	Luxembourg	11
LV	Latvia	5
NL	The Netherlands	14
PL	Poland	8
PT	Portugal	14
RO	Romania	8
SK	Slovakia	8
SL	Slovenia	5
UK	The United Kingdom	10



Note: In some large countries, dates of satellite images for regions may differ by several years. Therefore, as a provisional solution, a conventional average time period has been set between the two databases.

Countries covered in LEAC, Corine land cover 1990, 2000, Corine land cover change projects

Country	LEAC24: Acronyms and average number of years		CLC1990		CLC2000		CLC change	Comments
			Start	End	Start	End		
Albania			(1995)	(1996)	1995	1996	No	CLC1990 considered CLC2000
Austria	AT	15	1985	1986	1999	2001	Yes	
Belgium	BE	10	1989	1990	1999	2000	Yes	
Bosnia and Herzegovina			(1998)	(1998)	1998	1998	No	CLC1990 considered CLC2000
Bulgaria	BG	10	1989	1992	2000	2001	Yes	
Croatia	HR	10	1990	1991	1999	2000	Yes	
Cyprus					2000	2000	No	No CLC1990 available
Czech Republic	CZ	8	1989	1992	1999	2001	Yes	
Denmark	DK	10	1989	1990	1999	2001	Yes	
Estonia	EE	6	1993	1995	1999	2001	Yes	
Finland	FI		1986	1994	1999	2002	No	No CLC1990 revised version available (8/2005)
France	FR	10	1987	1994	1999	2001	Yes	
Germany	DE	10	1989	1992	1999	2001	Yes	
Greece	GR	10	1987	1991	2000	2001	Yes	No CLC1990 revised version available (8/2005)
Hungary	HU	8	1990	1992	2000	2000	Yes	
Ireland	IE	10	1989	1990	2000	2001	Yes	
Italy	IT	10	1990	1993	1999	2002	Yes	
Latvia	LV	5	1994	1995	1999	2001	Yes	
Liechtenstein					2000	2000	No	No CLC1990 available
Lithuania	LT	5	1994	1995	1999	2001	Yes	
Luxembourg	LU	11	1991	1991	2000	2000	Yes	
Malta					2001	2001	No	No CLC1990 available
Macedonia			(1995)	(1996)	1995	1996	No	CLC1990 considered CLC2000
Netherlands	NL	14	1986	1988	1999	2000	Yes	
Poland	PL	8	1989	1992	1999	2001	Yes	
Portugal	PT	14	1985	1987	1999	2002	Yes	
Romania	RO	8	1989	1992	2000	2001	Yes	
Slovak Republic	SK	8	1989	1992	2000	2001	Yes	
Slovenia	SL	5	1995	1996	1999	2000	Yes	
Spain	ES	14	1984	1990	1999	2002	Yes	
Sweden	SE				1999	2002	No	No CLC1990 available
United Kingdom	UK	10	1989	1990	1999	2002	Yes	No CLC1990 revised version available (8/2005)

European Environment Agency

Land accounts for Europe 1990–2000
Towards integrated land and ecosystem accounting

2006 — 107 pp. — 21 x 29.7 cm

ISBN 92-9167-888-0

SALES AND SUBSCRIPTIONS

Publications for sale produced by the Office for Official Publications of the European Communities are available from our sales agents throughout the world.

How do I set about obtaining a publication?
Once you have obtained the list of sales agents, contact the sales agent of your choice and place your order.

How do I obtain the list of sales agents?

- Go to the Publications Office website http://publications.europa.eu/
- Or apply for a paper copy by fax +352 2929 42758

TH-AL-06-009-EN-C

Price (excluding VAT): EUR 15.00

European Environment Agency
Kongens Nytorv 6
1050 Copenhagen K
Denmark

Tel.: +45 33 36 71 00
Fax: +45 33 36 71 99

Web: eea.europa.eu
Enquiries: eea.europa.eu/enquiries

ISBN 92-9167-888-0
9 789291 678884

Publications Office
Publications.europa.eu

European Environment Agency