European Environment Agency Developments of Land and Ecosystem Accounts: General Overview

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ABSTRACT

The European Environment Agency has started the implementation of a programme of land use and ecosystem accounts, following the System of Environmental and Economic Accounts (SEEA) guidelines of the United Nations. The purpose is to integrate information across the various ecosystem components and to support further assessments and modeling of these components and their interactions with economic and social developments. This programme reflects the increasing demand for environmental policy integration in Europe, both vertically through thematic policies as well as horizontally across policies in those sectors that contribute most to environmental impacts. The construction of land and ecosystem accounts is now feasible due to continuous improvements in monitoring, collecting and processing data and progress with the development of statistical methods that facilitate data assimilation and integration. The accounts are based on explicit spatial patterns provided by comprehensive land cover accounts that can be upscaled and downscaled using a 1km² grid to any type of administrative region or ecosystem zone (e.g., river basin catchments, coastal zones or bio- geographic areas). Land cover accounts have been produced for 24 countries in Europe and published in EEA Report in 2006.

Keywords: Land use change analysis, Europe

1. INTRODUCTION

Environmental-economic accounting is a response to the need for integrating environmental policies into the overall system of decision making. It aims first at clarifying and quantifying the use of the environment in the broader sense, marketed resources as well as services not presently internalized by the economy. The purpose is to assess public and private benefits and costs and to optimize the use of environmental resources taking into account a longer time frame and future options. Direct benefits and costs have to be assessed together with indirect – sometimes "hidden" – ones, in order to supply private and public decision makers with adequate information about the trade offs they face. This means addressing in clear terms the possible impacts of environmental degradation on the economy, on population as well as on the ecosystems themselves.

Because ecosystem stress is subject to threshold values, aggregate statistics are not sufficient; the spatial distribution of risks and conflicts is essential. Monitoring programmes have been launched to collect this information, making use of earth observation satellites as well as technologies of ground positioning, automated monitoring and data transmission. In Europe, a special effort has been made to monitor land cover change in a standardized way. The so-called Corine[1] Land Cover (CLC or "Corine") inventory has been created from satellite imagery in the early 1990's and a second time in 2000 using the same methodology. This common database used by a large number of organizations in Europe and co-financed by the European Commission and the Member States has been processed by the European Environment Agency (EEA) for producing land cover accounts, following the SEEA guidelines for "land and ecosystem accounts". Beyond the immediate results of CLC and land cover accounts, the database is now a core element for the EEA's information system. It is a basic module that structures ecosystem accounts and bridges the realms of land use, biodiversity and water.

Policy background

During the early years of EU environmental policies, specific directives were elaborated for a broad range of issues. The purpose was to protect European citizens against air and water pollution, to regulate waste flows, to protect nature and landscapes as well as to avoid distortions in the economic competition due to uneven national emission standards. A fuller understanding of sustainability issues followed and led to a redefinition of environmental strategies. This development culminated in the 1998 launch of the integration process[1], a process with the joint objectives of streamlining environmental legislation, improving the efficiency of policies, and, in 2001, the European sustainable development strategy[2]. The latter, also known as the Gothenburg Strategy, from the name of the city where it was approved, is an attempt to coordinate a range of issues concerning climate change, congestion of transport, threats to public health, the challenge of an ageing population, poverty and social exclusion as well as the loss of natural resources and biodiversity. It contained a commitment to halt the loss of biodiversity by 2010.

Some of the notable achievements include the following:

- The Water Framework Directive, which is based on the concept of river basin management, targets the ecological quality of water bodies, and the full recovery of the costs of water protection and management.

- Agri-environmental policies, initially seen as a way to support farmers' income, is moving towards greater integration with ecological goals. One such programme, called "high nature value farmland areas,"[2] promotes cultivation practices (e.g. extensive grazing) that best maintain ecological potential.

[1] CORINE - Coordination of information on the environment program of the European Commission managed by the European Environment Agency

[2] High nature value farmland - Characteristics, trends and policy challenges - EEA Report No 1/2004

- Nature conservation has progressively moved from species protection towards habitat conservation, arguably the key to halting biodiversity loss in Europe.

- The Environmental Liability Directive (ELD), adopted in April 2005, is an attempt to apply the 'polluter pays principle', whereby polluters bear the cost of cleaning up the environmental damage that they cause. Ecosystem integrity and ecosystem services are fully considered in the assessment of damage and the choice of remedial actions.

Despite these positive changes, the way in which the 2010 objective to halt the loss of biodiversity will be met is uncertain. Urban sprawl is increasing and affects both agricultural and natural land in many regions. The continuous development of transport infrastructure and its acceleration in the new EU countries increase the fragmentation of landscapes (and rivers) that would otherwise guarantee some connectivity to the core areas of the ecological network. Though European rivers are on average less polluted than in the past, they are highly fragmented by dams. Dams block the routes of migratory species and isolate spawning areas. Recent climate change is accompanied by northward extension in the distribution areas of some species, like butterflies, a warning of possibly undesired modifications of ecosystems.

In all these domains, policies require coherent and comparable information on the baseline situation, on past and likely future trends, on causes and effects, interactions, costs and benefits, risk or priority areas. Land and ecosystem based assessments can contribute to providing at least part of the information needed.

2. LAND AND ECOSYSTEM ACCOUNTING AT THE EUROPEAN ENVIRONMENT AGENCY

Land and ecosystem accounting at the EEA is an attempt to answer in a coordinated way the demands for information to support environmental policies in many fields and facilitate integrated assessments and analytical modeling. It helps the EEA integrate its own information system and improve its capacity to assimilate data and information produced by its own network of national organizations as well as it institutional partners. These partners are, first, European institutions in charge of policies, which collect official data from member states related to their compliance with European legislation. Accurate due to their legal dimension, these data are not in all cases representative. From an environmental assessment perspective they can even be extremely biased (e.g. the data on designated areas for nature conservation refer only to these areas, not to nature in general or an entire country). Another group of partners includes Eurostat, the statistical office of the European Community, and the Joint Research Centre (JRC). Eurostat coordinates national statistical institutes for the collection of basic economic and social statistics, in particular for updating the European system of national accounts. Eurostat is also active in collection of environmental statistics, mainly from national statistical offices. The Joint Research Centre develops novel methodologies of observation and modeling for the needs of the European Commission and runs data collection in areas where its network of research institutes is on the forefront, such as for soil data. Annual crops assessment from satellite images is their responsibility as well. On a less regular basis, research programmes funded by the European Commission are also part of the information system.

The EEA has started the implementation of the land and ecosystem accounts by adapting the framework proposed in the SEEA. A particular emphasis has been put on the spatial dimension of the accounts, indispensable both for assessing complex interactions and delivering useful information to potential users, policy makers at the higher levels as well as decision makers at the various levels of implementation of policies.

The framework of Land & Ecosystem Accounting is presented as a platform of *core land cover accounts*, inter-connected with two sets of accounts which address the *use of land* and the *ecosystem* dimension of the territory. *Land use accounts* target economic and social functions and assess the services used – in particular by the ecosystems – as well as the change in artificiality of land and intensity of its use. Land use accounts are populated with geographical information as well as with socio-economic statistics for production, consumption, natural assets, infrastructures, technologies and population. *Ecosystem accounts* target measurement of the supply of ecosystem goods and services, assessing the ecosystem potentials and their integrity, health and viability. Ecosystem accounts are populated with geographical information as well as with monitoring data on atmosphere and climate, the water systems, fauna and flora, and soils.

Land cover accounts

Land cover accounts have been produced by the EEA for the years 1990 and 2000, based on Corine land cover. Land cover accounts were tested in two feasibility studies steered by the EEA, supported by the Eurostat[3,4]; they are now produced for 23 EEA member countries[3] from Corine land cover. Using a scale of 1/100 000 and 44 different land cover classes, Corine is a database and a map which delivers information on the use of land, and the natural or modified ecosystems that cover it, and its change over time. The coverage is comprehensive and the data comparable among countries and over time. Moreover, the CLC can be used in conjunction with other statistical sources such as sampling surveys, censuses or administrative registers as well as with satellite or in situ monitoring data.

In the land cover accounts, the 1892 possible changes from class to class computed in the basic Corine matrix are grouped according to the processes that have generated them. These processes, called *land cover flows,* result mostly from land use but also from natural factors. Land cover accounts describe the stocks at two dates as well as the flows of consumption (of initial land cover) and formation (of new land cover). These flows are presented according to drivers such as urban development (urban residential sprawl, sprawl of economic activities), agriculture (conversion from forested & natural land to agriculture, agriculture internal conversions, withdrawal of farming with or without forest creation), forestry (forest creation and management), water bodies creation and management. A final item then registers the changes due to natural and multiple causes (natural rotations, coastal erosion, fires, melting of glaciers).

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 LEAC database that has become the foundation of the work undertaken by the EEA. Basically this involved the creation of a system of grids, starting from the 100m x 100m CLC raster files and

[3] 24 countries with both 1990 and 2000 data are presently covered. Several other countries having started the Corine programme in 2000 only, this number is expected to rise up to 30 with the next update of Corine 2006, currently under preparation.

then producing a statistical assimilation of the data to 1km x 1 km, 5km x 5km and 10km x 10 km. Statistical assimilation differs from cartographic generalization in the sense that the former preserves the original values (which lead to a layer by item of the nomenclature) when the latter incorporates the small objects to the larger ones (the only ones that can be mapped altogether on a single smaller scale map).

The 1km x 1km accounting grid for the whole of Europe, which can be used to store, analyze 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[4]. The accounting grid in fact stores all the information that are available in the 100x100m grids. It is not an aggregation to one single value but an aggregation in terms of representation in the dataset.

The central 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[5]. The accounting grid consists of approximately 4.5 million 1km x 1km cells, each of which can hold a data record in the LEAC database.

The LEAC Database

The LEAC database (Figure 1) holds records for each of the 1km x 1km cells in the accounting grid that has been used by the EEA for this study. 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.

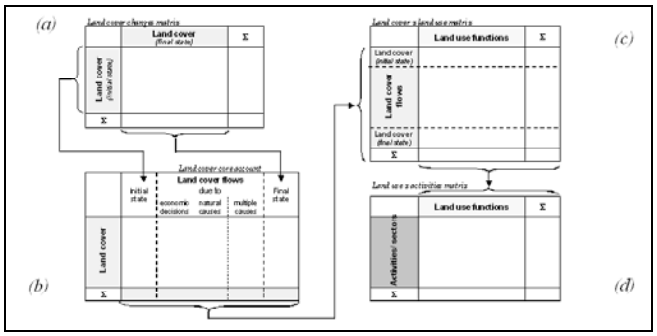

Figure 1. The structure of land cover and land use accounts

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 1(a)). Because such matrices are difficult to read, these data can more usefully be presented in the form of the 'flow account' shown in Figure 1(b).

[4] The European reference standard grid can be produced with any GIS software package. However, it is highly recommended to use already produced one to avoid possible problems coming from various software packages. http://dataservice.eea.europa.eu/dataservice/available.asp?type=azlist&letter=E

[5] INSPIRE (Infrastructure for Spatial Information in Europe) is an EU directive that aims at making available relevant, harmonized and quality geographic information to support formulation, implementation, monitoring and evaluation of Community policies with a territorial dimension or impact.

The approach described in Figure 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 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 1 (d)).

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 link between the two main tables is established 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. For example the various NUTS[6] administrative units and its social-economical data are stored there and can be attributed to a cell for analytical and reporting proposes.
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.
The classification of changes was derived from the cross tabulation of the 44 level 3 CORINE land cover classes, which produced 1936 possible parings of all potential initial and final cover classes. Of these, 44 of represented 'no change' (i.e. they were arranged along the leading diagonal of the matrix), and 1892 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 flow, which themselves could be grouped into just nine major categories of change. The latter represented 'level 1' in the resulting nomenclature of change.

Access to the LEAC database

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 we describe the access tools that the EEA has made available so that users can make their own analyses of the accounts data.

Up to present the EEA has been the main user of the land accounts data, and so the results have been published mainly in the form of reports i.e.[5]. However, it is clear that the applications developed to date by no means exhaust the types of analysis that is possible using these data. Thus the EEA is keen to make the data available so that

[6] NUTS-Nomenclature of territorial units for statistics: an used administrative division for the EU statistics collected by Eurostat.

their potential can be fully realized. Thus 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; and,
- Through a set of interactive reporting and analysis tools to support desktop applications.

Corine land cover datasets can be downloaded from the EEA's dataservice at: http://dataservice.eea.europa.eu/dataservice/available.asp?type=azlist&letter=C. 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 web site of the EEA topic centre at: http://terrestrial.eionet.europa.eu/CLC2000

Due to its volume, the LEAC database is not downloadable on line; instead, but it can 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 Systems' software. Using systems such as ArcGis, for example, the accounts data can be displayed in map for by using the 1km x 1km accounting reference grid.

The accounts data can be accessed from the EEA data service (Figure 2) from 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

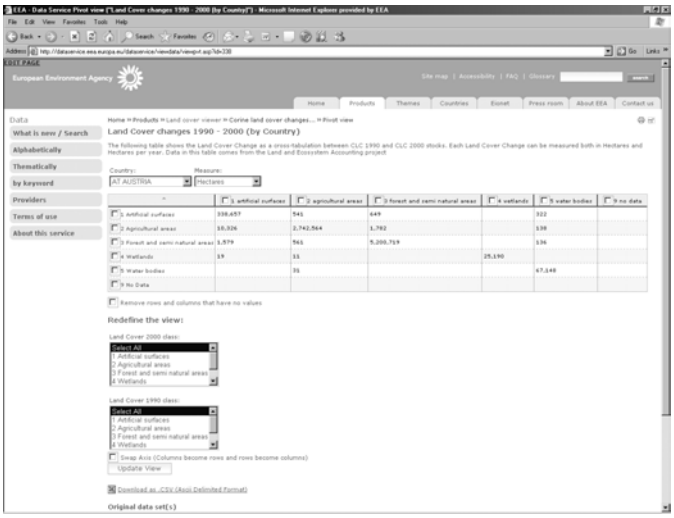

Figure 2. On-line access to the land accounts from the EEA webpage

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 1000 m. The spatial reference system is ETRS LAEA 5210 and the positions of their cells match the 1km European Standard Grid definition.

Interactive reporting tools: If users do not wish to download the information, they can nevertheless gain interactive use with the information held at the EEA via a range of other routes. For example, users may link to the accounts data held in the form of an OLAP database at the 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
- **Maps:** The ARCGIS LEAC OLAP database facility allows users as well 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

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

Statistics can be produced interactively in-screen via a set of pivot tables which can be customized 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. 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 online map service for LEAC is under development (Figure 3). However, it is possible presently 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/ .

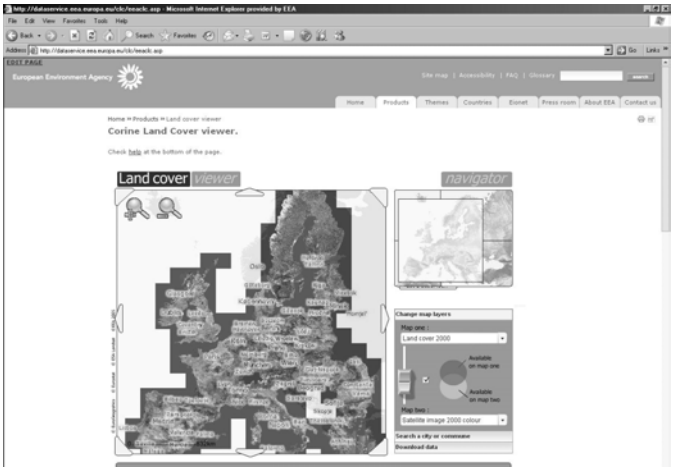

Figure 3. Land Cover viewer of the EEA

This service will eventually be expanded to include the presentation of the LEAC data themselves.

A full explanation of the methodology applied for the development of the LEAC can be found in EEA Report [6]

3. EXAMPLES OF APPLICATION

This comprehensive statistical data base of land use changes can be used for various analyses. At this moment the LEAC database was used as an input to general report of the EEA regarding the changes of land use at the European level[6]. Analysis of Urban Sprawl [7] and changes of the cost zone, further to this analysis the tool is also used in assessment of the changes in agricultural and forestry as well as it's impact on the rural areas and mountain areas.
Below some examples of the application that can be made with this tool is presented.

Changing Europe
Land-cover change is important both in terms of the total amount or net change in types of cover, and the actual locations where these changes occur. To understand the potential impacts on nature, both change information and spatial information are needed.
Starting with Europe (Figure 4) as a whole, the net change(Figure 5) in land cover between 1990 and 2000 highlights the increases in urban and other artificial land development and forest area, and the decrease in agricultural and natural area. The net change in artificial land area is a good indicator of urban sprawl, which is mostly an irreversible one-way process. The trends for total turnover confirm that urban sprawl was a key process in Europe in the 1990s, driven by economic growth and increasing consumption, suburbanization and the implementation of the internal market (including transport infrastructure).

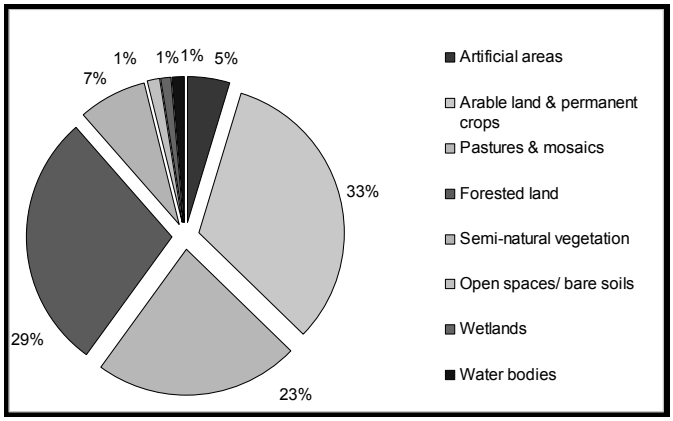

Figure 4. Total Land cover in 2000

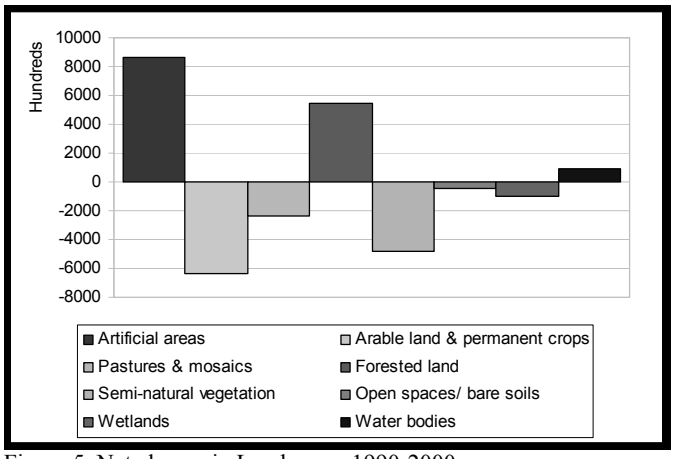

Figure 5. Net change in Land cover 1990-2000

This sprawl is partly at the expense of natural land, and this development has important consequences for the long-term potential of the land to continue to provide ecological services and amenities.

In addition to demographic trends in rural areas, which in many places took the form of depopulation, the changes in agriculture and forestry can be ascribed mainly to the extension of the common agricultural policy, combined in some countries with rapid economic growth fostered by their accession to the EU and access to the internal market.

Urban sprawl in Europe
The process of urbanization in Europe has evolved as a clear cycle of change during the post-war period from urbanization to suburbanization to de-urbanization and, most recently, to re-urbanization. Historically, the growth of cities was fundamentally linked to increasing population. In contrast, urban sprawl is a more recent phenomenon and is no longer tied to population growth. Rather to a variety of other powerful factors drive the development of the modern city, including individual housing preferences, increased mobility, commercial investment decisions, and the coherence and effectiveness of land use policies at all levels.
All available evidence demonstrates conclusively that urban sprawl has accompanied the growth of urban areas across Europe over the past 50 years. The areas with the most visible impacts of urban sprawl are in countries or regions with high population density and economic activity (Belgium, the Netherlands, southern and western Germany, northern Italy, the Paris region) and/or rapid economic growth (Ireland, Portugal, eastern Germany, the Madrid region).

Sprawl is particularly evident where countries or regions have benefited from EU regional policies. New development patterns can also be observed, around smaller towns or in the countryside, along transportation corridors, and along many parts of the coast usually connected to river valleys.

Hot spots of urban sprawl are also common along already highly populated coastal strips, such as in the case of Spain where the artificial areas may cover up to 50 % of the total land area. This is doubly worrying given the known vulnerability of coastal ecosystems and because the Mediterranean region is classified as one of 34 biodiversity hotspots in the world. Sprawl may also follow from the expected rapid economic development in many parts of the new Member States, as internal economic dynamism, greater access to EU markets, and Cohesion Fund and Structural Funds investments drive economies.

Indeed during the ten year period 1990–2000 the growth of urban areas and associated infrastructure throughout Europe consumed more than 8 000 km^2 (a 5.4 % increase during the period), equivalent to complete coverage of the entire territory of the state of Luxembourg. This is equivalent to the consumption of 0.25 % of the combined area of agriculture, forest and natural land. These changes may seem small. However, urban sprawl is concentrated in particular areas which tend to be where the rate of urban growth was already high during the 1970s and 1980s. Moreover, they run alongside the emerging problems of rural depopulation. On a straight extrapolation, a 0.6 % annual increase in urban areas, although apparently small, would lead to a doubling of the amount of urban area in little over a century.

Full analysis of urban sprawl in Europe can be found in EEA Report [7].

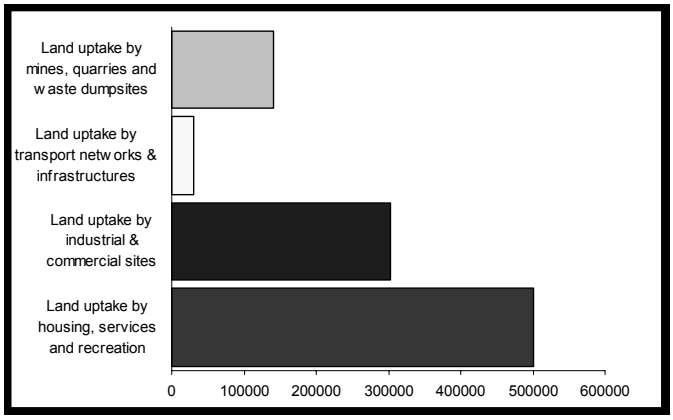

Figure 6. Drivers behind urban and infrastructure land development in Europe 1990-2000 - ha/year

4. CONCLUSIONS

This paper is presenting a new tool developed at the European Environment Agency in order to assess changes of land use at the European level. This type of tools are needed in order to understand the implications of changes in land cover and land use which are fundamental part of planning for sustainable development. Through the materials presented here, we have shown how the development of land accounts can contribute knowledge and understanding in this important area. The presented examples are showing how 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 accounts has now established a platform on which such developments can now take place.

One of the mandates of the EEA is to provide data at the European level to the stakeholders and public. This tool is one of the examples of data sets that will be available in future from the Agency web site. The IT developments in last years have created many possibilities to provide spatially distributed data in an easy format to the public. The data are accessible freely therefore any one can used them for academic/research, policy or private use. The current perspectives for future developments of the tool consist of a new Corine update of 2006, currently under development. Reconstruction of past data for the 1975 from various sources.

The presented approach in this paper is a transferable method of land use accounting that can be used not only in the European contents but also in other countries. As the tool operates at different scales the potential for its use is quite large one. Further developments will extend its usability to other fields.

5. REFERENCES

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