Land and ecosystem accounts for Europe
Towards geospatial environmental accounting

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Authors:
Eva Ivits (EEA), Roger Milego (UAB), Emanuele Mancosu (UMA), Mirko Gregor (s4e), Jan Erik Petersen (EEA), György Büttner (Umweltbundesamt GmbH), Manuel Löhnertz (s4e), Gergely Maucha (Lechner Knowledge Centre), Otto Petrik (Lechner Knowledge Centre), Annemarie Bastrup-Birk (EEA), Jana Tafi (EEA), Gerard Hazeu (WEnR).

ETC/ULS consortium partners: Environment Agency Austria, ALTERRA Research Institute, Department of Remote Sensing, Lechner Non-profit Ltd space4environment, GISAT, The International Council for Local Environmental Initiatives (ICLEI), Universitat Autonònoma de Barcelona (UAB), Universidad de Málaga (UMA), Ecologic

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European Topic Centre on Urban, Land and Soil Systems (ETC-ULS)
Environment Agency Austria
Spittelauer Lände 5
A-1090 Vienna/Austria

Tel.: +43 1 313 04
Fax: +43 1 313 04/5400

Web: http://uls.eionet.europa.eu/

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Land use and its change impact food security, carbon cycling, and landscapes and their features, among others. Land use and associated changes influence the integrity of ecosystems and our natural capital, which in turn are directly associated to a healthy environment and human well-being.

In order to support and guide policy actions acting between economy and environment, harmonized datasets, transparent methodologies and easily interpretable statistics are essential elements. The complex interaction between elements of natural capital also calls for a coherent approach to facilitate the understanding of the coupled human-environment system. Therefore, monitoring of the structure and condition of ecosystems and their trends, along with properly agreed methodologies are urgently needed.

Land and Ecosystem Accounting (LEAC) is an EEA initiative which is part of EEA`s geospatial environmental accounting system. Methods are in line with the framework of the UN System of Environmental Economic Accounting - Central Framework (SEEA-CF 2012), which provides internationally agreed standards for measuring the environment and its relationship with the economy. The EEA LEAC approach also supports the calculation of ecosystem accounts as proposed by the guidance issued by the United Nations Statistics Department on 'Experimental Ecosystem Accounting (SEEA-EEA[1]). This provides opportunity for an integrated measurement of trends for individual environmental assets within a given spatial area as proposed by the Ecosystem Natural Capital Accounts (ENCA) framework (UN-CBD, 2014).

The present report describes EEA`s approach for producing land accounts using geospatial data and providing statistical information in land cover and land use status and changes. After the introduction of the accounting concept, EEA`s accounting infrastructure, the Joint Environmental Data Infrastructure together with its data cube concept are presented. The report then describes the Corine Land Cover dataset which presently serves as a basis for the long-term land accounting reports of the EEA. This is followed by the presentation of interactive dashboards to illustrate how accounting statistics can be brought to the user. Finally, the land accounting method is explained on the basis of examples for agricultural land use, forested land and urban areas.

The concepts and methods presented in this report are flexible and may be used with any categorical geospatial data. See EEA`s released accounting databases below:

LAND ACCOUNTS 2000-2018
LAND TAKE ACCOUNTS 2000-2018
LAND RECYCLING ACCOUNTS 2006-2012
SOIL SEALING ACCOUNTS 2006-2015
NATURA2000 LAND COVER ACCOUNTS
FLOODPLAIN LAND ACCOUNTS

(1) https://seea.un.org/

1 Introduction

1.1 Land in key policy processes

Land is a unique environmental asset that delineates the space in which economic activities and environmental processes take place and within which environmental assets and economic assets are located[2]. Understanding the status and change of land cover and land use and its impact on natural capital is therefore required by many policy processes. This is clearly stated in the 7th Environmental Action Programme of the European Union (7th EAP), in particular under Priority 1 on 'Maintaining natural capital' and Priority 5 which sets targets to increase the knowledge about environment and widen the evidence base for policy. While the EU Biodiversity Strategy 2020 already formulated the need for an integration of geospatial data, the new EU Biodiversity Strategy 2030 repeats this need implicitly in the context of the new EU Nature Restoration Plan and by the intent to put in place a monitoring and review mechanism, including a clear set of indicators.

Land cover and land use status and change are important elements to inform the development and implementation of policies that deal with the management of our land resources, such as agriculture, forestry, biodiversity and climate policies or regional planning. Land cover status and change statistics are also needed to address the "no net land take" by 2050 target of the 7th EAP. An integrated management of natural capital is also a key target of other EU environmental policies, such as those on nature (i.e. Birds and Habitats Directives), water (Water Framework Directive) and marine (Marine Strategy Framework Directive) which are also aiming at integration with sectoral policies and a broader assessment of systemic challenges regarding ecosystem management.

Although a binding legislative mechanism for the sustainable management of land at the level of the European Union (EU) is lacking (Frelih-Larsen et al., 2017), the sustainable management of land is crucial to ensure that land continues to provide its functions now and in the future. Some EU policies already frame conditions for land use, e.g. the Common Agricultural Policy. Others will affect it increasingly in the coming years, including a new EU regulation for land-based carbon accounting (land-use, land-use change and forestry - LULUCF) and EU renewable energy and climate goals. At the same time a wide range of EU environmental policies have a major stake in land management, for example the EU Biodiversity Strategy with its target to 'maintain and restore ecosystems and their services' (Land system concept, EEA, 2018).

At international level, with the adoption of the UN Sustainable Development Goals in 2016, European countries, which are party to the UNCCD, and the EU have committed themselves to implement 'Land Degradation Neutrality' (LDN) in their mandate areas in the period up to 2030. The corresponding SDG target is target 15 on land to "protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss". Moreover, the SDG target 15.9 postulates "By 2020, integrate ecosystem and biodiversity values into national and local planning, development processes, poverty reduction strategies and accounts". The international System of Environmental-Economic Accounting (SEEA) is a key reporting framework for these targets and for a better ecosystem management in general. It comprises inter alia standards on land and water accounting, published in the 'Central Framework' (SEEA CF), and guidance on ecosystem accounting (SEEA EEA), which will be updated by 2021.

(2) https://seea.un.org/sites/seea.un.org/files/seea_cf_final_en.pdf

1.2 Monitoring of land and ecosystems as natural capital

The natural capital (next to manufactured, human and social capitals) provides the basic conditions for human existence (SOER EEA, 2015). It is divided into two main components: ecosystem capital and abiotic components. Different components of natural capital can be classified according to a number of criteria, e.g. whether they depletable, able to self-regenerate, resilient etc. Ecosystem capital is generally considered to be the most vulnerable (EEA, 2019). Productive land and fertile soil are part of our shared natural capital. Appropriate management of land and soil is therefore fundamental for sustainable resource use and the delivery of ecosystem services (SOER, 2020).

The complex interactions between different elements of natural capital and human society calls for a coherent approach to understand the coupled human-environment system. Land use and its change impact food security, carbon cycling, and water cycles, among others. Land use and changes influence the integrity of ecosystems and our natural capital, which in turn underpin a wide range of ecosystem services and ultimately human well-being. In order to understand and tackle anthropogenic impacts on ecosystems spatially explicit information on the extent and changes of land and associated ecosystems is a crucial piece of knowledge. This monitoring must be supported by quantitative, robust, reliable and comparable methods to map the condition and degradation of ecosystems and their services and thus supplying a standardized framework for ecosystem assessment and accounting.

In the EU, the analysis of the links between natural capital and human economy and well-being is supported by the EU INCA project and the MAES initiative (Mapping and Assessment of Ecosystems and their Services) under the EU Biodiversity Strategy to 2020. This initiative brings together EU bodies and Member State organisations to map and assess European ecosystems and their services based on a conceptual framework for EU-wide ecosystem assessment. The analytical goal is to measure the state of biodiversity and ecosystems and to evaluate the level of ecosystem services provided to people. This would show the connections between the environment and the economy (economic sectors) by considering the ecosystems from which the services are derived and the different benefits to human society that are affected by changes in the supply of services (Maes et al., 2013).

1.3 Land and ecosystems in the accounting framework

Land and Ecosystem Accounting (LEAC), is an EEA initiative aiming to build and apply a European accounting system for land and ecosystems (EEA, 2006). This work builds on the framework of the UN System of Environmental Economic Accounting - Central Framework (SEEA-CF, 2012), which provides internationally agreed standards for measuring the environment and its relationship with the economy. Together with the Experimental Ecosystem Accounts (SEEA-EEA[3]) these methods integrate individual environmental assets within a given spatial area. The support that the LEAC approach provides for ecosystem accounting is described in the 'Quick start package for Ecosystem Natural Capital Accounts' (ENCA- CBD, 2014). Additional work of the EEA on ecosystem accounts, water accounts, pilot marine accounts etc. is set out in EEA report No 26/2018 (EEA, 2019).

Work on environmental accounts in the European Union is based on EU Regulation No 691/2011 on European Environmental economic accounts[4]. This is complemented by the European strategy for environmental accounts for 2019 to 2023[5] which is a programme of further work agreed by the Commission (Eurostat) and the Member States and adopted by the European Statistical System Committee. This strategy coordinates European efforts and paves the way for possible new modules. The EU-level INCA project (Commission, 2019) is a cooperation between several partners in the European Commission and the EEA to test and implement a system for integrated natural capital accounting within the SEEA-EEA. Together with ongoing initiatives at country-level they provide a platform for the further development of ecosystem accounting within the EU statistical system.

The European LEAC database provides the basis for European land accounts. It quantifies the land cover extent as stocks and changes (increase and decrease in the extent) as flows between one time-step to another. The LEAC database is based on the Copernicus CORINE Land Cover data series available for every 6 years between 2000 and 2018 (https://land.copernicus.eu/pan-european/corine-land-cover). The first EU 1990-2000 land accounts using the LEAC database were produced for 24 countries by the EEA on the basis of CORINE Land Cover data. They have been updated for 2006, 2012, as well as for 2018 (for the 39 EEA countries) in 2019.

Additionally, the LEAC database was adopted as the common starting point to generate European ecosystem extent accounts in the EU projects MAES and INCA. Ecosystem extent accounts use the same logic as land accounts to quantify the extent and magnitude of change of different ecosystem types, in various spatial aggregations (e.g. Natura 2000 areas). The reclassification of CLC classes is based on the MAES ecosystem typology (tier I) and a hierarchical selection of CLC class groupings and individual level 3 classes (tier II and tier III) to generate ecosystem extent accounts for 2000, 2006, and 2012 (Natural Capital Accounting, EEA, 2019), and for 2018 updated in 2020.

(3) https://seea.un.org/
(4) https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:02011R0691-20140616
(5) https://ec.europa.eu/eurostat/documents/1798247/6191525/European+Strategy+for+Environmental+Accounts/

1.4 An efficient land and ecosystem accounting system

The development of the EEA land and ecosystem accounting system began nearly two decades ago with full methodological documentation of the approach published with the report 'Land accounts for Europe 1990 – 2000' (EEA, 2006). Since that period the EEA has published various other land and ecosystem accounting reports and accounting data bases.

At the same time the need to better manage land and ecosystem resources is as pressing as ever, and the pressures on our natural capital from climate change, biodiversity loss and socio-economic trends are only increasing. Fortunately, our capacity to monitor trends in natural capital via earth observation is also increasing, in particular via the EU Copernicus programme. This requires the development and implementation of a more efficient land and ecosystem accounting system to connect policy information needs with adequate analytical tools.

This document is one of several released by the EEA and ETC/ULS in 2020 to document the methodological and analytical advances in the EEA land and ecosystem accounting system. It focuses on the describing the data foundation and the accounting infrastructure that underpins the efficient geo-spatial accounting tools employed by EEA and ETC/ULS. This is complemented by illustrative examples of how land accounting methods can support the analysis of environmental pressures arising from land use sectors and land use change. Like the earliest EEA outputs in this domain, this publication is meant to document accounting methods developed at the EEA in support of ongoing international processes that aim to develop coherent global frameworks, methods and standards for land and ecosystem accounting, in particular within the UN system of environmental-economic accounting (see above).

2 Methodological background

2.1 Introduction

The previous section has described the environmental and policy context for land and ecosystem accounting and introduced the UN System of Environmental-Economic Accounting which provides the overall methodological frame for the work described in this report. A summary description of the SEEA framework can be found in the recent EEA report on 'Natural capital accounting in support of policy making' (EEA, 2019). Earlier EEA reports have reviewed the use of the land accounting method for tracking landscape scale changes ('Landscapes in transition' - EEA, 2017) and described the logic and methodological detail of EEA land accounts (EEA, 2006). The latter report provides a comprehensive and still relevant description of the set-up of the EEA land and ecosystem accounting approach. It also contains a detailed description of the land cover flow matrix which has been reviewed and brought up-to-date during the last two years. This limited update of the land cover flow matrix has been implemented in the EEA land and ecosystem accounting dashboards during the summer of 2020 and is described in this chapter.

This chapter presents key concepts and terms which are part of the land accounting approach (section 2.2), reviews the main land cover groupings that underpin the LEAC approach (section 2.3) and describes the revised land cover flow matrix (section 2.4).

2.2 Key concepts and terms of land and ecosystem accounting

Accounting: Accounting is a term related to the financial world which refers to the systematic process of identifying, recording, measuring, classifying, verifying, summarizing, interpreting and communicating financial information. It reveals profit or loss for a given period, and the value and nature of a firm's assets, liabilities and owners' equity[6].

LEAC: LEAC stands for Land and Ecosystem Accounting, a system that was developed by the EEA as a contribution to the UN's Integrated System of Environmental and Economic Accounting[7]. It began with land cover accounts and is meant to be complemented by land use accounts (in linkage to social and economic functions). The EEA LEAC approach also supports the development and calculation of European ecosystem extent accounts and the recording of ecosystem trends under the EU MAES project.

Land (cover) accounting: In the case of land accounting, what is accounted for is the area occupied by each land cover class over time, including gains, losses and transfers or flows between LC classes. 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 (EEA, 2006).

- **Consumption**: it is understood as the loss of a specific land cover class by conversion to any other classes over time.

(6) Business dictionary (http://www.businessdictionary.com/definition/accounting.html)
(7) https://seea.un.org/content/land-accounts

- **Formation**: it is understood as the gain of a specific land cover class by conversion from any other classes over time.

- **Balance**: the difference between formation and consumption for a specific land cover class over time.

- **Turnover**: the amount of change over time.

- **Land cover stock**: the amount of land cover existing at a specific time.

- **Land cover change**: a specific transition from one land cover class to another over time.

- **Land cover flow**: a set of land cover changes grouped by a specific process by which those changes have occurred.

- **CLC accounting layers**: specific land cover stock layers made for the purpose of accounting. They are built from the CLC stock layers and the CLC change layers over time. Due to the different MMU between CLC stock (25 ha) and change (5 ha) layers, the stock and change layers are combined into the CLC accounting layers product. Further details are provided in Chapter 3.

- **LEAC codes**: alternative land cover coding suitable for accounting purposes. The equivalences between CLC and LEAC codes are provided in Table 2-1.

- **MAES codes**: alternative land cover coding developed for accounting for MAES purposes. The equivalences between CLC and MAES codes are provided in Table 2-2.

- **JEDI:** Joint Environmental Data Infrastructure. EEA's system infrastructure for building data cubes especially made for land and ecosystem accounting.

2.3 The grouping of CLC classes for accounting in LEAC and MAES

2.3.1 Structure of LEAC classes built on Corine Land Cover

The nomenclature of the CLC datasets is depicted in table 22. CLC level 3 as the most detailed level has 44 classes, there are 15 intermediate classes at level 2 and five broad classes at level 1. Accounting for land cover change can in principle be implemented for individual level 3 land cover classes but for ease of interpretation and efficiency a different class combination is used. CLC level 1 and 2 classes are combined into 8 new groups, the so called LEAC (Land and Ecosystems Accounting) categories.

The purpose of the LEAC (Land and Ecosystems Accounting) categories is to build up a structured system for describing land cover changes that groups CLC classes with similar land use and/or environmental characteristics together. The agriculture class for example is split into 'Arable land and permanent crops' and 'Pastures and mosaic farmland'. Forests are also split into two classes: 'Standing forests' and 'Transitional woodland and shrub'. The latter mainly maps areas that have been recently felled or new plantations. 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 (EEA report no 11/2006). The structure of the current LEAC groupings and their link to CLC level 3 classes is set out in Table 2-1 below. In addition, Figure 2--2 maps CLC level 3 and LEAC 2B nomenclatures for comparison purposes.

Table 2-1 Aggregation used for land cover accounts (LEAC classes).

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.

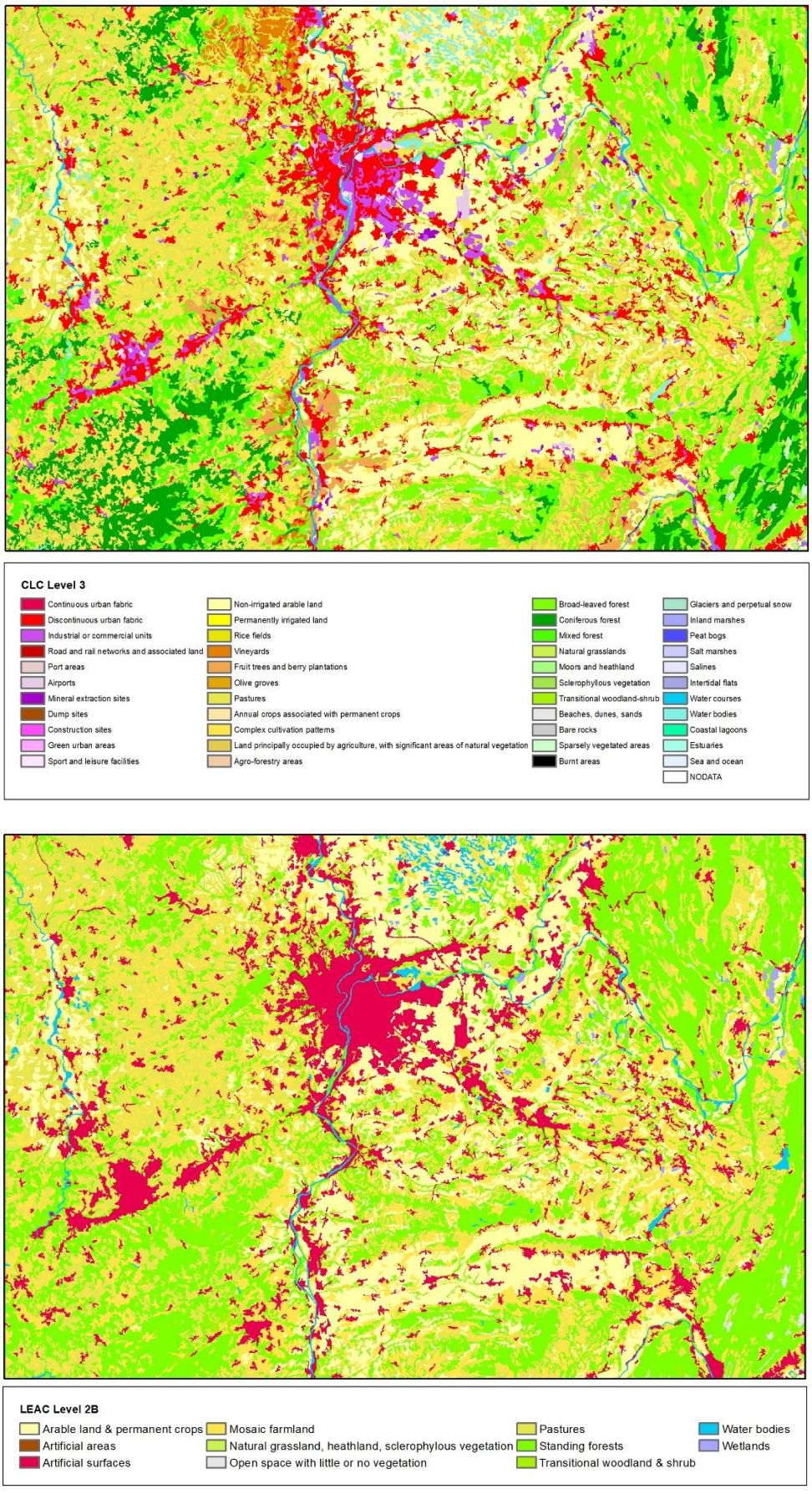


Figure 2--1 CLC level 3 and LEAC level 2B nomenclatures for the same extent

2.3.2 MAES classes

Following the mandate of EU's Biodiversity Strategy[8], the Working Group on Mapping and Assessment of Ecosystems and their Services (MAES) has been set-up to co-ordinate the mapping and assessment of the state of ecosystems and their services at EU-level. To this purpose, and in order to be able to account for changes in ecosystems, a correspondence in form of a reclassification was created between CLC classes and the so-called MAES ecosystem types. Table 2-2 shows this correspondence.

Table 2-2: Correspondence between CLC classes and MAES ecosystem types

Note: In the EEA ecosystem extent accounting approach (2020, forthcoming) the CLC class 3.3.4 is no longer allocated to an ecosystem type as it is a transitory state rather than an inherent ecosystem characteristic.
Source: MAES et al., 2013.

CLC Level 1	CLC Level 2	CLC Level 3	Ecosystem types level 2
1. Artificial surfaces	1.1. Urban fabric	1.1.1. Continuous urban fabric	Urban
		1.1.2. Discontinuous urban fabric	
	1.2. Industrial, commercial and transport units	1.2.1. Industrial or commercial units	
		1.2.2. Road and rail networks and associated land	
		1.2.3. Port areas	
		1.2.4. Airports	
	1.3. Mine, dump and construction sites	1.3.1. Mineral extraction sites	
		1.3.2. Dump sites	
		1.3.3. Construction sites	
	1.4. Artificial non-agricultural vegetated areas	1.4.1. Green urban areas	
		1.4.2. Sport and leisure facilities	
2. Agricultural areas	2.1.Arable land	2.1.1. Non-irrigated arable land	Cropland
		2.1.2. Permanently irrigated land	
		2.1.3. Rice fields	
	2.2. Permanent crops	2.2.1. Vineyards	
		2.2.2. Fruit trees and berry plantations	
		2.2.3. Olive groves	
	2.3. Pastures	2.3.1. Pastures	Grassland
	2.4. Heterogeneous agricultural areas	2.4.1. Annual crops associated with permanent crops	Cropland
		2.4.2. Complex cultivation patterns	
		2.4.3. Land principally occupied by agriculture, with significant areas of natural vegetation	
		2.4.4. Agro-forestry areas	
3. Forests and semi-natural areas	3.1. Forests	3.1.1. Broad-leaved forest	Woodland and forest
		3.1.2. Coniferous forest	
		3.1.3. Mixed forest	
	3.2. Shrub and/or herbaceous vegetation association	3.2.1. Natural grassland	Grassland
		3.2.2. Moors and heathland	Heathland and shrub
		3.2.3. Sclerophyllous vegetation	
		3.2.4. Transitional woodland shrub	Woodland and forest
	3.3. Open spaces with little or no vegetation	3.3.1. Beaches, dunes, and sand plains	Sparsely vegetated land
		3.3.2. Bare rock	
		3.3.3. Sparsely vegetated areas	
		3.3.4. Burnt areas	
		3.3.5. Glaciers and perpetual snow	
4. Wetlands	4.1. Inland wetlands	4.1.1. Inland marshes	Wetlands
		4.1.2. Peatbogs	
	4.2. Coastal wetlands	4.2.1. Salt marshes	Marine inlets and transitional waters
		4.2.2. Salines	
		4.2.3. Intertidal flats	
5. Water bodies	5.1 Inland waters	5.1.1 Water courses	Rivers and lakes
		5.1.2 Water bodies	
	5.2 Marine waters	5.2.1 Coastal lagoons	Marine inlets and transitional waters
		5.2.2 Estuaries	
		5.2.3 Sea and ocean	Marine

(8) EU Biodiversity Strategy to 2020: http://ec.europa.eu/environment/nature/biodiversity/strategy/index_en.htm

2.1.2 The LCF matrix

When it comes to land cover changes between two observation periods, the concept of Land Cover Flows (LCFs) has been developed to facilitate transparent accounting. The number of potential unique land cover changes is large (44*43 = 1,892), therefore grouping them into change categories, i.e. flows, is a good solution for transparent assessments. LCFs are defined using a hierarchical structure up to three levels, describing different processes of land cover or land use changes. Several LCF matrices may be derived, dependent on user needs. These matrices are used as Look Up Tables in the accounting infrastructure of EEA`s Integrated Data Platform (see Chapter 4). Below is an example of a possible grouping of land cover flows at level 1 hierarchy:

- **LCF1 - Urban land management**: Internal transformation of urban areas.
- **LCF2 - Urban residential expansion**: 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).
- **LCF3 - Expansion 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).
- **LCF4 - Agriculture internal conversions**: Conversion between farming types. Rotation between annual crops is not monitored by CLC.
- **LCF5 - Conversion from other land cover to agriculture**: Expansion of agriculture land use.
- **LCF6 - Increase in forest land cover and other semi-natural areas**: Farmland abandonment and other conversions from agriculture activity or others in favour of forests or semi-natural land.
- **LCF7 - Forest internal land cover changes**: Conversions between forest classes or between transitional woodland and shrubs and forest.
- **LCF8 - Water body and wetland creation and management**: Creation of dams, reservoirs and wetlands, and possible consequences of the management of the water resource on the water surface area.
- **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, plus rare or not-applicable changes.

Figure 2--2 and Figure 2--3 present “LCF2: Urban residential expansion” and “LCF61: Expansion of forest and shrub on agricultural area”. The 100m spatial resolution datasets were resampled to a 5km square resolution for visualisation purposes.

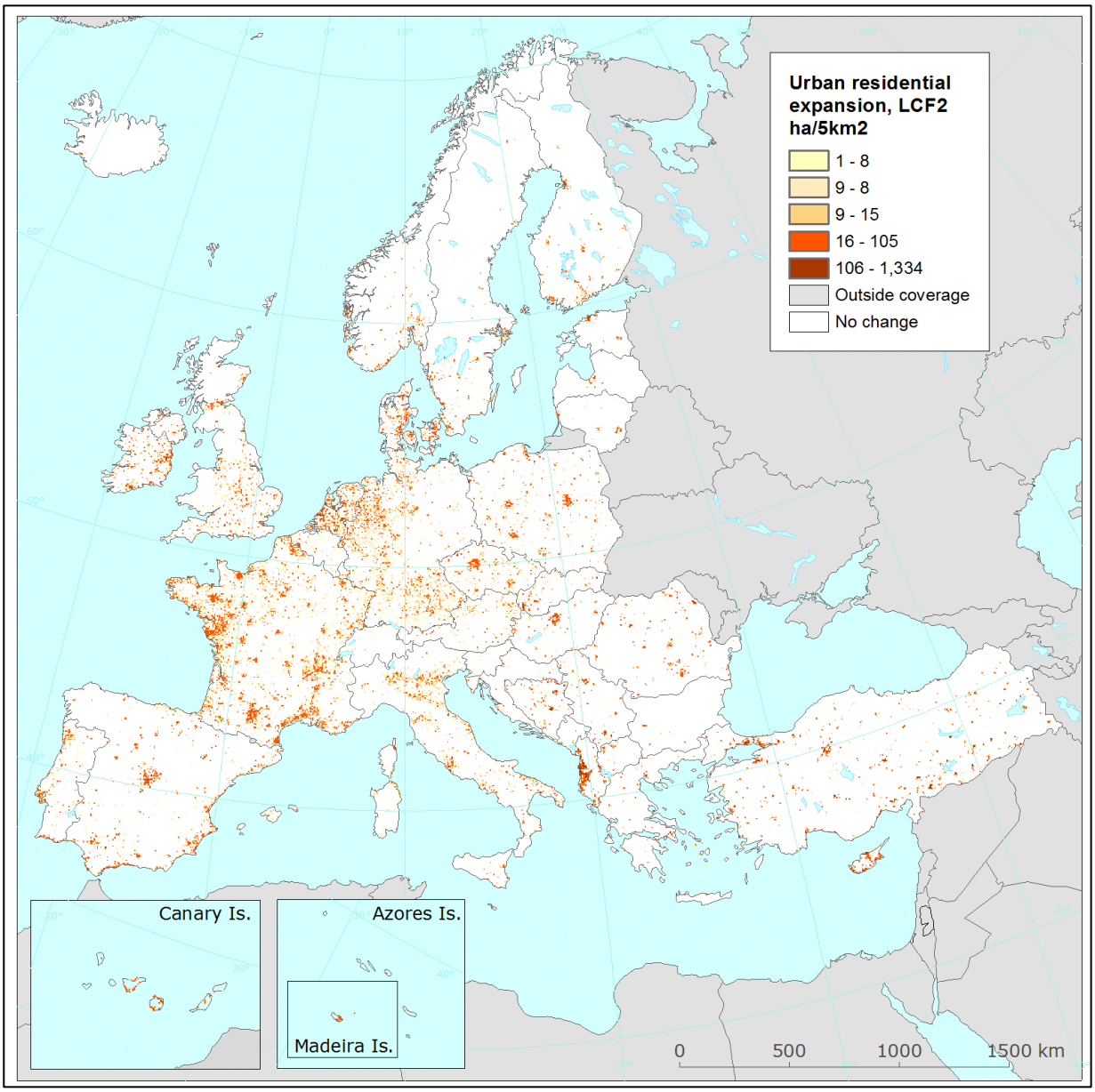


Figure 2--2 LCF2: Urban residential expansion 2000-2018.

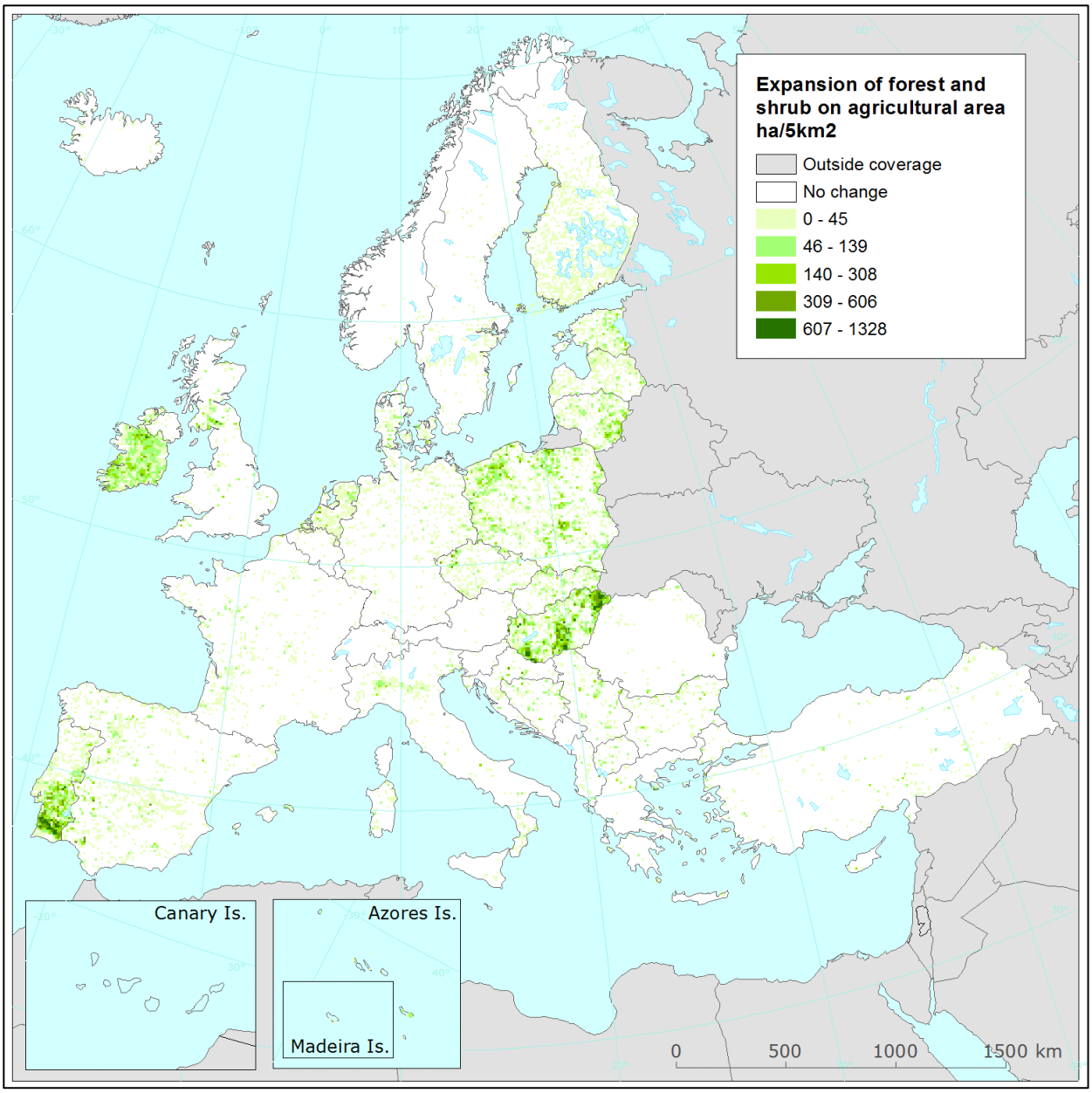
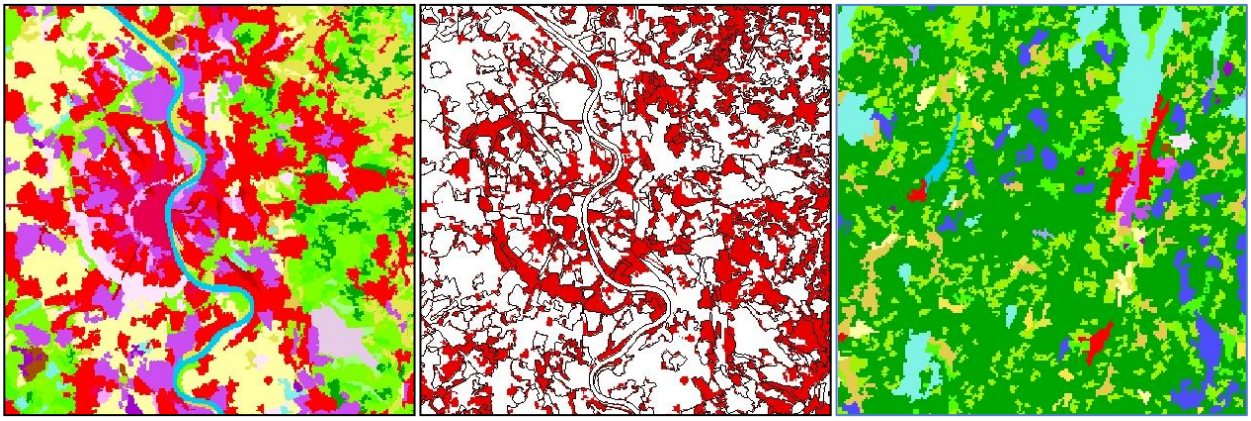


Figure 2--3 LCF61 – Expansion of forest and shrub on agricultural area 2000-2018, EEA-39.

The LCF matrix used for the maps above can be explored in ANNEX 1 - Matrix of Land Cover Flows , whereas the definition of the different land cover flows is included in ANNEX 2 - Definition of Land Cover Flows.

3 Datasets for land accounts



The CORINE Land Cover (CLC) datasets are produced since 1986 for European countries. Altogether five mapping inventories have been implemented in this period. These have produced five status layers (CLC1990, CLC2000, CLC2006, CLC2012, CLC2018) and four CLC-change (CLCC) layers for the corresponding periods (1990-2000, 2000-2006, 2006-2012, 2012-2018). Europe-wide (i.e. EEA-39) CLC and CLCC data are available as vector and raster products.

Due to the technical characteristics of CLC and CLCC data, evolution of CLC update methodology and refinements in the understanding of thematic content (Kosztra et. al, 2017), the time-series statistics derived directly from historical CLC data include several inconsistencies. In order to create a solid basis for CLC based time-series analysis a harmonization methodology was elaborated. This has created so-called 'accounting data layers', which are the data sets recommended to be used for land or ecosystem accounting purposes. The methodology for producing this data series is described in this chapter.

3.1 Summary of CLC mapping methodology

The first CLC mapping started in 1986 in Portugal, other countries started the mapping later. The first European CLC inventory (named CLC1990) includes CLC status information with various reference years between 1986 and 1996, depending on timing of the national mapping project. The second European inventory (CLC2000) already fixed the reference year at 2000 (±1) year, depending on good quality (cloud free) satellite image availability. Three other inventories followed in 6-year periods (CLC2006, CLC2012 and CLC2018). CLC status layers are characterised with 25ha Minimum Mapping Unit (MMU) and 100m Minimum Mapping Width (MMW)

The mapping of CLC changes started with the 2nd CLC inventory. Due to different reference status years in case of the CLC1990 inventory, the first CLC-Change (CLCC) layer (named CLCC 1990-2000) shows land cover changes for various length of periods from 1985-2000 to 1998-2000, while all following CLCC layers represent the fixed average length of period of 6 years[9].

CLC change layers are characterized with 5 ha MMU and 100m MMW. Delineated CLC change polygons are characterized with 2 x 3 digit change types:

- Consumption code: CLC status code at first reference year, understood as the loss of a specific land cover class by conversion to any other classes over time.

- Formation code: CLC status code at second reference year, understood as the gain of a specific land cover class by conversion from any other classes over time.

(9) Note, at certain locations the reference period may vary in extreme cases from 4 to 8 years due to the ±1 year tolerance for satellite image status.

Although with 44 classes the possible number of change combinations is numerous (44 x 43 = 1832), many combinations are impossible or at least improbable in practice. CLC changes within EEA-39 include altogether 909 occurring CLC change types for the period between 2012-2018.

Initial CLC datasets are provided in vector format by national teams for each update period. The national CLC inventories are further integrated into a seamless CLC map of Europe. As a next step, seamless vector layers are converted into 100m resolution raster datasets. Most of the modelling and statistical applications are based on the 100m raster version of CLC data. The European vector and raster mosaics are distributed via Copernicus Land portal[10].

The traditional way of creating CLC & CLCC layers is Computer Assisted Photo-Interpretation (CAPI). Photo-interpretation experts, while performing the visual interpretation and manual delineation, apply a complex set of interpretation and generalization rules by human abstractions to ensure the production of vector CLC & CLCC layers fulfilling the technical and thematic specifications. Besides the original and still dominating CAPI methodology, there is an increasing number of countries using advanced (bottom-up) solutions (see section 3.1.2).

Original mapping instructions created for the CLC2000 inventory included the recommendation to create CLC 1990-2000 changes as the difference of CLC1990 and CLC2000 status layers. However, due to the scale difference between CLC and CLCC data determined by varying (25ha vs 5ha) MMUs this solution resulted in the issue that a significant part of valid CLC changes between 5-25 ha size were missing from the CLCC database. As drawbacks of this strategy were clarified only after the CLC2000 mapping started, one part of the countries has created CLCC 1990-2000 data by intersection of two status layers, the other part of the countries applied the newly developed "change mapping first" approach. The consequence is that resulting CLCC 1990-2000 data and statistics are not fully comparable between countries.

Based on a decision made by EEA, from the CLC2006 inventory onward the method to be used for derivation of CLC-Change database is producing a change database directly, by means of computer-aided visual image interpretation.

The key steps of CLC update & CLCC mapping are (Büttner and Kosztra, 2017):

1. Revision of previous CLC status layer (photo-interpretation)
2. Delineation of CLC changes (photo-interpretation)
3. Creation of „new" CLC status layer:
    a) $CLC_{new} = CLC_{old,\ revised}$ + CLC changes (GIS operation automated)
    b) Generalizaton (eliminating polygons smaller than 25 ha by semi-automatic GIS operations)

The key advantage of a workflow based on change mapping first is the direct, visually controlled delineation of CLCC features, which ensures a significantly higher reliability of CLCC data than any other change derivation method could provide.

(10) https://land.copernicus.eu/pan-european/corine-land-cover

3.1.1 Role of CLC revision

The revision of the previous CLC status layer is an obligatory step, this is being performed in parallel with the delineation of changes (Büttner and Kosztra, 2017). Basically three kinds of revision were made in the history of CLC production:

- Systematic correction of specific CLC classes: Class definitions of some CLC classes were refined, in this case a systematic re-interpretation or elimination of these classes were performed within the country database.

- Systematic visual examination of the total area looking for possible mistakes before starting CLC change interpretation.

- Ad-hoc revision of the CLC layers, correcting remaining mistakes found during change mapping.

The great advantage of CLC revision is the additional visual correction step ensuring higher thematic quality in all three resulting new layers:

- Revised CLC status layer of previous reference date (e.g. revised CLC2012)

- New CLC-change layer (e.g. CLCC 2012-2018)

- New CLC status layer (e.g. CLC2018)

On the other hand, since the revision is not harmonized with any of previous CLC or CLCC data, the thematic consistency may be lost at several locations between the latest and previous CLC layers.

3.1.2 Bottom-up approaches

Starting with the CLC2006 inventory, some countries have deviated from the traditional CAPI methodology by introducing sophisticated, but unique solutions for CLC creation. All of these new methods (referred as bottom-up approaches) are strongly influenced by the available high-quality land cover related national in-situ data. New CLC status layers are usually created by means of intelligent combination of available GIS data supported occasionally by image classification and / or visual interpretation. Different solutions exist for change mapping, in many cases this is done by the traditional CAPI method based on bottom-up created CLC-status, or in some cases CLCC data are derived in a (semi-) automatic way.

The on-going work of the EAGLE CLC+ initiative, as a kind of “essence of national bottom-up methods”, proposes a conceptual strategy for a harmonized European land monitoring, including the harmonized collection of land cover, land use and other related spatial data and a robust processing chain and rulesets to derive CLC compatible results.

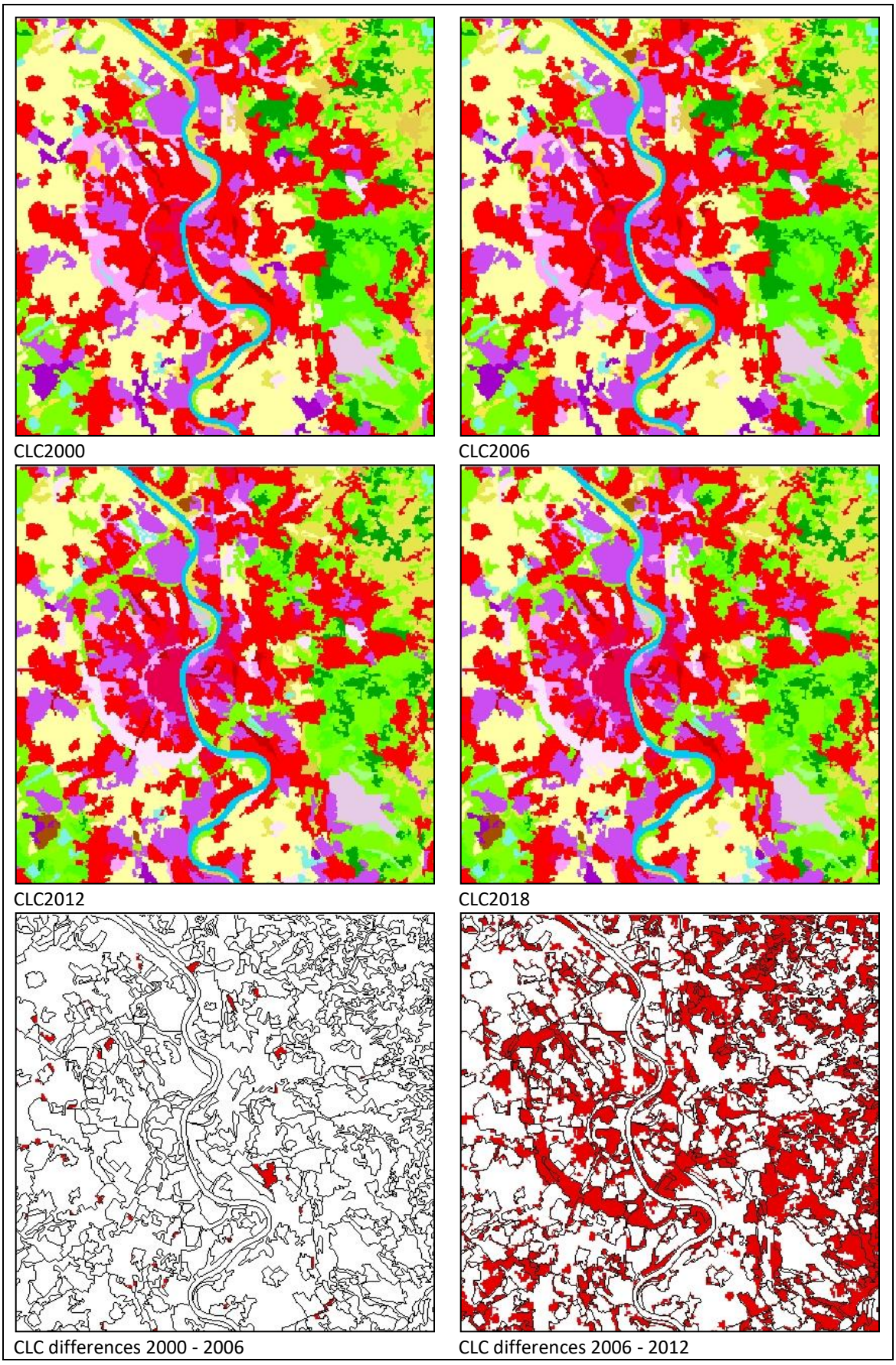
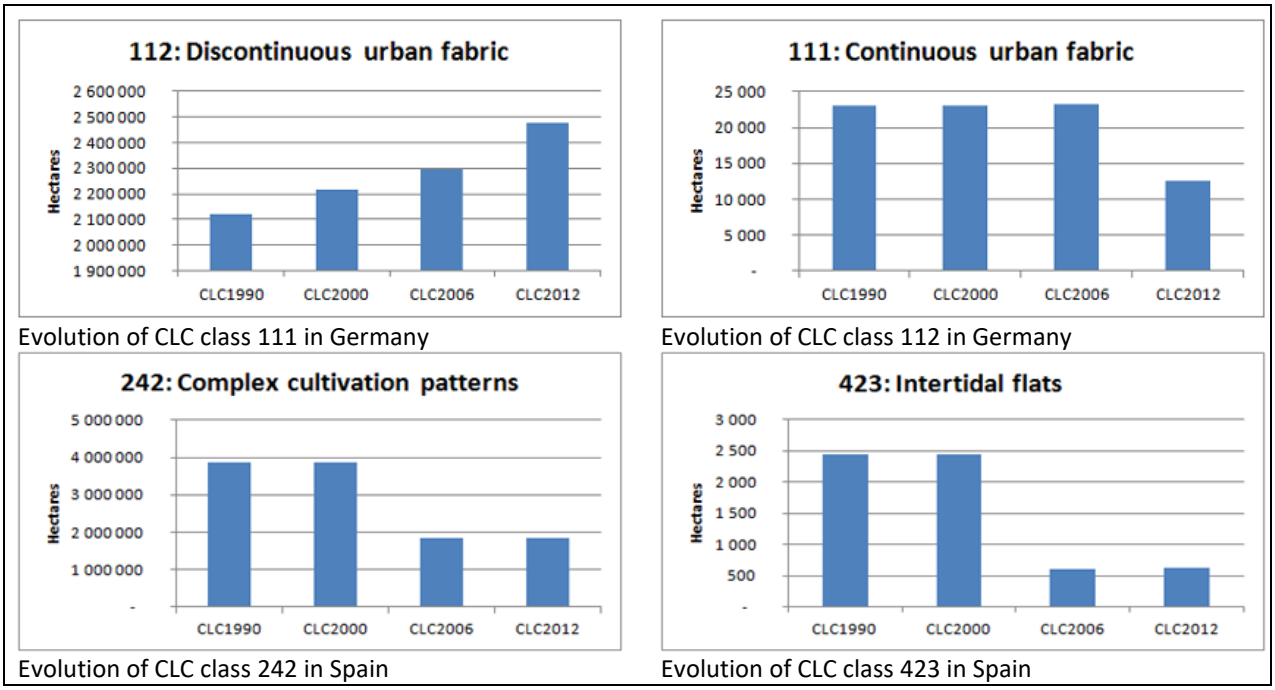


Figure 3--1 CLC time-series of the city of Köln, Germany.

The bottom-up method was introduced with the 2012 inventory. There is an obvious difference between the amount of CLC differences between periods 2000-2006 and 2006-2012.

3.2 Harmonization of CLC time-series

Several environmental indicators are based on CLC status or CLC change layers. These indicators are usually calculated as the combination of certain CLC classes or CLC change types (e.g. land take indicator). In order to be able to filter out possible bias caused by CLC methodological changes, it is important to understand the (country specific) evolution of CLC classes and possible biases within these. CLC time-series statistics were created on a country basis, showing evolution of specific CLC classes including available four reference dates. While the evolution of some CLC classes seems to be as expected, some CLC classes may show critical breaks in the evolution.



Evolution of CLC class 111 in Germany

Evolution of CLC class 112 in Germany

Evolution of CLC class 242 in Spain

Evolution of CLC class 423 in Spain

Figure 3--2 CLC time-series statistics calculated on the basis of original CLC data - 100m resolution raster, version 18.5

While the evolution of CLC class 112 (Discontinuous urban fabric) shows a logical increasing trend in Germany, the sharp loss of class 111 (Continuous urban fabric) area from 2006 to 2012 is more a methodological issue than a real signal. Similarly, the sharp loss of 242 (Complex cultivation patterns) and 423 (Intertidal flat) class areas from 2000 to 2006 in Spain refers to the lack of harmonization in the time series statistics.

The explanation in both cases originates in changes of CLC mapping approaches. Spain introduced a bottom-up CLC mapping methodology during the 2006 update, while Germany introduced similar changes during the 2012 update. Although CLC data created by both, visual interpretation or bottom-up approaches correspond to original CLC specifications and status maps are similar (see Figure 3--2), the delineation of resulting features as well as statistical results may lose comparability.

Besides of major changes in the CLC mapping and update methodology, other possible reasons causing inconsistencies in time-series were identified:

- Evolution of CLC class definitions: Based on verification experiences of past CLC inventories, understanding of CLC class content as well as instructions for photo-interpretation were refined in several steps[11].

- The CLC update methodology does not consider the full time-series, concentrates only on the revision of past status and to the correct delineation of changes.

3.2.1 Methodology for harmonization

The solution applied for the harmonization of CLC time-series is applicable for the European CLC mosaics from 2000 onwards. It is based on the idea to combine CLC status and change information in order to create a homogenous quality time series of CLC / CLC-change layers for accounting purposes fulfilling the relation:

CLC change = CLC accounting new status – CLC accounting old status.

Additional criteria of the realization were:

- Add more detail to the latest CLC status layer (CLC2018) from previous CLCC information and use this "adjusted" layer as a reference

- Create previous CLC status layers by "backdating" of the reference, realized as subtracting CLCC based information for CLC2018

Based on the above principles, the working steps of the creation of CLC accounting layers is as follows:

1) Include formation information from CLC-change layers into current CLC2018 status by creating CLC2018 accounting layer.

    a. Overwrite CLC2018 with code_2006 from CLC-change 2000-2006. Intermediate result: A1_CLC2018.

    b. Overwrite A1_CLC2018 with code_2012 from CLC-change 2006-2012. Intermediate result: A2_CLC2018.

    c. Overwrite A2_CLC2018 with code_2018 from CLC-change 2012-2018. Result: **CLC2018 accounting layer.**

2) Create CLC2012 accounting by including consumption information (code 2012 from CLC-change 2012-2018) into CLC2018 accounting layer. Result: **CLC2012 accounting layer**.

3) Create CLC2006 accounting by including consumption information (code 2006 from CLC-change 2006-2012) into CLC2012 accounting layer. Result: **CLC2006 accounting layer**.

4) Create CLC2000 accounting by including consumption information (code_2000 from CLC-change 2000-2006) into CLC2006 accounting layer. Result: **CLC2000 accounting layer**.

(11) The latest CLC technical guidelines as well as present and previous instructions for photo-interpreters are available at the technical library of Copernicus land portal: https://land.copernicus.eu/user-corner/technical-library

Figure 3--3 CLC harmonization process steps 1. a-c shown by example.

CLC2018 accounting + CLC changes 2012-2018

CLC2012 accounting + CLC2012 original polygons

CLC2012 accounting + CLC changes 2006-2012

CLC2006 accounting + CLC2006 original polygons

CLC2006 accounting + CLC changes 2000-2006

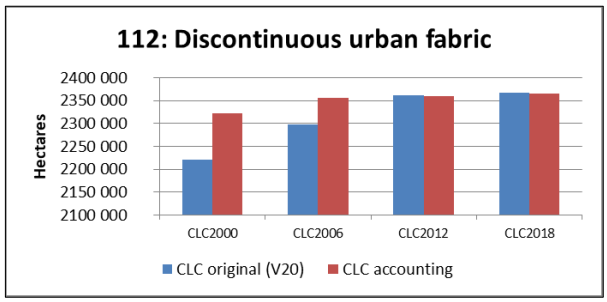
CLC2000 accounting + CLC2000 original polygons

Figure 3--4 CLC harmonization process steps 2-4 shown by example.

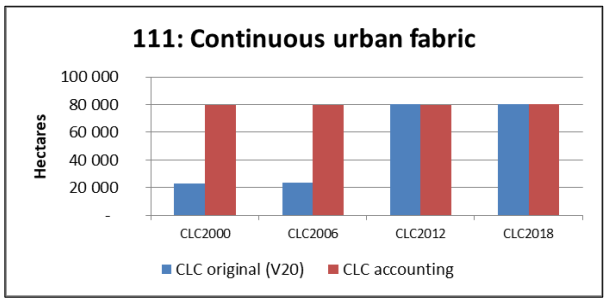
3.2.2 Results: Harmonized CLC statistics

Harmonization leads to an increased comparability in CLC time series statistics as many effects causing apparent false changes are filtered out (Figure 3--5). The resulting data layers are known as accounting data layers and are used presently by EEA's Land and Ecosystem Accounting system. They are publicly available via the following link:

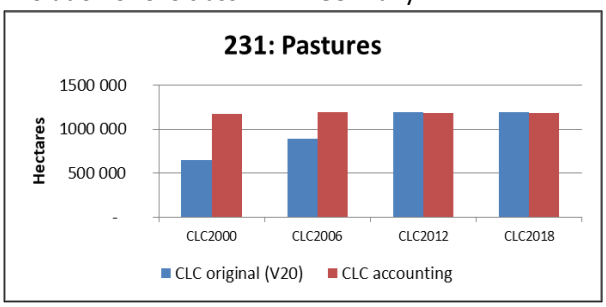
- https://www.eea.europa.eu/data-and-maps/data/corine-land-cover-accounting-layers/clc-accounting-layers



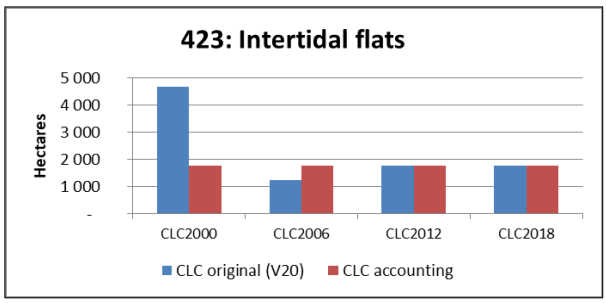
Evolution of CLC class 112 in Germany



Evolution of CLC class 111 in Germany



Evolution of CLC class 242 in Spain



Evolution of CLC class 423 in Spain

Figure 3--5 Harmonized time-series statistics after the accounting process. Evolution of CLC class areas in country statistics shows significantly higher plausibility.

3.2.3 Known issues

There still remain some known conceptual and practical issues, which were introduced with the accounting methodology:

- The generalization level of CLC status layers (25 ha MMU) and CLC change layers (5 ha MMU) is different, correspondingly these datasets are statistically not fully comparable.

- As a consequence of the harmonization methodology, under MMU features (i.e. smaller than 25 ha) appear in accounting CLC status layers. This does not mean, that the overall spatial resolution of the CLC status layer was increased, high resolution features appear occasionally, bound to location of CLC changes.

- The presence of under MMU features in a status layer contradicts the original CLC rules and biases statistical characteristics of resulting CLC data.

- Although the "change mapping first" approach assures a high reliability of CLC-change features, no cross-harmonization was ensured between CLC-change inventories. This may lead to contradictions

in CLC evolution processes captured by distinct CLC-change datasets and finally may appear in a form of unrealistic features in CLC accounting data.

- While the revisions were included to the new CLC layer, the pan-European mosaics of previous reference dates were not consequently updated with revised CLC layers in CLC2000 and CLC2006 inventories → inconsistency between „new" and „old" status. *Example: National CLC2006 was created via revision and update of national CLC2000. This leads to harmony between national CLC2000 and CLC2006 status, but the revisions in national CLC does not appear in European CLC2000 mosaic, leading to local inconsistencies of European mosaic of CLC2000 and CLC2006 layers.*

- Revisions were not applied to all previous status layers → inconsistency between „old" and „older" status. Example: CLC2018 was created *via revision and update of CLC2012, these revision were included to European CLC2012, but not harmonized with CLC2006 and CLC2000 leading to but local inconsistencies with previous (CLC2006, CLC2000) status.*
- Revisions were not applied to previous CLC changes → inconsistency between revised „old" status and previous change layer.

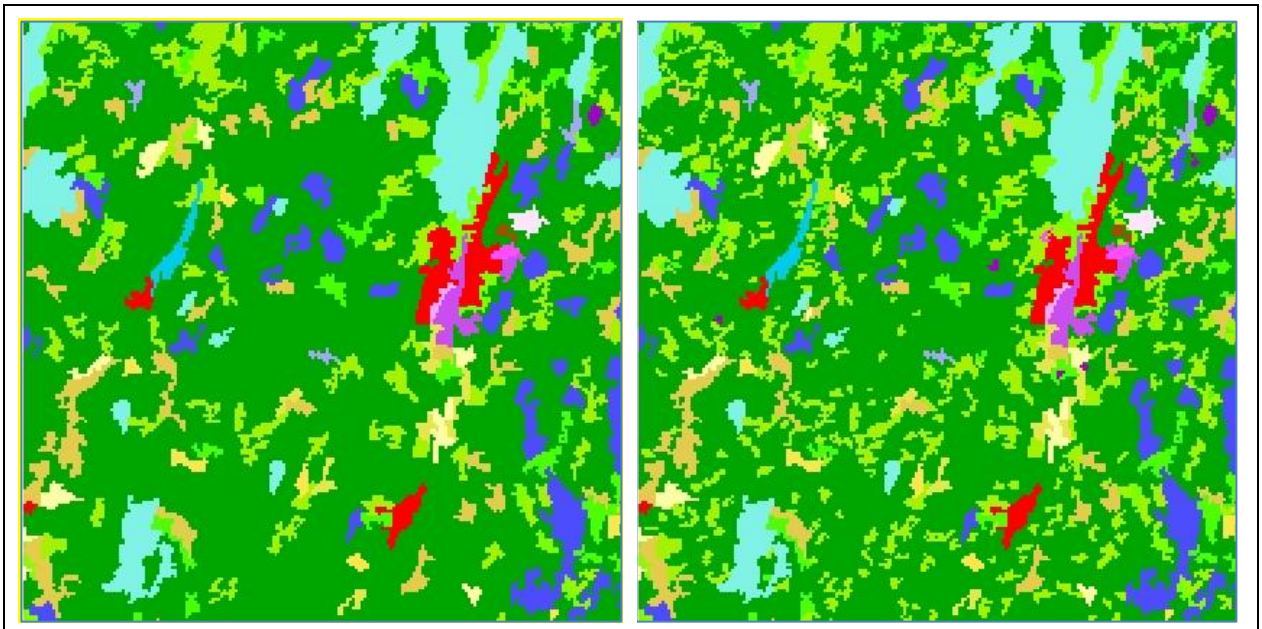


Figure 3--6 CLC2018 and CLC2018 accounting layers near Almhult, Sweden.
Under MMU (smaller than 2-5 ha) features appear in accounting CLC status layers.

Figure 3--7 demonstrates inconsistencies caused by missing harmonization between revised status and past change layers. This is an example of the consequences of non-consequent application of "change mapping first" method. Even if previous mistakes were corrected during latest update and CLC2018 status shows the correct situation, unrealistic features appear in CLC2018 status because of the lack of harmonization between previous CLC-change inventories.

Part of the known issues present in actual version of accounting layers might be eliminated via performing raster generalization on accounting results. Conceptual developments within the EAGLE CLC+ initiative are also targeted on developing a methodology for creating harmonized CLC compatible time-series.

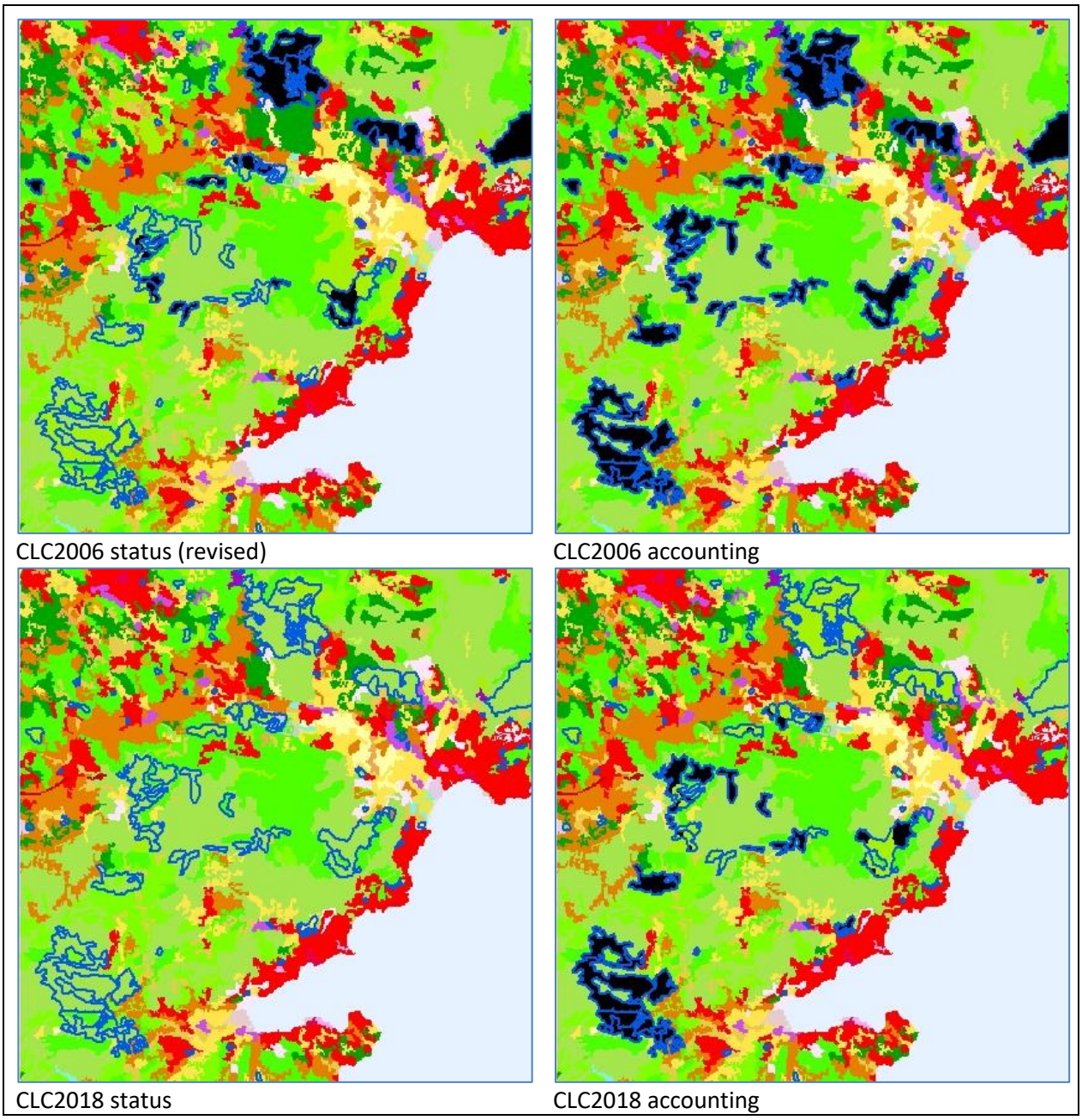


Figure 3--7 Example of inconsistencies caused by missing harmonization between revised status and past change layers.

Forest fire damage (near Val Daubert, South France) around 2006 was recognised by CLC changes (blue outlines), but not handled consequently during the update process. Consequence: Some of the burnt areas appear erroneously in the CLC2018 accounting layer.

3.3 The administrative boundaries layer

Land cover and use trends derived from the combination of the time-series of CLC accounting layers provide information at European scale. A detailed understanding of European land cover dynamics is facilitated with the inclusion of thematic or geographical dimensions, such as the political subdivisions of countries, regions and municipalities. Within the land accounting system, a standard administrative boundaries layer which covers the whole EEA-39 continental Europe is key for identifying regional trends to support national policy objectives.

The Administrative boundaries EEA-39 layer is a harmonized dataset that combines boundaries represented by the Nomenclature of Territorial Units for Statistics (NUTS) relative to the EU-28 Member

States (in 2019), with the equivalent administrative units relative to the five non-EU EEA member countries (Iceland, Liechtenstein, Norway, Switzerland, and Turkey) and the six cooperating countries (Albania, Bosnia and Herzegovina, Kosovo[12], Montenegro, North Macedonia and Serbia).

In addition to the official release of Eurostat GISCO[13], the administrative boundary layer has been combined with the Economic Exclusive Zone dataset[14] to assign a country code on the coastal area of the CLC accounting layers not covered by the NUTS. This way a perfect matching between the CLC coverage and administrative boundaries was achieved.

The dataset is produced in raster format (GeoTiff) at the same resolution as the accounting layers (100m) and contains the aggregation level by Country (NUTS0 and NUTS0+EEZ), NUTS1, NUTS2, and NUTS3 regions.

(12) under the UN Security Council Resolution 1244/99
(13) https://sdi.eea.europa.eu/catalogue/srv/eng/catalog.search#/metadata/83f8aa7a-0e3f-4f31-ad95-f9651626d74a
(14) http://www.marineregions.org/

4 The Integrated Data Platform accounting infrastructure

Land and ecosystem accounts describe how ecosystems and land resources change over time in a consistent and systematic way so that the implications of change can be better understood. They are two components of natural capital that are vulnerable to depletion and cannot be re-created over periods relevant to most policies. Change can lead to total elimination of ecosystem types; however, for land it is mostly the potentials and functions that are transformed through human action. This is expressed by the different uses that particular types of land cover can support. A key concern of land cover and ecosystem extent accounts is the need to understand the way in which the stocks of different land covers and ecosystem types are transformed over time.

The land and ecosystem accounting approach adopted by the EEA follows the one recommended in SEEA handbooks and guidance (see section 1.3). 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. An equivalent approach is recommended for ecosystem extent accounts.

The EEA approach for developing land and ecosystem accounts builds on the Integrated Data Platform (IDP) infrastructure. The Integrated Data Platform targets integrated geo-spatial data assessments. Through discovering semantic and contextual linkages between datasets, the IDP supports the understanding of how various elements of our natural capital can be best understood in relationships with each other and with other systems. This chapter describes the various building elements of this accounting infrastructure.

Products of the IDP derived through the tools below are published and maintained on EEA´s Geospatial Environmental Accounting website:

http://eeadmz1-dis3-wordpress-geo.azurewebsites.net/

4.1 The EEA reference grid as common data integrator

The use of reference grids has been recognised as key point for the integration of heterogeneous sources of data. The standard codification of grid cells makes the reference grids suitable for splitting the territory into a number of regular pieces that can be used as analysis units.

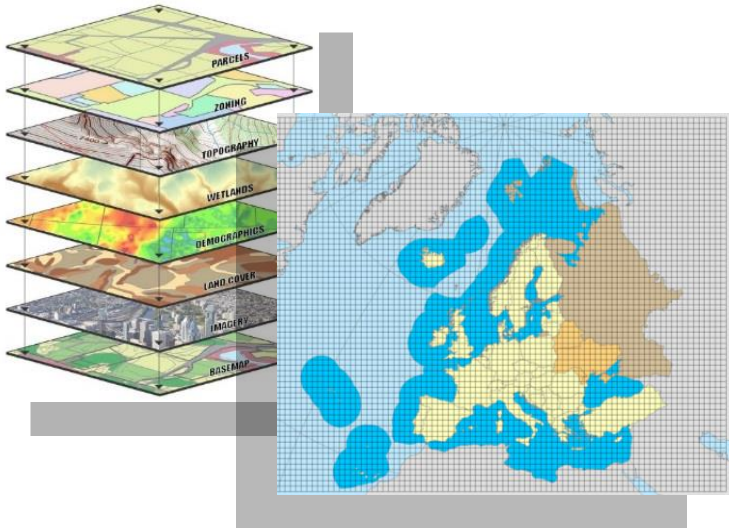


Figure 4--1 LCF6 – The EEA reference grid as a common data integrator.

The 1 km^2 European Reference Grid (ERG) was adopted by several European stakeholders at the First Workshop on European Reference Grids (JRC-IES-LMU-ESDI, 2003). This layer was adopted as the common EEA reference grid and data integrator layer. In this layer the grid cells store the land cover information (i.e. the area of land cover classes) and complementary information to be used as reporting units or ancillary datasets for the assessments. Depending on the nature of the dataset or variable, we distinguish:

- **Geographic dimensions**: define the geographical unit that each cell belongs to (NUTS region, NUTS, UMZ, biogeographical unit, etc.)

- **Thematic dimensions**: define a physical characteristic of a grid cell, such as land cover type.

- **Measures**: numeric variables which can be aggregated by any combination of the data dimensions available in the accounting model. They can be biophysical variables (e.g. vegetation productivity), climate (precipitation, temperature) but also socioeconomic figures (e.g. population, unemployment, GDP, etc).

The EEA-39 reference grid consists of 5 885 212, 1 km cells (CLC non-NULL), each of which can hold a data record in the LEAC database. The geographic and reference dimensions are intersected with the 1 km^2 EEA reference grid, in order to give each grid cell a unique feature code (e.g. a NUTS3 code, a Biogeographical region code, etc.).

Considering that some thematic layers have a higher resolution than 1 km^2 (e.g. Corine Land Cover is available at 100 m^2 resolution), the combination of such information is carried out at 100 m^2. In this way, it is possible to store, for instance, the different land cover classes and their surfaces for each grid cell. This means it is also feasible in principle to run account calculations at the 100 m^2 grid level. The grid cell index (unique identifier for each grid cell) might appear repeated in the resulting output table, as many times as different land cover classes exist within the square kilometre. Geographic dimensions will have their code repeated as well:

Index	NUTS99	NUTS03	NUTS06	NUTS10	FUA	LUZ04	LUZ12	MUA	UMZ00	CLC90	CLC00	CLC06	HA
26421951	1178	1202	1004	1141	745	267	535	1013	117593	111	111	111	58
26421951	1178	1202	1004	1141	745	267	535	1013	117593	112	112	112	42

UNIQUE COMBINATION OF UNITS

26421951-1178-1202-1004-1141-745-267-535-1013-117593-**111-111-111**
26421951-1178-1202-1004-1141-745-267-535-1013-117593-**112-112-112**

Figure 4-2 Example of unique combination of units within a grid cell

4.2 The accounting infrastructure

The EEA IDP project basically addresses 3 working areas:

1) **Organise knowledge - spatial data management:** This module is working on spatial data management. Tasks identify, describe and integrate key spatial datasets into EEA's Spatial Data Infrastructure (SDI).
   - Spatial data QA/QC and harmonization

- Spatial data registration in EEA's Spatial Data Infrastructure
- Linking SDI metadata to other EEA systems

2) **Inventory of knowledge - semantic inventory of spatial data sets** simplifies the complexity around geo-spatial data. The complexity is caused by numerous working areas and analytical expertise. The inventory module of the Integrated Data Platform therefore develops a contextual framework, by discovering, organizing and structuring semantic information about our geo-spatial data. This becomes a contextual inventory, summarizing the technical, thematic and contextual information of EEA's spatial datasets, which supports the needs of the analytical community. Three contextual inventories are developed:

- Interactive contextual data inventory
- Interactive data linkages
- Interactive web map platform

3) **Integrated analysis using organised knowledge:** Solutions in this working area directly enable integrated assessments by a system infrastructure combining geo-spatial and tabular datasets from a wide range of data sources and properties. Working area are:

- Data cubes
- Interactive data viewers
- Integrated modelling

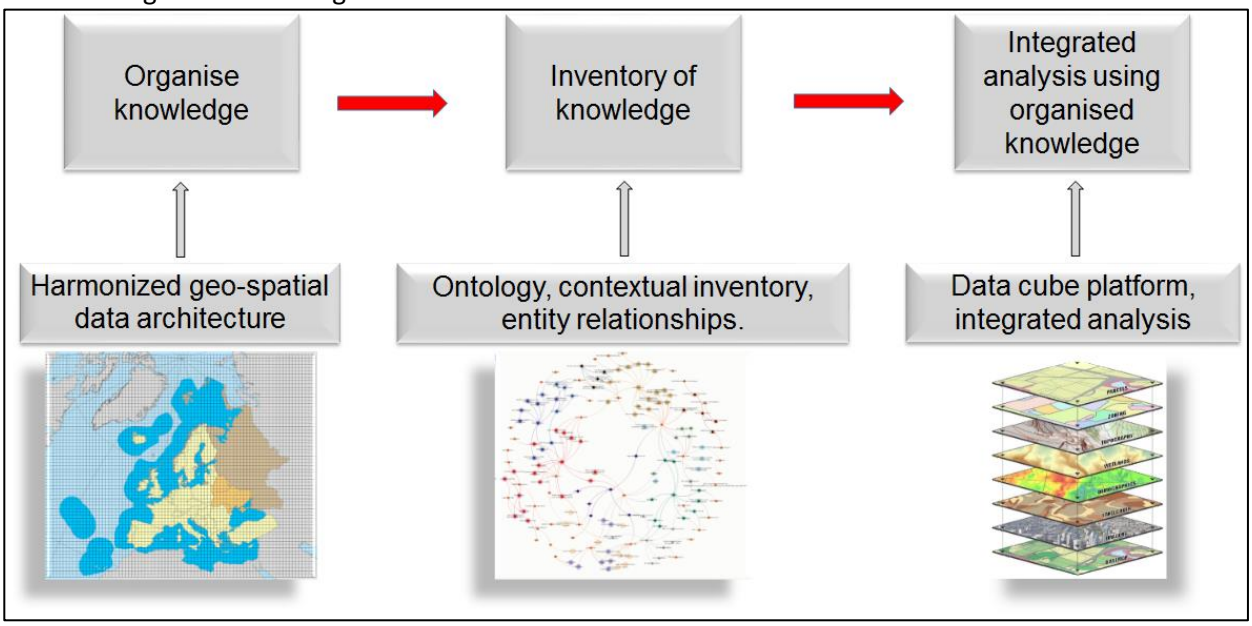


Figure 4--2 The three working areas of the EEA IDP project.

4.2.1 Spatial data harmonization

All EEAs accounting datasets must be harmonized and managed correctly so that they have the best possible quality. A spatial data delivery workflow was designed with Quality Assurance (QA) and Quality Control (QC) criteria for spatial datasets to be harmonized. Although these criteria are meant for spatial datasets, there are other types of information, which are closely related to spatial datasets. Map templates, draft maps, tabular data and the delivery of graphs related to spatial datasets are therefore also addressed. Compulsory deliveries which must accompany spatial datasets are 1) metadata, 2) web map services, 3) layer (*.lyr) files, draft maps and map templates if intended for publications.

4.2.2 *Spatial data registration in EEA's Spatial Data Infrastructure*

Without a structured inventory any work with data too often requires asking around for relevant datasets hoping that someone can point us to the right direction. Once a data set is found one may have to guess how to interpret it, whether it is right for the analysis. Clear and reliable documentation is required to know that the data is accurate, correct and that it does not contain errors. A structured and centralised system for documenting and searching data sets is needed to ensure that identification and use of data sets for assessment purposes can be done in an efficient manner.

All EEA spatial datasets are registered in EEA`s Spatial Data Infrastructure including a link to the corresponding Discomap web map services[15]. The data stored in the EEA`s SDI[16] are searchable through the SDI catalogue, accessible via:

- https://sdi.eea.europa.eu/

The website also contains a metadata editor to draft metadata, compliant with EEA metadata profile. The SDI wiki, which is also hosted on the website provides user manuals and details on the metadata profile.

The datasets, once validated, are physically stored in the SDI file system. Public datasets are available to any user without need to log in. Restricted datasets are only accessible with an Eionet log-in (EEA staff, European Topic Centres and other Eionet partners). The actual metadata (for public and restricted datasets) are publicly available.

EEA has a thematic node in its SDI on Environmental Analytical Reference Layers (EARL)[17], which are harmonized and QA/QCd and can be used for environmental accounting.

4.2.3 *Interlinking IT systems - Contextual Data Inventory*

Organised and harmonised storage of spatial datasets and their metadata is indispensable for a data architecture, which is to enable a transparent and repeatable accounting of our natural capital. However, these spatial data specifications are difficult to retrieve for thematic experts because they are not organized according to the needs of analytical objectives. In some cases, the information is encrypted in a technical language that that is not easily understandable for non-IT-experts. For a comprehensive information system, SDI specifications (e.g. spatial resolution, data format) should be enhanced by thematic and contextual information (e.g. DPSIR[18] elements, policy objective, topics). These semantics need to be brought together in a Contextual Data Inventory (CDI). Therefore, SDI specifications are linked to EEA`s Semantic Data Service (SDS) so that technical information of spatial datasets can be harvested in a way which targets specific user groups.

This information is stored in several distinct systems, such as the SDI, the EEA Website CMS (Content Management System), the Semantic Data Service and the server for web map services. These are brought together in EEA`s Contextual Data Inventory:

- Explore the ***Interactive Contextual Data Inventory*** on the Geospatial Environmental Accounting portal (see under Inventory/Contextual data inventory).

(15) https://discomap.eea.europa.eu/Index/
(16) http://sdi.eea.europa.eu/
(17) https://sdi.eea.europa.eu/catalogue/srv/eng/catalog.search#/search?any=idp_*&facet.q=status%2Fnotobsolete&resultType=details&sortBy=relevance
(18) Elements of the DPSIR framework are: Drivers, Pressures, State, Impact and Response. See https://www.eea.europa.eu/publications/92-9167-059-6-sum/page002.html

Populating the inventory is generated at regular time intervals (once a day): once the datasets are registered in the SDI and other information are entered in the CMS the information are automatically extracted from different systems.

4.2.4 Interactive data linkages

The geospatial data inventory is supported by interactive entity relation diagrams in order to increase the transparency and accessibility of the contained information.
In such a visual analytics tool, connections are established on demand, following the users' interest, in order to facilitate the efficient identification of similarities, differences, gaps and complex relationships between datasets. Much of the interdisciplinary information is hidden in second or third order relationships; visual analytics will facilitate the design of integrated spatial data assessments by unlocking knowledge from various domains and actors.

Although these entity relationship diagrams are centred on geo-spatial data, the underlying database links spatial datasets across different domains to numerous other entities, such as EEA indicators, projects, deliverables, models, products, publications etc. Therefore, this inventory may also become an effective planning tool and can be used for communication to a non-technical audience and policy makers.

- Explore ***data linkages*** on the Geospatial Environmental Accounting portal (see under Inventory/Linked data).

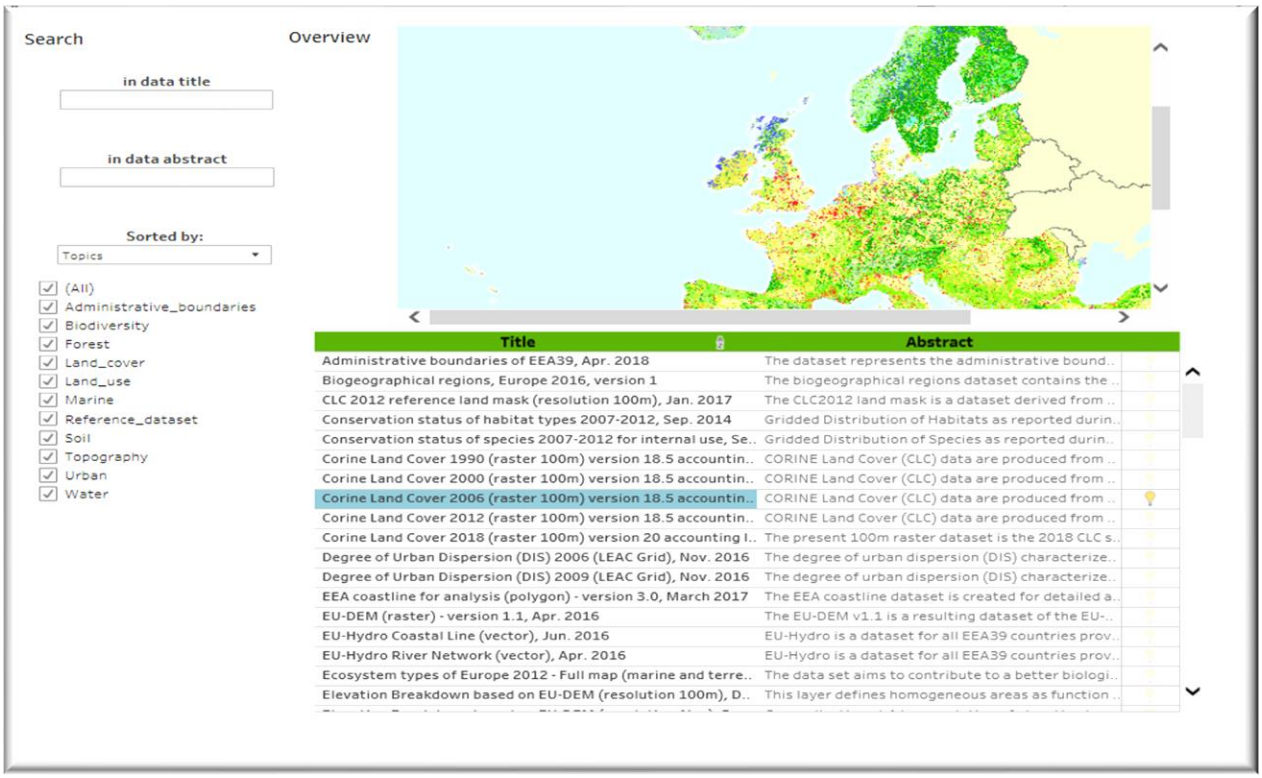


Figure 4--3 Screen shot from the Interactive Contextual Data Inventory

4.2.5 Interactive web map viewer

The Integrated Data Platform also visualizes spatial datasets by producing web map services and visualizing them in web map viewers. Web map services are protocols for serving georeferenced map images, which a map server generates using data from a GIS database. Web map viewers enable spatial overlays so that

the datasets can be interactively explored also by project managers without GIS expertise or without immediate access to a GIS software. Web map services are produced in ArcGIS desktop and visualized in ArcGIS Online. Once a web map service is quality controlled the services are registered in the SDI and read in the IDP Web Map Viewer through the Contextual Data Inventory application.

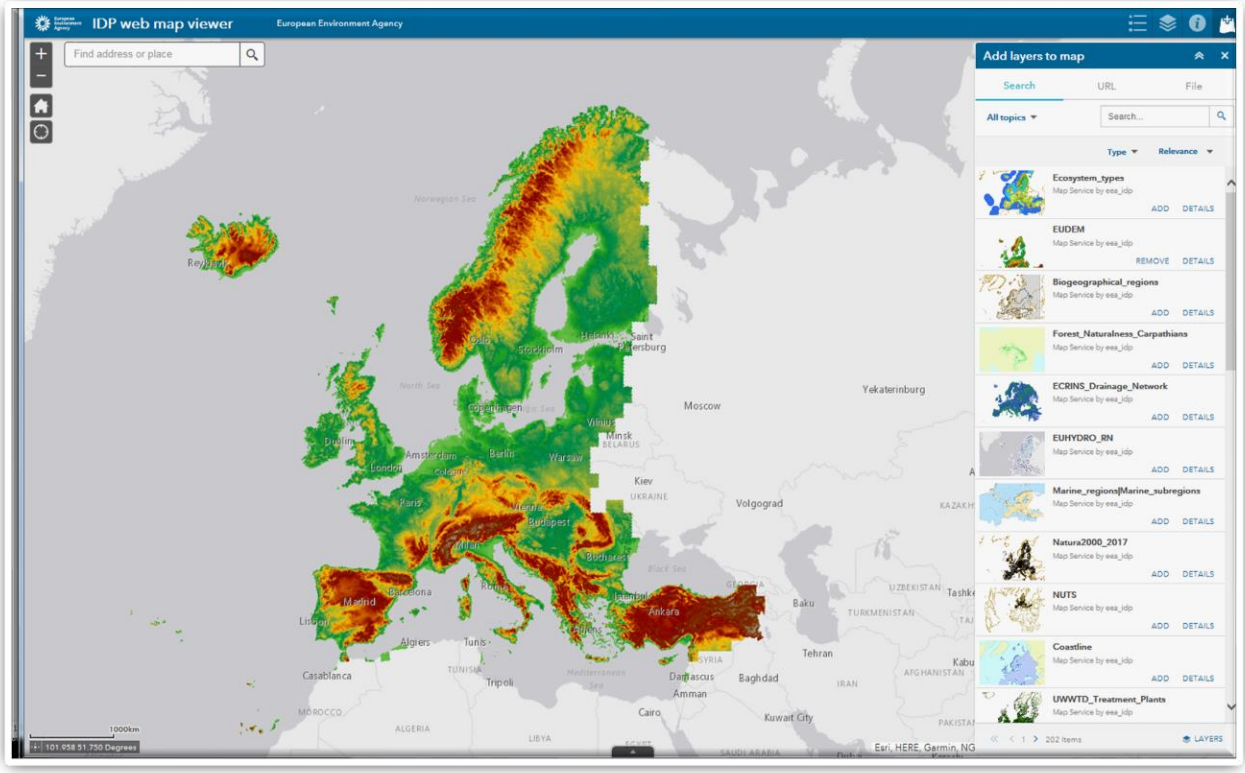


Figure 4--4 Screen shot from the Geospatial Environmental Accounting Portal

- Explore the ***map viewer*** on the Geospatial Environmental Accounting portal (see under Inventory/Linked data).

The web application offers three main functions to the user for data exploration:

1) Search for a web map service: the search uses 1) keywords (i.e. tags such as land use), or 2) topic names (such as biodiversity). The keywords are also searched in the abstract of the related spatial dataset, which is harvested from the SDI. Hence, all datasets can be found which have e.g. Corine Land Cover in their abstract.
2) The user is able to visualise and explore the services identified by the search function. Furthermore, the selected web map can be overlaid for further exploration of commonalities between spatial datasets.
3) Once the wished services are found and explored by overlays and zoom functions, the user can find all relevant semantic information of the spatial datasets when activating the info button. This semantic information are combinations of technical information coming from the SDI and other semantics harvested from the content management system.

4.2.6 Data cubes

In the past, the OLAP database (OLAP Cube) was used to organise and query huge volumes of geospatial data. OLAP stands for Online Analytical Processing; it is a computer-based technique to answer multi-dimensional analytical queries. OLAP tools enable users to analyse multidimensional data interactively from multiple perspectives. It experienced a strong growth in the late 90s, but it had been mainly applied to business data in the search for business intelligence.

The former OLAP database has been replaced by EEA`s own data cube technique, the Joint Environmental Data Infrastructure (JEDI). The JEDI system uses cloud infrastructure to integrate diverse data types in near real time. JEDI is component based in order to accommodate flexibility and change, while new user requirements are shaped over time. JEDI prepares tabular data cubes for accounting and serves these data cubes to the Business Intelligence software Tableau. The database is a *.csv file and hence can be opened with other software than the default choice of Tableau. Year to year changes or area statistics of land surface processes can then be calculated and results plotted in a user friendly, attractive and interactive way.

The system architecture of JEDI is rather complex using various software: Microsoft .NET for IIS (website), Microsoft SQL (DBMS), FME Server and Microsoft Azure (data processing) and Microsoft SQL + Tableau (output) (Figure 4--5). JEDI can be accessed at http://jedi.discomap.eea.europa.eu for users with EEA's Common Workspace credentials.

JEDI reads spatial datasets into a regular grid (see section 4.2) where every cell has a unique identifier. These cells become the geo-reference identifier for every other spatial dataset integrated in JEDI. Through this common identifier JEDI can relate and calculate areas based on the same cell identifier. After reading the geo-spatial layers, JEDI converts them into a tabular format, i.e. dimension. All, or any user selected dimensions, can be then aggregated within user defined spatial units. These aggregated dimensions are then added into one database (a data cube) which can be directly accessed by a data visualisation software environment, called Tableau.

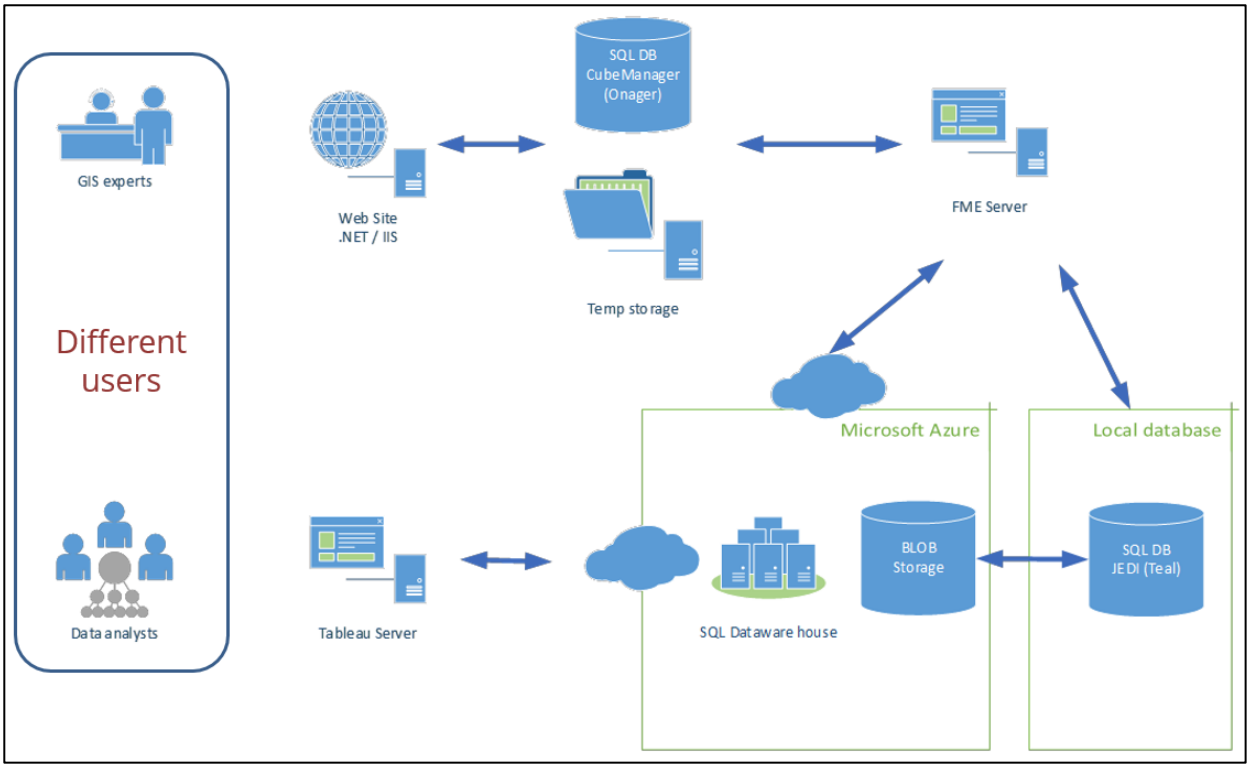


Figure 4--5 JEDI system architecture

JEDI dimensions, look up tables and cubes

The main elements in JEDI are dimensions, look up tables (LUT) and cubes:

- Dimension: a spatial dataset distributed in a grid and ready to become part of a cube.
- Look up table: table aimed at enriching the attributes of a dimension.

- Cube: multidimensional database built from several dimensions and look up tables and based on a grid.

There are three potential **dimension** sources:
- ESRI Shapefile (vector)
- GeoTIFF (raster)
- External dimension file (CSV)

Dimensions can be processed at 100x100m or 1x1km grid resolution. **Look up tables** add additional information to the dimensions in an efficient way. They can be Excel or .csv files. A LUT can be linked to one or many dimensions, by any of the dimension fields.

JEDI **cubes** are created by selecting a set of dimensions and choosing which fields from these dimensions or the related LUT should be seen in the output database. The cubes can be created at 100x100m, 1x1km or 10x10km grid resolution.

When a cube is ready a Tableau *.tds file is created. This extension stands for Tableau data source file. They do not contain any data, but a link to the data source, in this case the SQL database of the cube. When opened from JEDI, Tableau will show a project connected to the cube, and the different dimensions and measures will be available for querying and producing charts and/or maps.

JEDI LEAC Cube

JEDI can calculate and store several cubes, including different sets of dimensions. As for the land accounting, a so-called Land and Ecosystem Accounting (LEAC) 2018 cube (http://jedi.discomap.eea.europa.eu/Cube/Show/22) has been created. That Cube contains the following dimensions:

- Administrative boundaries for EEA-39
- Biogeographical regions 2016
- Coastal zones
- CLC accounting layers 2000, 2006, 2012, 2018
- LCFs 0006, 0012, 0018, 0612, 0618, 1218.

These dimensions can be flexibly complemented with any other thematic or stratification layers thereby enriching the accounting information to be deducted from the data cube. This cube is the basis for the LEAC viewer, both the basic and advanced versions, and it is used also for the analysis of land take (land take viewer).

5 Tools for land and ecosystem accounts and assessments

This chapter describes the accounting tools and web viewers that EEA has developed. These are mainly produced as interactive dashboards, so that interested users can build their own accounts or extract statistics of interest. The growing number of accounting dashboards are also presented on the **Geospatial Environmental Accounting portal**, under the section ***Explore Europe in Numbers***.

5.1 Land cover and change statistics: interactive accounting dashboards

An accounting cube may be directly exploited in the Business Intelligence software Tableau, by means of the creation of queries that offer tabular, chart or map results. The different dashboards that one can create in Tableau can be published on Tableau Server and can be shared as a direct URL or embedded in any website. The Land cover and change 2000-2018 interactive dashboard is published on EEA`s website. **https://www.eea.europa.eu/data-and-maps/dashboards/land-cover-and-change-statistics**

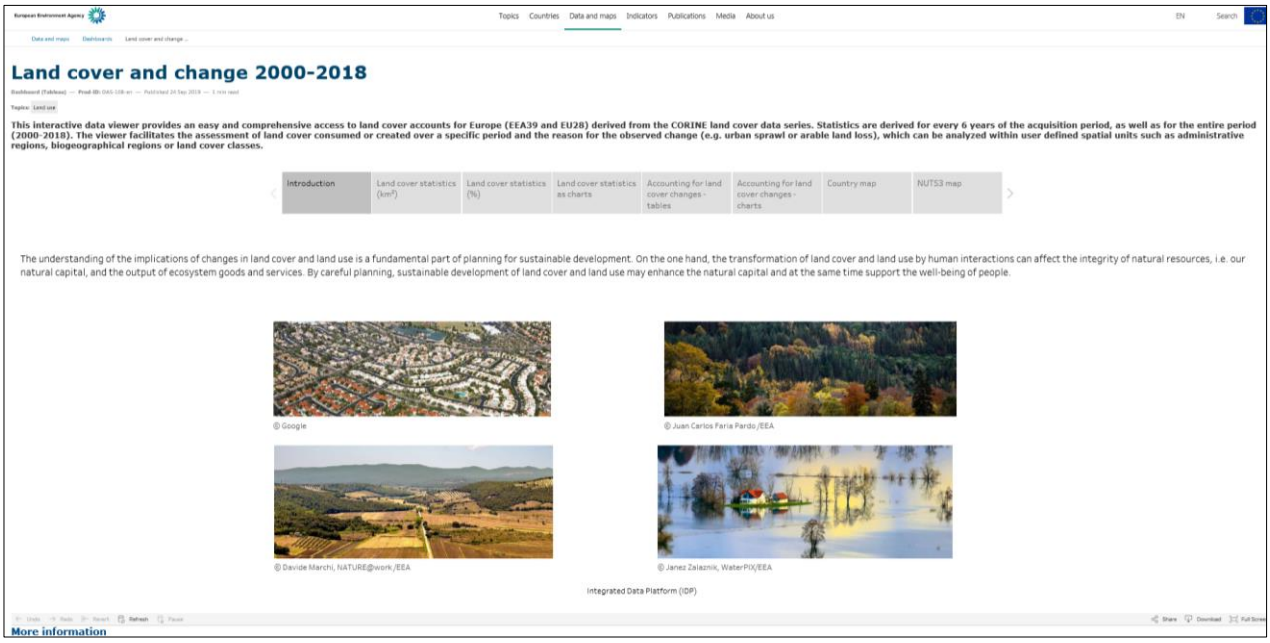


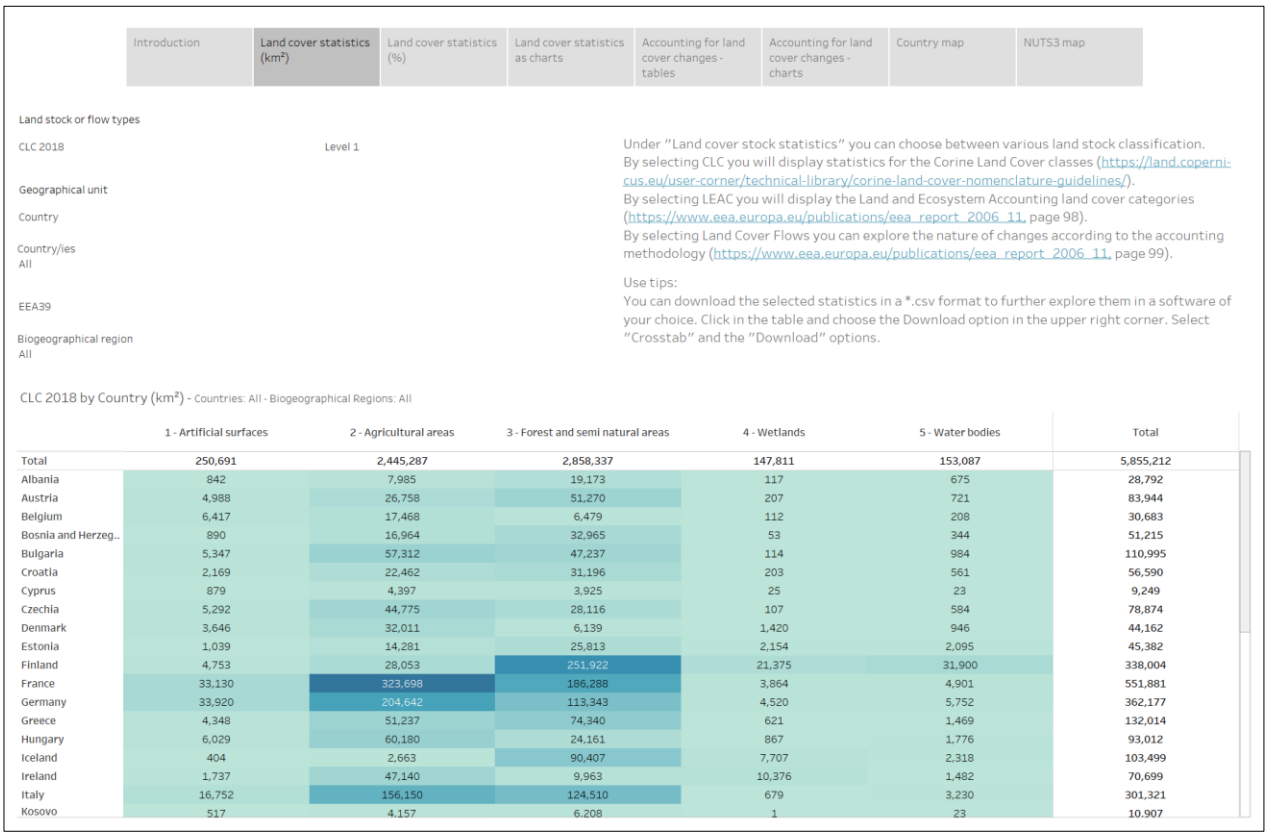
Figure 5--1 Land cover and change statistics, embedded in EEA's website

5.2 Deriving accounting statistics for land cover stocks

The "Land cover statistics (km^2)" and "Land cover statistics (%)" tabs in the interactive dashboard allow the accounting for land cover stocks in Europe, with a breakdown for countries and with various selection choices. One can select the CLC, LEAC and MAES categories on various hierarchical levels. By changing these settings, the table changes accordingly displaying the chosen statistics.

One might be interested in land cover statistics in certain NUTS3 classes or biogeographical regions, which can be chosen under the "Select geographical unit" filter. The default geographical unit selection is countries and the table below shows accordingly the land cover stock break-down per country. The column totals of the table sum the country specific break down of the land cover categories and hence display the European totals. Selecting EEA-39 or EU-28 allows the user to explore the total area of land cover categories within these geographic areas at once.

The “Land cover statistics as charts” tab in the interactive dashboard allows the exploration of land cover stock statistics in chart format. This allows the direct comparison of countries in terms of their land cover characteristics as the chart is ordered in decreasing order of area extent of the various classes.



	1 - Artificial surfaces	2 - Agricultural areas	3 - Forest and semi natural areas	4 - Wetlands	5 - Water bodies	Total
Total	250,691	2,445,287	2,858,337	147,811	153,087	5,855,212
Albania	842	7,985	19,173	117	675	28,792
Austria	4,988	26,758	51,270	207	721	83,944
Belgium	6,417	17,468	6,479	112	208	30,683
Bosnia and Herzeg..	890	16,964	32,965	53	344	51,215
Bulgaria	5,347	57,312	47,237	114	984	110,995
Croatia	2,169	22,462	31,196	203	561	56,590
Cyprus	879	4,397	3,925	25	23	9,249
Czechia	5,292	44,775	28,116	107	584	78,874
Denmark	3,646	32,011	6,139	1,420	946	44,162
Estonia	1,039	14,281	25,813	2,154	2,095	45,382
Finland	4,753	28,053	251,922	21,375	31,900	338,004
France	33,130	323,698	186,288	3,864	4,901	551,881
Germany	33,920	204,642	113,343	4,520	5,752	362,177
Greece	4,348	51,237	74,340	621	1,469	132,014
Hungary	6,029	60,180	24,161	867	1,776	93,012
Iceland	404	2,663	90,407	7,707	2,318	103,499
Ireland	1,737	47,140	9,963	10,376	1,482	70,699
Italy	16,752	156,150	124,510	679	3,230	301,321
Kosovo	517	4,157	6,208	1	23	10,907

Figure 5--2 Interactive queries of land cover stock statistics in tabular formats

While selecting CLC or LEAC categories as “Land stock types” will display the absolute extent of land cover classes and hence larger countries will have more land cover, other land stock options allow the relative comparisons. Selecting e.g. “Land Cover Flows 2018” as land stock type allows the direct comparison of land use (or natural) changes of the land stock of all countries. As before, the NUTS regions or biogeographical regions may be queried instead of countries and EEA-39 or EU-28 country groups can be selected as well.

5.3 Deriving accounting statistics (consumption and formation) from LCFs.

General statistics on land cover stock or land cover change over time, by different reporting units, are one of the main purposes of accounting. Another important element is assessing the different land use processes that have occurred and analysing which classes have gained or lost area at the expense of other classes, i.e. land cover flows. In other words, what is interesting is analysing not only the quantitative figures of changes, but also the qualitative aspects (from which classes and/or to which classes a specific transition has occurred). The “Accounting for land cover changes – tables” and “Accounting for land cover changes – charts” tabs of the interactive dashboard provide such kind of assessments to users.

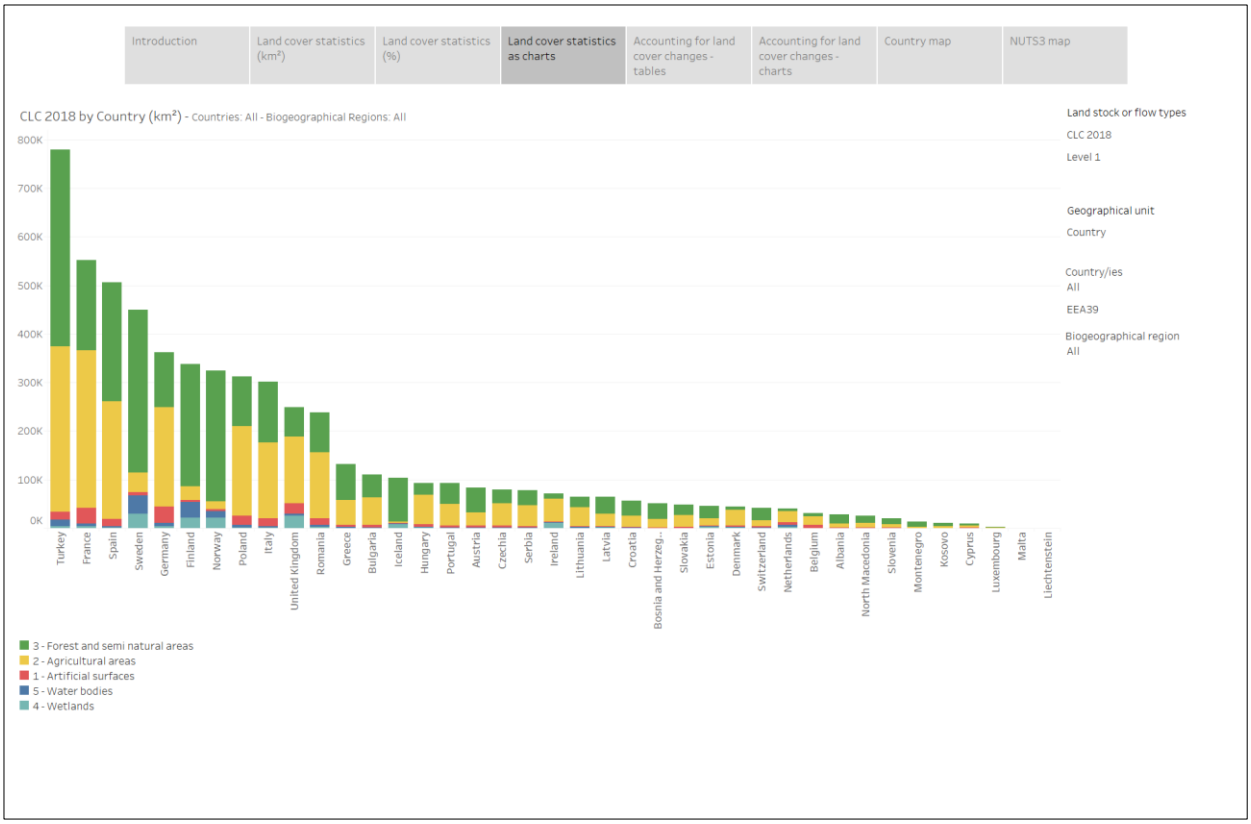


Figure 5--3 Interactive queries of land cover stock statistics in charts

Selecting level 1 Land Cover Flows in EEA-39 in the "Accounting for land cover changes – tables", displays, for example, that in the period 2000-2018, 24 388km^2 of arable land were transformed (Consumption) whereas 17 160km^2 of arable land were added to the existing stock. The difference of these values indicates that 7 228km^2 of arable land was lost. Furthermore, and importantly, the rows of the tables break down these changes to the various land cover flow categories. This way one can analyse the causes for losses and gains of different land cover types. With regards to arable land for example, the statistics indicate that major fraction of arable land loss (6 222km^2) was due to the sprawl of economic sites and infrastructures.

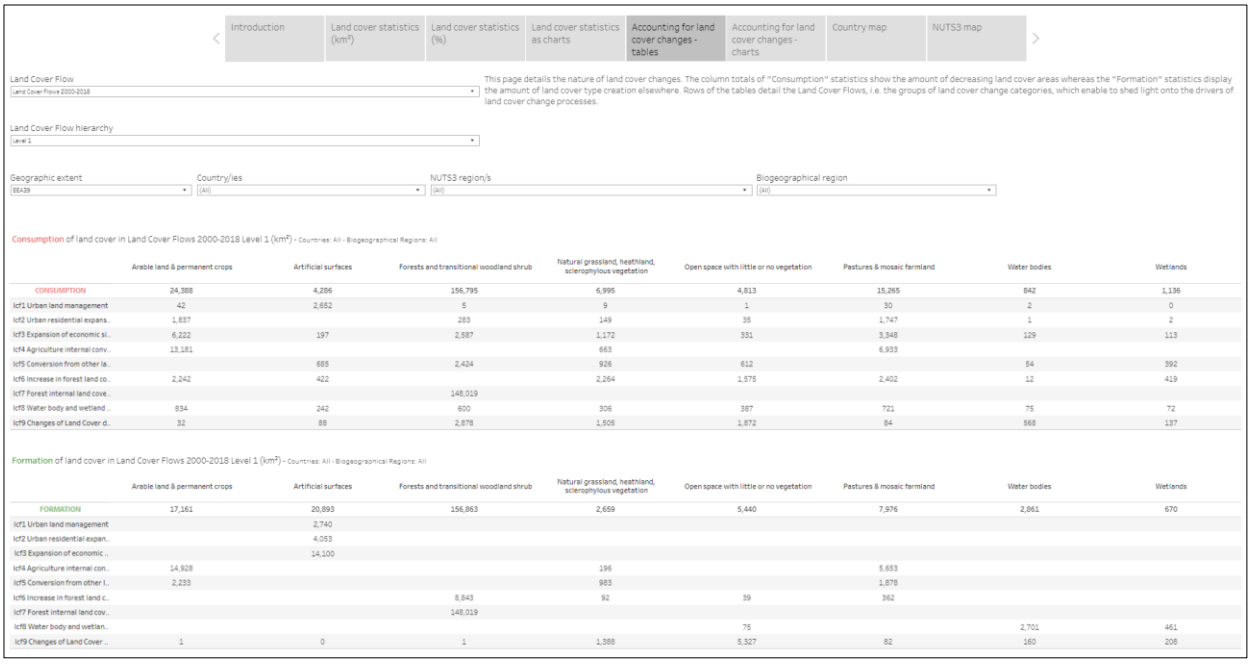


Figure 5--4 Interactive accounting of land cover stock changes in tables

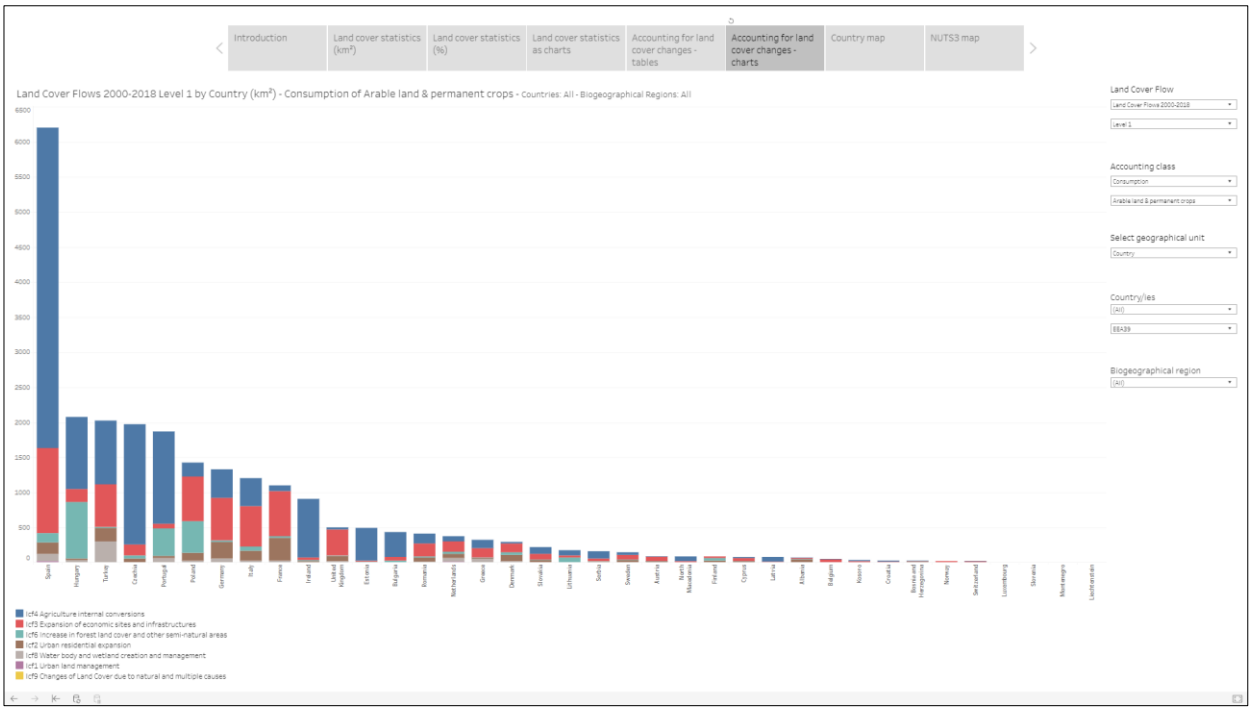


Figure 5--5 Interactive accounting of land cover changes in charts

The “Accounting for land cover changes – charts” tab adds advanced land accounting features to the interactive dashboard. Firstly, in this tab statistics are broken down to the countries, NUTS regions or biogeographic regions in charts and hence direct comparison is facilitated. By selecting the consumption or formation “accounting class” the user can explore gains and losses of land covers and by detailing these according to the various land cover flows the (land use) drivers of changes can be analysed. Furthermore, by selecting all or a combination of land cover classes all these changes may be analysed in certain conditions according to assessment needs.

5.4 Mapping land stock and land cover changes statistics

The interactive application for land cover accounting allows the mapping of stocks and changes, aggregated within NUTS3 and NUTS0 regions for the various periods. By selecting the observation year, the hierarchy of the classification and the land cover of interest, the application will map the query. For instance, in Figure 5--6arable land and permanent crops (level 1 classification hierarchy) for the year 2018 are mapped for the EEA-39 region (in % of the total area of the administrative unit). In case land cover flow is of interest, the user may select the land cover flows on a given hierarchy (thematic detail) for a given change period. Figure 5--7 shows the flow 'Increase in forest land and other semi-natural areas' (LCF6) for the period 2000-2018 for the EEA-39 region. The changes are shown in percentage of the NUTS3 regions for the purpose of comparability.

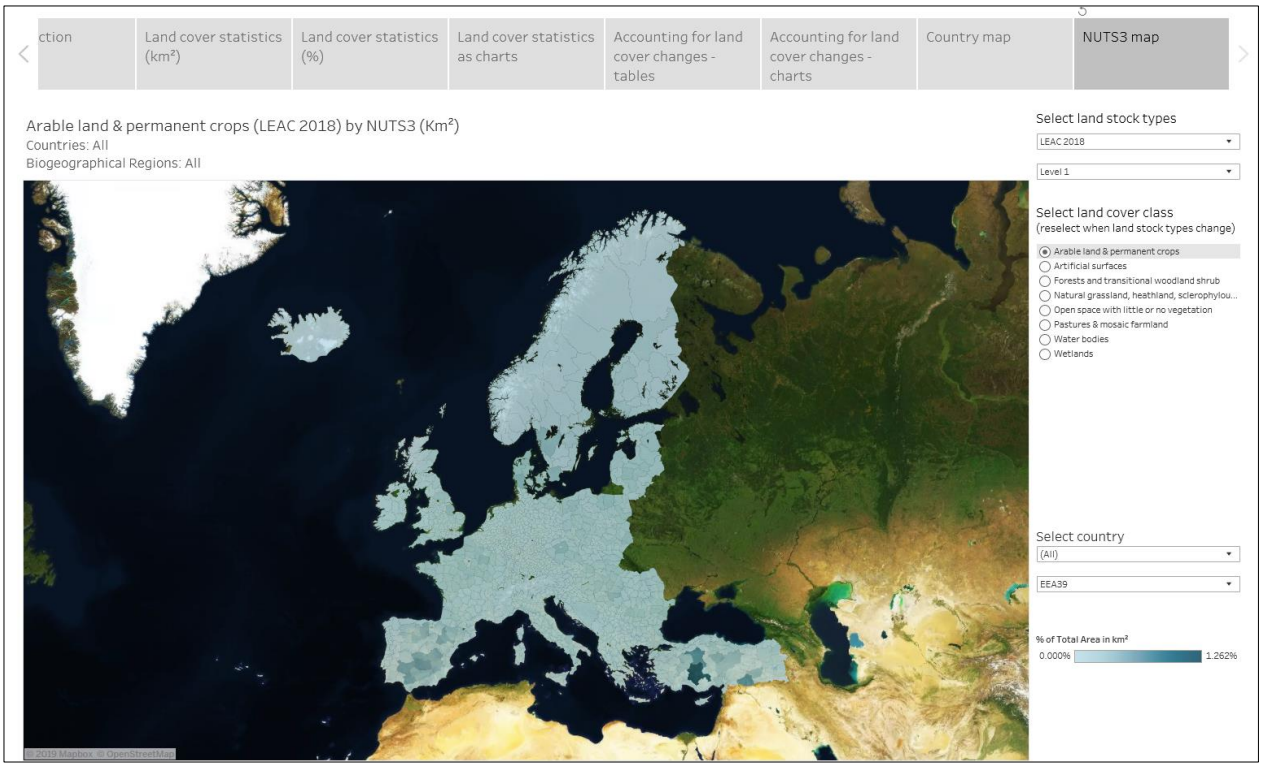


Figure 5--6 Interactive mapping of land cover stock in NUTS3 regions

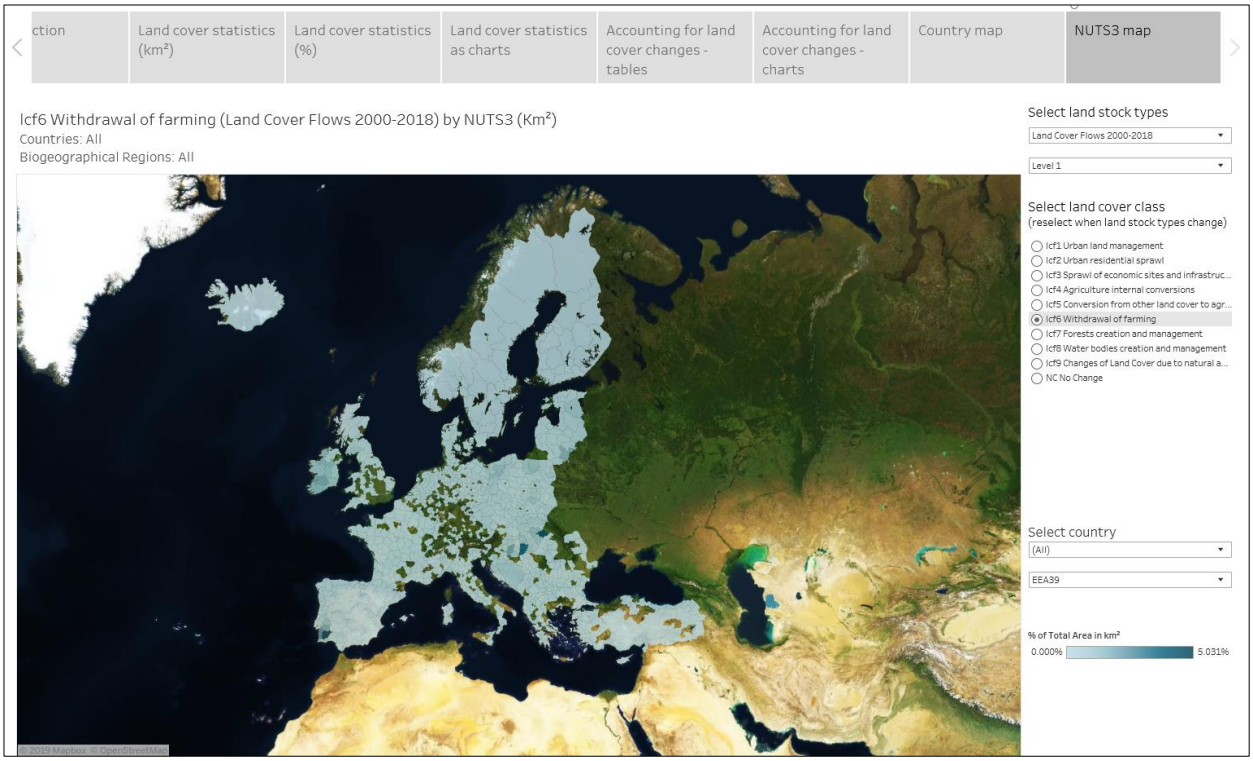


Figure 5--7 Interactive mapping of land cover flows in NUTS3 regions

6 Implementing land accounting

This chapter aims at bringing the rather specific technical and conceptual descriptions of the previous chapters into a more practical context. To do so, several use cases are presented that focus on important land cover change processes in Europe:

- Urban areas
- Changes in extent and composition of agricultural land
- Change in forest area and composition

The chapters below take a closer look at some of the processes related to the issues mentioned above with statistics, charts and maps derived from the land accounting database.

6.1 Urban areas and land take

Almost three quarter of the European population lives in cities (Dijkstra et al., 2016) with a tendency of this share to increase until 2050 (Kompil et al., 2015). At the same time, also artificial surfaces are expected to increase (Lavalle and Barbosa, 2015).

Land take is the process in which urban areas and sealed surfaces occupy agricultural, forest or other semi-natural and natural areas (EEA, 2019a). The EEA land take indicator (CSI 014, LSI 001) addresses the change in the area of agricultural, forest and other semi-natural land "taken" for urban and other artificial land development (hence the name "Land take"). Land take includes areas sealed by construction and urban infrastructure, as well as urban green areas and sport and leisure facilities. The main drivers of land take are grouped in processes resulting in the extension of:

- housing, services and recreation;
- industrial and commercial sites;
- transport networks and infrastructures;
- mines, quarries and waste dumpsites; and
- construction sites.

In some cases, artificial land is returned to other land categories (recultivation). The balance between taken and recultivated land is net land take — the concept behind the EU's 'no net land take' target. This non-binding commitment of the EU was stipulated in the Roadmap to a Resource-Efficient Europe and repeated in the 7th Environmental Action Programme.

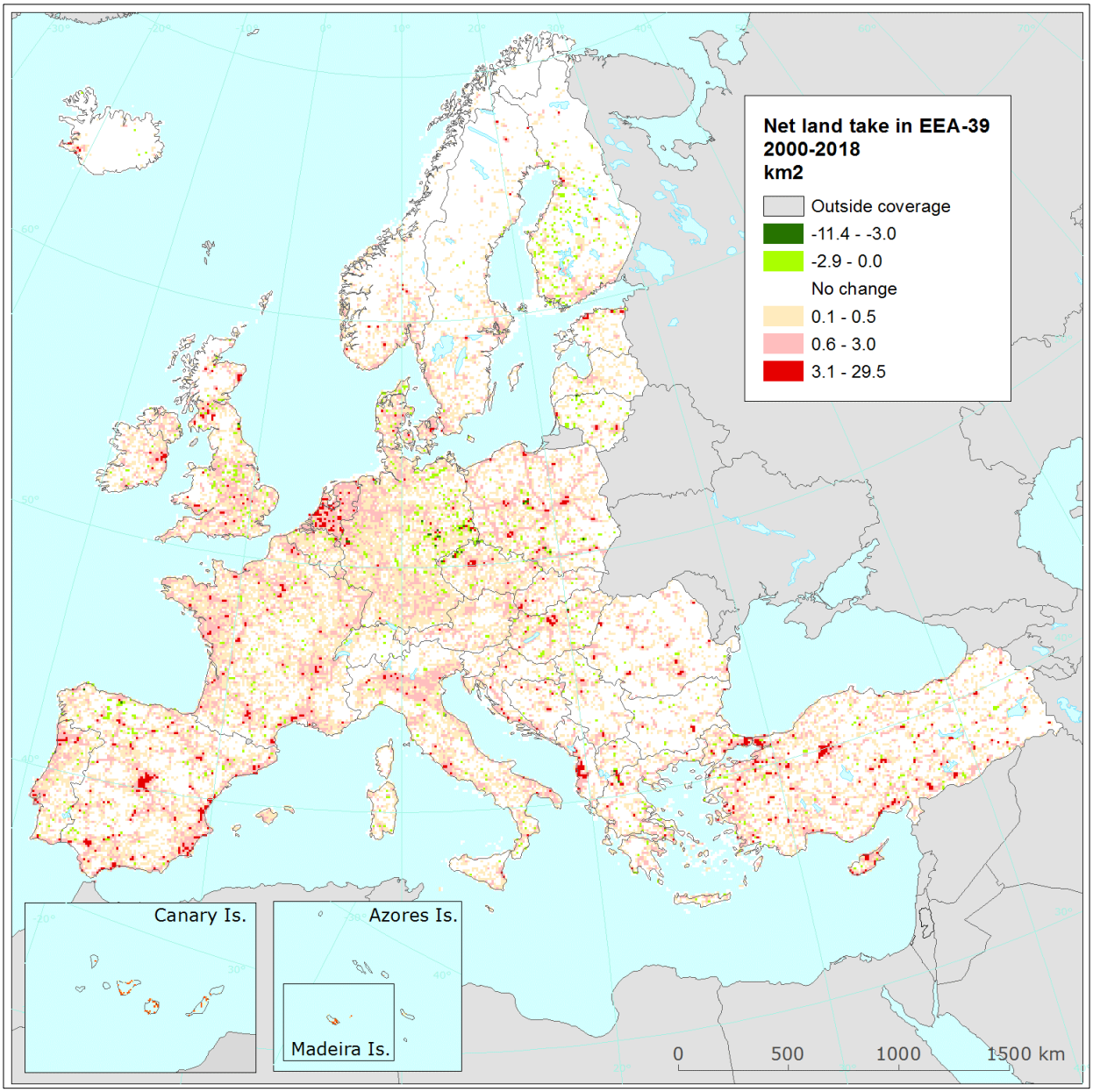


Figure 6--1 Spatial pattern of net land take in EEA-39 during the period 2000-2018

Recent data[19] shows that annual net land take (see[20]) in the EEA-39 decreased from 922 km²/year in the period 2000-2006 to 440 km²/year in the period 2012-2018. These values can be deducted from the interactive dashboards on land take accounting statistics accessible at https://www.eea.europa.eu/data-and-maps/indicators/land-take-3/assessment. Selecting the tab "Overview statistics" and choosing "Net land take" as "indicator type" for the EEA-39 extent, the column total for the period 2000-2006 gives 5530.26 km² net land take for the entire area. Broken down to yearly values, annual net land take was 922 km² for the period 2000-2006 (i.e. the total of 5530.26 km divided by 6).

During the entire period 2000-2018, land take concentrated around larger urban agglomerations (Figure 6--1). Accounting for the land cover types affected by land take during the period 2000-2018 shows, that 80 % of land take was at the expense of arable land and permanent crops and of pastures and mosaic farmlands. This can be derived from the tab "Land take processes - table" by selecting the period 2000-2018 and the EEA-39 geographic extent. Total land take was 14049 km² of which (i) 7098 km² land were taken from arable land and permanent crops (around 50 % of the total) and (ii) 3824 km² land from

(19) https://www.eea.europa.eu/data-and-maps/dashboards/land-take-statistics
(20) https://www.eea.europa.eu/data-and-maps/indicators/land-take-3/assessment

pastures and mosaics (almost 30 %). The top bar and the third bar from the bottom in the chart in Figure 6--2 also illustrate that land take affected these two land cover types the most (see the tab “Land take statistics – chart” in the dashboard, “observation period” 2000-2018, “LEAC code”, Chart type “Land cover lost” and “EEA-39”).

While in the beginning of the accounting period (i.e. between 2000 and 2006) the largest drivers of land take were construction activities and diffuse urban sprawl (tab “Land take statistics – chart”, “observation period” 2000-2006, “LEAC code”, Chart type “Land take drivers” and “EEA-39”), this changed towards “construction” and “industrial and commercial developments” in the following periods whereas urban sprawl did not play such an important role anymore between 2012 and 2018. Over the 18-year period from 2000 to 2018, industrial and commercial activities accounted for the largest share of land take processes in EU-28, ca. 3500 km² (Figure 6--3). Urban sprawl (around 3000 km²), the establishment of construction sites (around 2700 km²) and mining (ca. 2100 km²) were further drivers of land take in Europe.

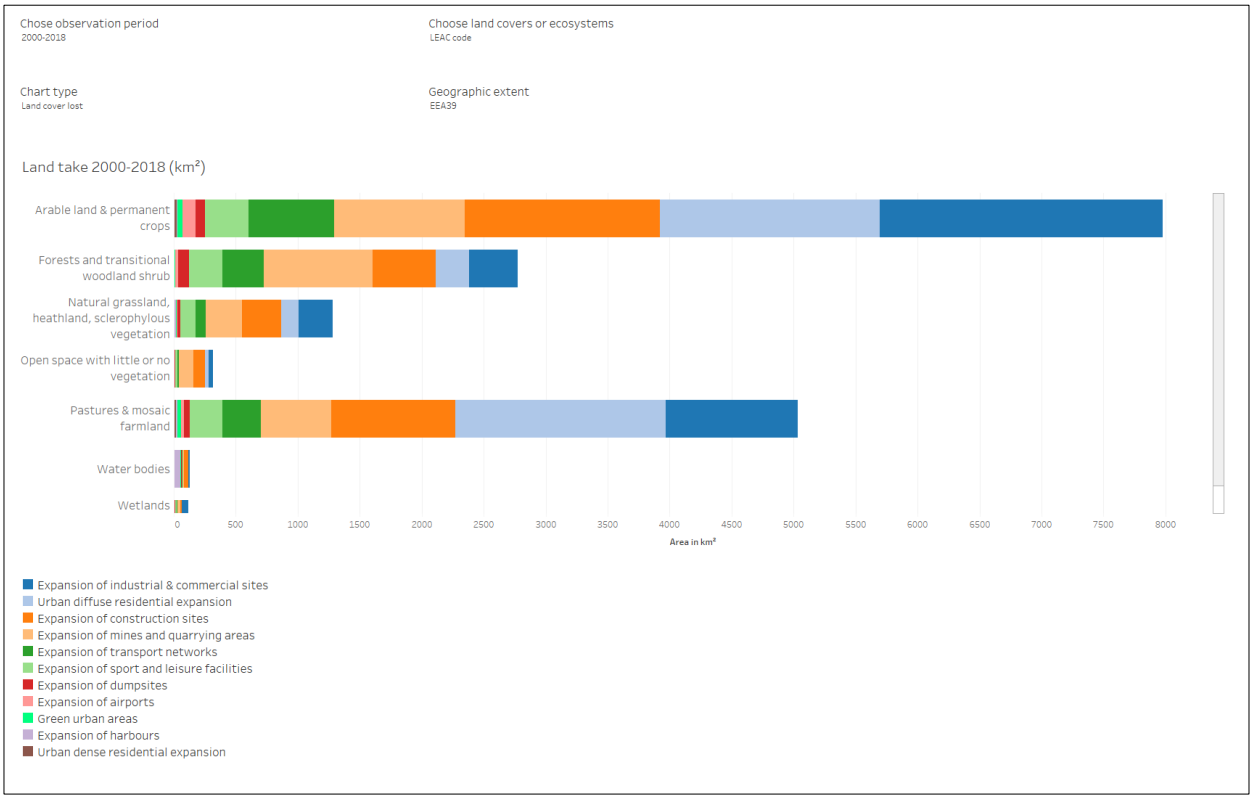


Figure 6--2 Loss of land cover classes due to land take broken down to land take processes. EEA-39, 2000-2018.

Source: https://www.eea.europa.eu/data-and-maps/dashboards/land-take-statistics

Taking recultivation measures between 2000 and 2018 into account, four main processes of reusing formerly developed land appear: water body creation, creation of semi-natural areas, agricultural development and forest creation (afforestation) (see Figure 6--4), the bars that extend towards the left of the y-axis). Taking recultivation measures between 2000 and 2018 into account, four main processes of reusing formerly developed land appear: water body creation, creation of semi-natural areas, agricultural development and forest creation (afforestation) (see Figure 6--4), the bars that extend towards the left of the y-axis). This chart can be retrieved in the same dashboard as before, opening the tab “Net land take statistics – chart” and selecting “2000-2018” as observation period and “Land take drivers” as chart type, using the "LEAC code” for the “EEA-39” extent.

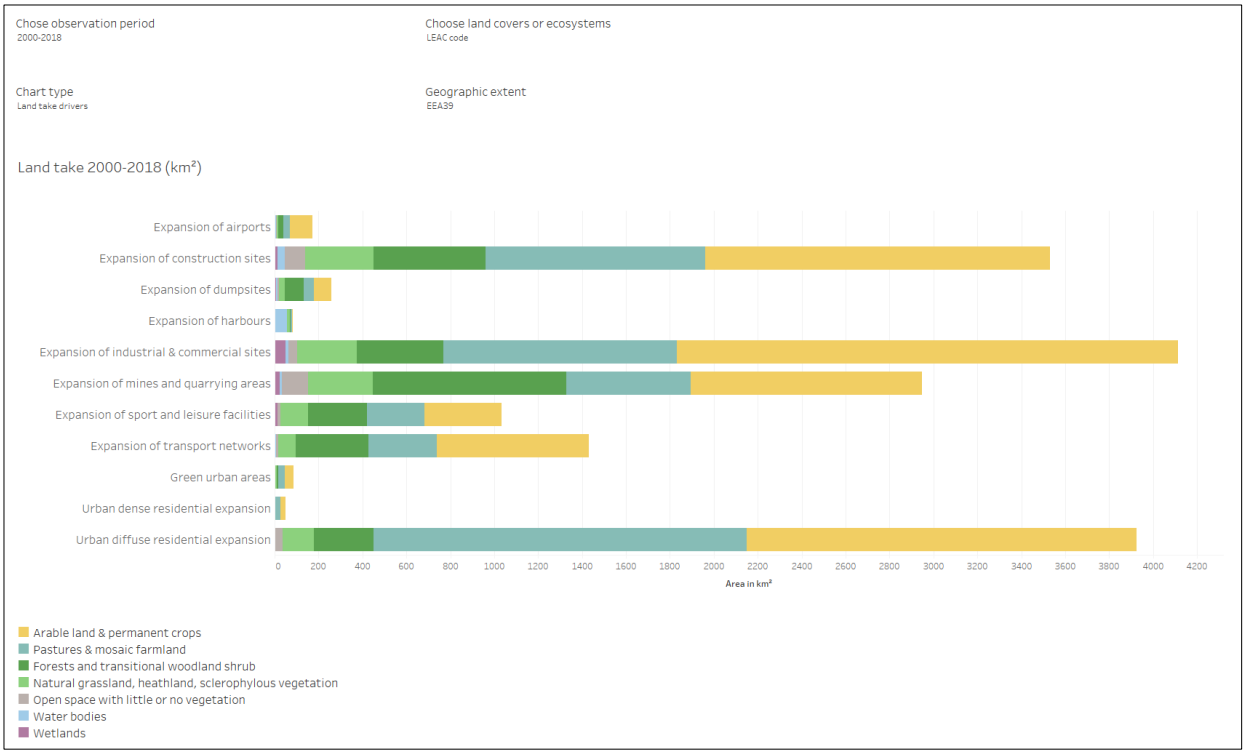


Figure 6--3 Major drivers of land take processes broken down to land cover classes. EEA-39, during the period 2000-2018

Source: https://www.eea.europa.eu/data-and-maps/dashboards/land-take-statistics

The interactive dashboard on "Land cover and change statistics 2000-2018"[21] allows to analyse in detail the Land Cover Flows (LCFs) responsible for the formation of artificial surfaces at national level. Opening the tab "Accounting for land cover changes – charts", the relevant values can be derived by selecting the desired LCF period (using LCF Level 2), then choosing "Formation" (i.e. gain in accounting terms) and "Artificial surfaces" under "Accounting class". Geographic unit is "Country", the extent "EEA-39". As demonstrated in Figure 6--55 to Figure 6--9, the expansion of construction sites (lcf37) together with the sprawl of industrial and commercial sites (lcf31) as well as diffuse urban development (lcf22) have the largest impact in most of the countries. Spain shows the highest levels of artificial area formation in the first two periods 2000-2006 and 2006-2012, while Turkey climbs the ranking in each of the periods up to be the country with the largest artificial surface formation between 2012 and 2018. In the same period, the formation of artificial surfaces declined substantially in Spain and is only one quarter of what it used to be in the previous periods.

(21) https://www.eea.europa.eu/data-and-maps/dashboards/land-cover-and-change-statistics

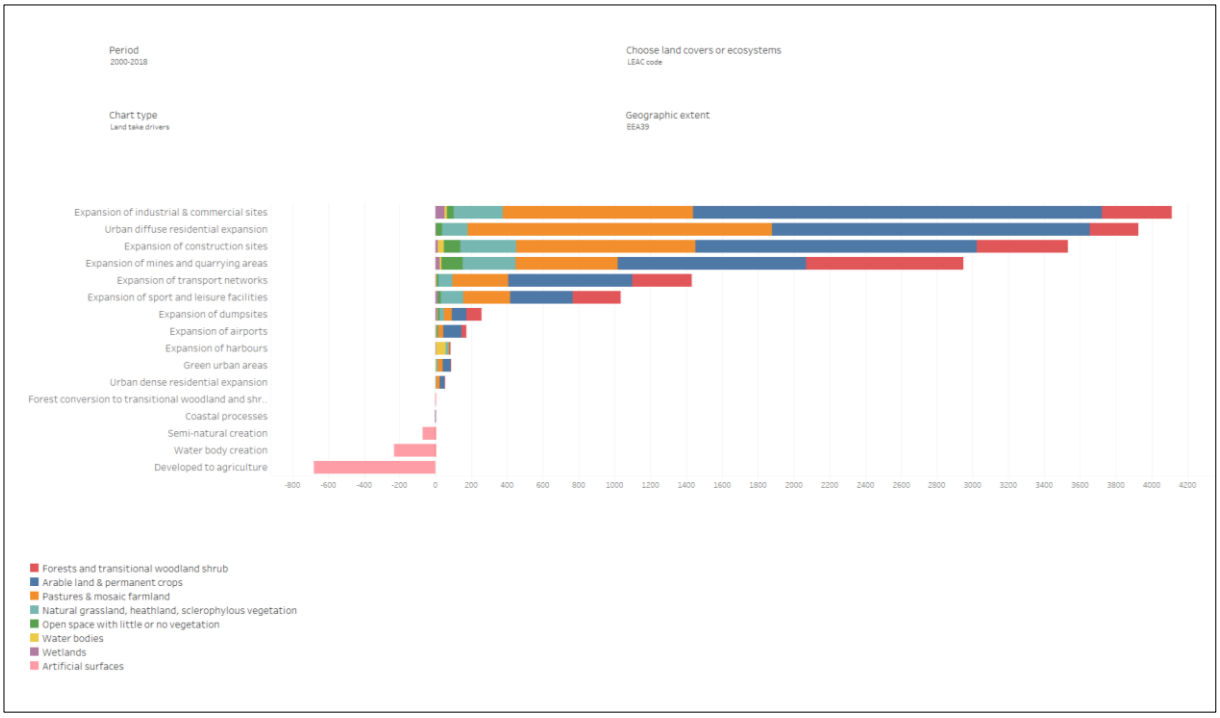


Figure 6--4 Major drivers of net land take processes broken down to land cover classes. EEA-39, during the period 2000-2018

Source: https://www.eea.europa.eu/data-and-maps/dashboards/land-take-statistics

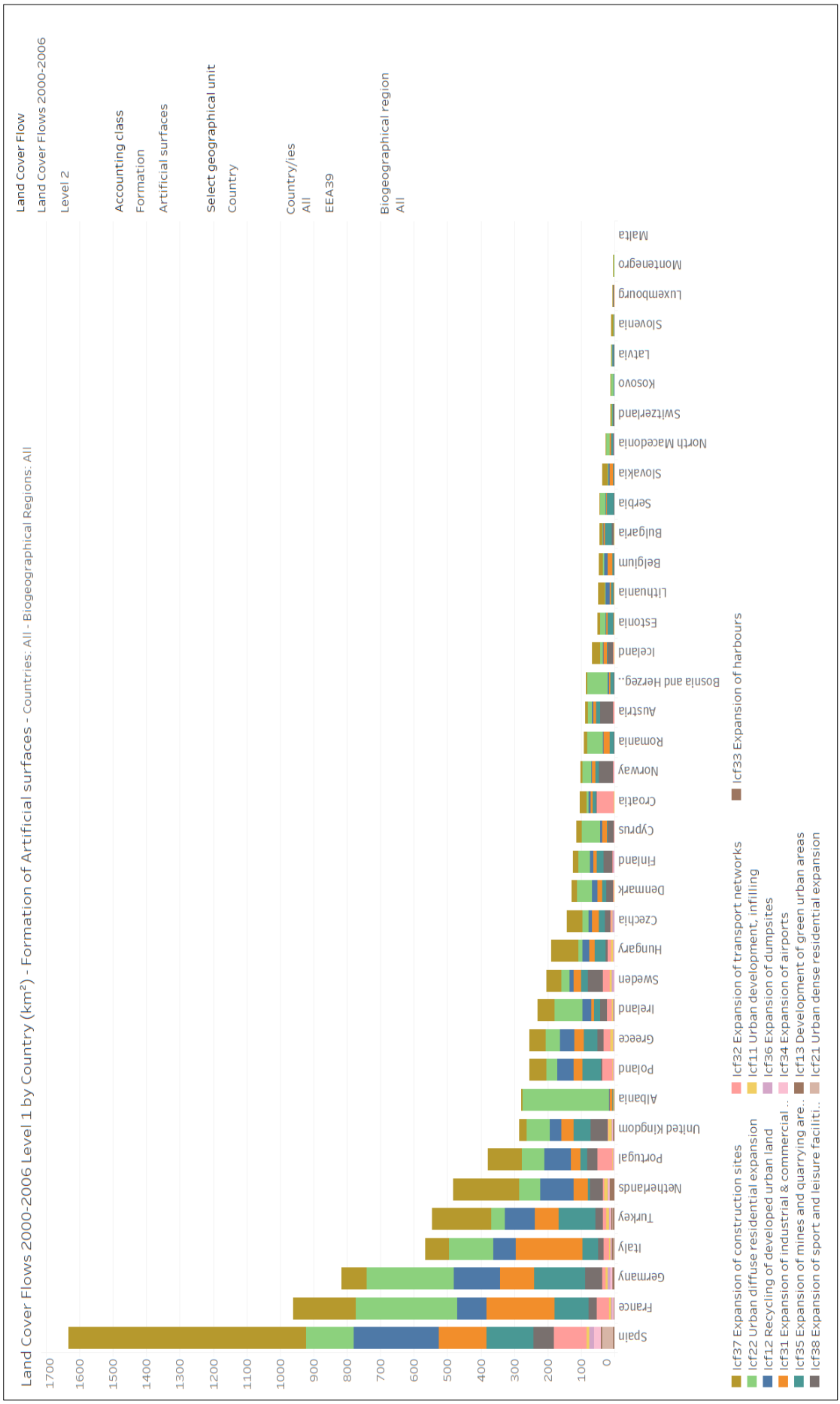


Figure 6--5 Proportion of LCFs responsible for artificial surface formation, by country, 2000-2006

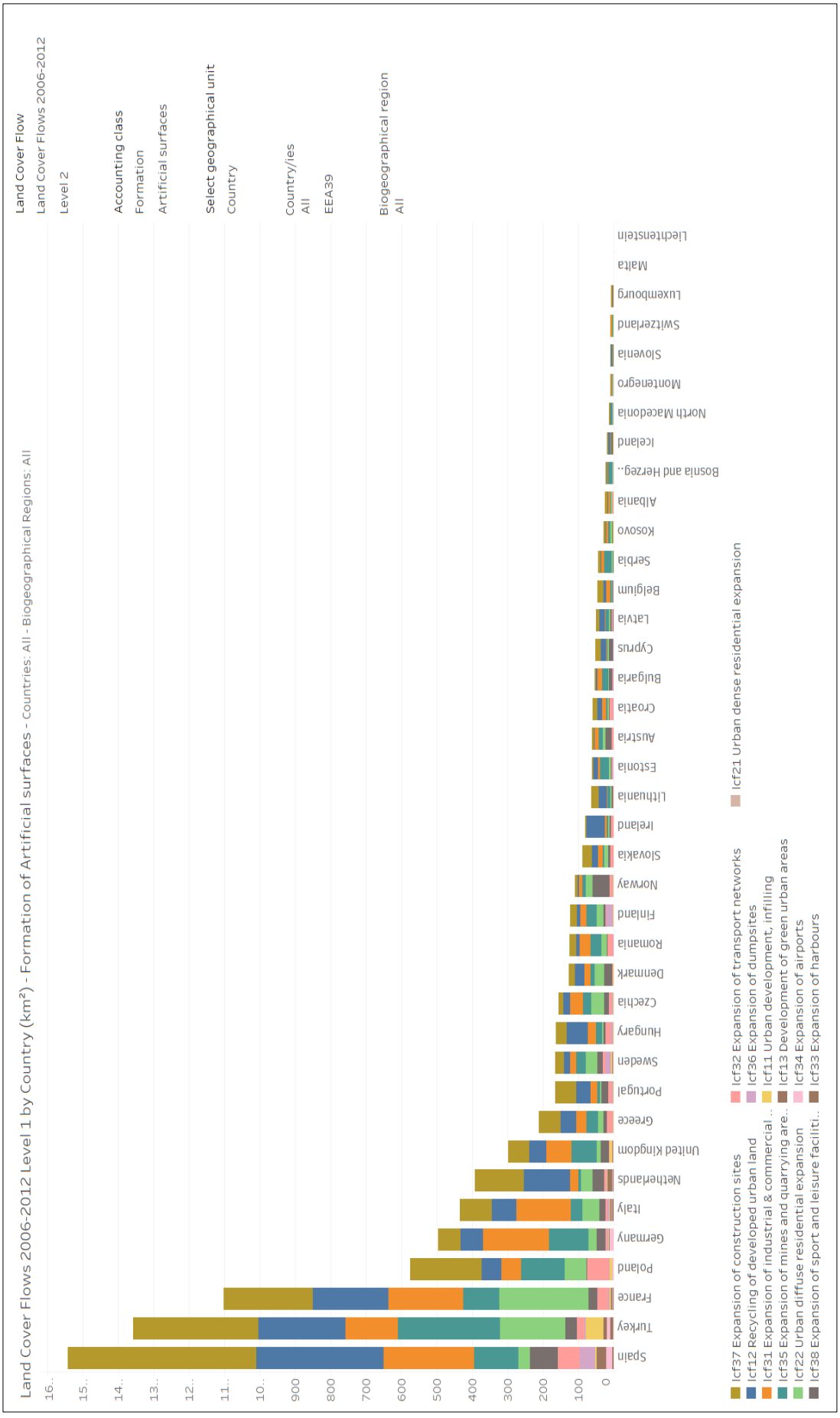


Figure 6--6 Proportion of LCFs responsible for artificial surface formation, by country, 2006-2012

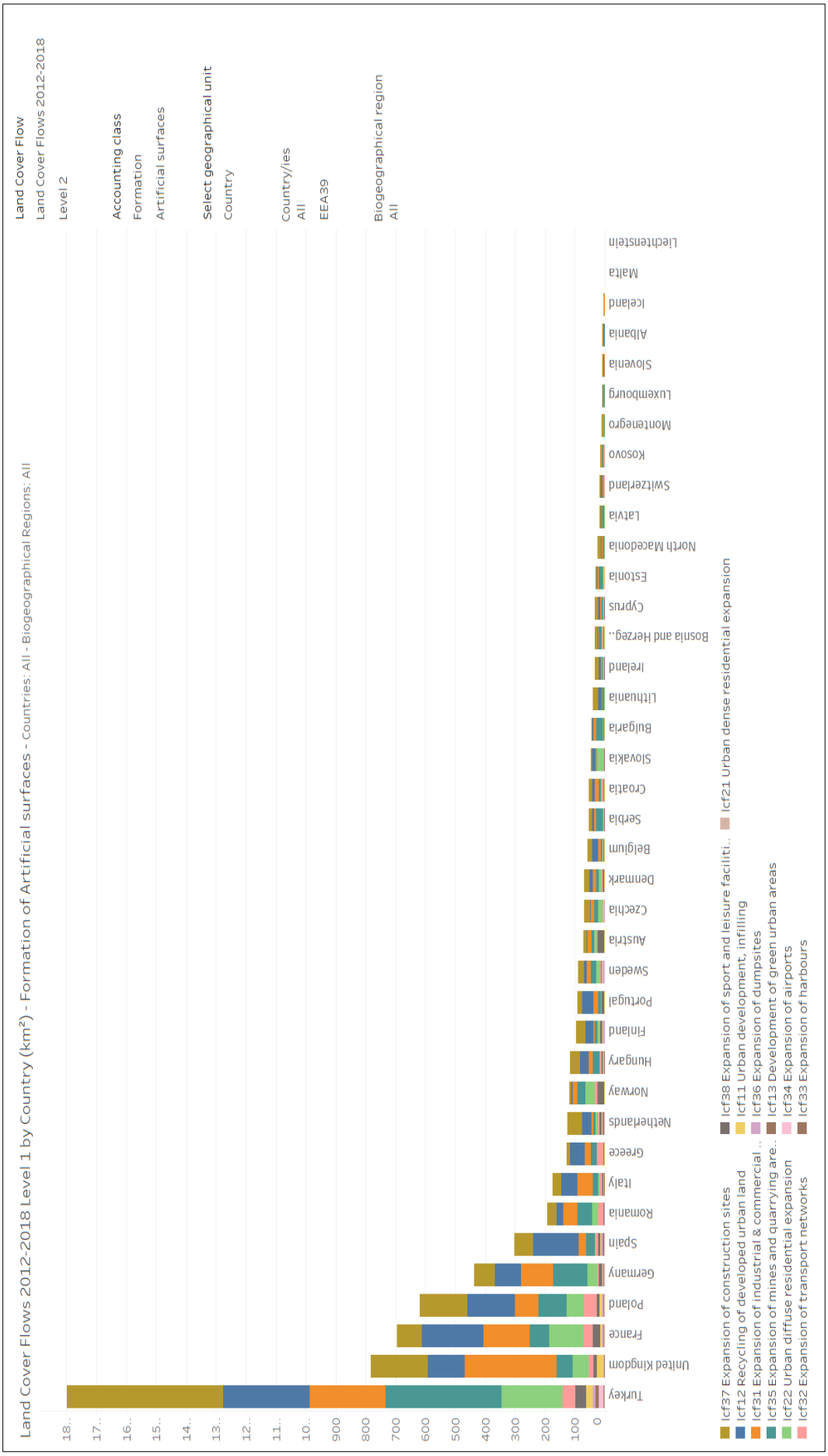


Figure 6--7 Proportion of LCFs responsible for artificial surface formation, by country, 2012-2018

6.2 Agricultural land

This section presents selected examples on how the land accounting system developed by EEA and ETC/ULS can be used to analyse trends in agricultural land cover and to some degree agricultural land use. It needs to be stated that the data presented on agricultural land area in this report are based on Corine land cover and thus not fully comparable to Utilised Agricultural Area (UAA), which is based on agricultural statistics. Nevertheless, they allow a very comprehensive tracking of trends in agricultural land area and of farming-related land cover trends that show the sources and losses of agricultural land area in great spatial detail.

The overall land area for agricultural production has decreased substantially between 2000 and 2018, leading to a reduction of ca 14532 km^2 in the EEA-39 in this period, a loss of ca 0.6% of the initial stock of farmland. However, while the consumption of agricultural land (considering both arable land/permanent crops and pastures/mosaics) had its peak in the period 2006-2012, it has declined by around 25% compared to the previous period between 2012 and 2018 (see Figure 6--8).

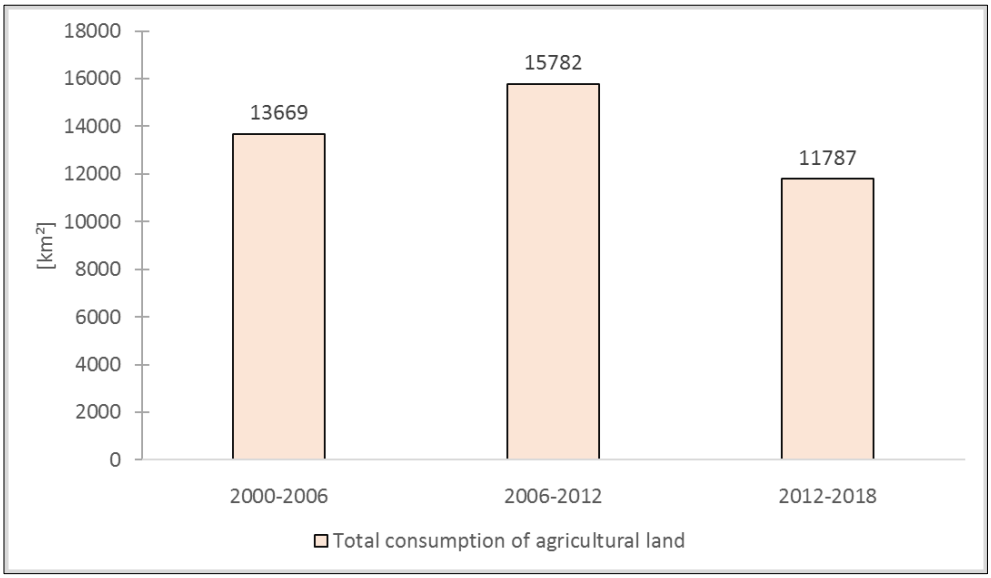


Figure 6--8 Total consumption of agricultural land during 2000-2018, by period, EEA-39

The pattern can be explained by deducting statistics from the land accounts viewer (22) by comparing the areas that the various LCFs consume under agricultural land use between the period 2000-2006, 2006-2012 and 2012-201823. Plotting these by countries shows that the main factors behind the decline in the last accounting period are (i) the substantial decrease of the expansion of discontinuous urban fabric as well as economic and commercial sites in several large countries (e.g. -97 % and -80 % in Spain or -62 % -39 % in France and -87 % decline of residential sprawl in Germany); (ii) decreasing conversion of farmlands to forests or other semi-natural lands (e.g. -84 % in Hungary); and (iii) a decrease of construction development in Spain (-91 %). Separating the two categories indicates that it is in particular arable land and permanent crops for which the consumption decreased after 2012, whereas the consumption of pastures/mosaics remained rather stable in all accounting periods (see Figure 6--12).

(22) https://www.eea.europa.eu/data-and-maps/dashboards/land-cover-and-change-statistics

(23) See land accounts in https://www.eea.europa.eu/data-and-maps/dashboards/land-cover-and-change-statistics#tab-based-on-data. Tabular information can be retrieved from the tab "Accounting for land cover changes – tables" by selecting the respective Land Cover change period, LCF "Level 2" and reading the values for "Arable land and permanent crops" as well as "Pastures & mosaic farmland" for the relevant LCF, i.e. in this case "lcf22 – Urban diffuse residential sprawl", "lcf31 – Sprawl of industrial and commercial sites", "lcf37 – Construction" and "lcf61" and "lcf62". A visual representation of the tabular values is available via the tab "Accounting for land cover changes – charts".

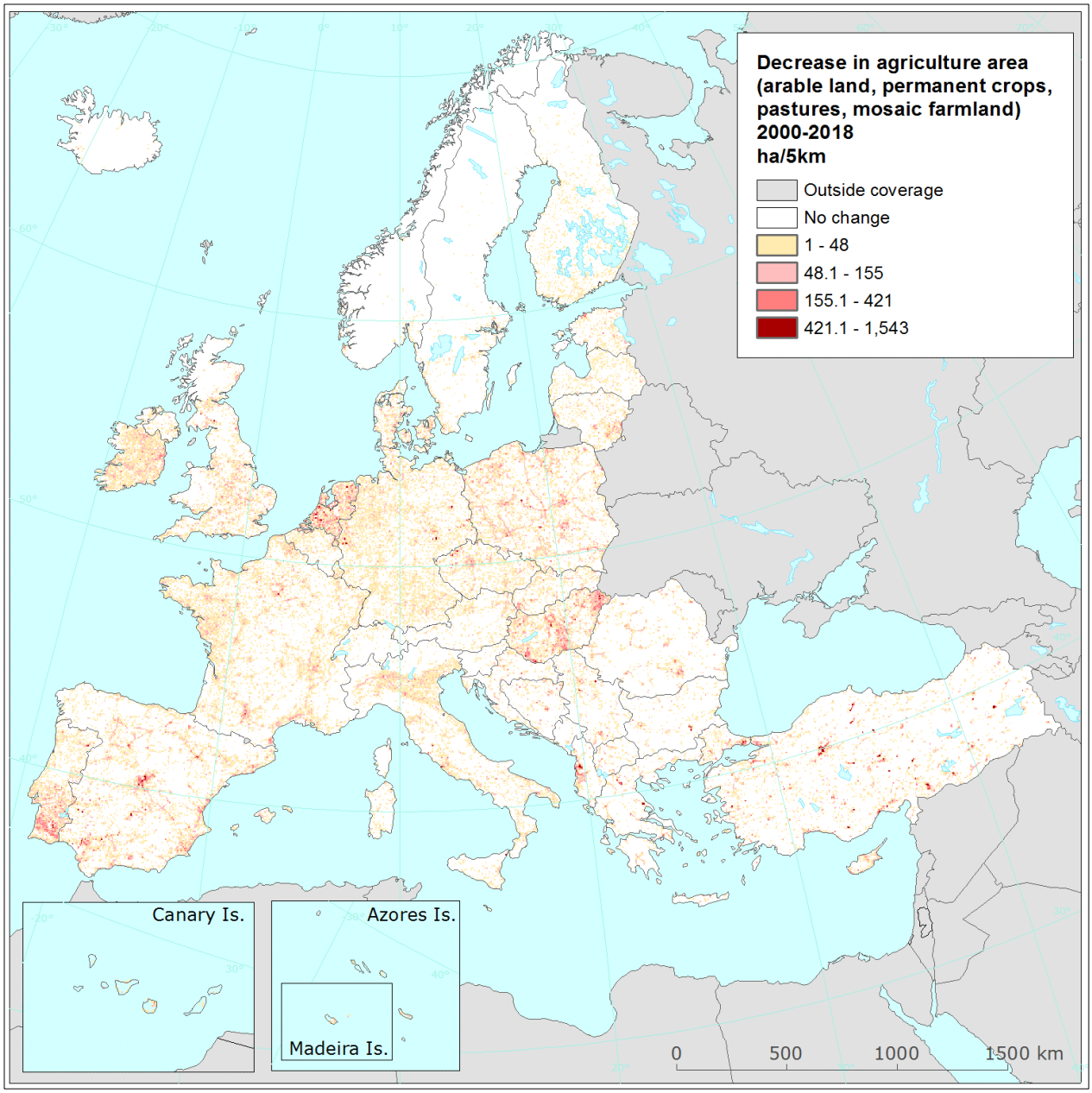


Figure 6--9 Decrease of agricultural land during 2000-2018, EEA-39.

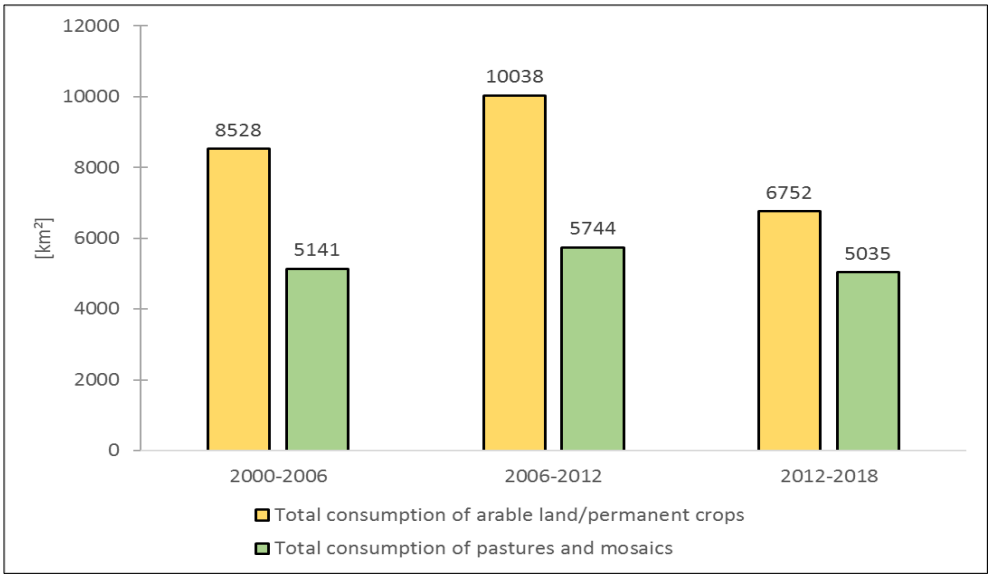


Figure 6--10 Comparison of the consumption of arable land/permanent crops to pastures/mosaics for the three periods, EEA-39.

Analysing the loss of arable land and permanent crops regionally, the largest losses of arable land and permanent crops between 2000 and 2018 were observed in Czechia, Hungary, the interior and southern part of Spain and southern Portugal, as well as in Ireland and Estonia (see Figure 6-11). While in Hungary, Poland and Portugal the main factor was converting agricultural land to forests and other semi-natural vegetation, in Czechia and Ireland the loss of arable land and permanent crops is to a large extent caused by the increase in the area of longer term fallow land and pastures (78 % and 92 %, respectively). However, such conversion into other types of (potential) agricultural lands are reversible processes and are often part of standard rotations of land use on farms. In Spain, the main drivers were construction and sprawl of economic sites and infrastructures ([24]). Turkish arable lands and permanent crops were affected by several drivers to an almost equal extent: irreversible processes concerned water bodies creation, urban diffuse residential sprawl and sprawl of economic sites and infrastructures. The process of converting agricultural land to long term fallow land is however part of standard rotations, as explained above, and hence it is a reversible process. Nevertheless, all these processes were responsible for between 10 and 14 % of loss.

The largest gains of arable land and permanent crops were observed in northern Portugal, southern Spain, the Baltic countries (in particular Latvia) and central Finland. While in the Baltic countries of Estonia, Latvia and Lithuania arable land was created by converting pastures, in central Finland the gains were due to converting forests and wetlands into agricultural areas. In Portugal and Spain, the main reasons were the conversion of pastures, forest and semi-natural land.

One reason for the decreasing consumption of arable land and permanent crops is the decreasing conversion of agricultural land to forests and other semi-natural vegetation (50 % less area affected between 2012 and 2018 compared to the previous periods), see Figure 6-12. These figures can be retrieved by opening the tab “Accounting for land cover changes – tables” with the properly selected “Land Cover change period” on “Level 2” for “All” countries on “EEA-39” extent. On a national level ([25]), expansion of forest and shrub on agricultural area (lcf61) is most prominent in Poland (in particular in the period 2012-

(24) See land accounts in https://www.eea.europa.eu/data-and-maps/dashboards/land-cover-and-change-statistics#tab-based-on-data. Select tab “Accounting for land cover changes – charts”. After selecting the wished observation period (here 2000-2018), Level1, Consumption and “Arable lands and permanent crops” from the drop down list, the chart displays the area lost per country by the land use process (i.e. that land cover flow) leading to the process.

(25) See land accounts in https://www.eea.europa.eu/data-and-maps/dashboards/land-cover-and-change-statistics#tab-based-on-data. Select tab “Country map”, choose the relevant land stock type (i.e. “Land Cover Flows” for the period of interest) using LCF level 2; then select “lcf61” or “lcf62” under “land cover class” for all countries of “EEA39”.

2018) and Hungary (periods 2000-2006 and 2006-2012) as well as in Portugal (2000-2006). Expansion of semi-natural area on agricultural area (lcf62) reaches its highest values in the Netherlands and Spain (2000-2006 and 2006-2012) as well as Portugal (2012-2018). Over the full period of almost 20 years (between 2000 and 2018), more forest and shrubland expanded to agricultural area than semi-natural areas (see Figures 2-3 and 6-12). Hotspots of converting agricultural land to forests and other semi-natural vegetation could be observed in southern Portugal, Ireland, the Netherlands, and a region from the Baltic countries down to Hungary (see Figures 2-3 and 6-12).

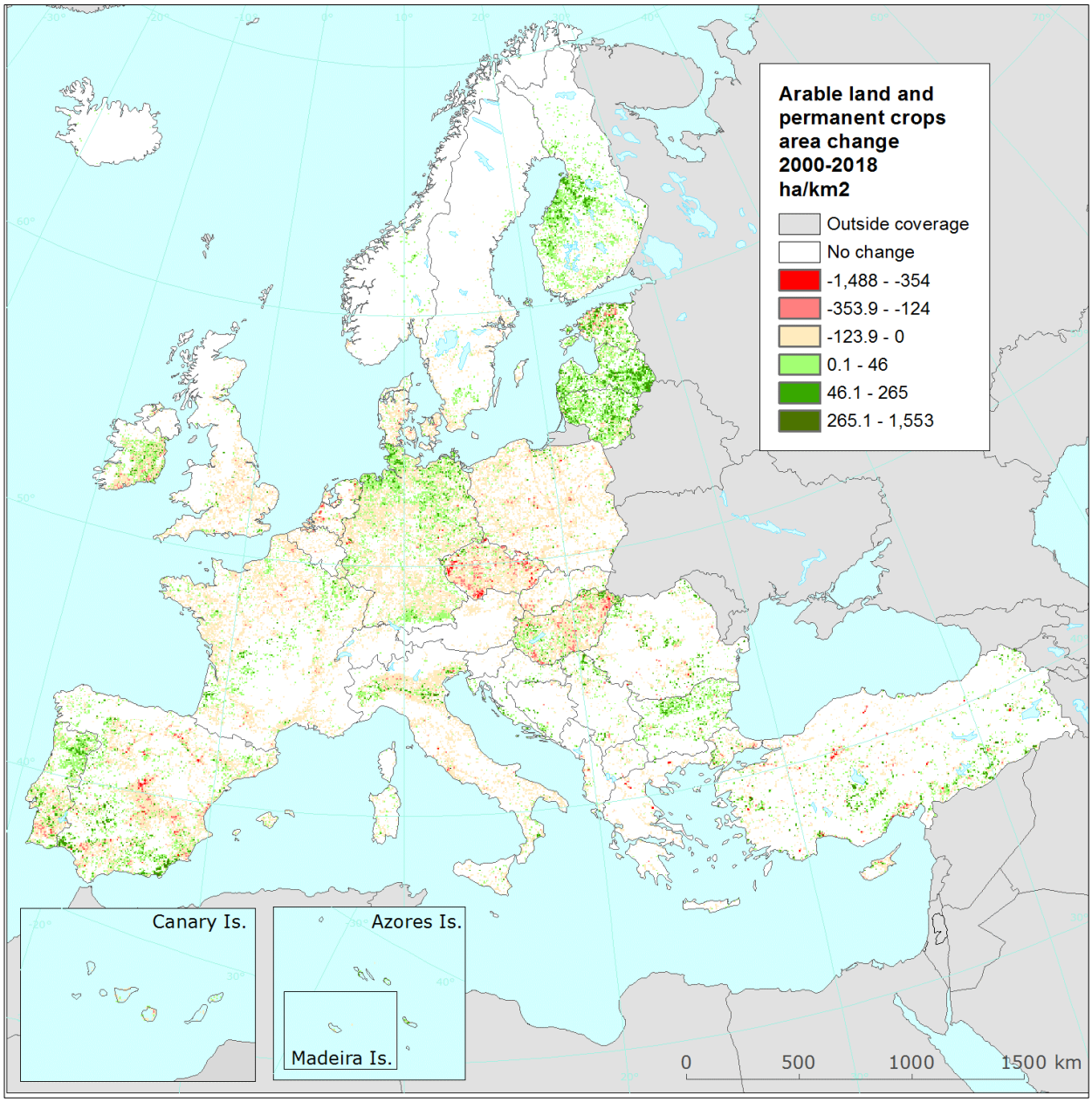


Figure 6--11 Arable land and permanent crops gains and losses during the period 2000 – 2018, EEA-39.

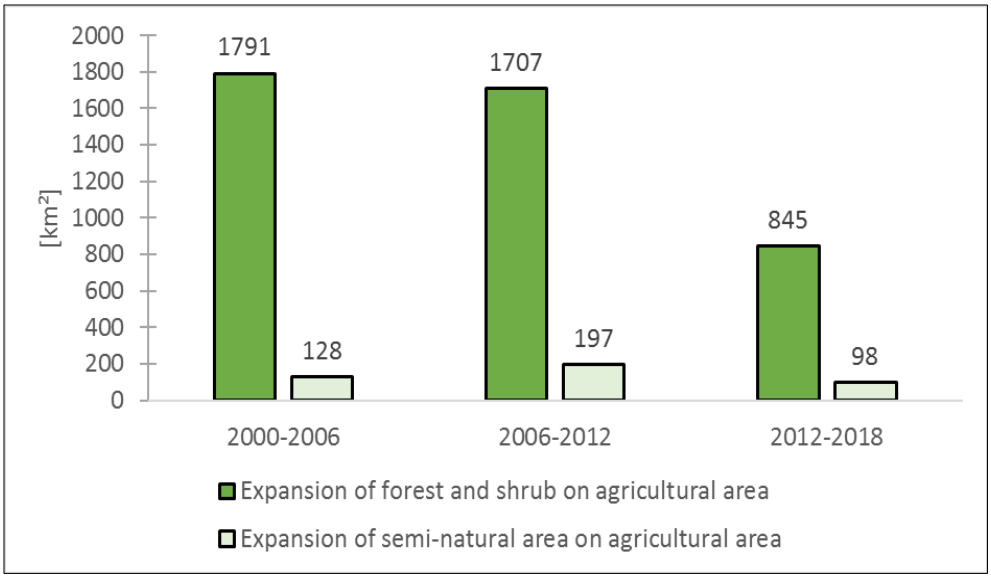


Figure 6--12 Expansion of forests, shrubs and other semi-natural areas on agricultural land during the observation periods 2000-2006, 2006-2012 and 2012-2018, EEA-39.

In addition, a distinct change in the structure of agriculture-internal conversions contributed to the modest reduction in the overall consumption of arable land ([26]). While the first two observation periods (2000-2006 and 2006-2012) saw an almost equal share of conversions from arable land into pastures and vice versa, between 2012 and 2018 conversions from arable land into grassland was only half of the conversions from grassland into arable land (Figure 6--13). However, such conversions are often part of standard rotations of land use on farms and are reversible processes.

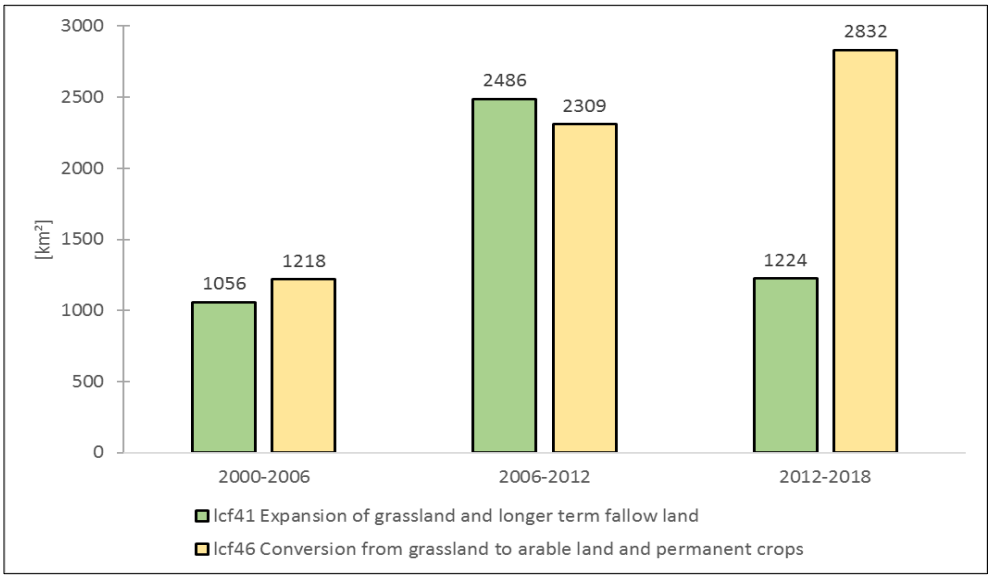


Figure 6--13 Comparison of arable land/permanent crops and pastures/mosaics conversions to grasslands (lcf41) and vice versa (lcf46), EEA-39.

The analytical examples presented above show how the EEA Land and ecosystem accounting system can be used to look at land cover trends in agriculture and their potential land use implications. The trend that raises particular concern with regard to preserving Europe's natural capital is the significant loss of

(26) See land accounts in https://www.eea.europa.eu/data-and-maps/dashboards/land-cover-and-change-statistics#tab-based-on-data. Select tab "Accounting for land cover changes – tables", the respective "Land Cover change period" using "Level 2" of the LCF hierarchy. Conversions from arable land/permanent crops into pastures and mosaics are represented by "lcf41 – Extension of set aside fallow land and pasture", whereas conversions in the other directions are given by "lcf46 – Conversion from pasture to arable land and permanent crops".

productive farmland due to urbanisation and infrastructure development, shown above and analysed in more detail in the preceding section.

6.3 Forested land

The forested area in Europe has expanded because of afforestation programmes and through spontaneous regeneration on abandoned agricultural land in many European countries. Afforestation has taken place when new forests (i.e. broadleaved, coniferous or mixed forest) are planted or seeded on land that was previously not covered by forest. Alternatively, forest re-growth can be observed on land that used to be forest in the recent past which has undergone some clear-felling, other management activities, or natural disturbances (storms) so that it was classified as transitional woodland thereafter. Within the land accounting concept, both forest and transitional woodland belong to the same category as, in general terms, they together represent the forest land use area.

In Europe, forest expansion on previous farmland (lcf61, representing a real gain of forested land) declined substantially between 2012 and 2018, which is one possible explanation for the decline in arable land loss (see previous section on agricultural land). On the other hand, this land use change process might be one of the reasons for the net concurrent loss of forested land in the period 2012-2018 (see Figure 6--14, consumption of forest surpassed its formation). At the same time, the proportion of internal forest conversions, i.e. changes from one forest type into another or changes from forest into transitional woodland and shrub and vice versa (represented by lcf71 – Conversion of transitional woodland and shrub to forest, lcf72 – Forest conversion to transitional woodlands and shrubs, and lcf73 – Conversion between broadleaved, coniferous and mixed forest), to total forest formation increased from around 91 % between 2000 and 2006 to more than 96 % between 2012 and 2018. The total values of those LCFs can again be taken from the tab “Accounting for land cover statistics – tables” by selecting the respective period, using “Level 2” and extracting the corresponding values of the mentioned LCFs in the column “Forest and transitional woodland shrub” for the “Formation of land cover”. The total formation can be read in the last row under the same column. A caveat is the need for discriminating the forest-internal changes within lcf74. This information is not directly readable in the land accounts viewer, but has to be derived by separately combining the LCF data with the CLC classes to be able to split lcf74 into changes within the LEAC category “Forest and transitional woodland” and changes that do not remain within this category. Once those values have been retrieved, the proportion of forest-internal changes to total formation of forest can be calculated easily.

This increase in the proportion of forest-internal changes indicates that most all new forest areas are, with increasing tendency, not new, i.e. previously non-forest, areas, but developing out of transitional woodland. Consequently, when internal conversions are becoming more important, real gains in new forest areas, as defined by the land accounting approach (combining forests and transitional woodlands into one category), are decreasing.

Changes in forest land cover are mainly found in a few European countries (Forest Europe, 2015). Figure 6--15, covering the period 2000-2018, shows the relation between forest area increase and decrease ([27]) and, hence, highlights regions where forest area increase (in green) or forest area decrease (in red) dominate. Local clusters of regions with a dominance of forest area increase can be found in eastern Europe from the Baltic countries down to Hungary, else in Ireland and southern Scotland as well as in the Iberian Peninsula. This distribution of regions with high forest area increase matches well with the distribution of regions that show a significant decrease of farmland area (see Figure 6--11, Converting

(27) Afforestation is the establishment of forest through planting and/or deliberate seeding on land that, until then, was not classified as forest, while natural expansion of forest happens through natural succession on land that, until then, was under another land use (e.g. forest succession on land previously used for agriculture). Deforestation describes the conversion of forest to other land use or the long-term reduction of the tree canopy cover below the minimum 10 percent threshold. (FAO, 2010)

arable lands and permanent crops to forests and other semi-natural areas between 2000 and 2018). Regions of high forest land cover decrease are clustered in Scandinavia and along the Mediterranean Sea from Croatia over Italy, southern France, Spain and Portugal.

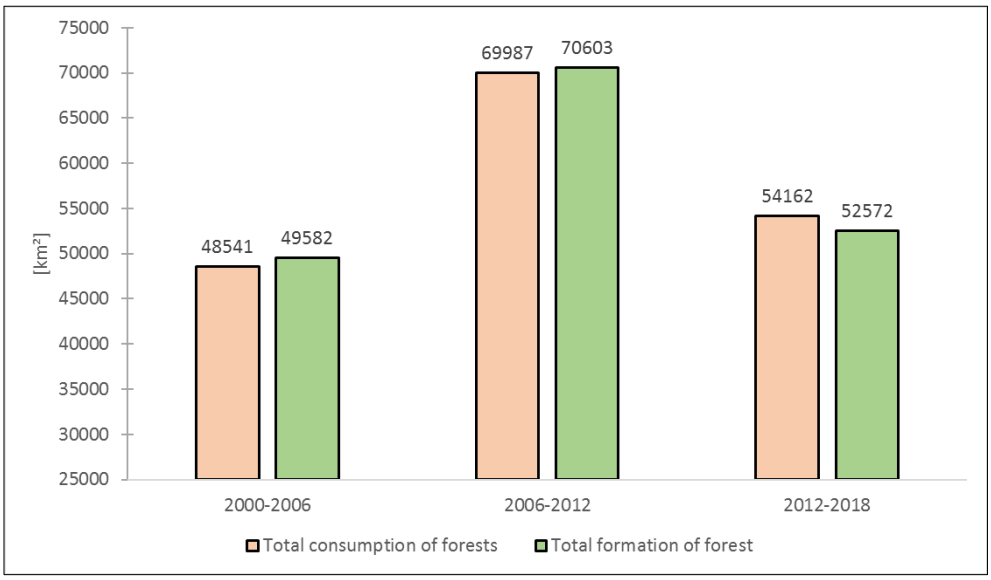


Figure 6--14 Total consumption and formation for forests during the three periods.

One reason for the (temporary) loss of forest area is forest fires. While they occurred in the past as well, their frequency and intensity increased in the last couple of years ([28]). Fires mainly hit southern European countries along the Mediterranean coast and in south-eastern European countries where temperatures have always been generally higher. Over the full 18-year period, Portugal was most impacted by forest and shrub fires (Figure 6--15), with the largest damages occurring in the periods 2012-2018 and 2000-2006. In Spain, mainly the period 2000-2006 was concerned. Like Portugal, Italy recorded the highest consumption through fires in the most recent period, whereas Greece and Albania showed high values in the period 2006-2012 (see period details in Figure 6--16 to Figure 6--19).

A Nordic exception to the listed Mediterranean countries is Sweden, which recorded relatively large losses of forest and transitional woodland shrubs through fires between 2012 and 2018. The reason was the exceptional wildfires in 2018 caused by unusually hot and dry conditions in spring and early summer ([29]), a situation that already continued in early 2019 ([30]).

(28) https://ec.europa.eu/info/research-and-innovation/research-area/environment/forest-fires_en and https://www.euronews.com/2019/08/15/there-have-been-three-times-more-wildfires-in-the-eu-so-far-this-year

(29) https://en.wikipedia.org/wiki/2018_Sweden_wildfires

(30) "According to Copernicus, the EU Commission satellite service, there have been a total of 1,207 forest fires as of April 24, compared to 112 at this date last year. Additionally, the agency has recorded more than 180,000 hectares of burnt area to date this year compared to 24,000 hectares last year." (https://www.euronews.com/2019/04/24/sweden-and-norway-concerned-by-unusual-pre-season-forest-fires)

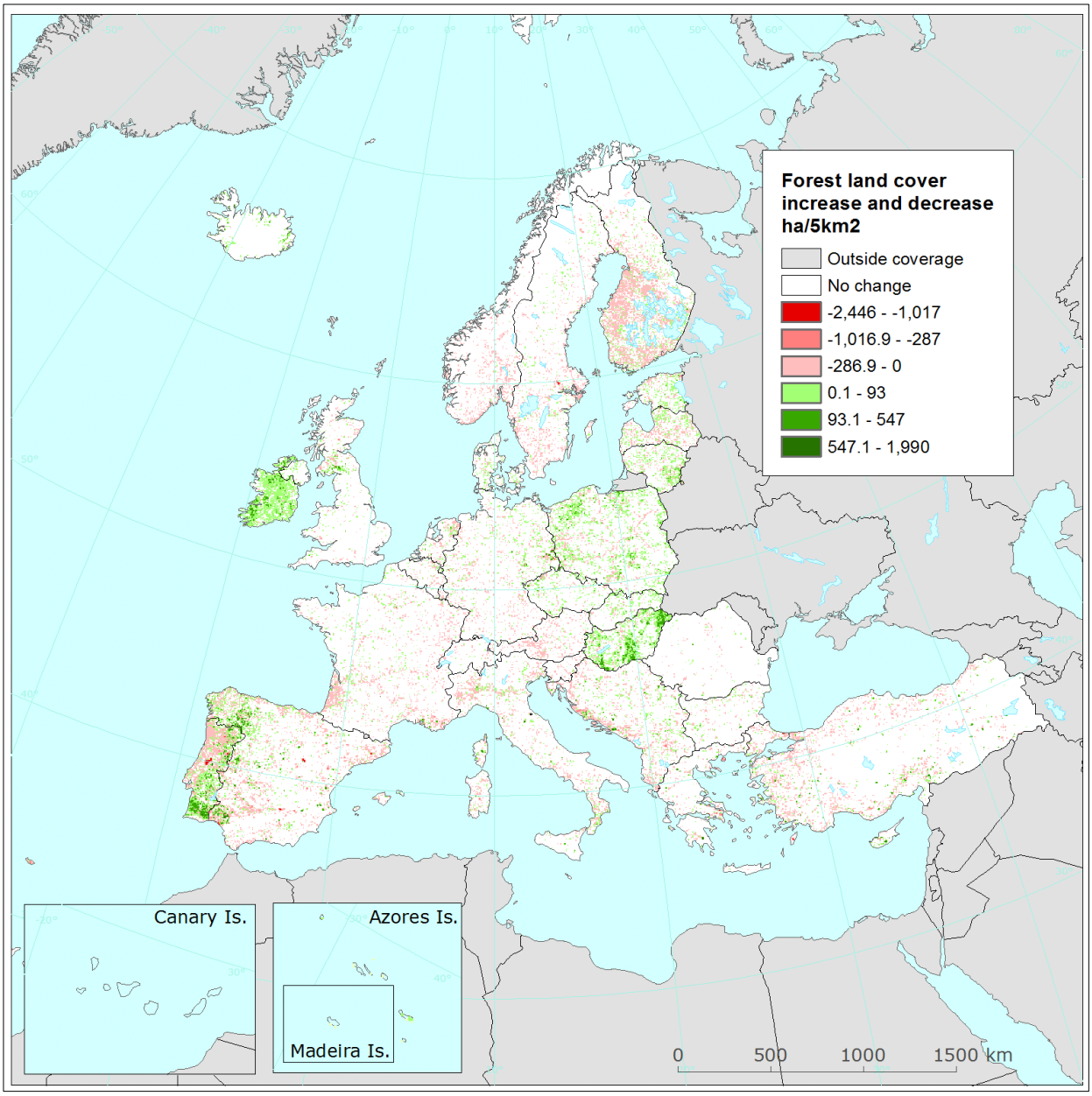


Figure 6--15 Forest area increase and decrease in EEA-39, 2000 – 2018

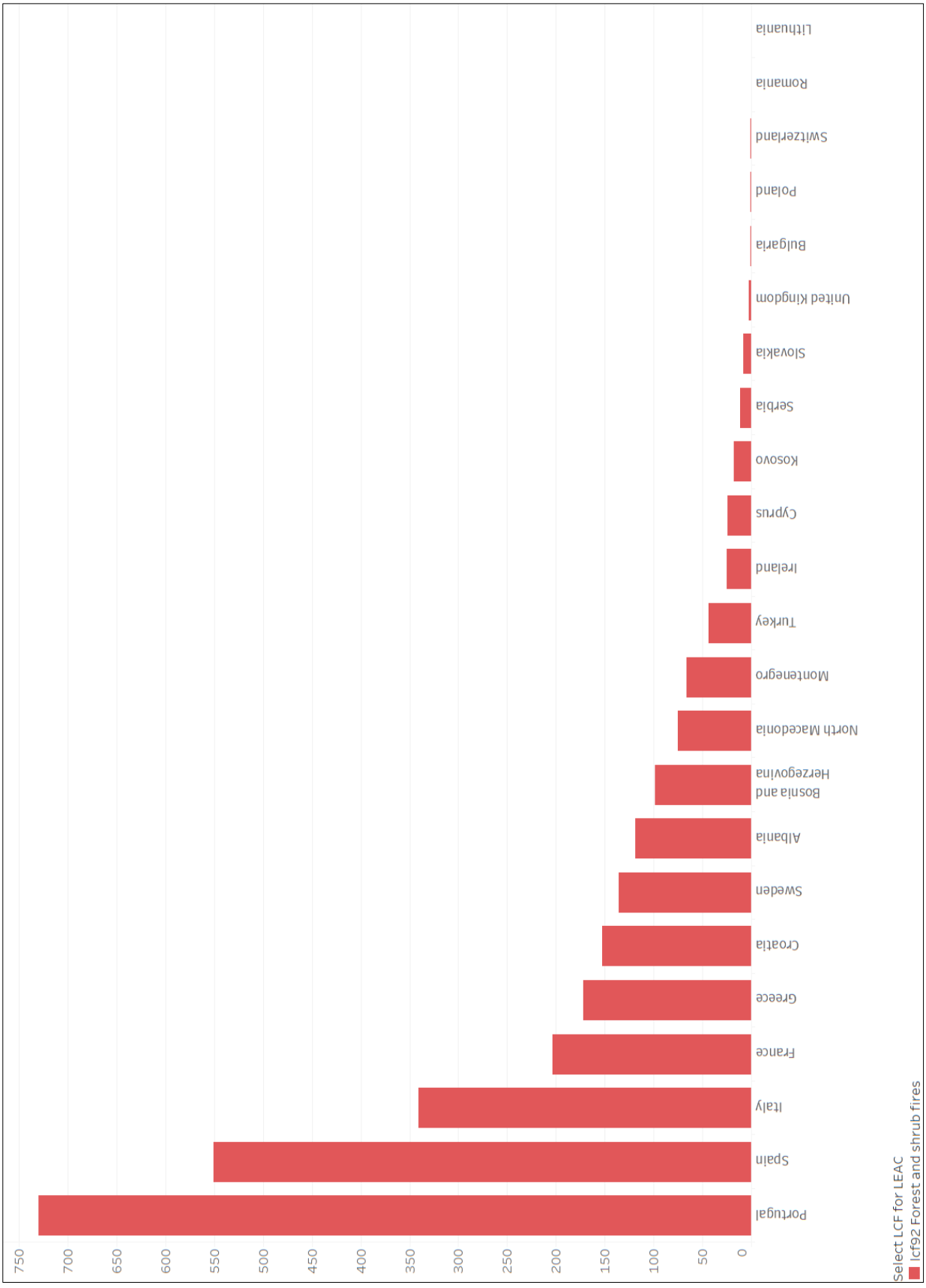


Figure 6--16 Loss of Forest and transitional woodland shrub and natural grassland, heathland and sclerophyllous vegetation due to forest and shrub fires between 2000 and 2018, by country.

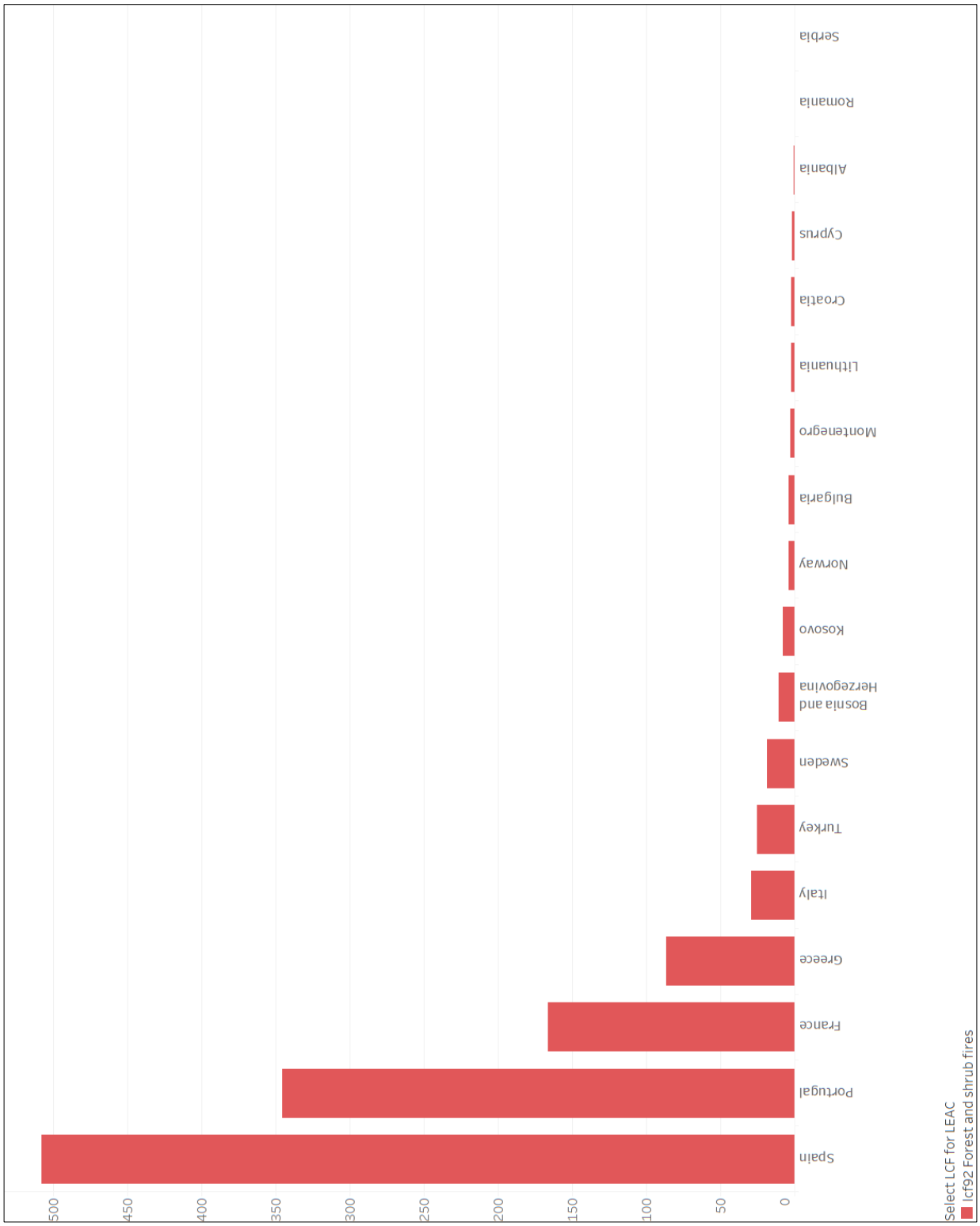


Figure 6--17 **Loss of Forest and transitional woodland shrub and natural grassland, heathland and sclerophyllous vegetation due to forest and shrub fires between 2000 and 2006, by country**

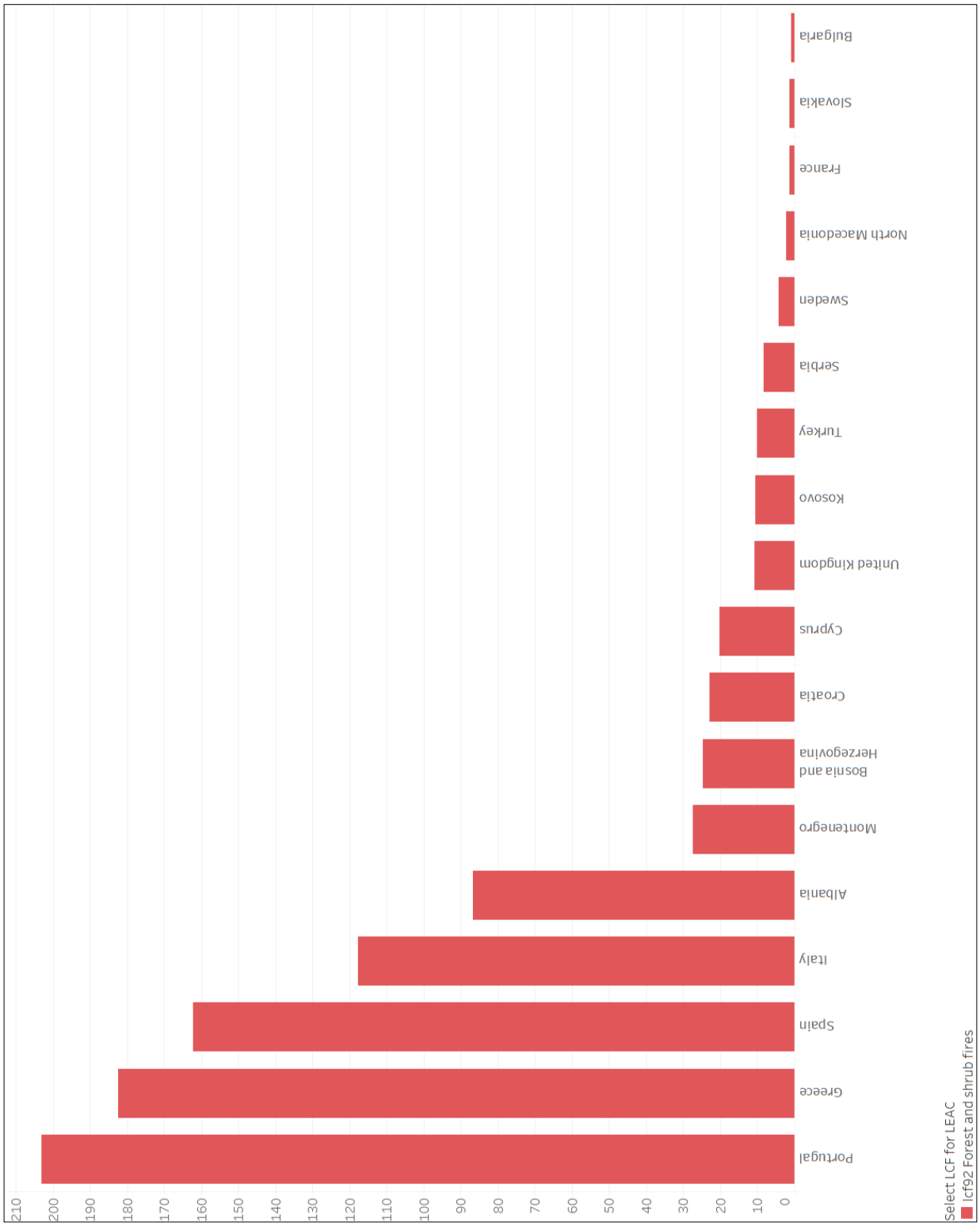


Figure 6--18 Loss of Forest and transitional woodland shrub and natural grassland, heathland and sclerophyllous vegetation due to forest and shrub fires between 2006 and 2012, by country

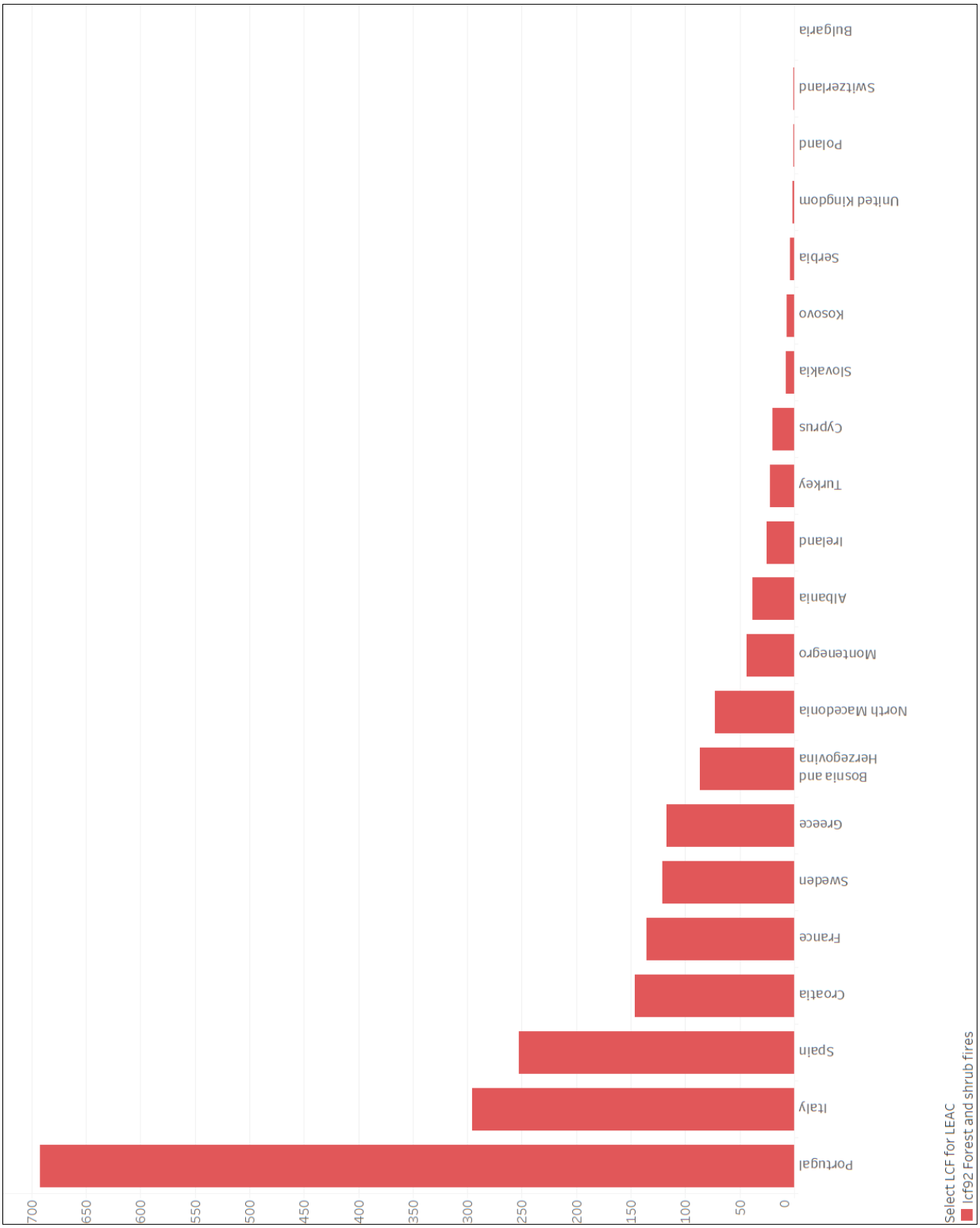


Figure 6--19 Loss of Forest and transitional woodland shrub and natural grassland, heathland and sclerophyllous vegetation due to forest and shrub fires between 2012 and 2018, by country

7 Summary and Outlook

The status and change of land and ecosystems are important elements to inform the development and implementation of policies that impact on these components of natural capital, such as water, climate, agricultural land, forest, biodiversity and regional planning. Key EU policy documents, i.e. the Seventh Environment Action Programme and the Biodiversity Strategy to 2020, set as main objectives the development of natural capital accounts in the EU, with a focus on ecosystems and their services, including land. Furthermore, work at international and European level drives forward the development and update of ecosystem accounting standards and related accounts. For example, the 2019 European strategy for environmental accounts describes priorities and actions to be developed for the use of environmental accounts in a harmonised way. For serving the European policies especially on natural capital and biodiversity, enlarged production of ecosystem accounts, forest accounts, water accounts and land accounts have been identified.

EEA has developed land and ecosystem accounting methods for about two decades. This report describes the state of the art of concepts and methods for geospatial environmental accounting at EEA and ETC/ULS, which aim to be transparent, repeatable and efficient. They are designed to facilitate the assessment of status and trends in natural capital and provide efficient input to analysis supporting environmental and sectoral policies. The methods presented in this report are flexible and may be used to any categorical geospatial data to account for gains and losses as well as other geo-spatial analysis.

The core data set underpinning the EEA land and ecosystem accounting system is Corine land cover but many other data sets are also integrated into EEA's approach. The CLC accounting layers enable the consistent assessment of land accounts for the almost 20 years period of 2000-2018. The CLC accounting layers may be freely integrated with other datasets, such as biogeographical regions, administrative boundaries, geo-physical variables such as elevation classes, other land use information such as landscape fragmentation or socio-economic variables such as population density to shed light on drivers and pressures of land cover and land use change. The EU Copernicus earth observation programme and the increasing collection of geo-spatial data on ecosystems and biodiversity will increase the data sets available for land and ecosystem accounting manifold. This is an aspect already taken into account for developing EEA's future land and ecosystem accounting approach.

EEA's Integrated Data Platform allows the efficient, transparent, repeatable and hence quality controlled integration of geo-spatial datasets in accounting statistics. By converting geo-spatial datasets into analysis-ready formats, the workflow is faster and more effective than performing GIS analysis on raw data. In case for example a new version of one of the input geo-spatial datasets becomes available, update of the accounting cubes is efficient as only the dimension in question needs to be renewed. Furthermore, as the dimensions are stored in the cloud environment, the use of the same inputs are ensured in case of several existing versions of the same input dataset. This allows the system to deal with the increasing set of input data sets as well as of analytical demands efficiently.

With the increasing number of high spatial and temporal resolution Earth Observation images, data are becoming bigger and bigger in size, in many cases reaching several hundreds of terabytes. The management and processing of big data is therefore a necessity in order to ensure fast, efficient, up-to-date and state-of-the-art policy support. This is the way forward in EEA`s future geospatial environmental accounting system and will allow a more versatile support to a wider range of policy questions.

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ANNEX 1 - Matrix of Land Cover Flows

Part A. Formation of artificial surfaces

		111	112	121	122	123	124	131	132	133	141	142
		Continuous urban fabric	Discontinuous urban fabric	Industrial or commercial units	Road and rail networks and associated land	Port areas	Airports	Mineral extraction sites	Dump sites	Construction sites	Green urban areas	Sport and leisure facilities
111	Continuous urban fabric		lcf12	lcf12	lcf12	lcf12	lcf12	lcf12	lcf12	lcf12	lcf13	lcf38
112	Discontinuous urban fabric	lcf11		lcf11	lcf11	lcf11	lcf11	lcf12	lcf12	lcf11	lcf13	lcf38
121	Industrial or commercial units	lcf12	lcf12		lcf12	lcf12	lcf12	lcf12	lcf12	lcf12	lcf13	lcf38
122	Road and rail networks and associated land	lcf12	lcf12	lcf12		lcf12	lcf12	lcf12	lcf12	lcf12	lcf13	lcf38
123	Port areas	lcf12	lcf12	lcf12	lcf12		lcf12	lcf12	lcf12	lcf12	lcf13	lcf38
124	Airports	lcf12	lcf12	lcf12	lcf12	lcf12		lcf12	lcf12	lcf12	lcf13	lcf38
131	Mineral extraction sites	lcf12	lcf12	lcf12	lcf12	lcf12	lcf12		lcf12	lcf12	lcf13	lcf38
132	Dump sites	lcf12	lcf12	lcf12	lcf12	lcf12	lcf12	lcf12		lcf12	lcf13	lcf38
133	Construction sites	lcf12	lcf12	lcf12	lcf12	lcf12	lcf12	lcf12	lcf12		lcf13	lcf38
141	Green urban areas	lcf11	lcf11	lcf11	lcf11	lcf11	lcf11	lcf11	lcf11	lcf11		lcf38
142	Sport and leisure facilities	lcf11	lcf11	lcf11	lcf11	lcf11	lcf11	lcf11	lcf11	lcf11	lcf13	
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	lcf99	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	lcf99	lcf38
423	Intertidal flats	lcf21	lcf22	lcf31	lcf32	lcf33	lcf34	lcf35	lcf36	lcf37	lcf99	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

Part B. Formation of agricultural areas

		211	212	213	221	222	223	231	241	242	243	244
		Non-irrigated arable land	Permanently irrigated land	Rice fields	Vineyards	Fruit trees and berry plantations	Olive groves	Pastures	Annual crops associated with permanent crops	Complex cultivation patterns	Agriculture mosaics with significant natural vegetation	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	lcf99	lcf99	lcf99	lcf99	lcf99	lcf99	lcf99	lcf99	lcf99	lcf99	lcf99
142	Sport and leisure facilities	lcf54	lcf54	lcf54	lcf54	lcf54	lcf54	lcf54	lcf54	lcf54	lcf54	lcf54
211	Non-irrigated arable land		lcf421	lcf421	lcf451	lcf451	lcf452	lcf411	lcf49	lcf49	lcf62	lcf471
212	Permanently irrigated land	lcf422		lcf422	lcf451	lcf451	lcf452	lcf411	lcf49	lcf49	lcf62	lcf471
213	Rice fields	lcf422	lcf422		lcf451	lcf451	lcf452	lcf411	lcf49	lcf412	lcf62	lcf471
221	Vineyards	lcf442	lcf441	lcf441		lcf433	lcf432	lcf411	lcf444	lcf49	lcf62	lcf471
222	Fruit trees and berry plantations	lcf442	lcf441	lcf441	lcf433		lcf432	lcf411	lcf444	lcf49	lcf62	lcf471
223	Olive groves	lcf443	lcf441	lcf441	lcf431	lcf431		lcf411	lcf443	lcf49	lcf62	lcf471
231	Pastures	lcf462	lcf461	lcf461	lcf462	lcf462	lcf462		lcf462	lcf49	lcf62	lcf471
241	Annual crops associated with permanent crops	lcf442	lcf441	lcf441	lcf48	lcf48	lcf48	lcf411		lcf49	lcf62	lcf471
242	Complex cultivation patterns	lcf49	lcf49	lcf49	lcf48	lcf48	lcf48	lcf412	lcf49		lcf62	lcf471
243	Agriculture mosaics with significant natural vegetation	lcf49	lcf49	lcf49	lcf48	lcf48	lcf48	lcf412	lcf49	lcf49		lcf471
244	Agro-forestry areas	lcf472	lcf472	lcf472	lcf472	lcf472	lcf472	lcf412	lcf472	lcf472	lcf472	
311	Broad-leaved forest	lcf511	lcf511	lcf511	lcf511	lcf511	lcf511	lcf511	lcf511	lcf511	lcf512	lcf512
312	Coniferous forest	lcf511	lcf511	lcf511	lcf511	lcf511	lcf511	lcf511	lcf511	lcf511	lcf512	lcf512
313	Mixed forest	lcf511	lcf511	lcf511	lcf511	lcf511	lcf511	lcf511	lcf511	lcf511	lcf512	lcf512
321	Natural grassland	lcf462	lcf461	lcf461	lcf462	lcf462	lcf462	lcf99	lcf462	lcf49	lcf62	lcf471
322	Moors and heathland	lcf521	lcf521	lcf521	lcf521	lcf521	lcf521	lcf521	lcf521	lcf521	lcf522	lcf522
323	Sclerophyllous vegetation	lcf521	lcf521	lcf521	lcf521	lcf521	lcf521	lcf521	lcf521	lcf521	lcf522	lcf522
324	Transitional woodland shrub	lcf511	lcf511	lcf511	lcf511	lcf511	lcf511	lcf511	lcf511	lcf511	lcf512	lcf512
331	Beaches, dunes and sand plains	lcf521	lcf521	lcf521	lcf521	lcf521	lcf521	lcf521	lcf521	lcf521	lcf522	lcf522
332	Bare rock	lcf521	lcf521	lcf521	lcf521	lcf521	lcf521	lcf521	lcf521	lcf521	lcf522	lcf522
333	Sparsely vegetated areas	lcf521	lcf521	lcf521	lcf521	lcf521	lcf521	lcf521	lcf521	lcf521	lcf522	lcf522
334	Burnt areas	lcf521	lcf521	lcf521	lcf521	lcf521	lcf521	lcf521	lcf521	lcf521	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	lcf99	lcf99	lcf99	lcf99	lcf99	lcf99	lcf99	lcf99	lcf99	lcf99	lcf99
423	Intertidal flats	lcf53	lcf53	lcf53	lcf53	lcf53	lcf53	lcf932	lcf53	lcf53	lcf53	lcf53
511	Water courses	lcf53	lcf53	lcf53	lcf53	lcf53	lcf53	lcf912	lcf53	lcf53	lcf53	lcf53
512	Water bodies	lcf53	lcf53	lcf53	lcf53	lcf53	lcf53	lcf912	lcf53	lcf53	lcf53	lcf53
521	Coastal lagoons	lcf53	lcf53	lcf53	lcf53	lcf53	lcf53	lcf932	lcf53	lcf53	lcf53	lcf53
522	Estuaries	lcf53	lcf53	lcf53	lcf53	lcf53	lcf53	lcf932	lcf53	lcf53	lcf53	lcf53
523	Sea and ocean	lcf53	lcf53	lcf53	lcf53	lcf53	lcf53	lcf932	lcf53	lcf53	lcf53	lcf53

Part C. Formation of forested or open natural surfaces

		311	312	313	321	322	323	324	331	332	333	334	335
		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	lcf63	lcf63	lcf63	*lcf54*	lcf911	lcf911	lcf63	lcf911	lcf911	lcf911	lcf99	lcf99
112	Discontinuous urban fabric	lcf63	lcf63	lcf63	*lcf54*	lcf911	lcf911	lcf63	lcf911	lcf911	lcf911	lcf99	lcf99
121	Industrial or commercial units	lcf63	lcf63	lcf63	*lcf54*	lcf911	lcf911	lcf63	lcf911	lcf911	lcf911	lcf99	lcf99
122	Road and rail networks and associated land	lcf63	lcf63	lcf63	*lcf54*	lcf911	lcf911	lcf63	lcf911	lcf911	lcf911	lcf99	lcf99
123	Port areas	lcf63	lcf63	lcf63	*lcf54*	lcf911	lcf911	lcf63	lcf911	lcf911	lcf911	lcf99	lcf99
124	Airports	lcf63	lcf63	lcf63	*lcf54*	lcf911	lcf911	lcf63	lcf911	lcf911	lcf911	lcf99	lcf99
131	Mineral extraction sites	lcf63	lcf63	lcf63	*lcf54*	lcf911	lcf911	lcf63	lcf911	lcf911	lcf911	lcf99	lcf99
132	Dump sites	lcf63	lcf63	lcf63	*lcf54*	lcf911	lcf911	lcf63	lcf911	lcf911	lcf911	lcf99	lcf99
133	Construction sites	lcf63	lcf63	lcf63	*lcf54*	lcf911	lcf911	lcf63	lcf911	lcf911	lcf911	lcf99	lcf99
141	Green urban areas	lcf99	lcf99	lcf99	lcf99	lcf99	lcf99	lcf99	lcf99	lcf99	lcf99	lcf99	lcf99
142	Sport and leisure facilities	lcf63	lcf63	lcf63	*lcf54*	lcf911	lcf911	lcf63	lcf911	lcf911	lcf911	lcf99	lcf99
211	Non-irrigated arable land	lcf61	lcf61	lcf61	*lcf411*	lcf62	lcf62	lcf61	lcf62	lcf62	lcf62	lcf99	lcf99
212	Permanently irrigated land	lcf61	lcf61	lcf61	*lcf411*	lcf62	lcf62	lcf61	lcf62	lcf62	lcf62	lcf99	lcf99
213	Rice fields	lcf61	lcf61	lcf61	*lcf411*	lcf62	lcf62	lcf61	lcf62	lcf62	lcf62	lcf99	lcf99
221	Vineyards	lcf61	lcf61	lcf61	*lcf411*	lcf62	lcf62	lcf61	lcf62	lcf62	lcf62	lcf99	lcf99
222	Fruit trees and berry plantations	lcf61	lcf61	lcf61	*lcf411*	lcf62	lcf62	lcf61	lcf62	lcf62	lcf62	lcf99	lcf99
223	Olive groves	lcf61	lcf61	lcf61	*lcf411*	lcf62	lcf62	lcf61	lcf62	lcf62	lcf62	lcf99	lcf99
231	Pastures	lcf61	lcf61	lcf61	lcf99	lcf62	lcf62	lcf61	lcf62	lcf62	lcf62	lcf99	lcf99
241	Annual crops associated with permanent crops	lcf61	lcf61	lcf61	*lcf411*	lcf62	lcf62	lcf61	lcf62	lcf62	lcf62	lcf99	lcf99
242	Complex cultivation patterns	lcf61	lcf61	lcf61	*lcf412*	lcf62	lcf62	lcf61	lcf62	lcf62	lcf62	lcf99	lcf99
243	Agriculture mosaics with significant natural vegetation	lcf61	lcf61	lcf61	*lcf412*	lcf62	lcf62	lcf61	lcf62	lcf62	lcf62	lcf99	lcf99
244	Agro-forestry areas	lcf61	lcf61	lcf61	*lcf412*	lcf62	lcf62	lcf61	lcf62	lcf62	lcf62	lcf92	lcf99
311	Broad-leaved forest		lcf73	lcf73	lcf511	lcf913	lcf913	lcf72	lcf913	lcf913	lcf913	lcf92	lcf99
312	Coniferous forest	lcf73		lcf73	lcf511	lcf913	lcf913	lcf72	lcf913	lcf913	lcf913	lcf92	lcf99
313	Mixed forest	lcf73	lcf73		lcf511	lcf913	lcf913	lcf72	lcf913	lcf913	lcf913	lcf92	lcf99
321	Natural grassland	lcf61	lcf61	lcf61		lcf62	lcf912	lcf61	lcf912	lcf912	lcf912	lcf99	lcf99
322	Moors and heathland	lcf63	lcf63	lcf63	lcf521		lcf99	lcf63	lcf912	lcf912	lcf912	lcf92	lcf99
323	Sclerophyllous vegetation	lcf63	lcf63	lcf63	lcf521	lcf99		lcf63	lcf912	lcf912	lcf912	lcf92	lcf99
324	Transitional woodland shrub	lcf71	lcf71	lcf71	lcf511	lcf913	lcf913		lcf913	lcf913	lcf913	lcf92	lcf99
331	Beaches, dunes and sand plains	lcf63	lcf63	lcf63	lcf521	lcf912	lcf912	lcf63		lcf912	lcf912	lcf99	lcf99
332	Bare rock	lcf63	lcf63	lcf63	lcf521	lcf912	lcf912	lcf63	lcf912		lcf912	lcf99	lcf912
333	Sparsely vegetated areas	lcf63	lcf63	lcf63	lcf521	lcf912	lcf912	lcf63	lcf912	lcf912		lcf92	lcf912
334	Burnt areas	lcf63	lcf63	lcf63	lcf521	lcf912	lcf912	lcf63	lcf912	lcf912	lcf912		lcf99
335	Glaciers and perpetual snow	lcf99	lcf99	lcf99	lcf99	lcf99	lcf99	lcf99	lcf94	lcf94	lcf94	lcf99	
411	Inland marshes	lcf63	lcf63	lcf63	lcf53	lcf912	lcf912	lcf63	lcf99	lcf99	lcf99	lcf99	lcf99
412	Peatbogs	lcf63	lcf63	lcf63	lcf53	lcf912	lcf912	lcf63	lcf99	lcf99	lcf99	lcf92	lcf99
421	Salt marshes	lcf63	lcf63	lcf63	lcf53	lcf912	lcf912	lcf63	lcf99	lcf99	lcf99	lcf99	lcf99
422	Salines	lcf99	lcf99	lcf99	lcf53	lcf912	lcf912	lcf99	lcf912	lcf99	lcf912	lcf99	lcf99
423	Intertidal flats	lcf99	lcf99	lcf99	lcf932	lcf99	lcf99	lcf99	lcf932	lcf932	lcf932	lcf99	lcf99
511	Water courses	lcf63	lcf63	lcf63	lcf912	lcf912	lcf912	lcf63	lcf912	lcf912	lcf912	lcf99	lcf99
512	Water bodies	lcf63	lcf63	lcf63	lcf912	lcf912	lcf912	lcf63	lcf82	lcf82	lcf82	lcf99	lcf99
521	Coastal lagoons	lcf63	lcf63	lcf63	lcf932	lcf912	lcf912	lcf63	lcf932	lcf932	lcf932	lcf99	lcf99
522	Estuaries	lcf932	lcf932	lcf932	lcf932	lcf99	lcf99	lcf63	lcf99	lcf99	lcf99	lcf99	lcf99
523	Sea and ocean	lcf932	lcf932	lcf932	lcf932	lcf99	lcf99	lcf63	lcf99	lcf99	lcf99	lcf99	lcf99

Part D. Formation of wetlands and water surfaces

		411	412	421	422	423	511	512	521	522	523
		Inland marshes	Peatbogs	Salt marshes	Salines	Intertidal flats	Water courses	Water bodies	Coastal lagoons	Estuaries	Sea and ocean
111	Continuous urban fabric	lcf99	lcf99	lcf99	lcf99	lcf931	lcf81	lcf81	lcf931	lcf931	lcf931
112	Discontinuous urban fabric	lcf99	lcf99	lcf99	lcf99	lcf931	lcf81	lcf81	lcf931	lcf931	lcf931
121	Industrial or commercial units	lcf99	lcf99	lcf99	lcf99	lcf931	lcf81	lcf81	lcf931	lcf931	lcf931
122	Road and rail networks and associated land	lcf99	lcf99	lcf99	lcf99	lcf931	lcf81	lcf81	lcf931	lcf931	lcf931
123	Port areas	lcf99	lcf99	lcf99	lcf99	lcf931	lcf81	lcf81	lcf931	lcf931	lcf931
124	Airports	lcf99	lcf99	lcf99	lcf99	lcf931	lcf81	lcf81	lcf931	lcf931	lcf931
131	Mineral extraction sites	lcf83	lcf99	lcf99	lcf99	lcf931	lcf81	lcf81	lcf931	lcf931	lcf931
132	Dump sites	lcf99	lcf99	lcf99	lcf99	lcf931	lcf81	lcf81	lcf931	lcf931	lcf931
133	Construction sites	lcf99	lcf99	lcf99	lcf99	lcf931	lcf81	lcf81	lcf931	lcf931	lcf931
141	Green urban areas	lcf99	lcf99	lcf99	lcf99	lcf931	lcf81	lcf81	lcf931	lcf931	lcf931
142	Sport and leisure facilities	lcf99	lcf99	lcf99	lcf99	lcf931	lcf81	lcf81	lcf931	lcf931	lcf931
211	Non-irrigated arable land	lcf83	lcf83	lcf99	lcf99	lcf931	lcf81	lcf81	lcf931	lcf931	lcf931
212	Permanently irrigated land	lcf83	lcf99	lcf99	lcf99	lcf931	lcf81	lcf81	lcf931	lcf931	lcf931
213	Rice fields	lcf83	lcf99	lcf83	lcf83	lcf931	lcf81	lcf81	lcf931	lcf931	lcf931
221	Vineyards	lcf99	lcf99	lcf99	lcf99	lcf931	lcf81	lcf81	lcf931	lcf931	lcf931
222	Fruit trees and berry plantations	lcf99	lcf99	lcf99	lcf99	lcf931	lcf81	lcf81	lcf931	lcf931	lcf931
223	Olive groves	lcf99	lcf99	lcf99	lcf99	lcf931	lcf81	lcf81	lcf931	lcf931	lcf931
231	Pastures	lcf83	lcf83	lcf83	lcf99	lcf931	lcf81	lcf81	lcf931	lcf931	lcf931
241	Annual crops associated with permanent crops	lcf83	lcf99	lcf99	lcf99	lcf931	lcf81	lcf81	lcf931	lcf931	lcf931
242	Complex cultivation patterns	lcf83	lcf83	lcf83	lcf99	lcf931	lcf81	lcf81	lcf931	lcf931	lcf931
243	Agriculture mosaics with significant natural vegetation	lcf83	lcf83	lcf83	lcf99	lcf931	lcf81	lcf81	lcf931	lcf931	lcf931
244	Agro-forestry areas	lcf83	lcf99	lcf99	lcf99	lcf931	lcf81	lcf81	lcf931	lcf931	lcf931
311	Broad-leaved forest	lcf83	lcf83	lcf99	lcf99	lcf931	lcf81	lcf81	lcf931	lcf931	lcf931
312	Coniferous forest	lcf83	lcf83	lcf99	lcf99	lcf931	lcf81	lcf81	lcf931	lcf931	lcf931
313	Mixed forest	lcf83	lcf83	lcf99	lcf99	lcf931	lcf81	lcf81	lcf931	lcf931	lcf931
321	Natural grassland	lcf83	lcf83	lcf83	lcf83	lcf931	lcf81	lcf81	lcf931	lcf931	lcf931
322	Moors and heathland	lcf912	lcf912	lcf912	lcf99	lcf931	lcf81	lcf81	lcf931	lcf931	lcf931
323	Sclerophyllous vegetation	lcf912	lcf912	lcf912	lcf99	lcf931	lcf81	lcf81	lcf931	lcf931	lcf931
324	Transitional woodland shrub	lcf83	lcf83	lcf99	lcf99	lcf931	lcf81	lcf81	lcf931	lcf931	lcf931
331	Beaches, dunes and sand plains	lcf912	lcf99	lcf912	lcf99	lcf931	lcf81	lcf81	lcf931	lcf931	lcf931
332	Bare rock	lcf99	lcf99	lcf99	lcf99	lcf931	lcf81	lcf81	lcf931	lcf931	lcf931
333	Sparsely vegetated areas	lcf912	lcf912	lcf912	lcf99	lcf931	lcf81	lcf81	lcf931	lcf931	lcf931
334	Burnt areas	lcf912	lcf912	lcf912	lcf99	lcf931	lcf81	lcf81	lcf931	lcf931	lcf931
335	Glaciers and perpetual snow	lcf99	lcf99	lcf99	lcf99	lcf94	lcf94	lcf94	lcf94	lcf94	lcf94
411	Inland marshes		lcf99	lcf99	lcf99	lcf99	lcf81	lcf81	lcf912	lcf931	lcf99
412	Peatbogs	lcf912		lcf912	lcf99	lcf99	lcf81	lcf81	lcf912	lcf99	lcf99
421	Salt marshes	lcf99	lcf99		lcf99	lcf931	lcf81	lcf99	lcf912	lcf931	lcf931
422	Salines	lcf99	lcf99	lcf912		lcf931	lcf81	lcf99	lcf99	lcf931	lcf931
423	Intertidal flats	lcf99	lcf99	lcf912	lcf99		lcf81	lcf99	lcf931	lcf931	lcf931
511	Water courses	lcf912	lcf912	lcf99	lcf99	lcf99		lcf912	lcf912	lcf931	lcf931
512	Water bodies	lcf912	lcf912	lcf99	lcf99	lcf931	lcf99		lcf99	lcf931	lcf931
521	Coastal lagoons	lcf912	lcf912	lcf912	lcf83	lcf931	lcf99	lcf99		lcf931	lcf931
522	Estuaries	lcf912	lcf912	lcf912	lcf99	lcf931	lcf99	lcf99	lcf99		lcf931
523	Sea and ocean	lcf99	lcf99	lcf912	lcf83	lcf932	lcf99	lcf99	lcf912	lcf912	

ANNEX 2 - 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 expansion: Land uptake by residential buildings altogether with associated services and urban infrastructure (classified in CLC 111 & 112) from non-urban land (extension over sea may happen).

- lcf21 Urban dense residential expansion: Land uptake by continuous urban fabric (CLC 111) from non-urban land.
- lcf22 Urban diffuse residential expansion: Land uptake by discontinuous urban fabric (CLC 112) from non-urban land.

LCF3 Expansion 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 Expansion of industrial & commercial sites: Non-urban land uptake by new industrial and commercial sites.
- lcf32 Expansion 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 Expansion of harbours: Development of harbours over non-urban land and sea.
- lcf34 Expansion of airports: Development of airports over non-urban land and sea.
- lcf35 Expansion of mines and quarrying areas: Non-urban land uptake by mines and quarries.
- lcf36 Expansion of dumpsites: Non-urban land uptake by waste dumpsites.
- lcf37 Expansion of construction sites: Conversion from non-urban land to construction site.
- lcf38 Expansion 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 land cover/use types. Rotation between annual crops is not monitored by CLC.

- lcf41 Expansion of grassland and longer-term fallow land: Conversion from crop land to grassland as an agricultural rotation or for cattle husbandry.
  - lcf411 Uniform expansion of grassland and longer-term fallow land: Large parcels conversion from crop land to grassland.
  - lcf412 Diffuse expansion of grassland and longer-term fallow land: 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 permanently irrigated land: Extension of permanent irrigation (incl. rice fields) over arable land.
  - lcf422 Other internal conversions of arable land: Other conversions between arable land and permanently irrigated land and 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 permanently irrigated land: Conversion from permanent crops (incl. CLC241) to permanently irrigated land 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 crops (CLC241).
    - lcf444 Diffuse conversion from permanent crops to arable land: Conversion from vineyards and orchards to associations of annual and permanent crops (CLC241).
- lcf45 Conversion from arable land to permanent crops: New plantation of vineyards, orchards and olive groves on arable land.
    - lcf451 Conversion from arable land to vineyards and orchards: New plantation of vineyards, orchards on arable land.
    - lcf452 Conversion from arable land to olive groves: New plantation of olive groves on arable land.
- lcf46 Conversion from grassland to arable land and permanent crops: Conversion from grassland to arable and permanent crops.
    - lcf461 Conversion from grassland to permanently irrigated land: Conversion of grassland to permanently irrigated area and rice fields.
    - lcf462 Uniform conversion from grassland to non-irrigated arable land and permanent crops: Conversion of uniform grassland areas to non-irrigated annual and permanent crops.
- lcf47 Changes of agroforestry: Conversion between cultivated land or open pasture and agroforestry systems such as dehesas.
    - lcf471 Conversion from any agriculture class to agroforestry: Conversion from any agriculture class to agroforestry.
    - lcf472 Conversion from agroforestry to any other agriculture class: Conversion from agroforestry to any other agriculture class.
- lcf48 Conversion of complex agricultural areas into permanent crops: Conversion of complex agricultural areas into permanent crops.
- lcf49 Other internal conversion of complex (mosaic) agriculture classes: Other internal conversion of complex (mosaic) agriculture classes.

LCF5 Conversion from other land cover to agriculture: Expansion of agriculture land use.

- lcf51 Conversion from forest to agriculture: Deforestation for agriculture purpose, including agricultural conversion of transitional woodland shrub.
    - lcf511 Uniform 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 fellings, 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 Uniform 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.
- lcf53 Conversion from wetlands and water to agriculture: Conversion of wetlands and water to any type of farmland (CLC2xy).
- lcf54 Conversion from developed areas to agriculture: Conversion of urban land to any type of farmland (CLC2xy).

LCF6 Increase in forest land cover and other semi-natural areas: Farmland abandonment and other type of withdrawal of agriculture activity or other land cover in favour of forests or semi-natural land.

- lcf61 Expansion of forest and shrub on agricultural area: 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 Expansion of semi-natural area on agricultural area: Farmland abandonment in favour of natural or semi-natural landscape (except forests and transitional woodland shrub, see lcf61). Some odd cases are recorded as lcf99 Rare or not-applicable changes.
- lcf63 Forest creation, afforestation: Forest and woodland creation from other semi-natural, wetlands, water or artificial areas.

LCF7 Forest internal land cover changes: Conversion between forest classes and / or the transitional woodland and shrub class.

- lcf71 Conversion of transitional woodland and shrub to forest: Conversion from transitional woodland to broadleaved, coniferous or mixed forest, taking place when trees have reached the canopy closure and heigh defined for mature forest (30% and 5-7 m in CLC in general but can be different e.g. for Boreal forests).
- lcf72 Forest conversion to transitional woodland and shrub: Conversion from forest to transitional woodland and shrub class (CLC324).
- lcf73 Conversion between broadleaved, coniferous and mixed forest: Conversions between broadleaved, coniferous and/or mixed forest (CLC311, 312 and 313).

LCF8 Water body and wetland creation and management: Creation of dams, reservoirs, wetlands and possible consequences of the management of the water resource on the water surface area.

- lcf81 Water body creation: Extension of water surfaces resulting from the creation of dams and reservoirs.
- lcf82 Water body management: Shrinking of water bodies because of management or natural reasons.
- lcf83 Wetland creation and expansion of peat extraction: Wetland creation and expansion of peat extraction.

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, plus rare or not-applicable changes.

- 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 without forest reduction: Rotation between the dry semi-natural and natural land cover types of CLC (except forest and transitional woodland shrub).
    - lcf913 Semi-natural rotation by forest reduction: Rotation from forest and transitional woodland shrub to dry semi-natural classes.
- lcf92 Forests and shrubs fires: Forest and shrub 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 10 years interval, except for very aggregated statistics.
- lcf93 Coastal processes: Any process of coastal erosion or accretion.
    - lcf931 Coastal erosion: Conversion of all land cover types to intertidal flats, estuaries or sea and ocean. As the tide level when the satellite image is shot being unknown for the photointerpreters, the coastal erosion flow has to be used very carefully.
    - lcf932 Coastal accretion: Conversion from intertidal flats, estuaries or sea and ocean to other classes.
- lcf94 Decrease of permanent snow and glaciers: 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 Rare or not-applicable changes: In this category are recorded land cover changes that are rare, more likely improbable or not applicable due to definitions in nomenclature.

European Topic Centre on Urban, Land and Soil Systems (ETC-ULS)
Environment Agency Austria
Spittelauer Lände 5
A-1090 Vienna/Austria
Tel.: +43 1 313 04
Web: http://uls.eionet.europa.eu/

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