# D4.2 – Part A:

# Land and Ecosystem Accounting in the coastal zones of the Mediterranean and Black Sea Basins

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## Table of Contents

## Executive Summary

*Land and ecosystem accounts provide the user with a picture of the ecological status of an area, or region, so that management decisions can be made. Such accounts are designed to provide key indicators or metrics that characterise the integrity of the ecosystems being considered. In this work we show how they have been developed for the Mediterranean and Black Sea Basins. Accounting methods are fundamentally data driven and application focussed. In this report we describe what data resources are available for land cover, biodiversity and ecosystem productivity, and for land cover how they can be processed to make a consistent set of accounts for the two sea basins. We also describe the work that has been done to test the robustness of these accounts and how they can be used to support decision making at the regional and CASE scales.*

*We recommend that*

*(1) accounting methods are taken forward in conjunction with the wider indicators that PEGASO has initiated, and that appropriate institutional mechanism for maintaining these sources of information are considered as part of the Business Plan that is now being developed as a legacy of the Project; and,*

*(2) that wherever possible accounting methods are considered in any future work programme undertaken by the Platform to make periodic regional assessments and analysis at the CASE scale, so that the outcomes and benefits of such work are fed back to the wider community.*

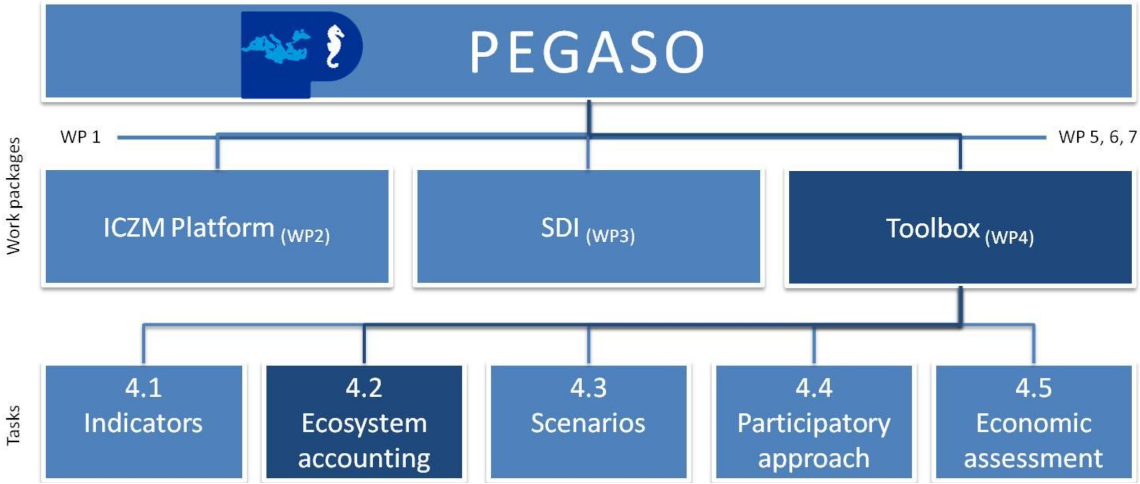
## 1. Introduction

Integrated Coastal Zone Management (ICZM) has been promoted as a set of principles to support decisions and policies aiming to resolve conflicts over multiple resource use demands which are often found competing in limited coastal zone spaces. The Mediterranean and Black Sea coasts exhibit a diverse range of ICZM practices that address a number of complex resource issues. In recent decades, the fast-growing demands for mass tourism, intensive agriculture, fisheries, transport and energy supply have brought wide-spread concerns of environmental degradation and generated conflicts over resource access and use. To help address these problems an Ecosystem Accounting methodology was developed in Europe (EEA, 2011) with the goal of assessing major environmental assets including land and water resources and their use and also primary ecosystem functions such as carbon sequestration, production of biomass and habitats for biodiversity.

### The context of PEGASO

The main objective of PEGASO is to build on existing capacities and develop common novel approaches to support integrated policies for the coastal, marine and maritime realms of the Mediterranean and Black Sea Basins in ways that are consistent with and relevant to the implementation of the ICZM (Integrated Coastal Zone Management) Protocol for the Mediterranean. PEGASO seeks to do this through three innovative actions:

a) Constructing an ICZM governance platform (WP2) as a bridge between scientist and end-user communities;
b) Refine and further develop efficient and easy to use tools for making sustainability assessments in the coastal zone (WP4). These tools include indicators, environmental accounting, scenario construction, participatory approaches and valuation. The aim is to create a suite of tools and techniques that can be used to make a multi-scale assessment in the coastal zone in the Mediterranean and Black Sea Basins. They will be tested and validated in a multi-scale approach for integrated regional assessment through a basin wide diagnostic and a number of relevant pilot sites; and,
c) Implementation of a Spatial Data Infrastructure (SDI), to organize, harmonize and standardize spatial data (WP3). This interactive web portal will support information sharing as well as manage communications, normalisation and dissemination of consortium spatial and statistical information datasets.




PEGASO general organization, work packages and tasks (from DoW).

In fact, these three innovative actions are linked: Developing a good governance platform help the improvement of the objectives of the project through the exchange of experience and data. Moreover the building of the SDI which is a basic PEGASO service will allow technically, countries and stakeholders to share and use SDI information as they need. Finally, the toolbox will use data from the SDI but in turn feed it with new data, indicators, accounts, etc.

The following report forms "PART A: LEAC" for the overall final deliverable D4.2 "Report and Accompanying database and supporting materials on LEAC Methodology and how to apply it in the CASEs".

In this Part on LEAC we set out the background to and results for the work on land and ecosystem accounting that was done in PEGASO. Throughout the aim has been to build on the experience that has been build up on Europe, and extend the concept and methods to the whole of the Mediterranean and Back Sea Basins. In **section 2** we describe the history of the concepts and the accounting approach. **Section 3** reviews methods, data sources and results. **Section 4** describes the accounts themselves and **section 5** describes the way the outputs were tested and then **section 6** moves on to look at some applications. In the final **section 7** of this Part of the deliverable we look at the lessons learned and make recommendations for future work on land and ecosystem accounts.

## 2. Review of Ecosystem Accounting

### 2.1. History of Accounting

Accounts, whether they be financial or environmental are primarily decision support tools. They are designed to provide the user with a picture of the financial or material status of an organisation or system, so that management decisions can be made. In terms of what makes a good set of accounts, therefore, the most important thing is that they track the *key indicators* or *metrics* that characterise the integrity of the organisation or system being considered. They are therefore fundamentally *data driven and application focussed*. In a financial context these metrics might be profit and loss, costs and expenditures. In an environmental context, they might be measures of the stock of resources and how they are dissipated or restored over time.

In this part of our report we focus on environmental accounts. They are a tool that is especially important in the context of ICZM, which is primarily concerned with the governance of the coastal zone. A key ingredient of 'good governance' (see Deliverable D2.1C, Haines-Young et al., 2013) is reliable information presented in a way that enables users to make evidence-based judgements. Environmental accounts therefore provide part of the platform on which effective ICZM can be built. By way of introduction we outline the history and wider interest in the idea of environmental accounts, so that the contribution of the work done in PEGASO can be more easily seen.

The need to develop and apply systems of economic-environmental accounting has been widely recognised by the international community. Much of the interest over the last two years can be traced to 'Rio' and Agenda 21, which emphasised the need for reform of national systems of economic accounting. The aim was to ensure that the value of environmental services and resources as well as the impacts of economic activities are expressed clearly when calculating our national wealth. Agenda 21 expressed the challenge as follows:

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

Since that time, an international programme of development has been led by the United Nations Statistical Division (UNSD) and its 'London Group', to devise a System of Integrated Environmental and Economic Accounts, known as SEEA. These efforts have most recently culminated in the publication of a revised standard for the 'Central Framework' in May 2012. Work on the additional portions of the SEEA, and particularly those that are of interest in the context of PEGASO and ICZM, are covered in the work done for the second volume on 'Experimental Ecosystem Accounts and Applications and Extensions' (SEEA, 2012).

Although accounting concepts are well understood, the challenge for the environmental accounting community is to find a suitable set of metrics that can be used to characterise ecosystems. Edens and Hein (2013) have recently set out some of the challenges, which include definition of ecosystem services in the context of accounting, their allocation to institutional sectors, the treatment of degradation and rehabilitation, and valuing ecosystem services consistent with 'Standard National Accounting' (SNA) principles. In this work we focus particularly on problems of degradation and rehabilitation of ecosystems and ecosystem function in the coastal zone, approached from the perspective of land cover.

A key player in taking this kind of work forward in Europe has been the European Environment Agency (EEA), which through the developing of its Land and Ecosystem ACccounts (LEAC) has shown how spatially explicit accounts for land cover can now routinely be prepared (EEA, 2006). The methods grew out of work carried out in the mid-1990s by a UNECE task force on physical environmental accounts (see UNECE, 1995, Parker et al. 1996, and Haines-Young, 1996), which sought to describe the relationship between the stock of land and the associated uses as a set of linked tables. Building on this experience EEA (2011) has described how the concept of land accounts can be embedded in a more comprehensive set of 'Simplified Ecosystem Capital Accounts' which aim to construct balance sheets for assets and liabilities that describe the status of our natural capital in physical and monetary terms. It is suggested that these balance sheets can be used to estimate the magnitude of ecological debt in physical and monetary terms so that while conventional metrics such as GPD remain unchanged in accounting terms a more informed judgement can be made of what it tells us by supplementing it with appropriate adjusted new aggregate measured derived from the ecosystem accounts.

The construction and implementation of ecosystem capital accounts, and how we use them as part of more comprehensive wealth account systems is still a long term goal. Many technical and institutional barriers remain to implementing such approaches, not least relating to the way these would operate and influence decision making at different spatial and temporal scales. A project such as PEGASO cannot, by itself, overcome many of these issues. Nevertheless, it has sought to make a contribution to these important debates by exploring how land cover information can be used to represent the stock and change of key elements of natural of natural capital in the coastal zones of the Mediterranean and Black Sea Basins, and how species data can be used alongside that of land cover to understand the pressures on biodiversity. A particular contribution is the exploration of how concepts that have mainly been developed for the terrestrial environment can be transferred to the coastal and marine sectors so that a more holistic picture of the fate of natural capital in all these environments can be established.

In terms of the overall development of environmental accounting approaches we are now firmly in a phase of experimentation and piloting, prior to the implementation of the basic concepts. In addition to the testing that will be stimulated by the publication of Volume II of SEEA, the WAVES[1] Initiative being led by the World Bank will trigger further interest. The latter seeks to work with central banks and ministries of finance and planning across the world to integrate natural resources into development planning through environmental accounting. Thus for PEGASO the focus

[1] Wealth Accounting and the Valuation of Ecosystem Services; see http://www.wavespartnership.org/waves/

throughout has been to develop *practical*, *operational* procedures that are *relevant* to the needs of the ICZM 'end-user' community across the two sea basins.

## 2.2. Approaches to Environmental Accounting

Current approaches to integrated environmental and economic accounting generally regard environmental accounts as taking the form of a series of 'satellite' tables that sit alongside the economic accounts, and which can be used to better interpret changes in a broader measure of wealth. The approach has a number of advantages, not least that the accounting measures can be expressed in *physical* rather than monetary units. Thus environmental accounts can be used directly to describe the physical changes ('flows') of materials and energy, and hence the extent to which more sustainable patterns of consumption and production are being achieved. This might, for example, be done using some efficiency metric that expresses the 'decoupling' of economic growth from impact or dependency on natural resource systems. Alternatively, physical accounts can also be used as the basis of estimating the expenditures needed to manage, restore or protect the environment, and hence the defensive costs that society has to bear given the pressures it puts on natural capital. In keeping with this general philosophy, the accounts developed in PEGASO have also approached the problem of characterising the natural capital in the coastal zone in physical terms.

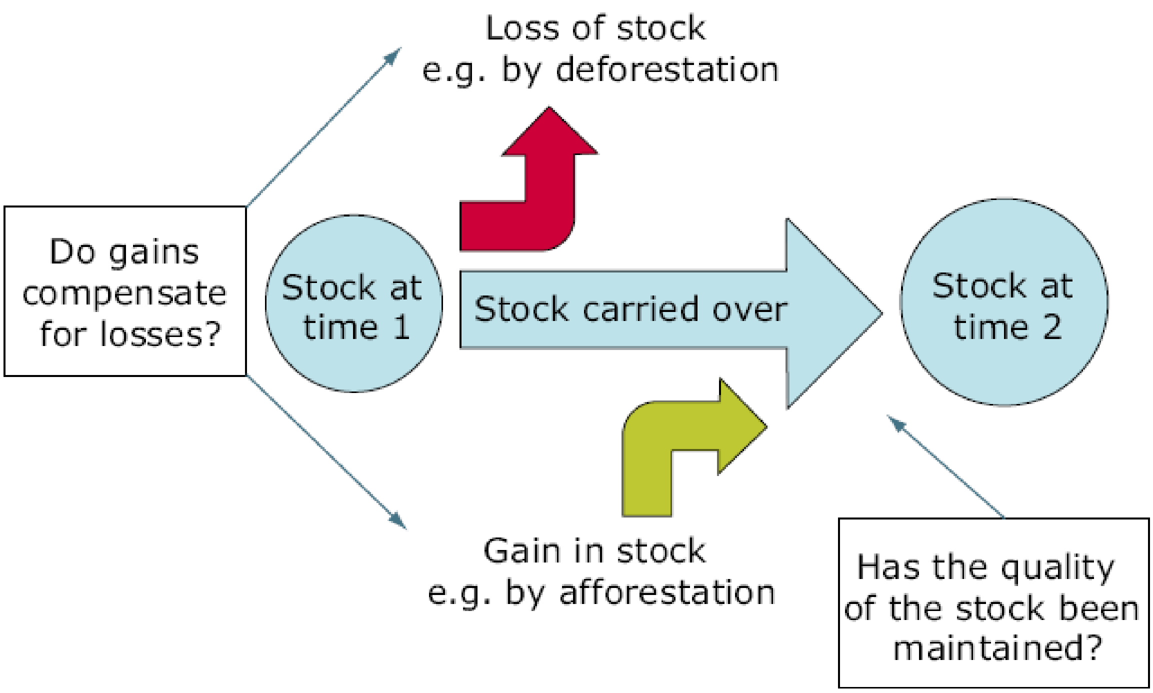



**Figure 1**: Environmental Accounting Model (after EEA, 2006; Haines-Young, 2009)

The overall methodology is best explained by reference to accounts for land cover (see Figure 1). If land cover changes over time, then the process can be documented by tracking the stocks of different types of land cover. In the case of wetlands, for example, there may be losses to the initial stock through drainage or conversion; while there might also be gains through restoration and natural succession. These stocks and flows can be recorded in an accounts which shows the opening and closing stocks for each type of resource and the 'flows' into and out of this stock that have been recorded. Although the simple mode shown in Figure 1 only deals with wetlands, it can clearly be applied to all the different types of land cover in an area and the processes of change that relate to them, and in this way a complete set of accounts set up. Despite its simplicity, however, the model does illustrate the valuable role that the accounting approach plays in policy and management debates. Thus observing the changes in stock or quantity of a particular type of land cover (measures in area units), such as wetland, we may ask whether the gains actually compensate the losses that were experienced over the same time period. Questions about compensation are fundamental to the issues associated with strong and weak notions of sustainability. Alternatively, we might be concerned as to whether the *quality* of the stock carried over from time 1 to time 2 has been maintained in terms of the benefits it provides to people or the support it offers to wider ecosystem functions. Maintaining the functional integrity (or condition) of natural capital stocks is also fundamental to planning for sustainability.

Ideally environmental accounts should therefore help users to understand changes in the quantity and quality of key stocks or resources. For land cover, we are well-placed in terms of monitoring changes in the area of different land cover types, but less well off in terms of measuring the functional status of these different resource categories. Limitations arise both from the difficulty of measuring ecological condition over wide areas, and of understanding precisely how condition relates to the benefits that people derive from natural capital via ecosystem services. Although the status of biodiversity is of interest in its own right, for the work undertaken in PEGASO we have also used accounts relating changes in the abundance, range and conservation prospect as a proxy of the overall condition of natural capital.

The model shown in Figure 1 is a simplification of the environmental accounting approaches currently being developed in Europe. For example, the EEA's ecosystem accounting framework (Weber, 2007) attempts to describe changes from both natural and human actions as they impact on primary ecosystem functions, such as productivity, biomass storage, habitat provision, water cycle and other aspects of environmental regulation. Energy and matter are incorporated in various forms within the ecosystem, such as biomass, habitats, soil organic carbon, all of which are essential for maintaining biodiversity and associated biophysical processes and ultimately the contribution that ecosystem make to human well-being though ecosystem services. Estimates of changes in the stock of natural capital are then made on the basis of the differences between the gains and losses of matter or energy per unit area.

The conceptual layout for these 'capital' accounts is shown in Figure 2. The rigor that the accounting approach brings to such calculations is that if the data are of sufficient quality, and no essential components are left un-accounted, then the account can be 'closed', meaning that the balance can be estimated, with the stocks and flows on the two sides of equation below showing the same amount of the accounted measures.

*Opening stock, yr1 + flows, yr1 (A, B) = closing stock, yr1 - flows, yr1 (C, D)*

| | | natural | human | |
|---|---|---|---|---|
| year 1 | **Opening stock** | flow A (+) | flow C (+) | Closing stock |
| | | flow B (-) | flow D (-) | |
| year 2 | Opening stock | flow A (+) | flow C (+) | Closing stock |
| | | flow B (-) | flow D (-) | |
| year 3 | Opening stock | flow A (+) | flow C (+) | **Closing stock** |
| | | flow B (-) | flow D (-) | |

**Figure 2**: The concept of flow accounts

For accounts to be constructed we need to identify the resource stocks that are of interest, and the time period over which the accounts will be constructed. A further consideration is the 'accounting unit' that will be used to report the information. In PEGASO, we have followed the approach developed by the EEA in their land accounting work, which has been based on constructing an 'accounting grid' at 1km x 1km resolution for the whole of Europe. The grid is used to record land cover and any other associated attributes for each grid cell (such as where it sites in the different tiers of administration, or its biophysical characteristics such as altitude), as well as information relating to the species and habitats found at that location. The data for each 'accounting cell' can then be aggregated, for reporting purposes and accounts generated for any larger spatial unit. In this way spatially explicit accounts can be generated and the key stocks and changes associated with them mapped.

For a brief overview on the methodology and approach of the Land and Ecosystem Accounting (LEAC) a fact sheet was produced (see Appendix), which is now also included in the PEGASO WIKI and can be downloaded at: http://www.pegasoproject.eu/wiki/Application_of_LEAC_in_PEGASO.

## 3. Building the PEGASO Land Accounting Framework

In PEGASO the European accounting grid has been extended to the entire coastal zones of both the Mediterranean and Black Sea Basins. For the purposes of making land accounts **'coastal zone' has then been defined as the areas within 50km of the coastline.** The accounting grid also extends across the near shore and marine parts of the study area so that both land and sea accounts can be constructed where data are available.

The relevance and practicality of the accounting approach proposed for Europe by the EEA (2011) was considered as the basis of the work done in PEGASO. Two criteria were important. First the availability of suitable data for all or the major parts of the study area. Second, the interest that the PEGASO end-user community had in developing the different accounting themes.

Conceptually, the EEA approach suggests that environmental accounts should span six major thematic areas: land, water, biomass, biodiversity, abiotic interactions and biotic interactions. In an initial phase of the work in PEGASO we looked at the availability of data for each of these areas (see Internal deliverable ID4.2.3 in Appendix, Ivanov et al., 2012a), and noted those where progress might be limited by lack of information. It should be noted that even in Europe the EEA have found that significant data deficiencies exist that hinder implementation of their approach. We found a similar picture in PEGASO, especially given the requirement to extend the work to coastal and marine waters.

**Table 1**: Criteria used to select data sources for building environmental accounts

| | FASTAT example (FAO, 2005) | PEGASO LEAC |
|---|---|---|
| **Spatial coverage** | Global coverage | Mediterranean and Black Sea coastal areas (at least 50 km from coastline) |
| **Data production** | Regular, committed sustainable data collection activities by the countries | Committed partners (contributions to SDI) |
| **Temporal coverage** | Time-series data | At least two points in time (years 2000 and 2011 |
| **Quality assessment** | Data quality assessment performed | Data quality assessment performed |
| **Metadata for users** | Statistical metadata available | Statistical metadata available |
| **Data release** | Data is edited and validated | Data is edited and validated |

Throughout the work in PEGASO the focus has been on developing a methodology that is *operational* in the sense that the methods are both fully reproducible and the datasets likely to be available in the future so that updating and hence maintenance of the accounts is possible. To assist in this process, the kinds of criteria used for the selection of national and international statistics was reviewed and adapted for the purposes of PEGASO. Table 1 shows the criteria suggested by the FAO, and how they were applied in PEGASO to the section of data. In applying these criteria particular attention was paid to the issue of data quality. Not only was the question of whether stocks and flows in the different thematic areas could be properly defined and quantified with the available data, but also their reliability was investigated by testing the estimates using them with a number of independent sources, where these were available.

**Table 2**: Data sources for PEGASO environmental accounts

| Themes | Space | | Biodiversity | | Water | | Productivity/ biomass | | Abiotic interactions | | Biotic interactions | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Land | Sea | Land | Sea | Land | Sea | Land | Sea | Land | Sea | Land | Sea |
| Accounting inputs | PLC CORINE LC Nile delta LC (NARSS) | CORINE LC (coastal waters) | Art. 17 Protect. Species Protect. areas | Art. 17 Prot. Species EMODNet (VLIZ) Prot. areas | AQUA-STAT (FAO) | | Bio-C (EEA) | FishStat (FAO) EMIS (JRC) | FATE (JRC) | | | |
| Testing phase | PLC/ CORINE: IRA PLC /CORINE: cases | | Protect. areas Art. 17 | | | | | | | | | |
| Modelling | | | | | | PSA, OXYRISK (JRC) | | | Coastal protection (JRC) | | | |

The results of the outcome of our review of data sources for PEGASO is summarised Table 2. The row for the 'accounting inputs' shows that there is potentially good coverage for land and some characteristics of coastal waters, as well as biodiversity, providing a way could be found to make the data consistent across the two sea Basins (this was achieved through the 'PEGASO Land Cover Product' (PLC) shown in the Table). It also appeared that there was the possibility of characterising ecosystem productivity, at least for the European area. The poor coverage of data for water, and biotic and abiotic interactions meant that these were eliminated from the work programme at an early stage. The other rows in Table 2 show where independent data were available that would allow us to test the accounts, or where in the absence of empirical measurements meant that model-based studies might be the only way of assessing ecosystem change. The latter mainly related to the extension of the accounting framework into marine space, using the outputs from the coastal protection analysis done by Liquete et al. (2013) and the eutrophication modelling done by Druon et al. (2004). Both are potentially capable of providing spatially explicit mapping of a range of indicators than can be used either to characterise aspects of the protection regulation service provided by coastal ecosystems or the threats to coastal zones from pollution. Details of this work and the potential it offers are provided in Internal Deliverable ID 4.2.4 (Ivanov et al., 2012b, see also Appendix).

**Table 3**: The PEGASO accounting matrix

| PEGASO Accounting Matrix | | | | | |
|---|---|---|---|---|---|
| | Biophysical accounts | | Ecosystem services accounts | Socio-economic accounts | |
| | Ecosystem conditions/capital | Human use of ecosystem capital/human impacts | Ecosystem services | Economic valuation | Maintenance of natural capital (investment/ restoration) |
| Land | Land cover/use | Land use (ex. urban sprawl/intensification of agriculture) | Provision of living space, recreation etc. | Wealth generated through real estate; incomes from mass tourism / restoration costs | |
| Biodiversity | Habitats and biodiversity | Protected areas, Homogenization, fragmentation | Resilience, regulatory services, tourism support etc. | Incomes from eco-tourism and mass tourism | Protected areas, conservation success |
| Biomass/ productivity | a) NPP (NDVI) and biomass<br>b) chlorophyll-a | Timber, livestock, crops harvest;<br>fisheries; aquaculture | Food and materials provision<br>Food provision | | |

In parallel with the review and evaluation of potential data sources, we also consulted the PEGASO end-users and Case partners to find out which accounting themes would be especially valuable in their ICZM work. The consultation process followed the interactive procedure for account construction described in PEGASO Internal Deliverable ID4.2.2 (Ivanov et al. 2012c, see also Appendix). Land cover change in the coastal zone was identified as important by many, followed by biodiversity. Less interest was identified for ecosystem productivity. As a result of this process it was decided to carry each of these themes forward, but to place most emphasis on the construction of land cover accounts for the two sea Basins. Table 3 provides an overview of the 'accounting matrix' that was developed as a result of the consultation process. It identifies the kind of biophysical account in the three thematic areas that were taken forward in PEGASO, and shows how they might link to the wider analysis of ecosystem services and socio-economic accounting. In the sections that follow we describe in more detail how the accounts for land cover, biodiversity and productivity were constructed.

## 3.1. Data sources for Land Accounts

For the construction of land accounts in PEGASO an extension of CORINE Land Cover methods used in Europe was extended over the Mediterranean and Black Sea Basins. The basis for the work was the classification of remotely-sensed MODIS multispectral imagery. European CORINE land cover data was used to calibrate a supervised maximum likelihood classification algorithm that was applied to these data. Other ancillary data were also used in the classification process.

The suitability of different data sources were examined in a pilot phase of the work (Ivanov et al., 2012c). In the case of GlobCover[2] and GlobCORINE[3] the mapping for 2005 and 2009 did not follow the same classification procedure as CORINE and so this prevented reliable change detection, or the extraction of 'flows' in the accounting sense. As an alternative MODIS[4] land cover data at 250m resolution was considered. These data are available for the whole globe and have been freely accessible since 2000. A range of products are available, including classified land cover maps, vegetation indices and multispectral reflectance data at 250 m, on a 14 day repeat cycle. The land cover data are published annually at a resolution of 500m but they are not suitable for multi-temporal analysis because the changes observed between years are more influenced by variations in precipitation variations and its influence on vegetation phenology rather than land use changes. As a result, the pilot work in PEGASO looked at the possibility of using the MODIS multi-spectral data to construct CORINE-compatible product.

CORINE[5] is a standardised land cover inventory for the EU and EEA associated countries, available for 1990, 2000 and 2006 at a spatial resolution of 100m. The data sources use to prepare CORINE have better thematic and spatial resolution than MODIS, and so in order to extend the CORINE approach across the two Sea basin other ancillary data were used to provide additional contextual information for the supervised classifier, namely:

- The DMSP-OLS Night-time Lights Time Series[6] was used to help identify urban areas and artificial surfaces. The data on nightlight intensity are available at 1km resolution for the entire globe; the images are composites of cloud-free scenes using all available smooth resolution data acquired during each calendar year since 1992.
- The SRTM 90m Digital Elevation Data (DEM) from NASA, at 90m resolution at the equator, were used to better separate classes by topographic context. For the current application the DTM were resampled at 250 m resolution, and along with altitude, were used to calculate slope and aspect.

A detailed account of the image classification methods used is provided by Ivanov et al. (2013a). The CORINE nomenclature was modified by merging some classes and excluding others to ensure separability using the MODIS multispectral and other inputs at 250 m spatial resolution. For example all the classes characterised by continuous hard or paved surface were merged in a single class '111', while the class of discontinuous urban land, including open spaces (agriculture, parks, green areas) is kept separate '112'. The procedure enabled a European CORINE land cover type product, to be extended over the African and Near-east Mediterranean areas and East European temperate areas. Land cover classifications were made for the years 2000 and 2011. Example output is shown in Figure 3. The classification used for the resulting 'PEGASO land cover product' is shown in Table 4.

[2] http://due.esrin.esa.int/globcover/
[3] http://dup.esrin.esa.int/prjs/prjs114.php
[4] MODIS land products can be accessed and downloaded from NASA's data centre: http://reverb.echo.nasa.gov/reverb/#utf8=%E2%9C%93&spatial_map=satellite&spatial_type=rectangle
[5] CORINE Land cover can be downloaded from EEA's data centre: http://www.eea.europa.eu/data-and-maps/data/corine-land-cover-2000-raster-2
[6] http://www.ngdc.noaa.gov/dmsp/downloadV4composites.html

**Figure 3**: The extent of the PEGASO land cover product

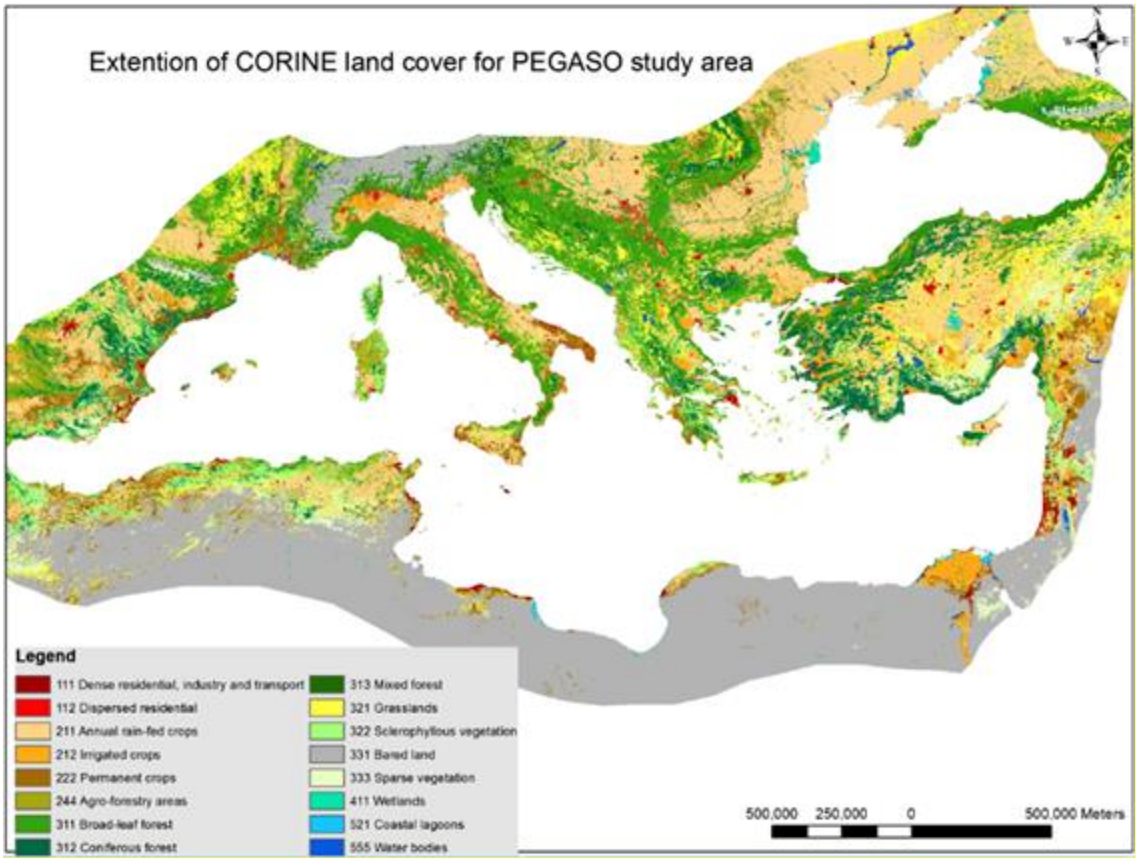



**Table 4**: PEGASO land cover nomenclature

| Land cover Level 1 | | Level 2 | Land cover Level 3 | |
|---|---|---|---|---|
| Urban and artificial cover | 1 | 1 | 111 | Dense residential, industry and transport |
| Urban and artificial cover | 1 | 1 | 112 | Dispersed residential |
| Agricultural land | 2 | 21 | 211 | Annual rain-fed crops |
| Agricultural land | 2 | 21 | 212 | Irrigated crops |
| Agricultural land | 2 | 22 | 222 | Permanent crops (orchards, vineyards, olives) |
| Agricultural land | 2 | 22 | 244 | Agro-forestry areas |
| Forest and semi-natural cover | 3 | 31 | 311 | Broad-leaf forest |
| Forest and semi-natural cover | 3 | 31 | 312 | Coniferous forest |
| Forest and semi-natural cover | 3 | 31 | 313 | Mixed forest |
| Forest and semi-natural cover | 3 | 32 | 321 | Grasslands (merged with pastures) |
| Forest and semi-natural cover | 3 | 33 | 322 | Sclerophyllous vegetation |
| Forest and semi-natural cover | 3 | 34 | 333 | Sparse vegetation |
| Forest and semi-natural cover | 3 | 34 | 331 | Bared land (beaches, rocks) |
| Wetlands | 4 | 4 | 411 | Inland marshes and salt marshes |
| Water | 5 | 5 | 521 | Coastal lagoons |
| Water | 5 | 5 | 555 | Water bodies (rivers, lakes) |

## 3.2. Data sources for biodiversity accounts

At present the construction of biodiversity accounts is experimental, not least because of the lack of consistent data across the two sea basins. Methods for using species and habitat data to construct biodiversity account, even where they are available, are not fully established. Thus the work undertaken in PEGASO was designed to explore what kinds of approach might be feasible in an operational context at least the European part of the study area.

For the implementation of the biodiversity accounts it was decided to explore the information available for a subset of around 1000 species of plants, mammals, amphibians, reptiles and arthropods, that were included in the Annexes of the Habitat Directive (Council Directive 92/43/EEC). These data have been generated by a policy processes that focussed on deriving information on species having European conservation importance. Although progress can be made using these sources, data availability and data quality are identified as the main constraints for constructing a complete set of accounts. A major challenge has been to extract and harmonise the available data, and report them spatially so that comparable results could be published across all the European countries for at least two time periods.

The work on species has focussed on three elements:

- the number of species of European conservation importance present in a given area; this is representative for the time when the countries carried out their assessments for the period 2001 - 2006;
- the prevailing trend of the population sizes of the species present in a given area, which indicates whether the conservation status of the species improved or worsened since their designation in the 1990s; and,
- the species’ prevailing future prospects, which can be used help to assess whether the current trend in conservation success may continue or change in the near future.

All of the data are part of the so-called ‘Article 17’ assessment database, which has been generated by reports from the EU member states and harmonized by the European Topic Centre on Biodiversity. For the purposes of the PEGASO project a new method of down-scaling these data was developed (Ivanov et al., 2012d). It involved using the European CORINE Land Cover data described above, to distribute the species records spatially in those locations to which they are most likely to apply. An example of the outputs generated by these methods using the Article 17 species data is shown in Figure 4. Although we are interested in the coastal zones on the Mediterranean, maps for the whole of Europe have been provided in order to better establish the plausibility of the results using this novel methodology.

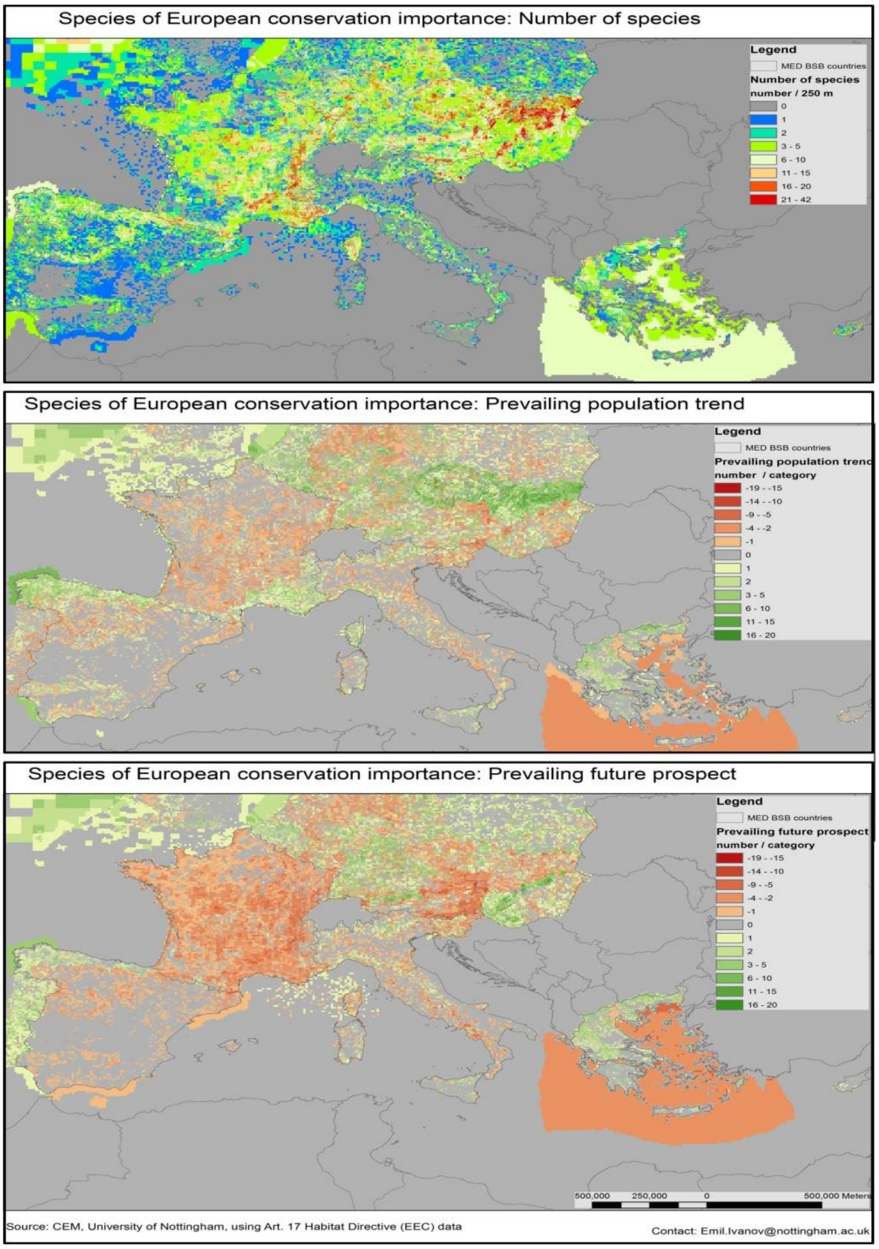



**Figure 4**: Biodiversity accounts based on Article 17 data

Clearly we are currently limited to making species accounts to the European part of the study area. In the future it is likely that other species data can be to extend the mapping to other areas in North Africa and the Black Sea. These other data sources include: the IUCN red-list species and the Protocol for Specially Protected Areas and Biological Diversity in the Mediterranean. The latter identifies species of Mediterranean conservation importance (Annex II: List of Endangered or Threatened Species) and commits the countries that have signed the Barcelona Convention to fulfil monitor and report their of conservation status, in a similar way as done for the European Article 17 Habitats Directive.

## 3.3. Data sources for carbon accounts

Carbon accounts are designed to assess ecosystem primary production and its changes resulting from to human use and impacts. The work reported here follows that being undertaken by the EEA in Europe, namely to find a way of mapping of the relations between ecosystems biomass production (carbon fixation, ecosystem vigour) and the human use of biomass for food, fibre, materials. By assessing each of these elements separately a set of indexes can be constructed to represent the relationships between the human uses and the ecosystem parameters. Such carbon accounts can then be used to assess whether countries (or other administrative units) are overusing their own, or other countries resources, to identify which ecosystems are under threat of degradation and where they are located.

Therefore the carbon accounting model used for the present study is based on the estimation of three parameters (Ivanov et al., 2012b):

- Carbon resource (or annual carbon stock), which is the annual sum of carbon sequestered as a result of Net Primary Production (NPP);
- Carbon storage, which is the multi-annual sum of carbon stored in woody plant material and soils; and,
- Carbon use: annual sum of carbon removed from the ecosystems in the form of crop harvest, timber extraction and grazed biomass by domestic livestock.

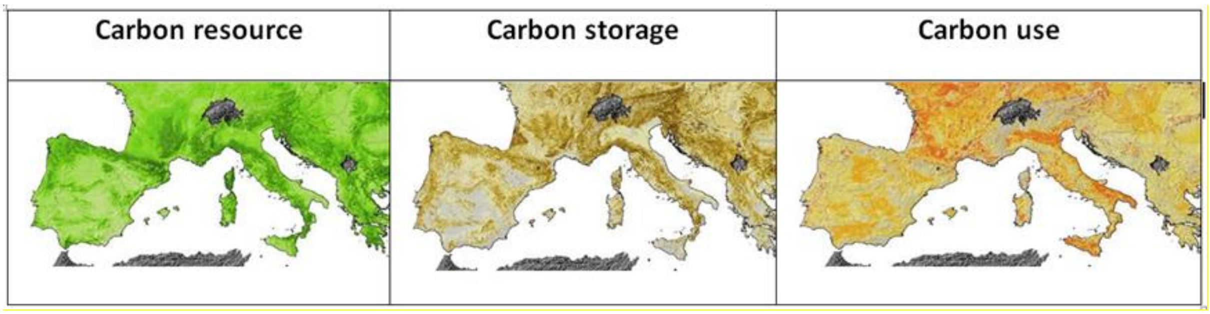



**Figure 5**: Components of the carbon accounting model estimated for year 2000

These parameters were measured and mapped across the [European Part of the] PEGASO accounting grid using the GEOSUCCESS NPP product and Spot-vegetation NDVI. CORINE land cover and national statistics on crops, timber and livestock from FAO were used to estimate carbon removals. All parameters were measures as tons of carbon per $km^2$ and per year (where relevant). Only exchanges related to living processes are considered at this stage, carbon sequestration in the ocean or processes related to fossil fuels were not considered.

On the basis of the analysis of the three separate elements, an aggregated index for carbon balance can be estimated (Figure 6); this is the difference between carbon stocks (annual and multiannual) and carbon use. The index can be used to assess whether the annual resources produced by the ecosystems, as well as the multi-annual stock accumulations are used sustainably by people, e.g.

when the balance is positive; and the reverse – assess if the ecosystems might be under risk of continuous degradation indicated by multi-annual trends of negative carbon balance.

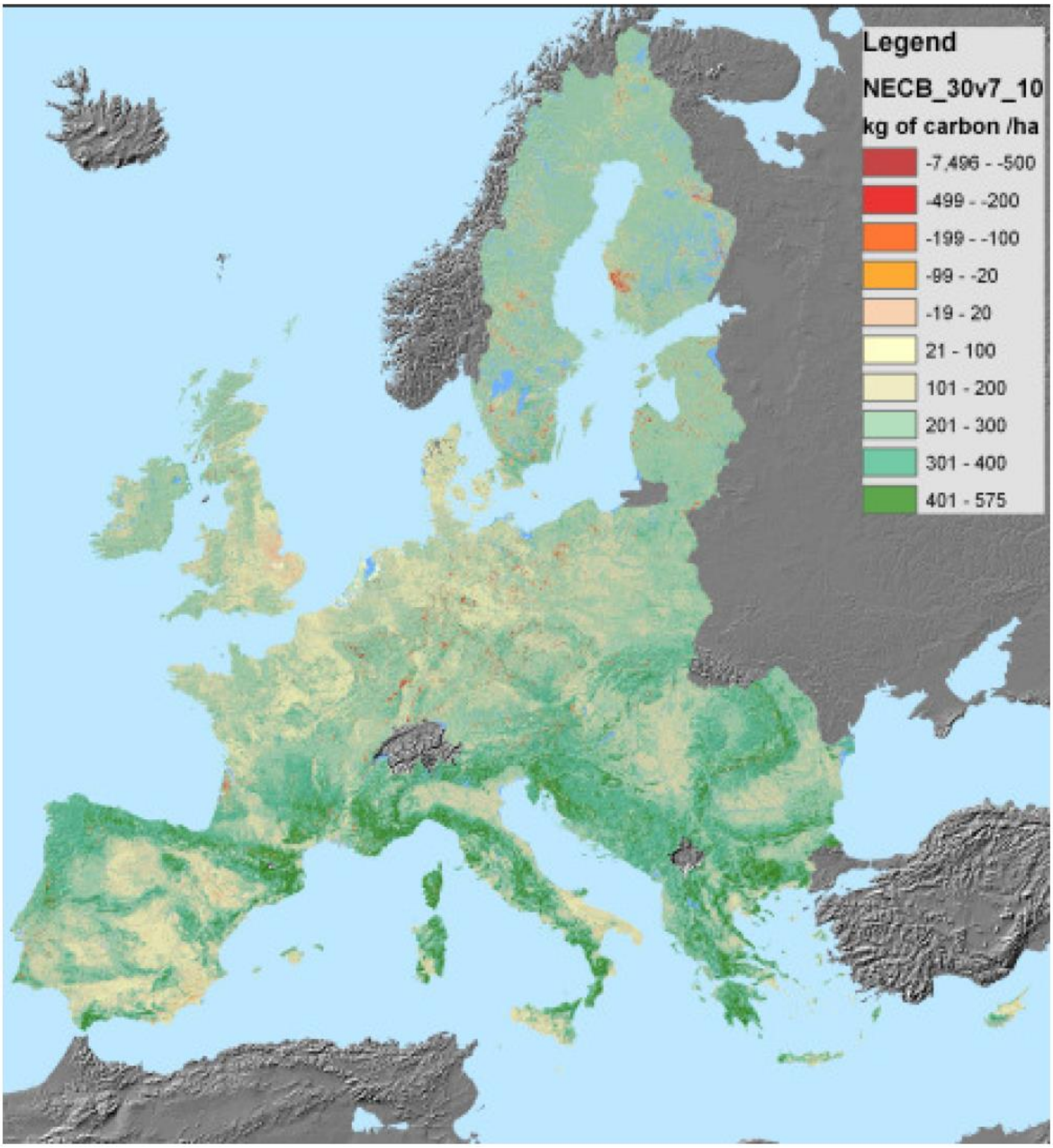



**Figure 6:** Carbon balance for Europe

As in the case of the productivity and biodiversity accounts the outputs are currently restricted to the European part of the PEGASO study area. However, with the new PEGASO Land Cover product, the mapping of biodiversity and carbon can potentially be extended over the whole Mediterranean and Black Sea Basins.

# 4. The PEGASO Coastal Accounts

## 4.1. The LEAC Database

An integrated LEAC database for PEGASO was constructed using the accounting inputs described in Section 3. The backbone of the data resource is the data for land cover for the years 2000 and 2011, the accounting units of land administrative divisions, buffers defining different widths of the coastal strip (i.e. 1km, 10km and 50km) and the boundaries of the PEGASO case study areas.

**Table 5**: Land cover nomenclature used for LEAC database

| | |
|---|---|
| 1 | Urban and artificial covers |
| 21 | Intensive agriculture |
| 22 | Mixed and extensive agriculture |
| 31 | Forest |
| 32 | Grassland |
| 33 | Shrubland |
| 34 | Desert and sparse vegetation |
| 4 | Wetlands |
| 5 | Water |

For the purpose of constructing the database the land cover was transformed from discrete classes at 250 m x 250 m to number of hectares within 1 km x 1 km grid, at level 2 of the PEGASO land cover nomenclature, shown in Table 5. Nine maps were produced in this way, each of them presenting the variability of the class as a continuous variable, in the form of the number of hectares from 0 to 100 (the total area of the grid-cell). The information was extracted to points located at the centroid of each cell and these were assigned unique reference number from the original accounting grid. This allowed the processing of the entire coastal zone of the two basins for the 50k coastal strip. The resulting database consisted of over a million of records. Spatial processing techniques were used to assign to each point further attribute data relating to its location in relation to country, administrative region and distance from coast. The integrated database was then used to extract stocks and flows of land accounts for different accounting units.

For the purposes of extracting data on the changes in land cover (i.e. the flows or stock changes represented in the accounts) the approach as used by the EEA to construct land cover accounts was applied. Overlaying the nine land cover maps described above, for two points in time (2000 and 2011), allowed a total of 81 potential land cover transitions between classes to be identified.

Following the EEA method, these were reviewed and only the plausible transitions retained for mapping purposes.

**Table 6**: Data sources by theme in PEGASO accounting framework

| Theme | | Dataset | Source | Link |
|---|---|---|---|---|
| Space | Land | PLC | UNOTT - PEGASO SDI | http://pegasosdi.uab.es/catalog/srv/en/main.home |
| | | CORINE LC | EEA | http://www.eea.europa.eu/themes/landuse/interactive/clc-download |
| | | Nile delta land cover | NARSS - PEGASO SDI | |
| | Sea | CORINE LC (coastal waters) | EEA | http://www.eea.europa.eu/themes/landuse/interactive/clc-download |
| Biodiversity | Land | Art. 17 | UNOTT - PEGASO SDI | http://pegasosdi.uab.es/catalog/srv/en/main.home |
| | | Protected species | IUCN | http://www.iucnredlist.org/technical-documents/spatial-data |
| | | Protected areas | WDPA | http://www.wdpa.org/ |
| | Sea | Art. 17 | UNOTT - PEGASO SDI | http://pegasosdi.uab.es/catalog/srv/en/main.home |
| | | Protected species | IUCN | http://www.iucnredlist.org/technical-documents/spatial-data |
| | | Protected areas | WDPA | http://www.wdpa.org/ |
| | | EMODNet | VLIZ | http://bio.emodnet.eu/portal |
| Water | Land | AQUA-STAT | FAO | http://www.fao.org/nr/water/aquastat/main/index.stm |
| | Sea (quality) | | | |
| Productivity and biomass | Land | Bio-C | EEA | |
| | Sea | EMIS | JRC | http://emis.jrc.ec.europa.eu/ |
| | | FishStat | FAO | http://www.fao.org/fishery/en |
| Abiotic interactions | Land | FATE | JRC | http://fate-gis.jrc.ec.europa.eu |
| | Sea | | | |
| Biotic interactions | Land | | | |
| | Sea | | | |

After the checking the reliability of the accounts (see Section 5, below) all the accounting inputs and outputs were transferred to the 'PEGASO SDI' both as maps and in the form of pivot tables. Table 6 summarises all the data sources across all the accounting themes in this work, and indicates which is stored on the PEGASO SDI and which are available from other sources.

## 4.2. Land cover stock accounts

Stock accounts for the nine land categories estimated for years 2000 and 2011 at level 2 in the PEGASO nomenclature are shown in Table 7. The data are disaggregated by continent and the 1, 10 and 50 km coastal buffer strips. All data are shown in terms of per cent cover. The stock accounts show the dominance of urban cover in the near coast zone, especially in Asia and the Near East. Agricultural lands and shrublands occupy highest share in Europe, while forests are the most extensive in Asia. The high figure of 8.4% wetlands on the European coasts reflects the existence of extensive wetlands on the north Black Sea coast. The figure on water bodies is also very high in the first 1km, because this includes coastal sea waters; the 10 and 50km buffer only includes freshwater. The second buffer, spanning 10 km from the coast line, shows high forest cover (circa 50%) for the Asian part of the Mediterranean and the Black Sea. In Europe over one third of the land cover is devoted to agriculture. A similar picture is found in the buffer strip beyond 10km. The dominance of deserts and shrubland is a particular feature of all zones in Africa.

The stock accounts reveal consistently larger areas of urban land in year 2011 than 2000, throughout the study region. Intensive agriculture areas were larger in year 2000 on the European and Asian coast, and smaller on the African. Forest stock increased in most of the coastal areas, except the 50 km zone of the Asian and European coast. Desert and sparse vegetation areas have slightly diminished in general. Wetlands and water bodies cannot be well compared for the first km zone, due to the impossibility to distinguish coastal sea waters, however while the stocks of wetlands seem very stable, there is certain decrease of water bodies surfaces on the 1 km and 10 km coastal zones. These changes of stocks of water resources need further investigation as sustained water provision is a key issue for the Mediterranean region.

**Table 7**: Stocks of land types in the Mediterranean and Black sea coastal

| Coastal buffer | Region | Land cover (%cover) | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Urban land | | Intensive agriculture | | Mixed agriculture | | Forest | | Grassland | | Shrubland | | Desert, sparse vegetation | | Wetlands | | Water | |
| | | 2000 | 2011 | 2000 | 2011 | 2000 | 2011 | 2000 | 2011 | 2000 | 2011 | 2000 | 2011 | 2000 | 2011 | 2000 | 2011 | 2000 | 2011 |
| 0-1km | Africa | 15.7 | 16.4 | 7.3 | 7.4 | 8.6 | 8.0 | 3.5 | 3.6 | 1.0 | 1.0 | 12.1 | 12.2 | 32.2 | 31.0 | 3.2 | 3.3 | 16.4 | 17.0 |
| | Asia | 21.5 | 22.3 | 15.8 | 15.4 | 6.7 | 7.1 | 23.3 | 23.5 | 0.5 | 0.5 | 14.1 | 14.0 | 6.2 | 6.2 | 2.5 | 2.5 | 9.5 | 8.5 |
| | Europe | 14.6 | 14.7 | 15.6 | 15.3 | 11.7 | 11.3 | 11.7 | 12.1 | 6.0 | 6.2 | 18.4 | 18.8 | 5.5 | 5.5 | 8.5 | 8.4 | 8.1 | 7.7 |
| 1-10km | Africa | 7.7 | 8.3 | 10.0 | 10.2 | 19.3 | 19.3 | 6.5 | 7.1 | 1.3 | 1.3 | 14.1 | 13.7 | 37.0 | 36.4 | 0.8 | 0.8 | 3.2 | 2.9 |
| | Asia | 7.6 | 7.6 | 20.6 | 20.5 | 6.6 | 6.6 | 46.8 | 47.2 | 0.6 | 0.6 | 11.3 | 11.1 | 4.1 | 4.0 | 0.5 | 0.5 | 1.9 | 1.8 |
| | Europe | 6.4 | 6.6 | 27.5 | 27.4 | 17.2 | 16.9 | 23.4 | 23.7 | 3.9 | 4.0 | 14.9 | 14.8 | 1.9 | 2.0 | 2.7 | 2.7 | 2.0 | 2.0 |
| 10-50km | Africa | 0.9 | 1.1 | 13.4 | 13.6 | 15.8 | 15.9 | 3.8 | 4.3 | 2.6 | 2.6 | 11.5 | 10.8 | 51.3 | 50.8 | 0.2 | 0.2 | 0.7 | 0.7 |
| | Asia | 3.3 | 3.4 | 18.9 | 18.8 | 4.5 | 4.4 | 46.5 | 46.1 | 5.0 | 5.5 | 9.3 | 9.2 | 11.8 | 11.8 | 0.2 | 0.2 | 0.6 | 0.6 |
| | Europe | 2.6 | 2.7 | 33.0 | 32.7 | 11.1 | 10.9 | 34.7 | 34.6 | 5.0 | 5.6 | 8.9 | 8.7 | 3.3 | 3.4 | 0.7 | 0.7 | 0.6 | 0.7 |

## 4.3. Land cover flow accounts

The flexibility of the LEAC database can be illustrated by the way more detailed accounts can be constructed using these data. As noted above, the areas of land occupied by forest represent an important asset in the Mediterranean and Black coastal zones, especially on the European and Asian parts. Complete forest 'flow accounts' for these areas can be extracted from the LEAC database for the period 2000-2011. Instead of using a tabular method to display the accounts, the results are shown in graphical terms in Figures 7 and 8.

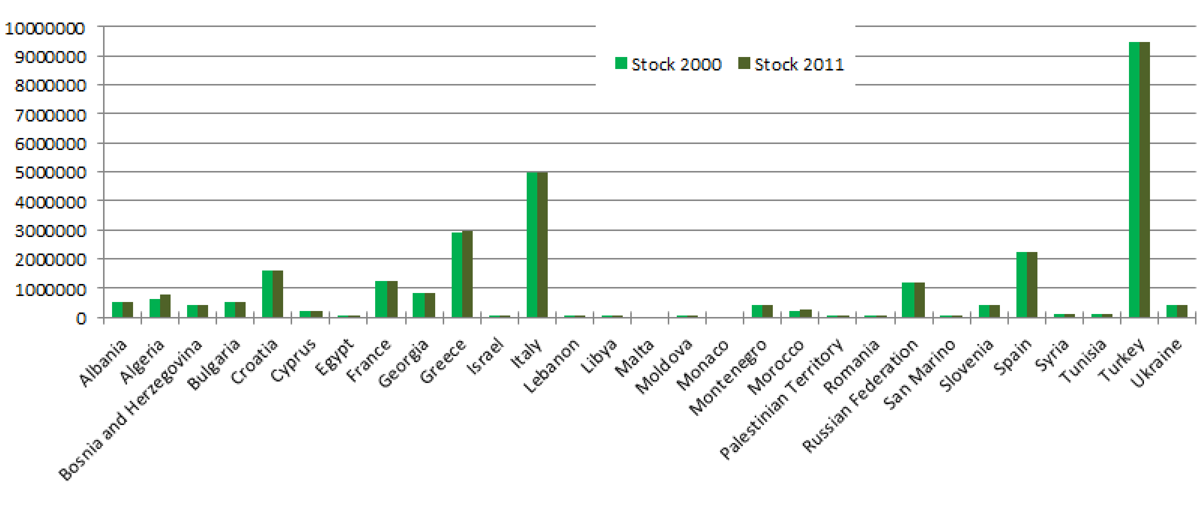



**Figure 7**: Forest stock [ha] in the 50km wide coastal zones (Mediterranean and Black Sea countries)

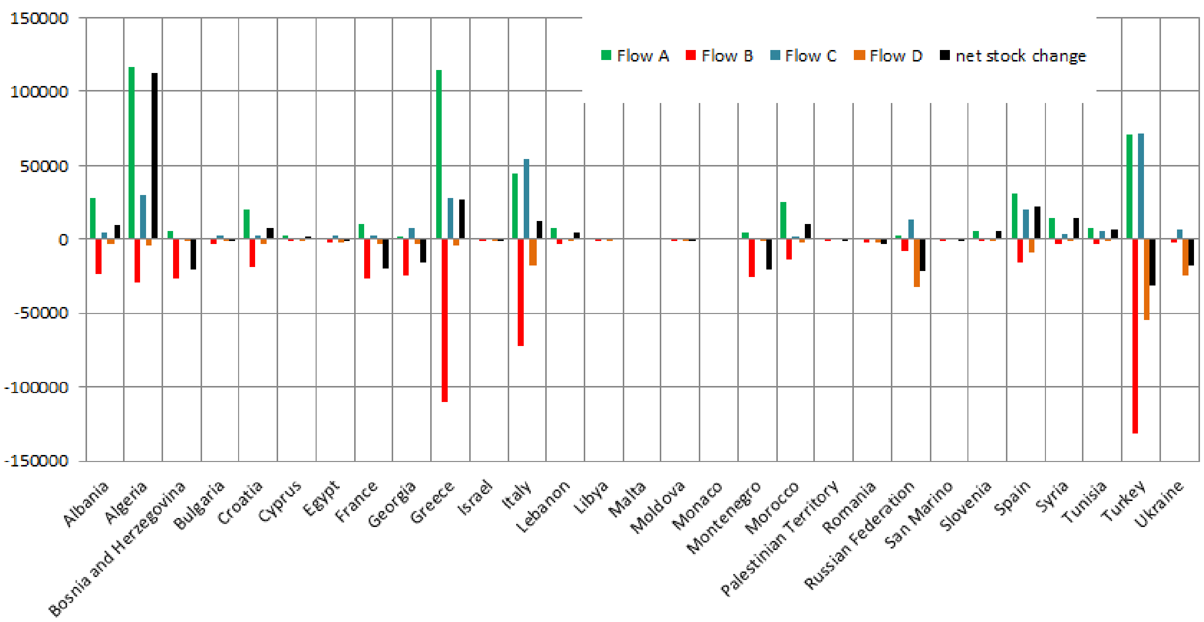



**Figure 8**: Forest flows [ha] in the 50km wide coastal zones (Mediterranean and Black Sea countries)

Figure 7 shows the 2000 opening and 2011 closing stock of forest by country. The flows (Figure 8) were estimated according to the accounting model described above. Flow A is the gain in forested land, which occurred on 'natural' land types, such as grasslands, shrublands, sparse vegetation and wetlands. These transitions can be considered mostly 'natural', following spontaneous processes, such as forest expansion and secondary succession, even if afforestation can take place on natural lands too. Flow B, is the opposite; that is loss of forest. This flow is also considered mostly 'natural'. Such transitions often occur as a result of fires, storms etc. Flow C, registers new forests which were established on previously agricultural or urban land. In this case, it can be assumed that the transition follows an element of human decisions. The new forest may be results of deliberate forest plantations or spontaneous secondary succession on croplands, but following land abandonment. Flow D registers forest loss where either cropland or urban land was established.

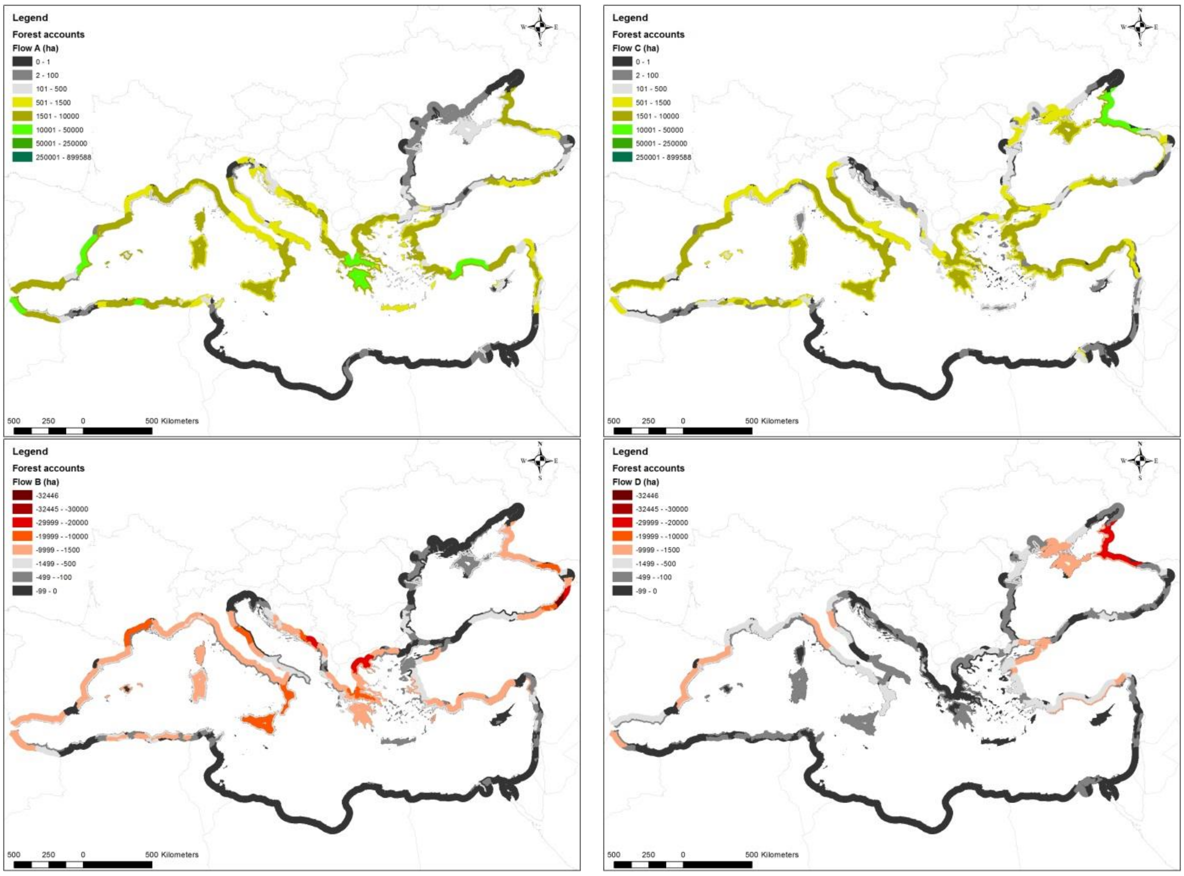



**Figure 9**: Forest flows [ha] in the 50km wide coastal zones shown per administrative unit and buffer zone

Figure 9 illustrates how the accounts data for forest can be mapped using the LEAC database. The maps show the data on the four types of flow discussed above for the 50km coastal buffer. The largest areas of forest lost due to natural factors (flow type B) are to be found in the Greek region of

Macedonia and the highest areas due to human factors (flow type D) – on the Russian Black sea coast. The areas of gains, indicate that also highest rate of afforestation occurred on the Russian coast, and suggest quite intensive land use changes.

## 4.4. Local scale accounts

The flexibility of the LEAC database can be further illustrated by the way data can be prepared for a specific local-scale area of interest, such as one of the PEGASO Case Study Areas. The example selected to show this is the Nile Delta (Figure 10).

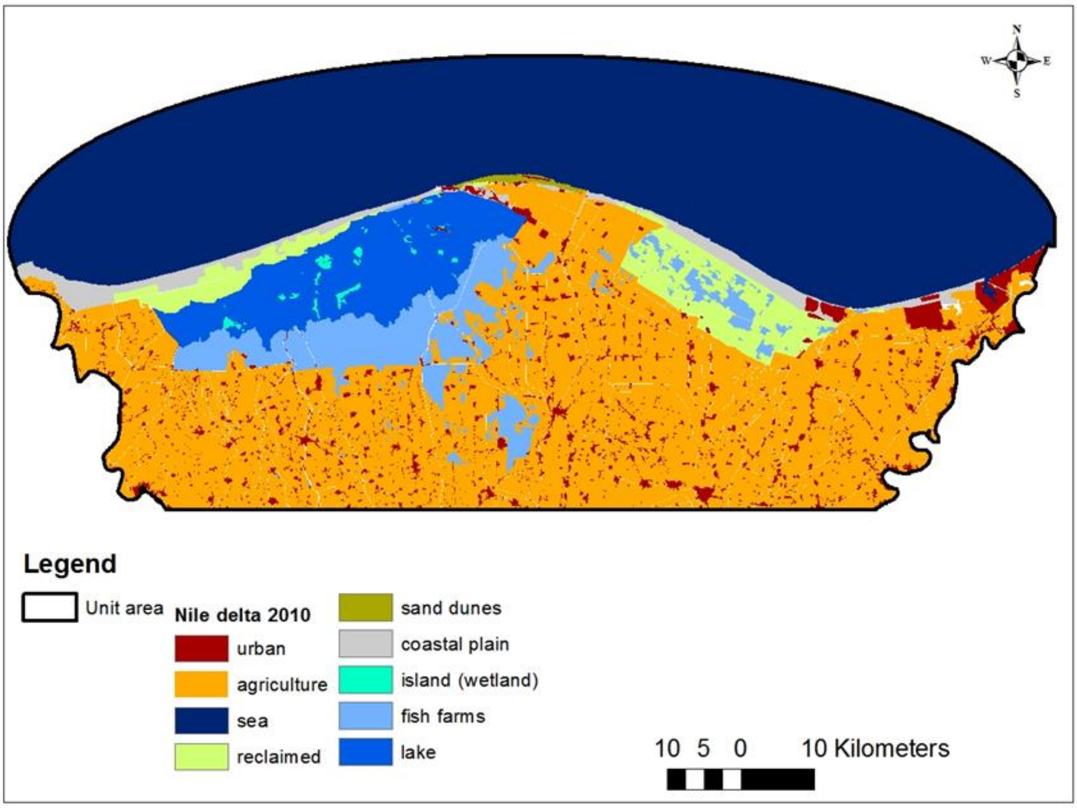



**Figure 10**: Land cover stock for the Nile Delta, 2010

The accounts were produced using NARSS data at very high spatial resolution, rather than from the sources used to develop the PEGASO Land Cover Product. However, in order to provide consistency with the broad scale analysis, these local data have been classified using the PEGASO Land Cover nomenclature. The analysis therefore illustrates how more detailed locally specific accounts can be prepared in a way that is compatible with the broader scale information that is available across the entire study area. As we will also see in section 5, such data can also be used to test the accuracy of these coarser scale analyses.

Using the PEGASO nomenclature, the stock of different cover types in 2010 for the Nile Delta in 2010 is shown in Figure 10. The accounts (Table 8) demonstrate very intensive land transformations in the Nile Delta, probably more so than anywhere else in PEGASO study area. There has been a massive increase of infrastructure. Fish farms area have increased by 15%, and natural coastal habitats (coastal plains and dunes) areas decreased by a quarter within seven year period. It has to be emphasized, that according to the regional land cover maps there has been also very intensive transformation around the Nile Delta in the surrounding desert and coastal areas. These transformations include high rates of urbanization and infrastructure development, as well as new irrigated areas for croplands.

**Table 8**: Nile delta land cover change accounts, 2002-2010

| **Land types** | **Stock 2002** | **Stock 2010** | **Net change** | **Per cent change** |
|---|---|---|---|---|
| Canals | 1458.6 km | 2363.0 km | 904.4 km | 62.0 |
| Roads | 2727.4 km | 3506.9 km | 779.5 km | 28.6 |
| Agriculture | 2759.1 $km^2$ | 2673.7 $km^2$ | -85.4 $km^2$ | -3.1 |
| Fish Farms | 357.2 $km^2$ | 412.9 $km^2$ | 55.7 $km^2$ | 15.6 |
| Lake | 465.0 $km^2$ | 438.5 $km^2$ | -26.5 $km^2$ | -5.7 |
| Reclaimed | 290.6 $km^2$ | 264.8 $km^2$ | -25.8 $km^2$ | -8.9 |
| Coastal plain | 208.7 $km^2$ | 155.8 $km^2$ | -52.9 $km^2$ | -25.4 |
| Sand dunes | 16.5 $km^2$ | 12.8 $km^2$ | -3.7 $km^2$ | -22.3 |
| Urban | 272.3 $km^2$ | 280.0 $km^2$ | 7.6 $km^2$ | 2.8 |

## 5. Testing the accounts

Having constructed the accounting database described above, its robustness was examined to assess the spatial and quantitative accuracy of the accounts on natural and urban areas, using independent and high resolution reference data sources. The accuracy was judged on the bases of linear correlation coefficients (R2) estimated between the reference data and the evaluated data (either CORINE or PEGASO version). For this purpose all the three datasets had to be processed to express the quantities of area estimates (in hectares) in comparable way. This was done by converting the discrete classes into continuous quantitative measure expressing number of hectares of either natural or urban land per one km grid cell. Consequently, the numbers of hectares were ‘sampled’ for around 500,000 centroid points. Each centroid represented each of the 1km cells, and could be linked with different spatial reporting units. The geographical units considered were countries, buffers around the coast and dominant land types. The correlations were analysed by comparing the average values for these spatial units.

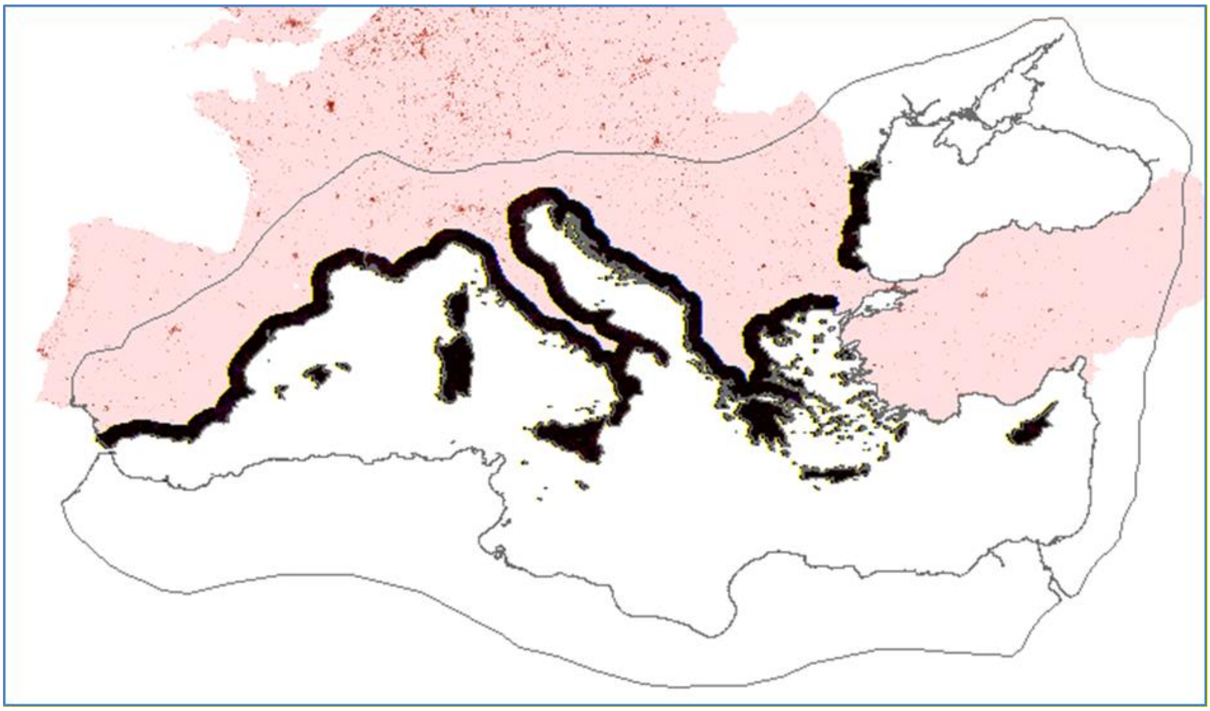


**Figure 11**: Evaluation data extent at regional level. The black dots are the 1km centroids of the grid-cells used to ‘sample’ the three data inputs for evaluation

The evaluation was made at two levels: (a) the ‘regional’, covering the entire 50 km coastal zone for the EU countries in which the three sources overlap completely in terms of areal coverage (Figure 11). It includes all the EU and associated countries; and, (b) the CASEs scale, for which the equivalent sources could be applied at local levels. The CASEs considered (Figure 12) were Bouches-du-Rhone, North Adriatic, Cyclades, Danube Delta and Nile Delta. The reference data used for the two themes, natural and urban land originates from different sources and needed separate processing procedures to derive comparable results.


**Figure 12**: Evaluation data extents at CASEs level

## 5.1. Evaluation of the accounts on natural areas

For natural areas, the accounts from PEGASO and CORINE land cover were compared with the JRC product of forest cover in year 2000. The JRC map was produced at 25m spatial resolution using LANDSAT imagery (see Ivanov et al., 2013b for details, in Appendix). For the evaluation purposes, the input from PEGASO and CORINE had to be processed and harmonised to match the semantic definitions of the JRC product. In this regard, the natural areas of forests and shrublands were grouped to express the total coverage of woody vegetation from PEGASO and CORINE Land cover, which was then compared to the JRC Forest areas map. The three products were compared after being converted to area coverage registering number of hectares woody vegetation per 1km grid cell. At regional level, the average number of hectares of woody vegetation of the coasts per country is shown in Table 9.

**Table 9**: Forested areas from JRC, PEGASO and CORINE land cover per country

| | mean JRC forest | mean PLC forest | mean CLC forest |
|---|---|---|---|
| Albania | 18.44 | 52.00 | 46.54 |
| Bosnia and Herzegovina | 24.70 | 70.18 | 63.35 |
| Bulgaria | 32.75 | 35.89 | 34.12 |
| Croatia | 42.64 | 71.66 | 59.62 |
| Cyprus | 11.05 | 44.12 | 37.11 |
| France | 33.83 | 54.85 | 50.25 |
| Greece | 14.46 | 52.74 | 43.83 |
| Italy | 23.52 | 35.38 | 30.07 |
| Malta | 0.49 | 0.37 | 12.17 |
| Montenegro | 40.50 | 76.96 | 62.24 |
| Romania | 4.11 | 6.91 | 9.09 |
| Slovenia | 79.65 | 85.92 | 72.12 |
| Spain | 20.47 | 53.51 | 40.43 |

The average per country were analysed considering the JRC as the 'most precise' estimate. In comparison to it, PEGASO land cover averages are generally higher than the other two sources which imply an over-estimation of woody vegetation in the latter. The correlation coefficient for CLC is slightly higher, as shown on the Figure 13. Similar coefficients are estimated when considering the much higher spatial variation when comparing the averages per coastal accounting units (defined by intersecting the three buffers around the coast and the administrative divisions).

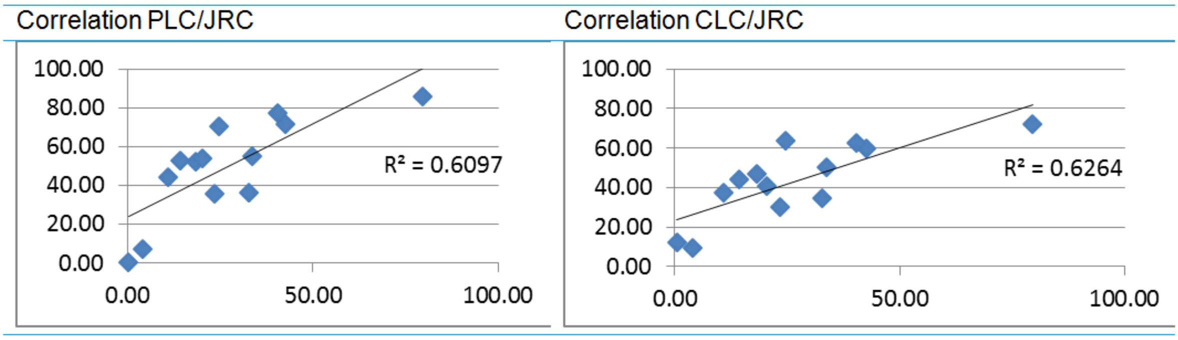



**Figure 13**: Scatterplots and linear correlation coefficients for woody vegetation from PEGASO land cover (PLC, left) and CORINE land cover (CLC, right) against average for country from JRC data

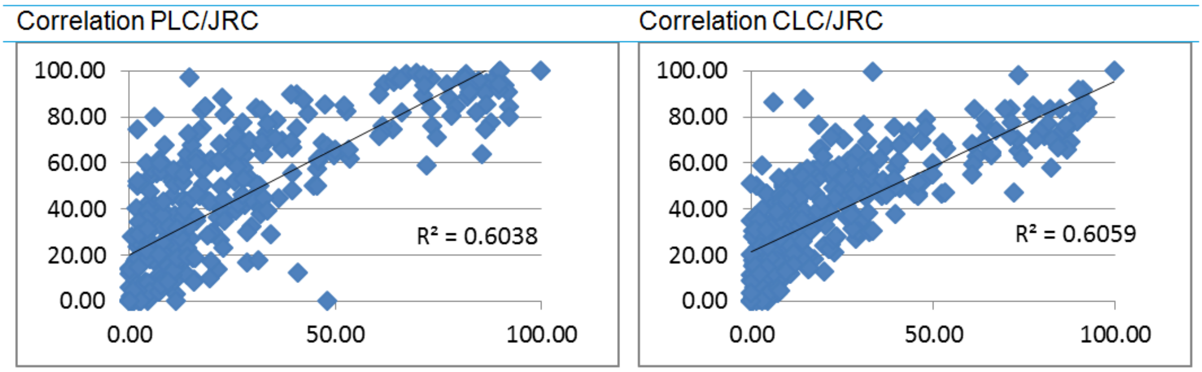



**Figure 14**: Scatterplots and linear correlation coefficients for woody vegetation from PEGASO land cover (PLC, left) and CORINE land cover (CLC, right) for average areas per ecosystem accounting unit estimated from JRC data

At the CASEs level, the same reference data for applied for the four EU cases and another product was applied for the Nile Delta case. It is the land cover map developed by NARSS at very high spatial resolution, specifically for the purposes of PEGASO. The average areas per case and buffer from coast are shown in Table 10. The correlations (Figure 14) for woody/natural vegetation for these five cases are rather low for the two sources (R2=0.22 for PEGASEO land cover and R2=0.39 for CORINE land cover).

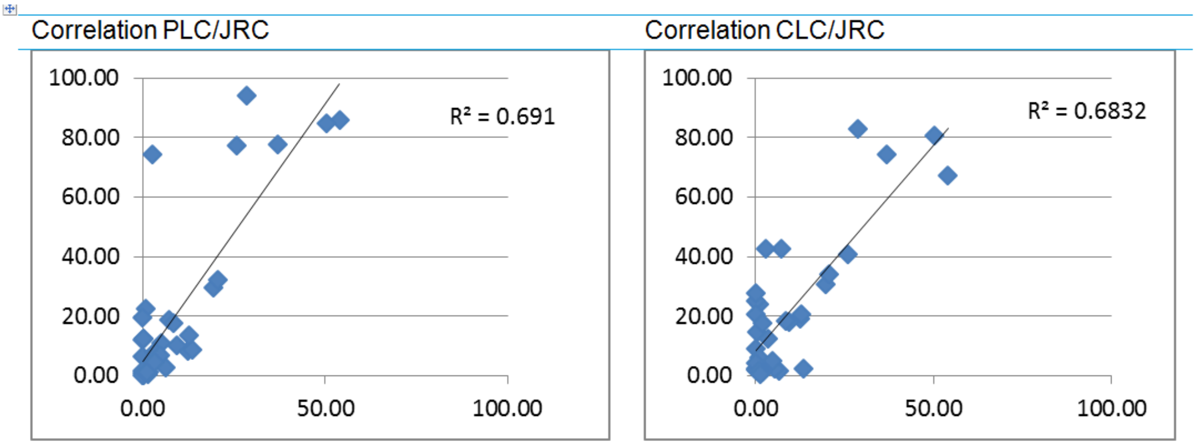



**Figure 15**: Scatterplots and linear correlation coefficients for woody/natural vegetation from PEGASO land cover (left) and CORINE land cover (right) per DLT and CASEs

**Table 10**: Forested areas and difference between CORINE, PEGASO and JRC forest map for the 5 CASEs

| cases | buffers | mean JRC forest | mean PLC forest | mean CLC forest |
|---|---|---|---|---|
| **Bouches-du-Rhone** | 10000 | 13.14 | 20.40 | 22.18 |
| | 50000 | 28.44 | 42.05 | 41.59 |
| **Cyclades** | 1000 | 0.91 | 27.68 | 24.72 |
| | 10000 | 3.69 | 57.05 | 37.51 |
| **Danube Delta** | 1000 | 0.93 | 3.75 | 13.05 |
| | 10000 | 1.70 | 3.52 | 6.09 |
| | 50000 | 6.38 | 10.12 | 11.79 |
| **North Adriatic** | 1000 | 4.09 | 3.01 | 3.60 |
| | 10000 | 2.67 | 1.81 | 1.86 |
| | 50000 | 1.64 | 3.06 | 1.37 |
| **Nile delta** | all | 3.35 | 4.45 | |

The two sources show quite similar averages for most units. Therefore, it can be confirmed that more accurate data sources are needed to analyse natural areas at case level. Higher correlations were registered, however when analysing the spatial variation as averaged per case and dominant land type, as shown on Figure 15. A possible reason, for obtaining higher correlation when considering DLT, rather than coastal buffers could be that much of the land within the first coastal buffer, of 1km may be affected by differences in the coast definition and detection by the three sources. In the case of PEGASO land cover, it was observed that most mountainous coasts facing west are obscured by 'shadowing' effects.

## 5.2. Evaluation of accounts on urban areas

Urban areas from PEGASO and CORINE Land cover were compared to high resolution map of per cent sealed soil (downloaded from EEA[7] website), representing artificialized surfaced in year 2006. Artificial cover was consequently considered equivalent to urban land cover and the corresponding classes from CORINE and PEGASO land cover, grouped at level 1. The artificial cover was mapped at 20m spatial resolution using SPOT imagery. For the purpose of comparing the three sources, the area coverage was sampled in the same way as for woody vegetation, and in addition a temporal adjustment had to be done for the PEGASO land cover product. The adjustment was done by estimating the difference between 2000 and 2011, deriving the annual rate of change, and applying 6-year increment to the value in year 2000. The mean area of urban cover per country and buffer zone is shown in Table 11.

**Table 11**: Urban areas from CORINE, PEGASO and EEA soil sealing map per country and buffer zones

| country | buffer | mean EEA sealed soil | mean PLC urban | mean CLC urban |
|---|---|---|---|---|
| Albania | 1000 | 3.03 | 4.64 | 8.27 |
| Albania | 10000 | 1.64 | 1.94 | 6.67 |
| Albania | 50000 | 0.76 | 1.67 | 3.31 |
| Bosnia and Herzegovina | 1000 | 6.64 | 3.82 | 7.64 |
| Bosnia and Herzegovina | 10000 | 0.69 | 0.55 | 0.79 |
| Bosnia and Herzegovina | 50000 | 1.19 | 1.55 | 1.38 |
| Bulgaria | 1000 | 11.72 | 13.86 | 21.64 |
| Bulgaria | 10000 | 3.09 | 3.86 | 6.69 |
| Bulgaria | 50000 | 1.12 | 1.68 | 4.24 |
| Croatia | 1000 | 4.98 | 4.73 | 8.03 |
| Croatia | 10000 | 2.30 | 1.82 | 2.90 |
| Croatia | 50000 | 0.93 | 0.44 | 1.09 |
| Cyprus | 1000 | 6.58 | 13.35 | 16.37 |
| Cyprus | 10000 | 3.65 | 6.27 | 8.62 |
| Cyprus | 50000 | 3.05 | 5.06 | 6.76 |

[7] http://www.eea.europa.eu/data-and-maps/explore-interactive-maps/european-soil-sealing-v2

| | | | | |
|---|---|---|---|---|
| France | 1000 | 11.13 | 17.96 | 22.44 |
| France | 10000 | 5.73 | 10.91 | 10.39 |
| France | 50000 | 2.08 | 3.88 | 4.34 |
| Greece | 1000 | 2.79 | 6.81 | |
| Greece | 10000 | 1.68 | 4.62 | |
| Greece | 50000 | 1.01 | 1.28 | |
| Italy | 1000 | 11.21 | 20.20 | 20.13 |
| Italy | 10000 | 4.12 | 9.22 | 6.28 |
| Italy | 50000 | 1.91 | 3.78 | 3.44 |
| Malta | 1000 | 10.27 | 56.04 | 18.94 |
| Malta | 10000 | 14.74 | 85.63 | 30.54 |
| Montenegro | 1000 | 7.66 | 5.12 | 15.25 |
| Montenegro | 10000 | 1.29 | 0.43 | 1.35 |
| Montenegro | 50000 | 1.17 | 1.75 | 1.60 |
| Romania | 1000 | 4.90 | 3.41 | 10.12 |
| Romania | 10000 | 1.85 | 3.07 | 4.22 |
| Romania | 50000 | 1.26 | 1.15 | 4.70 |
| Slovenia | 1000 | 20.66 | 31.75 | 23.69 |
| Slovenia | 10000 | 4.47 | 8.89 | 3.66 |
| Slovenia | 50000 | 1.29 | 1.41 | 1.39 |
| Spain | 1000 | 14.67 | 22.38 | 25.63 |
| Spain | 10000 | 6.63 | 11.58 | 8.95 |
| Spain | 50000 | 2.04 | 4.75 | 3.08 |

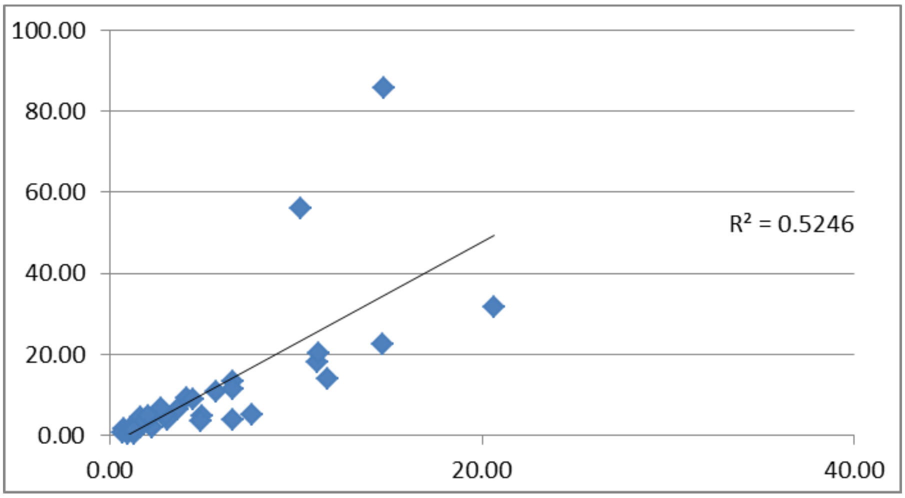



**Figure 16**: Scatterplot of mean urban area coverage/country & buffer zone from PEGASO land cover

The mean values from the three sources show lowest values from the highest precision source, the EEA's sealed soil; higher averages from the PEGASO land cover and generally highest from CORINE land cover, which implies that CORINE estimates are mostly exaggerated. The correlation coefficients (Figure 16), however, shows that CORINE's estimates ($R^2$ = 0.87) with the reference source are higher than PEGASO estimates ($R^2$=0.53). On the scatterplot several distinct outliers can be observed, which show exceptionally high of urban land in PEGASO land cover, e.g. for Malta. If these outliers are cleared the correlation coefficients will be $R^2$ = 0.89 for PEGASO land cover and $R^2$ = 0.86 for CORINE land cover. At the level of coastal accounting units, CORINE preserves very high correlation while PEGASO land cover diminishes.

**Table 12**: Mean coverage of urban/artificialized areas from CORINE, PEGASO and EEA soil sealing map per case and buffer zones

| **Case** | **buffer** | **mean EEA sealed soil** | **mean PLC urban** | **mean CLC urban** |
|---|---|---|---|---|
| Bouches-du-Rhone | 1000 | 15.77 | 26.45 | 24.80 |
| | 10000 | 8.62 | 21.29 | 15.00 |
| | 50000 | 4.55 | 15.05 | 8.98 |
| Cyclades | 1000 | 1.32 | 5.23 | |
| | 10000 | 0.58 | 3.66 | |
| Danube Delta | 1000 | 4.27 | 2.60 | 9.07 |
| | 10000 | 1.84 | 3.08 | 4.17 |
| | 50000 | 1.36 | 1.34 | 4.77 |
| North Adriatic | 1000 | 6.04 | 15.54 | 13.46 |
| | 10000 | 3.53 | 11.42 | 8.10 |
| | 50000 | 4.19 | 11.03 | 9.06 |
| Nile delta | all | 3.80 | 2.00 | |

At CASEs level, average coverage of urban area is shown for the coastal stripes of the cases in Table 12. At CASEs level the average coverage of urban land is exaggerated by the two sources, as shown on regional level. However for the French and Italian cases, the exaggeration is higher for PEGASO land cover. The correlation coefficients (Figure 17) are very high for CORINE land cover, but also high for the PEGASO product.

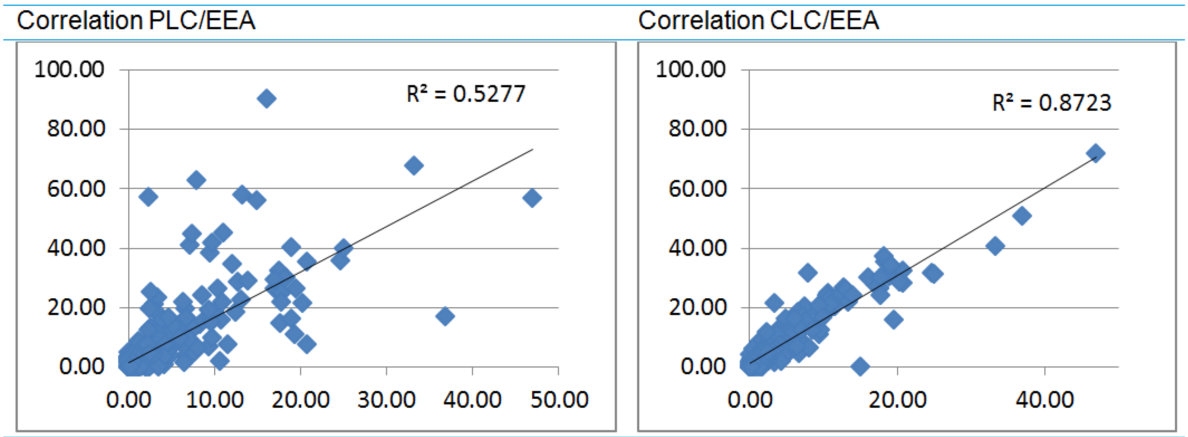



**Figure 17**: Scatterplots and linear correlation coefficients for urban/artificialized land from PEGASO land cover (left) and CORINE land cover (right) for average areas per ecosystem accounting unit

The correlation coefficient for PEGASO land cover increases to R2 = 0.83 when estimated for averages per DLT, possibly due to the same effects commented above, for woody and natural vegetation (Figure 18).

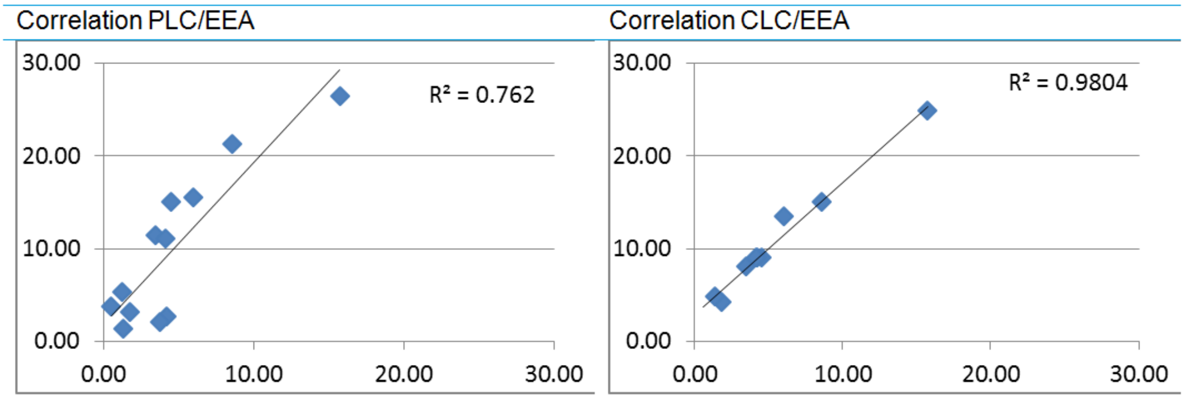



**Figure 18**: Scatterplot and correlation coefficients for cases with three coastal buffers

## 5.3. Testing the accounts: Implications for the Accounting Database

According to the evaluation results, both sources of accounting inputs CORINE land cover and PEGASO land cover compare well with independent and high precision reference data on forested and artificialized land in Europe. PEGASO land cover is more appropriate for assessments at wide regional level across the entire Mediterranean and Black Sea basins, while CORINE land cover performs better at higher spatial detail level. Both sources, show deficiencies of accuracy when assessed at local, CASEs level, although to a lesser extent for urban/artificialized areas. Clearly where more precise or customised land cover data are available, as in the Nile, it would be more appropriate to use these data sources for local applications. However, the existence of the PEGASO land cover product offers the possibly of comparing local trends and patterns with other areas using a consistent reference source. Thus also the data sources used for testing the accounting outputs were identified as separate elements in Table 2, all form part of the overall, integrated accounting resource made available by the Project.

# 6. Using Land and Ecosystem Accounts: Building ICZM Applications

As noted above, the focus of the accounting work in PEGASO has been to build practical applications that can support decision making in the coastal zones. We therefore now turn to the results from this work, which first cover the accounting input to the PEGASO Integrated Regional Assessment (IRA). In the second part of this section we look at more local types of application at the scale of three of the PEGASO Cases.

## 6.1. Accounting and the Integrated Regional Assessment[8]

The work done in support of the PEGASO IRA included:

- Application of land-cover and protected areas accounts to assess progress towards preservation of natural capital, and;
- Application of land accounts to assess to track progress towards balanced urban development in Mediterranean and Black-Sea coastal areas.

Two sources of land accounting inputs, covering a 50km wide coastal stripe of the Mediterranean and the Black Sea were used, the CORINE land cover and PEGASO Land Cover Product. The land cover data held in the LEAC database were extracted into a set of accounting units defined by intersecting administrative divisions (source: World administrative divisions) and the 1km, 10km and 50km buffers around the coastline of the two sea basins. In this way accounts for urban, natural and protected areas were prepared for various spatial units, namely: countries; countries and coastal buffer divisions; and units defined by the intersection of administrative divisions and the coastal buffers. The mapping and other data are available on the PEGASO SDI.

The extent of the area of urbanized land within the 50km coastal strips of the countries was assessed in four categories:

- Highly urbanized, above 25%
- Intermediate, between 3% and 25%
- Low, between 1 and 3%
- Very low, below 1%.

Change between 2000 and 2011was categorised as follows:

- Increase, exceeding 1.5% can be considered high
- Increase between 0.5 and 1.5% intermediate
- Increase between 0.1 and 0.5% is low
- Decrease between -0.1 and -0.5% is low
- Decrease between -0.5 and -1.5% – intermediate

[8] For full details see Santoro and Barbière (2013) (eds): *Report on the Mediterranean and Black Sea Basin Integrated Regional Assessment.* Deliverable D5.2. EU FP7 Project PEGASO Grant agreement nº: 244170

## 6.2. Urban sprawl assessment at the basin scale

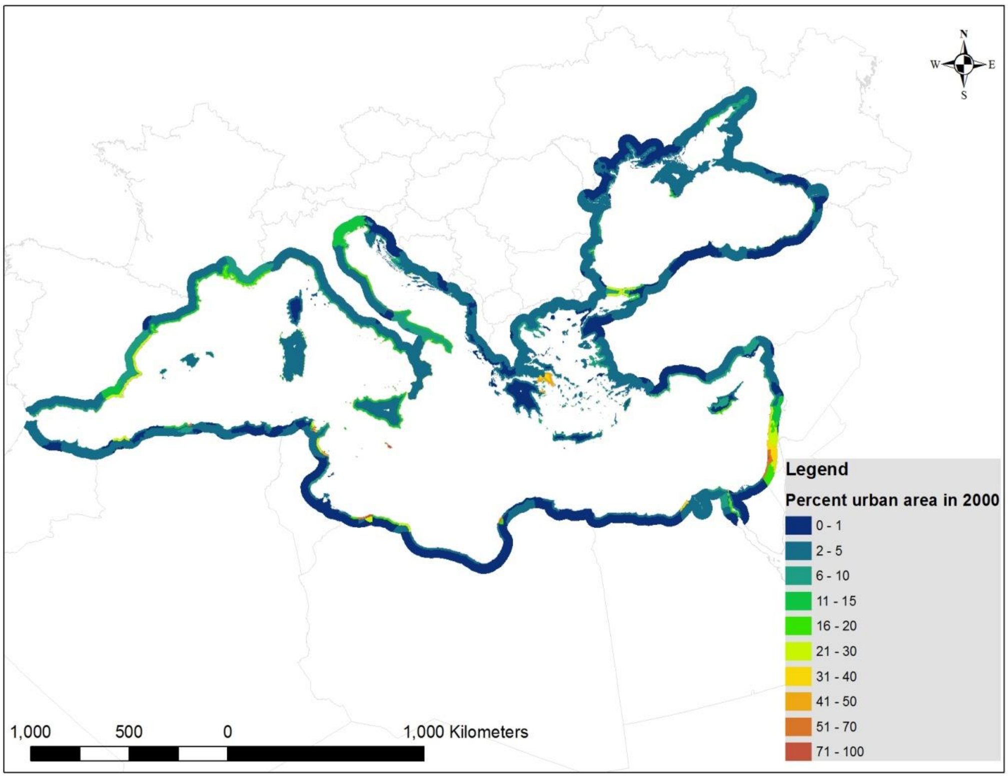



**Figure 19**: Map of proportion of urban areas from total are of coastal accounting units, estimated from PEGASO Land Cover in year 2000

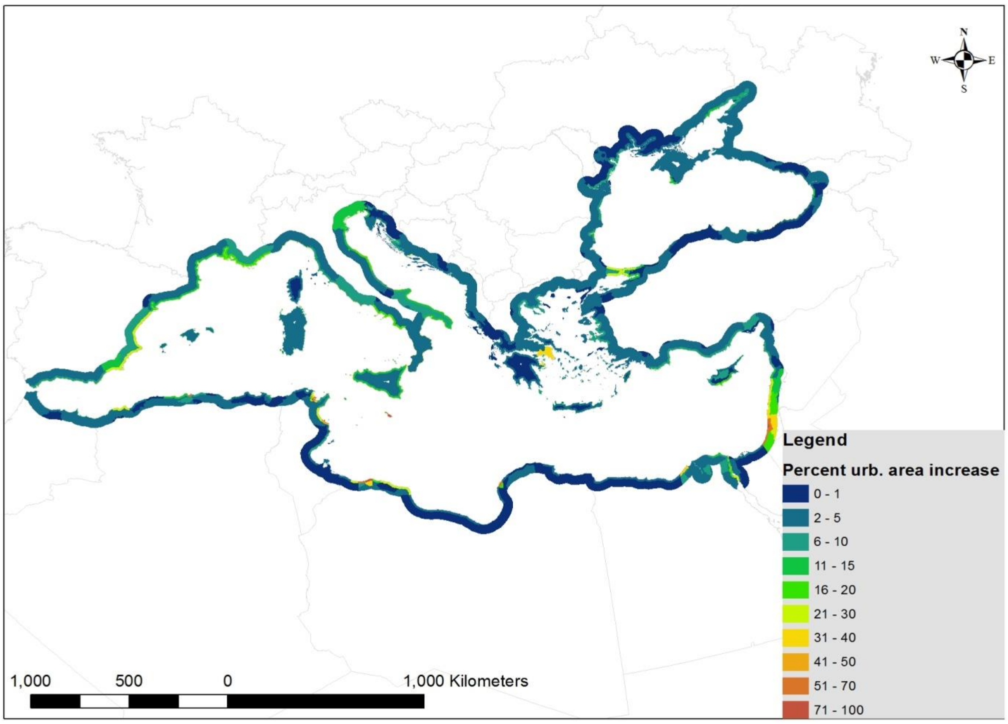



**Figure 20**: Map of proportional change in urban areas from total unit area between 2000 and 2011 from PEGASO land cover, per coastal accounting unit

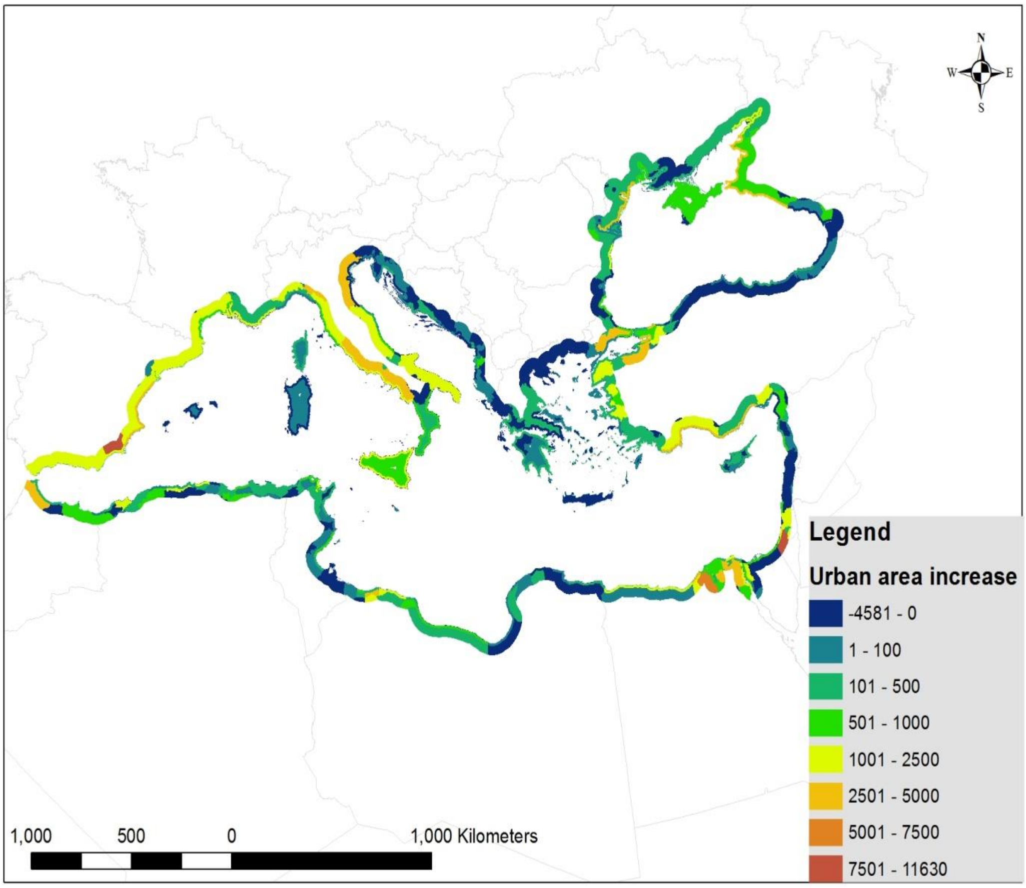



**Figure 21**: Number of hectares increase in urban areas between 2000 and 2011 from PEGASO land cover, per coastal accounting unit

The accounting outputs were extracted from the integrated database, using pivot tables, and linked to the coastal ecosystem accounting units. Examples of the mapped output are shown in Figures 19, 20 and 21. The first of these figures shows the stock of urban land in 2000. The high percentages of urbanized land on the Spanish and French coasts are apparent, along with the developed areas of Athens and Istanbul, and the Near-East Mediterranean coast. These data provide a baseline against which change can be measured for the different divisions and buffer strips. Figure 20 shows the change data for the administrative districts in the 50km coastal buffer, and highlights that in percentage terms it is highest on south and east Mediterranean coasts. Figure 21 shows the same data expressed as total numbers of hectares of urban area increase. Clearer patterns are to be seen in this map product, with marked increases in the north Mediterranean countries. High absolute rates of increase can also be observed in the north and west Black Sea Basin.

In the context of the PEGASO, these data were used to show that the different regions across the Mediterranean and Black sea coastal have had different trajectories in terms of urban land cover. Generally the northwest Mediterranean coast has been more extensively developed and at an earlier stage. Consequently, more development has taken place in the hinterland of the coastal zone during the last decade. In the south, developments have occurred more intensively during land decade but mostly in the vicinity of existing urban centres. The most densely and intensively developed coast is in the Near-eastern countries, namely Israel and Lebanon. In the Black Sea, rates of coastal development have been rather higher within the first kilometre of the coastal zone, compared to further inland.

## 6.3. Natural capital assessment at basin scale

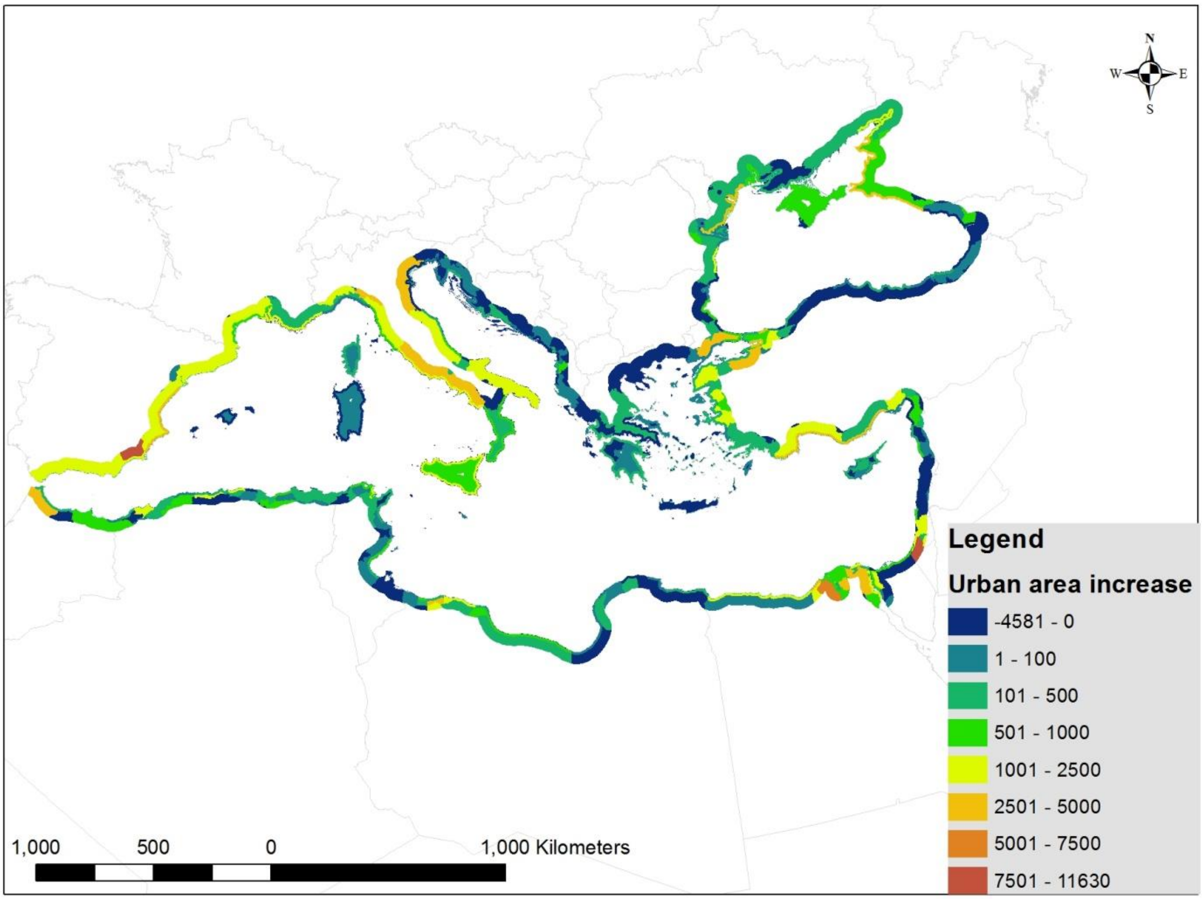



**Figure 22**: Map of natural area accounts from PEGASO land cover in year 2000, estimated as a proportion of the total area the coastal accounting unit

The accounts for natural capital were based on the areas of forests and open surfaces, wetlands and water surfaces (i.e. classes 3, 4 and 5 from level 1 of PEGASO and CORINE land cover classifications). The areas of these 'natural areas' within the 50 km coastal stripes of the countries are assessed in four categories:

- High, above 60%
- Intermediate, between 30% and 60%
- Low, between 15 and 30%
- Critically low, below 15 %.

The temporal changes in natural areas were assessed as follows:

- Increase, exceeding 2.5 % can be considered high
- Increase between 1 and 2.5% intermediate
- Increase between 0.1 and 1% is low
- Decrease between -0.1 and -1% is low
- Decrease between -1 and -2.5 – intermediate
- Decrease of more than -2.5, is high.

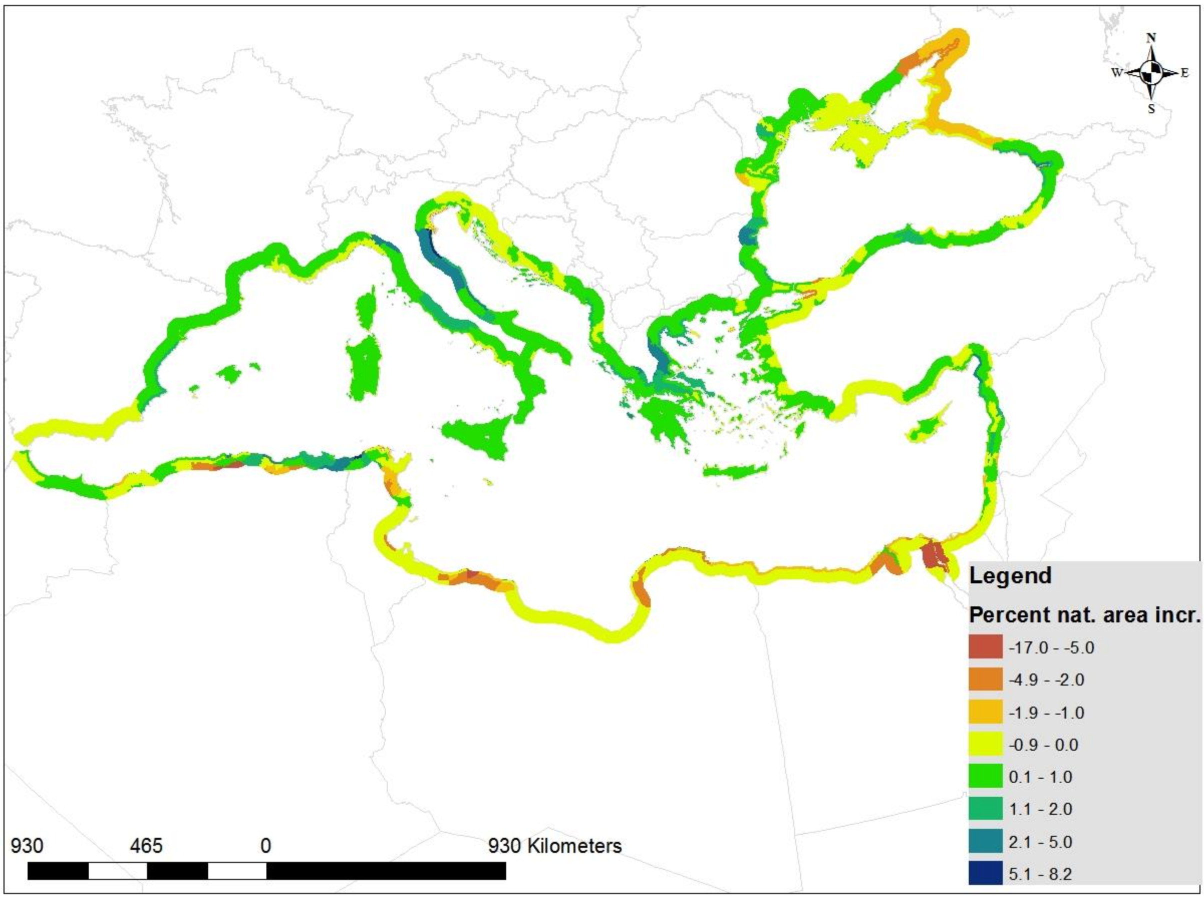



**Figure 23**: Map of temporal change of natural areas from PEGASO Land cover (between 2000 and 2011), expressed as a proportion of total unit area of the coastal accounting unit

The accounting outputs were prepared in the same way as for the urban areas and linked to the coastal accounting units as before. Figure 22 shows the share of natural areas in the coastal zone across the two sea basins. While overall the African coast of the Mediterranean stands out for having high levels of natural cover, the lower proportional cover along the north shore of the Black Sea is especially apparent. However, a more detailed comparison across the three coastal buffer strips indicates that coastal areas of the Black sea countries contain higher percentages of natural land compared to the hinterland (e.g. in Bulgaria, Romania, Ukraine and also in Algeria). Several of the Mediterranean countries (e.g. Spain, France, Israel and Italy) tend to show the opposite, that is a lower share of natural land closer to the coast line. Figure 23 shows the changes in natural cover between 2000 and 2011. From these data it is evident that there has been an increase of natural areas in the north Mediterranean (except Andalucía), and decrease in the south (except Algeria). The highest rate of natural area increase is to be found for the 10 km coastal zone of the Italian Adriatic area, and in parts of Spain, Greece, Bulgaria and Turkey.

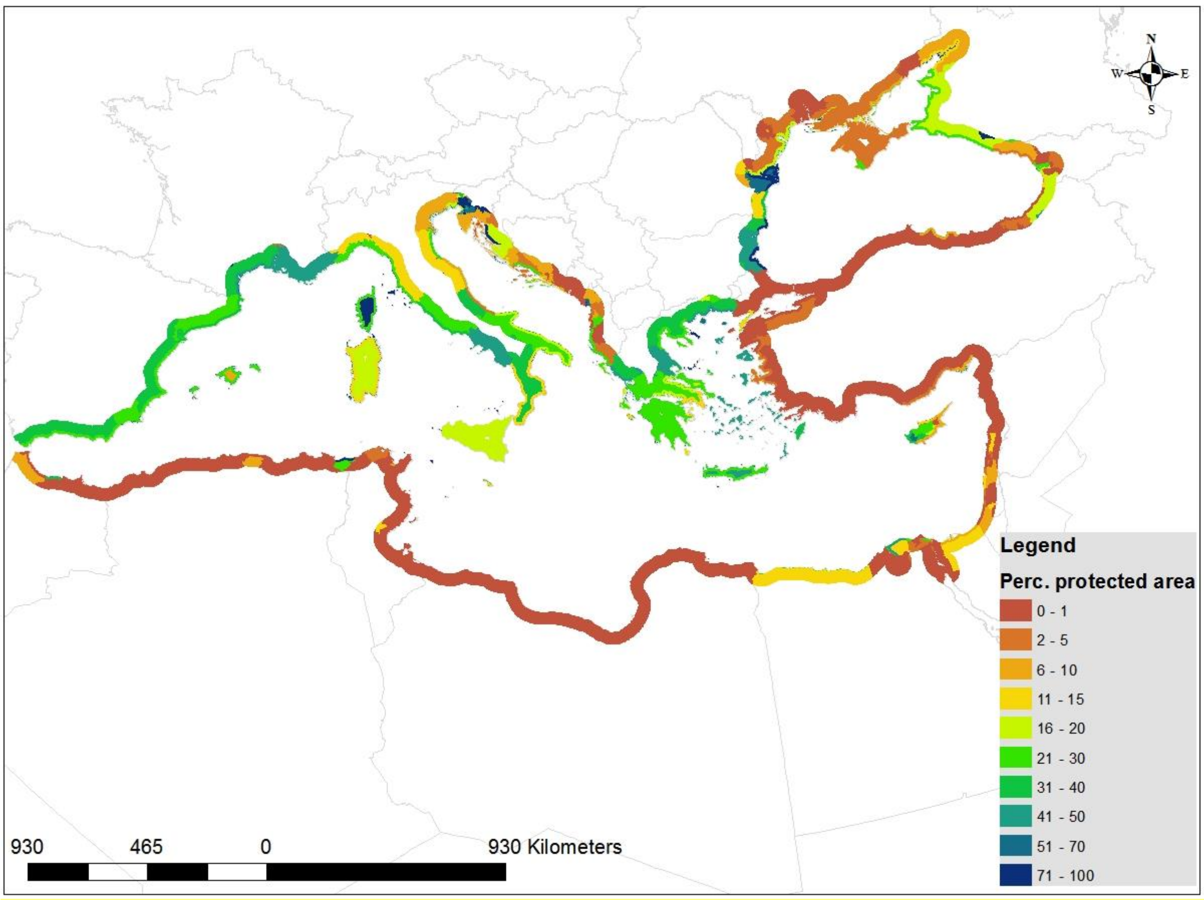


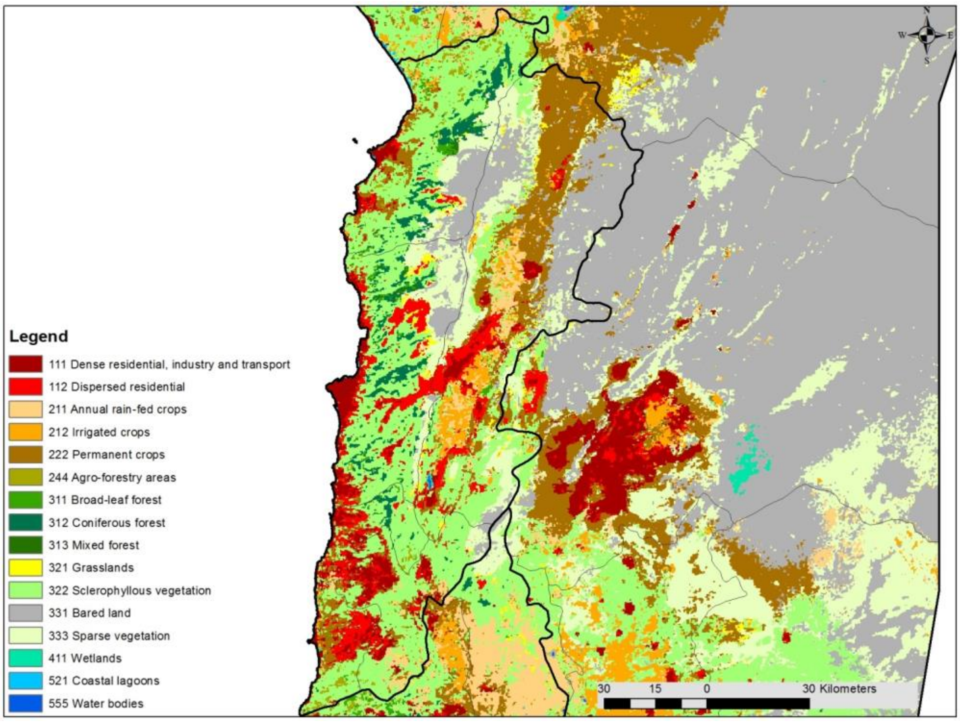

**Figure 24**: Proportion of protected areas for three coastal buffers per country

As a complement to the estimates of cover of natural areas, the proportional areas within a protected zone were also estimated by country and buffer strip, using the data from the *World Database of Protected Areas*[9] (Figure 24). The northern countries, especially the ones part of the EU have relatively high proportion of their coast within a protected area, while certain countries from the south Mediterranean do not appear to have any. It is important to note that this situation could be due the difficulty of collecting data for these countries for inclusion in the global source used for this assessment.

[9] http://www.wdpa.org/

## 6.4. Case-scale applications

| Urban area in 2011 and net change since 2000 | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | 1 km buffer | | | 10 km buffer | | | 50 km buffer | |
| | area unit (ha) | area urban (ha) | % | area unit (ha) | area urban (ha) | % | area unit (ha) | area urban (ha) | % |
| Lebanon | 18100 | 11456.25 | 63.29 | 188900 | 44456.25 | 23.53 | 708400 | 77762.50 | 10.98 |
| | net change (ha) | 1756.25 | 9.70 | | -4200 | -2.22 | | -4581.25 | -0.65 |



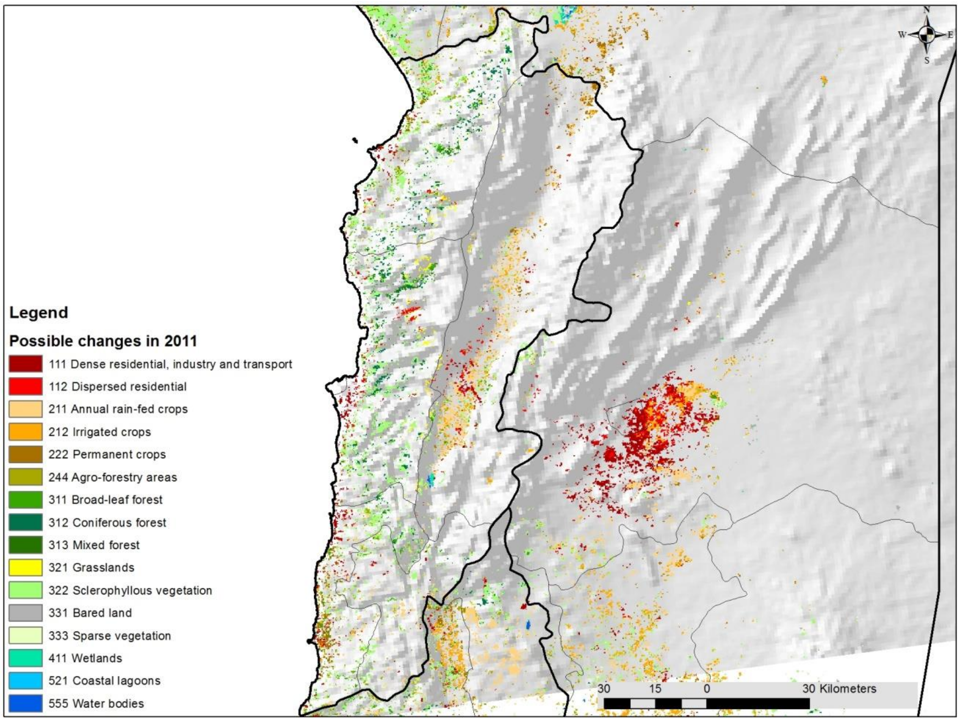




**Figure 25a**: Lebanon accounts from PLC

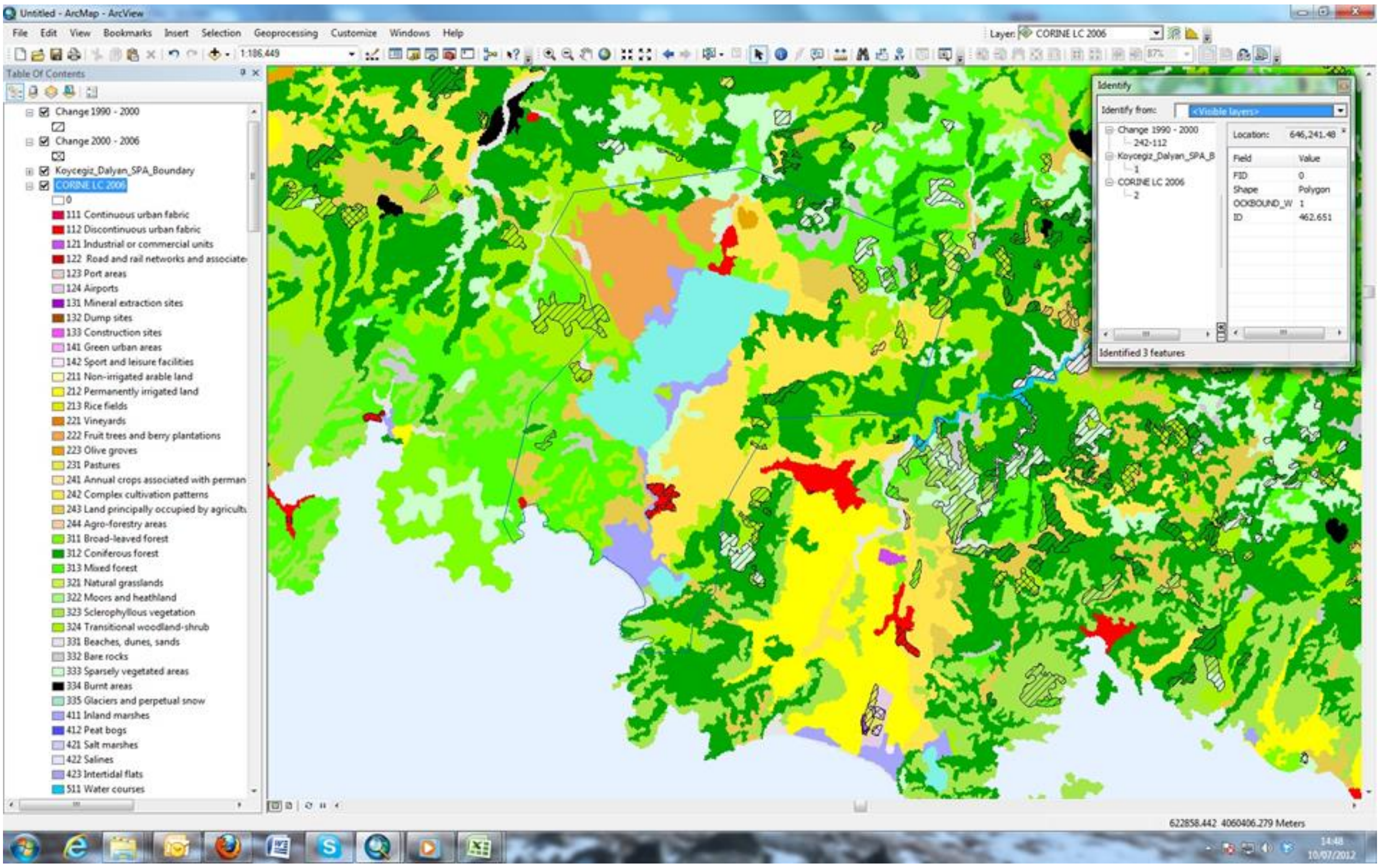



**Figure 26:** Koycegiz-Dalyan SPA site – fast growth of housing developments in Dalyan. Source: Cinar Muhendislik (2007)

**Table 13**: Areas to be submerged in Cyclades according to three scenarios of sea level rise, mapped by the Hellenic Centre for Marine Research

| | | sea level raise | | |
|---|---|---|---|---|
| | | 1m | 60 cm | 30 cm |
| | | area (ha) | area (ha) | area (ha) |
| 111 | Continuous urban fabric | 21.6 | 15.0 | 9.3 |
| 112 | Discontinuous urban fabric | 69.0 | 42.6 | 25.7 |
| 123 | Port areas | 1.1 | 0.6 | 0.3 |
| 131 | Mineral extraction sites | 9.2 | 6.9 | 5.1 |
| 133 | Construction sites | 0.7 | 0.2 | 0.0 |
| 142 | Sport and leisure facilities | 10.4 | 7.1 | 3.8 |
| 211 | Non-irrigated arable land | 61.5 | 44.1 | 29.0 |
| 221 | Vineyards | 3.5 | 2.1 | 1.0 |

| | | | | |
|---|---|---|---|---|
| 222 | Fruit trees and berry plantations | 10.9 | 9.6 | 8.6 |
| 223 | Olive groves | 4.5 | 1.5 | 0.1 |
| 242 | Complex cultivation patterns | 652.9 | 550.8 | 469.8 |
| 243 | Land principally occupied by agriculture, with significant areas of natural vegetation | 237.4 | 170.3 | 110.1 |
| 321 | Natural grasslands | 245.0 | 170.0 | 108.7 |
| 323 | Sclerophyllous vegetation | 174.4 | 123.2 | 80.8 |
| 324 | Transitional woodland-shrub | 0.1 | 0.1 | 0.0 |
| 331 | Beaches, dunes, sands | 10.2 | 8.1 | 5.3 |
| 333 | Sparsely vegetated areas | 6.9 | 6.0 | 3.5 |
| 334 | Burnt areas | 0.1 | 0.0 | 0.0 |
| 422 | Salines | 11.5 | 6.9 | 3.4 |
| | **Total submerged area (ha)** | **1530.7** | **1164.9** | **864.6** |

**Table 14**: Land accounts for Bouches du Rhone case

| Class of interest | 1990 | | 2000 | | 2006 | |
|---|---|---|---|---|---|---|
| | Area (ha) | % | Area (ha) | % | Area (ha) | % |
| Urban areas | 15225 | 8.78 | 15828 | 9.13 | 15978 | 9.21 |
| Agricultural land | 50082 | 28.88 | 49621 | 28.61 | 49481 | 28.53 |
| Natural or semi-natural land | 101363 | 58.45 | 96755 | 55.79 | 96691 | 55.75 |
| Transport infrastructures | 715 | 0.41 | 743 | 0.43 | 743 | 0.43 |
| Industries, mines, dumps | 5155 | 2.97 | 5174 | 2.98 | 5228 | 3.01 |
| Ports | 885 | 0.51 | 802 | 0.46 | 802 | 0.46 |

**Table 15**: Types of land conversion considered in the Bouches du Rhone case discussions with stakeholders

| Types of conversion |
|---|
| Conversion of agricultural land to urban area |
| Conversion of natural or semi-natural land to urban area |
| Conversion of natural or semi-natural land to agricultural land |
| Conversion of agricultural land to industrial area |
| Conversion of natural or semi-natural land to industrial area |
| Conversion of agricultural land to transport infrastructure |
| Conversion of natural or semi-natural land to transport infrastructure |
| Conversion of agricultural land to ports |
| Conversion of natural or semi-natural land to ports |

Accounts from PEGASO Land Cover Product and CORINE mapping extracted for all the PEGASO Cases and following discussion within the consortium were considered in detail for four of them. In summary using these data sources it was found that for:

- The Case area in the Lebanon, between 2000-2011, there has been a loss of urban land in the 10 and 50 km buffers from the coast, and increase of nearly 10 % in the first. (Figure 25). The increase in the first kilometre zone could be visually confirmed by very high resolution analysis of land cover change on the Lebanese coast during the period 1998 – 2010 (IOE-UOB, 2012).
- The Turkish Case area there was significant urban sprawl near the protected site within the study area in the period 1990 – 2000, but after this change was more limited and mainly related to forest degradation (Figure 26). There has been fast growth of housing developments in the town of Dalyan. The resident population increased from 2200 people in 1986 to nearly 5000 at present. There are many summer houses as well and these are occupied for a fraction of a year. This is certainly not tremendous urban sprawl, but rather fast increase. The more important problem however is housing developments outside the towns (around villages and over agricultural land) that are less controllable (personal communication Özhan, 2013).
- The Greek Case in the in Cyclades, significant areas of natural, agricultural and developed land would be vulnerable to loss as a result of sea level rise (Table 13). Different types of land to be flooded could be accounted by overlaying the CORINE LC maps for year 2000 with the coastal areas which would be submerged with 1 m sea level rise (largest area, in total 1530,7 ha), 60 cm and 30 cm (smallest area, 864.6 ha). The largest share of land at risk is occupied by 'complex cultivation patterns', grasslands and sclerophyllous vegetation. Developed land to be submerged amounts to 112 ha with 1 m rise, 72.4 ha with 60 cm and 44 ha with 30 cm. Of particular concern is the possible loss of some of the most valued beaches (according to personal communications with Conides and Klaoudatos, 2012). The CORINE class of 'Beaches, dunes, sands' indicates 10.2 ha to be submerged with 1 m sea rise, 8.1 ha in case of 60 cm rise and 5.3 ha with 30 cm.
- The Bouches du Rhone Case there was a loss of natural capital for the study area, with the proportion of natural surfaces falling from 58.45% to 55.75% between 1990 and 2006. These data were discussed extensively with local stakeholders in order to validate the patterns of loss detected in the accounts (Table 14). Particular interest was associated with the types of conversion listed in Table 15. It was concluded that the loss of natural areas is probably due to a sharp increase of the artificialization of the territory during the same period in some coastal zones. Urbanized areas increased from 8.78% to 9.21% and industrial areas increased from 2.97% to 3.01%. Changes were also seen through the conversion of natural habitats into agricultural areas.

## 7. Discussion, Lessons Learned and Recommendations

Environmental accounting concepts and the data needed to operationalise them are developing rapidly. In this part of PEGASO we have examined how they can usefully be designed to support ICZM. As has been highlighted elsewhere in the Project (Haines-Young and Potschin, 2011; Haines-Young et al., 2013), ICZM is mainly a governance issue, and can only be taken forward by developing appropriate *institutional structures* and *practices*.

In terms of the institutional structures needed to take ecosystem accounting in the coastal zones forward, international initiatives such as SEEA will clearly stimulate work at the national scale. However, the results of these new international standards and requirements will only be available in the long term, and coastal issues will be but one aspect of a much broader ranges of analyses. Thus focussed thematic initiatives such as PEGASO remain essential. The major challenge for such work is ensuring its perennity. The current accounting work in support of the IRA has shown that it is possible to implement an operational system for land accounting across the two sea basins, and that these data are capable of providing information relevant that is relevant for monitoring progress towards the goals of balanced development and protection of natural capital in the coastal zone. A key task for the ICZM governance platform that PEGASO seeks to establish is how to ensure that the data series for land cover that we have established is maintained.

The consistency in measurement that the broad scale PEGASO Land Cover product provides is the basis for a number of ICZM indicators. These will be a useful way of monitoring progress towards sustainable development across the two Basins. ***We therefore recommend that they are taken forward in conjunction with the wider indicators that PEGASO has initiated (Deliverable D4.1), and that appropriate institutional mechanism for maintaining these sources of information are considered as part of the Business Plan that is now being developed as a legacy of the Project (deliverable D2.4B).***

While new institutional structures are needed to ensure the perenity of the accounting methods described here, it is also important to note that one of the key lessons learned from his work namely that the accounts have to be relevant to decision making practice. Throughout the work that we have undertaken in PEGASO we have been aware of the tension between what is theoretically and practically possible in terms of generating environmental accounts and what is useful to those making decisions. We found that although the idea of environmental indicators and mapping was familiar to our CASE partners and end-users, the concept of environmental accounting was new to many of them. Thus while, through our work, some new capacity has been built in terms of understanding, much more remains to be done. The need to stimulate a faster rate of uptake of accounting concepts was one of the major lessons that we have drawn from the work that we have undertaken.

There are, given the range of data now available, opportunities to develop new consistent strategic accounting products across the two Basins for biodiversity and ecosystem productivity. Moreover, given the accounts that are now available and operational, there are opportunities to look more closely at how they can be used in decision making practice at the more local, case-scale. **We**

**recommend that both avenues are actively explored through the activities that will be coordinated through the ICZM Governance Platform.** Two priorities suggest themselves:

- Initiating further work with the case partners who have shown an interest in the current accounting work, to show how the data these accounts provides can be used in support of 'evidence-based decision making'. If other potential users are to be convinced about the utility of accounting methods then we urgently need some 'best-practice' examples that can demonstrate the added value of the accounting approach. ***We therefore further recommend that wherever possible accounting methods are considered in any future work programme developed at the CASE level as a result of their involvement in the PEGASO project, and that the outcomes and benefits of such work are fed back to the wider community through the Governance Platform.***
- Initiating the development of accounts at the broad, strategic scale, to stimulate interest across the two sea basins as a result of comparative analyses such as those done in the PEGASO Integrated Regional Assessment. A key lesson to be taken from the PEGASO Project is that the construction of accounts is not an end in itself. Rather to be useful such data need to be interpreted and the implications discussed and considered. One of the key functions of the ICZM Governance Platform being developed through PEGASO will be to provide this kind of strategic and comparative view. The Integrated Regional Assessment is a kind of 'state of the environment report' for the coastal zones of the Mediterranean and Black Sea Basins, and in the future the range of new issues could be considered, and the assessment extended to include reference to new accounting themes such as biodiversity and ecosystem productivity. The ability to map these data, along with land cover and land cover change, will enable people working at the CASE scale to see how their locality sits within the 'wider picture'. More importantly, such strategic mapping supported by the Governance Platform will enable decision makers to identify those areas undergoing the most rapid and potentially damaging change, or where policy interventions are having a beneficial effect. ***We therefore further recommend that accounting methods are used actively as part of the ICZM Governance Platform that is being put in place through PEGASO, and that the outputs are used to make period assessments of the state of the environment across the two sea basins.*** The availability of such strategic analyses will both help with additional capacity building and stimulate uptake of accounting methods at local scales.

Land and Ecosystem Accounting (LEAC) is one of the many tools that decision makers require to assist them in managing our coastal zones in a sustainable way. These tools therefore need to be integrated with the other tools being explored through PEGASO and seen as part of a broader menu of techniques and methods that are available to the user community (see deliverable D4.6 for more details). The integration and extension of these methods with those more applicable to the marine space is especially important. It is to these issues that the remaining parts of the report are now devoted.

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# Appendices

## A1: T4.2 Task description from DoW (13. September 2012)

This Part A only refers to LEAC

**T4.2: Coastal land and marine ecosystem accounting (P1 UAB and P9 UNOTT, Month 3-45)**
Land and Ecosystem ACcounts (LEAC) are used to characterise change in the terrestrial environment. They are an effective set of tools that can be used to systematically describe the processes by which land based resources are transformed over time, and as a framework for spatially explicit indicator development and policy appraisal.

The work undertaken in this task will therefore extend the accounting methodologies into the coastal zone using new data for land (e.g. GlobCover 2006 V2), data derived from the mapping of the sea bottom communities, and data on trends in water quality and key species provided by the project participants: IFREMER, IUCN, ACRI-EC and others.

The hierarchical classification frameworks presently employed in LEAC will facilitate a multi-scale approach to the production of statistical data for different parts of the coastal zones and marine areas. The work will proceed in close partnership with T4.1 to evaluate critically the role that accounting methodologies can play in providing operationally effective indicators. It will also link to the work on scenarios (T4.3), participatory methods (T4.4) and valuation (T4.5), to explore how accounts can be used as a framework for modelling plausible futures with stakeholders, and assess marginal change in values for the stocks of natural assets and the benefit flows associated with them.

- Test GlobCorine and its classification system for the dry coast in a buffer of 30 km
- Associated to an elevation model to define coastal areas on land.
- Build consistent km grid for Back Sea and Mediterranean sea.
- Review classification for the marine strip and identify main boundary lines at sea
- Make basic layers with administrative boundaries, river catchments, etc.
- Review available satellite images to inform about a number of processes (ecosystem health, fragmentation, HANPP, etc.)
- Identify attribute to fill the cells of the grid with information (fishing grounds, maritime activities, land and sea uses, sea bottom mapping, quality of water and habitats, data on species, etc.)
- Generation of initial accounting fact sheets (tables and maps) and their communication through the portal web
- Presenting result on accounting to the ICZM Platform and discuss them
- Operational training on how to use the tools in general Meetings and CASE Workshop
- Evaluation of testing and validation, implementing next phase from comments and need.

Leader T4.2
University of Nottingham, CEM
UNOTT / UK

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**Pegaso Project**
**People for Ecosystem based Governance in Assessing Sustainable development of Ocean and coast**

**Funded by the European Union under FP7 – ENV.2009.2.2.1.4 Integrated Coastal Zone Management**

**Specific Programme FP7 Collaborative Projects Large scale integrating project**

**Grant agreement nº: 244170**

Conceptual Framework for Coast and Sea Accounts

# *Revised report on LEAC methodology for coast and marine accounts (Deliverable ID4.2.2)*

| | |
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| Code | Pegaso/ID4.2.2/UNOTT/210611-I-2.0 |
| Date / version | 7th June 2011 (V1.0) as sent to Francoise Breton and Roy Haines-Young<br>21st June 2011 (V2.0) feedback on V1.0 incorporated and as circulated to WP4 and CASES Partners<br>2nd March 2012 (V3.0) final draft for deliverable 4.2.2 |
| Authors | Emil Ivanov<br>Megan Nowell<br>François Morisseau<br><br>With Contributions from :<br>UAB: Françoise Breton<br>UNOTT: Roy Haines-Young |

Resume
This is an internal document and written for the PEGASO team only and should not be circulated outside the team, e.g. stakeholders or end-users.

The aim of this document is to give an overview of the state-of the art of LEAC to PEGASO partners. Hence the objectives of this version (V3.0) are to

- give project partners a deeper inside into the LEAC methodology;
- consult them on their questions and possibly input into T4.2; and
- prepare for "training sessions"

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Notes:

A large part of this work was undertaking as part of the ETC-LUSI/ETC-SIA work programme, led by the European Environment Agency (EEA).

This work has been supervised by Jean-Louis Weber, a Special Adviser to Economic Environmental Accounting at the EEA

The views expressed here however do not reflect any of those organisations who lend their support. This document is intended to stimulate better understanding and uptake of these ideas in the PEGASO consortium.

This is draft and not for wider circulation. If you use this document please quote as:

Ivanov, E. & Nowell, M & Morisseau, F. (2012): Revised report on LEAC methodology for coast and marine accounts (Deliverable ID4.2.2). With contributions from Françoise Breton and Roy Haines-Young.

EU FP7 Project PEGASO Grant agreement nº: 244170.

## Contents

# Introduction

## 1.1. Context

Coastal ecosystems are amongst the most productive and valuable but also the most threatened ecosystems on Earth (MEA, 2005). Their degradation lead to a decrease of goods and services they provide to human wellbeing. This is especially true for the coast of Mediterranean Sea which has been historically one of the most densely populated regions on Earth (Airoldi and Beck, 2007). This population, the associated activities and infrastructures have led to growing pressure on terrestrial and marine coastal ecosystems which have resulted in a considerable loss of biodiversity and habitats especially in the more industrialized North-western part (Coll et al, 2010, Lotze et al, 2006).

Since Rio 92, the concept of "Ecosystem based" or "integrated" strategies which should mitigate degradations, is gaining importance and is more and more included on new policies. The Mediterranean ICZM protocol calls for better management within an ecosystem based framework at international, national, and local scales. Ratified in March 2011, the objectives of the ICZM Protocol are:

a) Facilitate, through the rational planning of activities, the sustainable development of coastal zones by ensuring that the environment and landscapes are taken into account in harmony with economic, social and cultural development;
b) Preserve coastal zones for the benefit of current and future generations;
c) Ensure the sustainable use of natural resources, particularly with regard to water use;
d) Ensure preservation of the integrity of coastal ecosystems, landscapes and geomorphology;
e) Prevent and/or reduce the effects of natural hazards and in particular of climate change, which can be induced by natural or human activities;
f) Achieve coherence between public and private initiatives and between all decisions by the public authorities, at the national, regional and local levels, which affect the use of the coastal zone.

The Pegaso Project aims to facilitate the implementation of the ICZM Protocol in the Mediterranean basin and the development of similar policies in the Black Sea.

## 1.2. The PEGASO Project

The main objective of Pegaso is to build on existing capacities and develop common novel approaches to support integrated policies for the coastal, marine and maritime realms of the

Mediterranean and Black Sea Basins in ways that are consistent with and relevant to the implementation of the ICZM (Integrated Coastal Zone Management) Protocol for the Mediterranean. Pegaso seeks to do this through three innovative actions:

a) Constructing an ICZM governance platform (WP2) as a bridge between scientist and end-user communities.
b) Refine and further develop efficient and easy to use tools for making sustainability assessments in the coastal zone (WP4). These tools include indicators, environmental accounting, scenario construction, participatory approaches and valuation. The aim is to create a suite of tools and techniques that can be used to make a multi-scale assessment in the coastal zone in the Mediterranean and Black Sea Basins. They will be tested and validated in a multi-scale approach for integrated regional assessment through a basin wide diagnostic and a number of relevant pilot sites.
c) Implementation of a Spatial Data Infrastructure (SDI), to organize, harmonize and standardize spatial data (WP3). This interactive web portal will support information sharing as well as manage communications, normalisation and dissemination of consortium spatial and statistical information datasets.

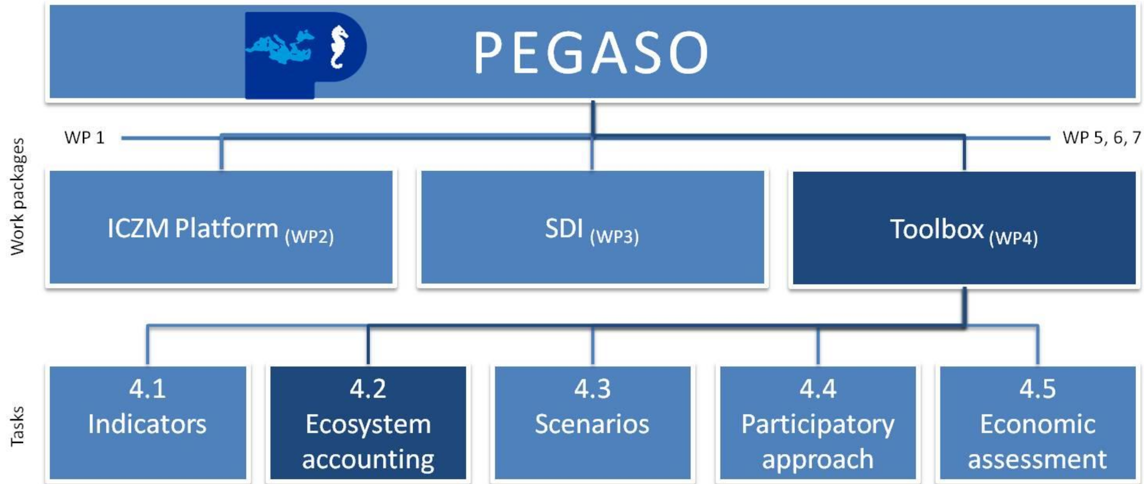



Figure 1: PEGASO general organization, work packages and tasks.

In fact, these three innovative actions are linked: Developing a good governance platform help the improvement of the objectives of the project through the exchange of experience and data. Moreover the building of the SDI which is a basic PEGASO service will allow technically, countries and stakeholders to share and use SDI information as they need. Finally, the toolbox will use data from the SDI but in turn feed it with new data, indicators, accounts, etc.…So the three actions are interactive along the project life.
The following report elaborates on the ongoing process for data assessment and use for the ecosystem accounting tool (Task 4.2) in the Work Package 4 Toolbox.

## 1.3. Ecosystem accounting approaches

The ecosystem accounts are an exercise serving to streamline a number of discourses and developments. It is jointly driven from statistics (System of National Accounts), sciences (ecosystem services valuation) and policy-making (climate change abatement, biodiversity conservation) towards (quantitative) assessment of ecosystem resources (capital) and their human uses, impacts and benefits. It contributes towards expressing these relationships in an index such as Green DGP, the need for which comes because traditional economic accounts did not take into account the environment, and the cost of tackling ecosystem degradation. The United Nations Statistical Division (UNSD) has initiated a process of integrating the economic and environmental accounts more than two decades ago, by drafting and revising a handbook 'System of environmental and economic accounts' (SEEA, http://unstats.un.org/unsd/envaccounting/seearev/ ), which includes a separate chapter on ecosystem accounts, and will help set out international standards.

”The SEEA was launched by the United Nations and the World Bank in 1993 as a response to recommendations of the 1992 Rio conference on sustainable development. The initiative sought to address the problem that the environment was not fully taken into account in the System of National Accounts (SNA) which is the framework used to calculate GDP. A revision of the SEEA was published in 2003 (SWWA, 2003) and work continues to establish the SEEA as an international standard. The importance of such work has recently been emphasised by the outcomes of COP10, which endorsed the development of national accounting systems for biodiversity and ecosystem services[1] (Strategic Goal A, Target 2). "

## 1.4. Introduction to the European ecosystem accounting approach LEAC

Land and ecosystem accounting (LEAC) is a method and approach being led and promoted currently by the EEA. The original ideas have been developed by Jean-Louis Weber for nearly 30 years. Since 2002 these ideas were put into practice in cooperation between the EEA and the European Topic Centre on Terrestrial Environment by producing the first Land accounts of Europe. Later on the land accounting method was extended into an ecosystem accounting framework with the participation of the University of Nottingham. The LEAC method was first published in the Journal of Ecological economics, in a Special Issue on Environmental Accounting by Weber in 2007. At present, we are producing a European example of ecosystem accounts as a proof of concept as well as testing other applications with more specific purpose as the case of PEGASO.

LEAC is a generic tool useful for different purposes of environmental assessment and monitoring and in a spatially explicit way. In particular it can provide spatial indicators for regional assessment of the status and degradation of natural capital due to the over-use of natural resources. Therefore the LEAC approach strives to address the biophysical or ecosystem condition part; the human use and derived socio-economic values and benefits at an equal footage. The human benefits, of course, often incur ecosystem condition

[1] http://www.cbd.int/nagoya/outcomes/

degradation, which needs restoration efforts to maintain the initial biophysical assessments. Currently, a major emphasis is on the bio-physical assessments however, for mapping the major ecosystem properties aiming to assess a degree of ecosystem integrity or health, as well as main degradation signals when and where present. This makes the LEAC approach distinctive from other assessment approaches. It involves a broad geographical approach at the start – top-down and holistic. It also aims to account for what is first obvious and most ecologically meaningful by collating widely available evidence, including scientific data, statistics and expert valuations.
LEAC is intended also to provide multi-scale (hierarchical) outputs, to facilitate the assessment of processes that manifest on different levels e.g. continental, country, region and local level. So far the European application has been well demonstrated in a report titled 'Land accounts for Europe 1990-2000' (EEA report, 2006). Regional applications were tested for exploratory assessments of Mediterranean Wetland areas of Europe, as well as more site specific applications for assessing four cases of Wetlands of major conservation importance in Europe: Danube Delta in Romania, Amvrakikos lagoon in Greece, Camargue delta in France and Doñana protected area in Spain. Major strengths and applicability of the method have been shown at larger scales e.g. for Europe due to the possibility to match multi-source and multi-theme data per country (as medium resolution remote sensing, country statistics etc). However, major difficulties were observed in applying LEAC at local levels (e.g. for the four wetland cases) where multi-variate assessments require high quality data inputs (sampling, measurements) and sophisticated modelling of the relations between the very complex structures in an ecosystem.

Currently the LEAC application in PEGASO addressing the Mediterranean and Black Sea countries is steered along possible applications in other areas from Australia, Canada and Colombia. The latter applications are result of the on-going developments at the EEA in promoting the method globally. The overall intention is to streamline the method into a global application with intended inputs for a UN standard. However, these applications do not have the same purpose, and so the approaches will differ. While in PEGASO the main objective is to deliver regional assessments of past and present states (that should feed into future scenarios) for support to decision making in the other areas it will contribute more to national environmental accounting initiatives.

This report is structured in two parts:

- the first one explaining the LEAC approach as an umbrella framework including a number of methods to address the main ecosystem subjects and
- the second part explaining the concrete developments and applications in PEGASO.

# Part I: Ecosystem accounting methodology

## 2.1 Elements for constructing ecosystem accounts

Essentially the ecosystem accounts aim to register properties or state of natural resources and ecosystem components in terms of quality (for example type of land-cover); quantity (volume of biomass, area of certain land-cover, number of species etc) and change in quality and quantity in time and space. The quantity and quality features are basically termed and accounted as physical "stocks", while the change features are accounted as "flows".

- Definition of stock – a mass or volume of something or area
- Definition of flow – flow is a rate of some kind

The inputs for characterizing stocks and flows are various, but generally they need to cover a unit of area, be it a country, region or continent, in a harmonized way (as coverage, signal and precision), otherwise one cannot compare the outputs.

For distinguishing differences in stock either as quantity or quality, the inputs are interpreted and classified into entities with clear, simple and transparent meaning that provides insights about conclusions regarding the integrity or health of the ecosystem/environmental resource in question. The interpretation and classification relies on predefined logical systems or filters for example land-use classification system, or water quality classification system. Likewise, the flows are also classified into most likely transitions which therefore allows one to track and explain what entities change to another entities and also how much of each entity was transformed. Concrete examples are given below when reviewing the details the concrete accounting subjects.

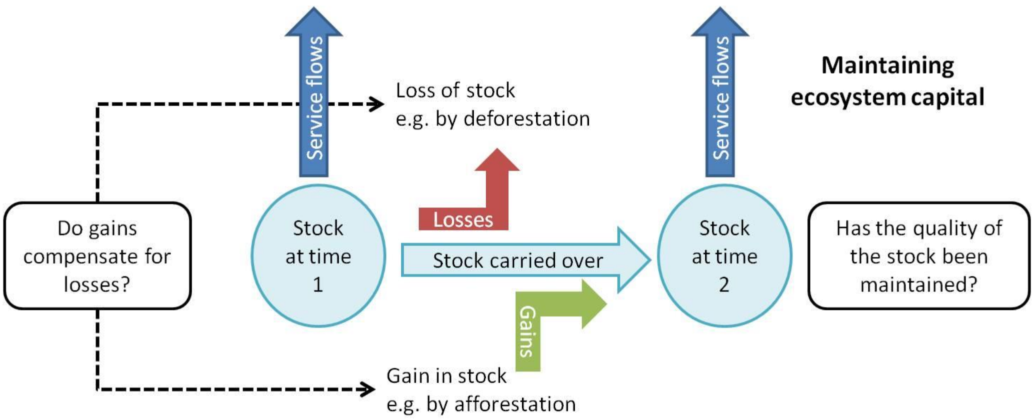



Figure 2. Ecosystem capital accounting: stocks and flows. (adapted from Haines-Young and Weber, in EEA, 2006)

The ecosystem accounting addresses multiple dimensions of inputs which aim to characterise the different properties of an ecosystem (abiotic, biotic and antropic), the major ones being productivity and biomass accumulation, richness of life forms (or habitats and biodiversity), dynamics, biotic regulation and stability, different environmental elements as water, topography, biotopes, different human presences and impacts (such as pollution, erosion, invasive species sprawl). The conception of such a complex ecosystem reality is underpinned by classical ecological works (Odum, 1971; Holling 1978, 2001) and also related large-scale applications such as the Millennium Ecosystem Assessment.

To synthesise all these different aspects as a coherent description of a single holistic entity, the ecosystems need to be defined as accounting unit. There are multiple attempts to define ecosystem and in a hierarchy of scales, e.g. in a chorological order –biotope, ecosystem, landscape, biome. All of these orders are now influenced by human presence and impacts, but often it is the landscape level where human and natural interactions produce a concrete result – the landscape. The notion of ecosystem accounting then allows the introduction of other elements (apart from land), like the sea and ocean (*seascape*), or even the atmosphere (*airscape*, where air pollution, noise, flight traffic, etc. take place). Air and ocean are used and transformed by humans like land. Ecosystem accounting is therefore a very relevant method to tackle wide range issues and environmental elements, including also management of the rivers, the land, the coast and the sea through a common ecosystem based framework.

To build an ecosystem account one needs to define and apply a unit able to incorporate a mixture of all those elements. Certain advances in this aspect are derived from the Socio-Ecological Systems (SES) approach. “A social-ecological system consists of a bio-geo-physical unit and its associated social actors and institutions. Social-ecological systems are complex and adaptive and delimited by spatial or functional boundaries surrounding particular ecosystems and their problem context” (Glaser et al., 2008). To be relevant for ecosystem accounting, it needs to be translated into a statistical category. This leads to the proposal of defining a proxy unit of SES for observation, statistical collection and economic-environmental accounting named socio-ecological landscape unit (SELU), as proposed by the UNSD and EEA and their expert group (EEA expert Group meeting, 2011). This definition is very useful for traditional modes of resource appropriation, where all is done locally or regionally. But in a global liberal system we can have enormous transfers of investments and benefits from natural capital extraction, where externalities remain locally, affecting or even destroying the living conditions of local population, leading to local conflicts (and even wars, etc). These new dimensions in resource management need to be addressed by the SELU framework.

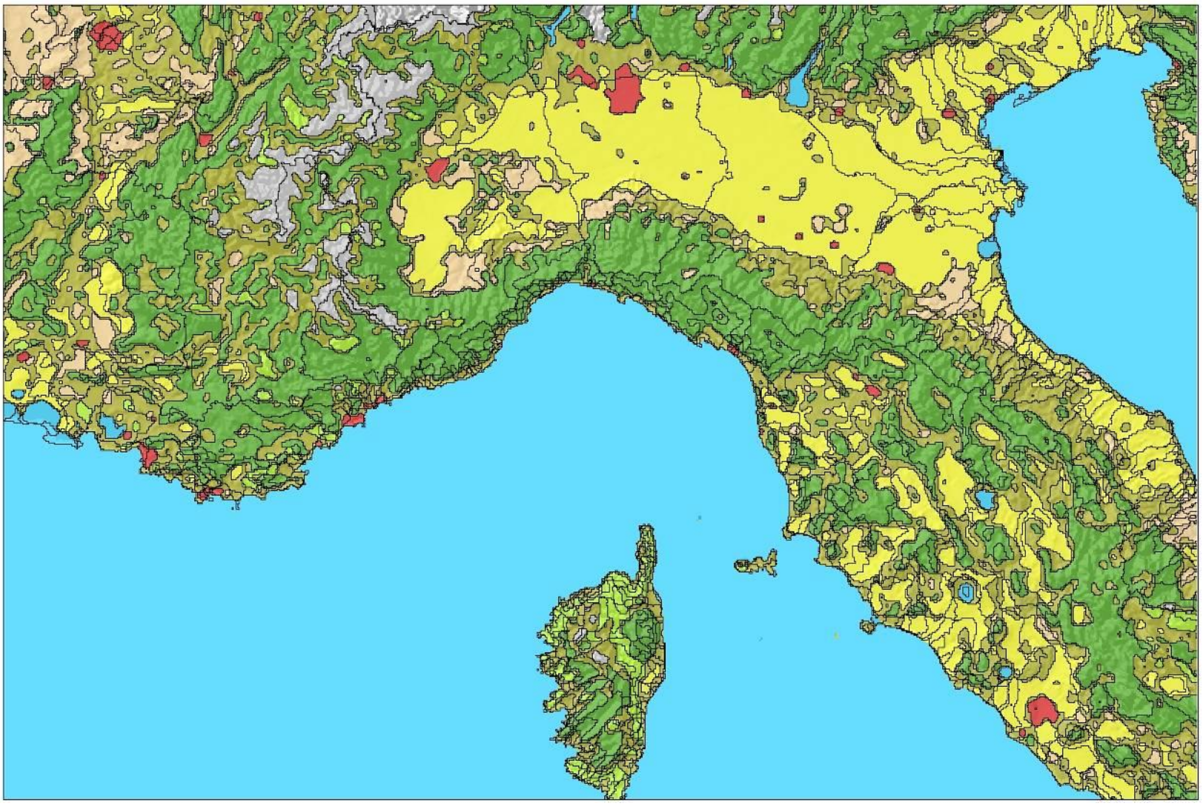


Figure 3. Defining the ecosystem accounting units for Europe (Weber and Ivanov 2011, EEA-CEM)

For developing ecosystem accounts the challenge is to match the different bio-physical and societal variables in relevant territorial units to understand how they interact in terms of resource management. The societal ones are readily and widely available as statistics for administrative units (NUTS), while the biophysical ones – more relevant for naturally defined units - as river catchments, different types of landscapes such as mountains, highlands, lowlands and different types of ecosystems, as forests, steppes, wetlands, etc. For all of these the human product of land-use needs to be added (e.g. pasture lands, croplands, residential areas etc.) in such a way that the appropriation modes upon the ecosystems are made more transparent, such as flows of private benefits made on common natural capital better known as well as the degradation rates of the basic ecosystem functions.

## 2.2 Conceptual framework of the European ecosystem accounts

Although proposed nearly three decades ago the concepts of ecosystem integrity and dynamics (Odum 1971; Holling, 2001; Rapport, 1985 ) have not been widely operationalized and applied, and this is still due to the difficulty to accomplish holistic, overarching and large-scale studies able to produce convincing and explicit results on ecosystem health. Recent accumulation of widely available and large-scale datasets as those resulting from remote-sensing, national statistics and expert valuations have now provided new opportunities to revive the ecosystem health assessment perspective. The EEA approach on Land and Ecosystem Accounting has pursued this perspective though developing an accounting concept and framework and has also produced first examples as a proof of concept. It aims to address the three key properties of productivity, richness and resilience by formulating concrete subjects to assess and produce quantitative accounts. The work is based on the fundamental ecological functions and factors such as primary productivity (carbon sequestration, biomass accumulation and nutrient turn-over rates), biodiversity (species abundance and distribution) and ecosystem stability (successional stages and equilibrium).

Essentially, these fundamental ecological considerations and derived spatial indicators are reviewed within a wider socio-economic context of policy-making and translated into a selection of key indexes as suggested by Weber (2009) following a "cubist approach". In this way the accounted ecosystem properties are translated for outlining environmental considerations of primary interest such as:

a) Landscape index – reflecting on the area and changes in land-cover, that is the result of human land use. This allows on one hand to assess the resulting pressures of certain land (and sea or space generally) uses on natural capital, or protected areas, etc., and on the other – the resulting ecological effects as connectivity and fragmentation (corridors, patch and matrix structures).
b) Carbon/biomass index – reflecting on the processes of accumulation of biomass and productivity (annual net primary production), the human use of both, and the resulting balance to assess maintenance of the ecosystem's vitality
c) Water index – reflecting on the quantity and quality of water resources linked to the available resources (aquifers, rivers, source, etc), their uses by sector, the social access to water, etc, the water resources managements and their impacts on the key ecosystem functions.
d) Biodiversity index – reflecting on the richness of species, the species community structures (food-webs and their disruptions) and their conservation status and prospects (endemic and threatened species versus invasion from aliens.
e) Dependency index – when ecosystem functions are under high inputs dependency to continue producing (e.g. water, nutrients, fertilizers, pesticides etc), that produce also high "toxicity" in the ecosystems. Generally this management dependency is linked with the production mode (intensive versus extensive, depredation from external agents versus local food subsistence, etc). Beach ecosystems are also in high dependency from sediment arriving after damming processes, then dependent on beach nourishment actions or other kind of protection that have important impacts on the land-sea interface. Protection actions for management of certain species can lead also to dependency of some species on human presence.
f) Health index – is intended to address issues of the health of species populations as well as human populations (e.g. bird flue, dispersal of new diseases by species affecting human health

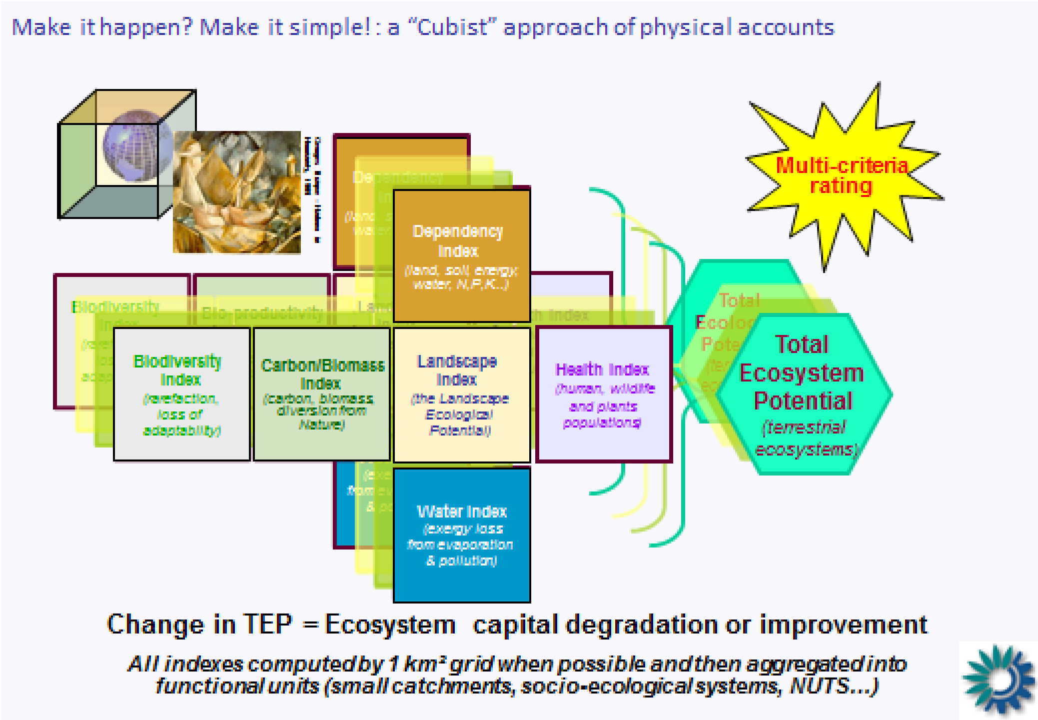



Figure 4. The ecosystem capital accounting cube, designed by J.L. Weber (EEA)

The above order of listing these indexes (each one representing a facet of the ecosystem cube) also shows the degree of their development.

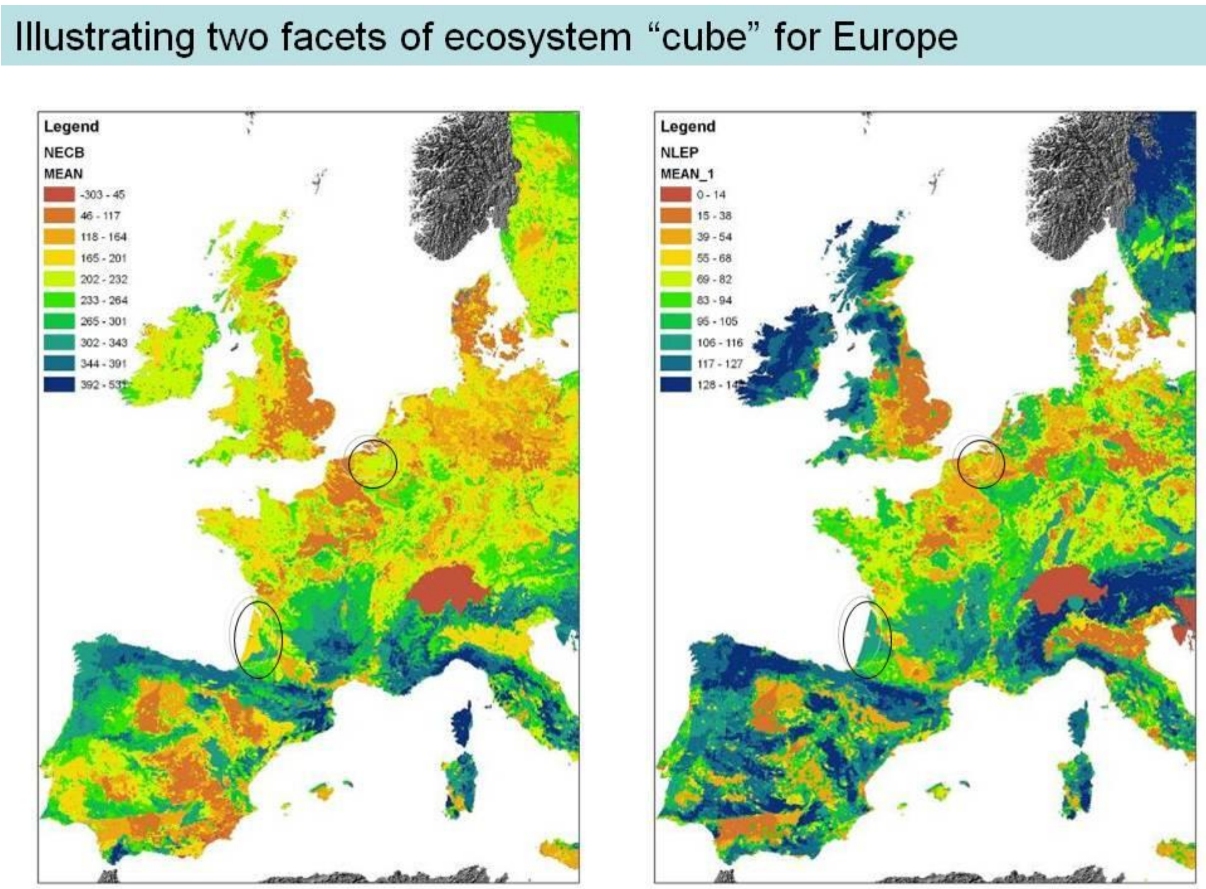


Figure 5. Net ecosystem carbon balance (left image) and Net Landscape ecological potential (right image) (Weber and Ivanov 2011, EEA-CEM)

The landscape index was first elaborated. The EEA (No 11/2006) report ¨Land accounts for Europe 1990-2000¨ written by Roy Haines-Young presents the first application of this method, demonstrating detailed characterisation (including quantitative estimations) of major land-use patterns and changes in EU – the urban, agricultural, forest and semi-natural land-cover classes.
The carbon/biomass index was calculated and mapped for the EU countries for year 2000 as a coarse demonstration and proof of concept. It will be soon reproduced as a time-series and then will be further improved and validated. Technical details and examples of the European land accounts are presented in Annex IV. The water and biodiversity indexes are still under development, but first results should be presented in May, 2012.

## 2.3 Data inputs for developing ecosystem accounts

Spatial data:

The spatial data includes continuous coverage, multisource, mainly medium resolution data for mapping phenomena of interest on wide geographical scales. Various data inputs are matched applying fuzzy logic and proper techniques (see below) for this purpose. Point data and more precise local data are used for cross-check and partial validation so far.

The spatial data, mainly derived from satellite remote sensing sources, that is used as inputs for LEAC includes a number of themes, land-cover being a key one. Vegetation biomass and primary production on land (derived from NDVI) and in water (derived from Chlorophyll-a estimations); habitat maps both on land and water; human impact maps including transport, settlements, agriculture and aquaculture etc are increasingly produced and improved sources of information on large geographical scales. See Annex 5 for detailed list of data inputs identified for PEGASO T4.2. The European CORINE LC, the GlobCORINE, MODIS land cover are key inputs. Medium-resolution satellite image providers (as MERIS and MODIS, SPOT-vegetation) are widely explored and applied for the vegetation productivity-related estimations with certain limitations such as saturation of the signal they carry. RADAR image providers as ALOS-PALSAR are still expected to provide better inputs on the near future, for improved biomass and habitat mapping.

Statistical data:

Statistical data and related estimations reported for various territorial units (such as municipalities, regions, countries, groups of countries) during the last five decades provides readily applicable multi-subject information to address a wide range of mainly human influence aspects related to the state and change of the ecosystems. EUROSTAT and FAOSTAT are the main sources explored so far, for estimations of annual production and harvest of crops, timber and livestock. Additional categories to be used include fisheries, fertilizers and pesticides use in agriculture, water use etc.

Expert judgements and valuations:

Include mainly subjects related to wide-scale biodiversity assessments. Such were produced for the EU countries and explored so far for the European ecosystem accounts e.g. the data reported for the Article 17 of the Habitat Directive on the distribution, conservation status and future prospects of selected species of European Conservation importance (excluding birds). IUCN data on threatened species, data from Birdlife international, Mediterranean Wetland Observatory and others is yet to be explored.

## 2.4 Methods, tools and techniques used for developing ecosystem accounts

Three broad categories of tools are applied for designing and implementing ecosystem accounts: spatial data exploring and assessment for selecting best inputs to produce accounts; spatial data processing and modelling for producing stock and flows of the accounts; multi-criteria analysis and assessments to derive information on ecosystem capital state and degradation. In addition several tools are designed to assist the exploration of the produced stocks and flows in an interactive way.

For fast and efficient exploration of the quality of the available data inputs, these are normally extracted using GIS (ArcMap) and/or Image processing tools such as RSI-ENVI. Then the data is integrated in a grid (of 1 km most often) using ArcMap, and afterwards the relationships between the different variables explored. Finally, accounting indexes are extracted per grid-cell using Excel pivot tables and/or statistical software such as SPSS. The assessment of the quality and reliability of the available data to be applied for large (continental) scale assessments is often visually assessed and approved or improved for assuring consistent geographical and landscape patterns on the basis of expert knowledge and judgements. New emerging tools and processes for harmonization and sharing of spatial data, such as SDIs are expected to greatly facilitate data sources exploration and selection.

Once the best data sources are selected, spatial data processing is done suing GIS (ArcMap), Matlab and a multi-dimensional database is constructed provided that the needed inputs are sufficiently available and of a good quality. When these inputs are missing or existing but need to be improved, then also image processing tools are applied again (such as the above mentioned RSI-ENVI and ERDAS IMAGINE).

Spatial modelling and transformation of the original data is done to derive various products, such as smoothed, more course versions which facilitate interpretation (such as agricultural pressure, urban pressure etc), or to derive specific indexes (like terrain map, or elevation breakdown) or which are needed for subsequent calculations (such as percentage of given land cover class in 1 km2 grid). These processes are designed and done using automated calculation scripts with ArcMap.

Another spatial data processing technique which is widely applied is the downscaling of the statistical data (on crops, timber, livestock) reported per unit area (country) to a spatially explicit map (in 1 km2 grid). The downscaling is a complex process including many steps. The downscaling procedures are first designed to produce satisfactory downscaled products, such as spatially explicit intensity of cropping, or timber harvest applying step-by-step calculations with ArcMap and assessments. Once approved, the whole process is then translated into an automated GIS calculation model.

Through the above techniques, the ecosystem accounts are produced including estimations of stocks and flows and related indexes (such as potentials, intensities etc). The latter are then included in interactive exploration tools such as OLAP cubes and pivot tables, online map overlay viewers and others.

Finally, all of the above tools provide single subject outputs which allow to portrait one aspect or element of the ecosystems. For assessing their complex properties in an integrated manner, a novel approach was designed by Haines-Young et al. (2010, 2011a, b). It applies probabilistic (loose) modelling with sets of variable and produces multi-criteria assessments. Bayesian Belief Networks (BBN) are explored for this purpose, they allow to make use of wide range of data in different forms and in a transparent way.

## 2.5 Summarising the accounting method

The ecosystem accounting methodology is a novel approach for integrated and large scale ecosystem assessments relying exclusively on available inputs. The exercise is data-driven. In accordance with the limitations of data availability it can provide several outputs: a complete numerical account (satisfying a number of criteria of what an ecosystem capital account is e.g. calculated stocks and flows); a map of a relevant spatial indicator or even a qualitative assessment (such as high-medium-low pressure of a human action).

According to our present experience, the process of developing an ecosystem account can be summarised in six steps:

| | Step | Note, clarification | Example (problem-oriented) |
|---|---|---|---|
| 1 | Define, or sketch a proposition (pre-concept) | Choosing a row from the above matrix to develop a line of reasoning | The effect of urban sprawl on coastal ecosystem |
| 2 | Perform a quick test with available and pertinent datasets | - Identified and collected for the above matrix;<br>- this may already allow to derive *preliminary exploratory accounts* (version 0).<br>- If the data available does not allow to extract complete stocks and flows, it can be applied to map at least some relevant spatial indicators at this stage<br>- next option would be try to improve it/develop it or to choose another *reasoning line* | - MODIS land-cover 10 year time-serie allows to extract areas of Urban land cover.<br>- Stock would be the area in hectares within a coastal region for ex. and a flow, the change till next year(s).<br>- However if the change cannot be validated as true (so no complete account can be derived), the information on current urban pressure can still be a relevant spatial indicator of coastal pressure to support ICZM |

| | | | |
|---|---|---|---|
| 3 | Define a detailed concept of work (jointly, in a teamwork) | Involving all partners with relevant inputs, according to their expertise (data, models, information at hand) | MODIS urban land has been assessed as not sufficiently sensitive to reflect on actual urban sprawl, therefore other sources are identified to enhance it (GlobCover, nightlight) |
| 4 | Develop an accounting model and database (jointly, in a teamwork) | - This includes a set of data processing and modelling tasks which allow to extract accounting tables and plot maps on the stocks and flows as defined in the previous steps<br><br>- the models need to be just fit for purpose (help convey information from existing data to decision-makers) | For example, the EEA's method for land-cover accounts contains procedures to extract and structure the information from CORINE LC in a form allowing to quantify and map urban sprawl and assess its effect on Venice lagoon for example. This is particularly useful to assess and map main pressures and impact on the coast. |
| 5 | Assess, validate and improve the models and databases | - via tests in the CASEs and the sub-regional assessments<br><br>- applying additional data | |
| 6 | Produce final ecosystem capital accounts | Version 1 or spatial indicators (if no account can be derived) or even qualitative assessment ... | |

The above presented methodology built for Europe is currently being extended and adapted for the purposes of the Mediterranean and Black sea coastal areas' management. The following part explains the main lines of work initiated so far.

# Part II: Ecosystem accounting applications in PEGASO

## 3.1 Setting up working sub-themes and ecosystem accounting applications

This part reflects on the efforts to built applications of ecosystem capital accounts specifically addressing the coast and marine parts of the wider coastal zones, by drawing on the experience of the land accounts. There were a number of initiatives, discussions and workshops, (after the General meeting in Romania, July 2011) to define and proposal several feasible applications. During a meeting at JRC-IES (Ispra, July 2011), certain difficulties of applying the EEA approach for *land accounts* were underlined, and alternative approaches were considered (e.g. upscaling the outcomes developing ecosystem accounts for selected cases (for example the north-Adriatic case). Yet additional efforts, to further develop elements of the EEA approach were also discussed, for example incorporating data on fires, crop irrigations, non standing forest biomass etc to better reflect the Mediterranean environment. Relevant approach for the sea part was suggested, targeting to analyse the influence of land-based activities, through river run-off (catchment approach) on coastal waters quality, eutrophication risk etc. The sea part of the work may also include analysis of the physics of the water column in relation to sea currents, temperature, upwelling events etc. The work needs an improved land cover map for the African and Near eastern parts of the study area. For this GlobCover or GlobCorine can be tested and compared with Corine land cover, and afterwards improved with additional data. This work is expected to deliver adequate accounting outputs spanning the entire Mediterranean and Black sea coastal region but still leaving empty the sea part. Consequently major efforts were devoted to address this gap, at the UAB, and a complementary approach termed SEAC was proposed, conceptually rich yet outlining major difficulties for its practical development, due to lack of data and far more complex marine system to be assessed and modelled. To address this problem a meeting was organized in Nottingham (December 2011). It was identified then that e a common vision for the accounts is needed and that the division between LEAC and SEAC was probably unhelpful. PEGASO should rather speak of ecosystem accounts and include within them integrated approaches covering land coast and sea. Aside, it was also identified that a more iterative and flexible working approach for developing ecosystem accounts was needed, and that at this stage 'right approach' was identified as more important than concrete calculations and mapping of accounts.

## 3.2 Building accounts for the coast and sea environment

Ecosystem accounts should provide statistics, values and maps which inform policymakers of environmental and natural resource availability, use, depletion and degradation over time and help identify the drivers. In Europe, the physical part of the account has been applied to the terrestrial environment using LEAC methodology and one of the goals of PEGASO is to extend this methodology to the marine part of the coastal zone for the Mediterranean and Black Sea.

For the purpose of the task, an inventory of ecological assets and human activity data including land and sea uses, both at a regional and local scale will be provided, first step for a multi-scale assessment on the state and threats on main relevant ecosystems at coast and sea in the Mediterranean and the Black Sea.

This work will allow to:

(1) Start the construction of a green/blue inventory (land/sea) at the basin scale which will feed into the Spatial Data Infrastructure (SDI) developed by PEGASO WP3.

(2) Test and develop a series of tools (maps, statistics, spatial indicators of pressures, models, etc), publicizing and making useful existing data for helping decision making, a starting point for the construction of an ecosystem based assessment at the basin scale identifying hotspots, potential for ecosystems to be degraded or to evolve in a sustainable direction (inputs to PEGASO WP5),.

(3) Produce a number of targeted physical ecosystem accounts (together with UNOTT, EEA) where data exist or expert judgment can provide qualitative information..

4) Start a participative process in order to apply the ecosystem based assessments for policy-support purposes, for example at the basin scale identifying hotspots, potential for ecosystems to be degraded or to evolve in a sustainable direction (inputs to PEGASO WP5).

These results will be a basis for other PEGASO tools such as participative scenarios and indicators, as well as economic and social valuation of some activities using relevant services of certain ecosystems. Inputs to the PEGASO toolbox (WP4), will allow a common knowledge shared and agreed by the PEGASO governance to support implementation of the ICZM Protocol in the Mediterranean and similar figure in the Black Sea. Stakeholders and users will be able to use these tools to discuss and take consensual decisions.

Therefore they will serve ICZM ecosystem based purposes becoming a necessary basis for Marine and coastal planning, but they will also be useful for future implementation of legislation such as the Marine Strategy framework Directive in the two basins.

Given the novelty of this approach and the lack of data for the marine environment, the methodology will be tested and developed at different scales following relevance of issues and constrains of data availability, but also in partnership with specific areas (AMPs, wetlands, islands, etc) which are not in the PEGASO partnership but are interested and relevant to this developments. This process will involve countries and PEGASO governance as an opportunity for us to understand better their needs and for them to understand our goal and therefore the usefulness of sharing data.

### 3.2.1 Rational

***(1) Following the ICZM protocol, ICZM is:***
*"... a dynamic process for the sustainable management and use of coastal zones, taking into account at the same time the fragility of coastal ecosystems and landscapes, the diversity of activities and uses, their interactions, the maritime orientation of certain activities and uses and their impact on both the marine and land parts."*

***(2) According to the CBD, the Ecosystem Approach (EA) seeks to:***
*"...places human needs at the centre of biodiversity management. It aims to manage the ecosystem, based on the multiple functions that ecosystems perform and the multiple uses that are made of these functions. The ecosystem approach does not aim for short-term economic gains, but aims to optimize the use of an ecosystem without damaging it."*

PEGASO and specifically task 4.2 should provide tools that help the implementation of an Ecosystem Approach (1) of ICZM (2) process following the Mediterranean ICZM protocol and a similar juridical tool in the black sea coast.

Starting from the common understanding of what the concept of ICZM and EA suppose, there is a wide recognition in scientific, grey literature, experts and guidelines that:

- Spatially explicit accounts on the distribution and changes of endangered habitats and communities are strongly needed for a sound implementation of ecosystem based strategies such as ICZM (Claudet and Frashetti, 2010, Frashetti et al, 2011).
- Improve the qualitative and quantitative understanding of how human activities both at land and sea impact coastal ecosystem (Halpern et al, 2008)
- Land sea linkage must be strengthened both at level of data (available and uniform for both part and their interface), planning and governance (include both land and marine stakeholders as Marine Protected areas managers).

Relying on those statements and on the ongoing reflection process in our team and with PEGASO partners, different issues/steps related to the task 4.2 has been defined.

### 3.2.2 Data issue

Mostly for accessibility reason, more information is generally available for the terrestrial part than for the marine part. Indeed, the development of satellite imagery, which associated to definition of a scheme of habitat classification such as Corine has lead to the possibility to have continuous maps of terrestrial proxy for ecosystems (CLC classes) and produce tools such LEAC in Europe. For this reason of accessibility, in the marine part, the habitat distribution and changes, biodiversity monitoring, etc, are very difficult and costly to assess and are far away from being achieved at the Mediterranean scale. Therefore, in a next future, it will be necessary to collect further seabed, marine biodiversity information and develop common monitoring protocol to fill the gap between land and sea data availability.

However the first step is to make best use (or re-use) of already existing information and maps and to properly publicize and disseminate it to the stakeholders, support decision making and to create a framework for enlarging future data collection, harmonization and sharing across the Mediterranean sea.
For those reasons a green blue inventory will be done as a first step for 4.2 tools development.

**Green Blue Inventory**
The existence of the governance platform and the SDI developed by PEGASO are an opportunity to start a first assessment of the data availability and develop a framework for a common understanding of data needs and the way to share them and make them useful. The effort of data gathering will be focus principally on:

*Ecological features:*

- Relevant land cover classes which support high biodiversity: small islands, deltas, lagoons, estuaries, dune fields, natural beaches, heritage landscapes, sea grasses including *Posidonia oceanica* meadows, etc.
- Places where important species (fish, coral, marine mammals, etc) have been detected as well as migration routes and sanctuaries hotspots, identifying most important corridors.
- Species richness index covering the whole Mediterranean and vulnerability spots
- Measurable stocks that can be monitored over time
- Priority areas for conservation and management

*Level of protection and legal uses*

- Denominated coastal areas of the Mediterranean and Black Sea Basins, including EEZ and other political boundaries and obligations (areas that have a political protection obligation)
- MPAs and other protected areas
- Water quality of the rivers discharging into the Mediterranean and Black Sea

*Pressures*

- Drivers and pressures from sea and land (boat traffic, aquaculture, fisheries, land use, ports, etc.)

Make data useful; improve the visibility and understanding of pressures and changes:

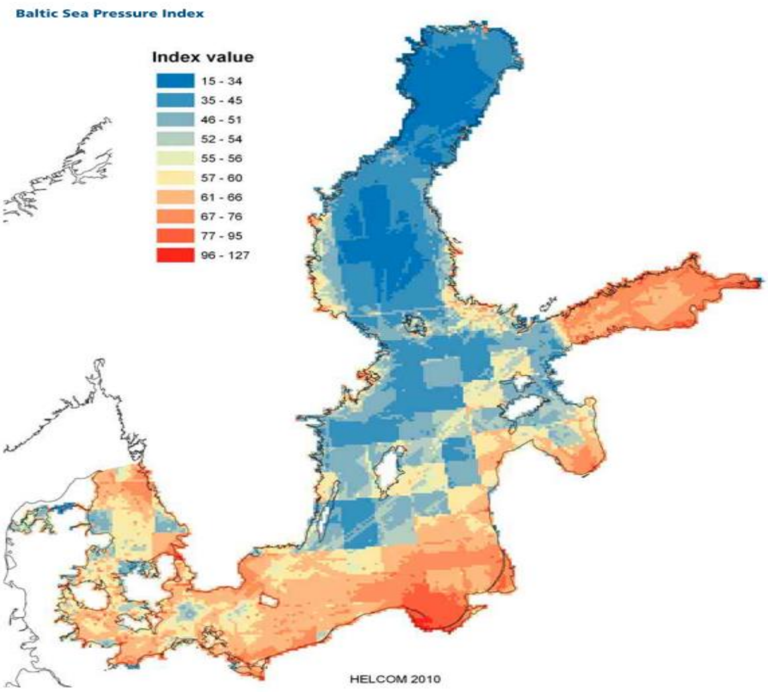


Figure 6: Map of cumulative potential pressures in the Baltic Sea based on the Baltic Sea Pressure Index. The blue color indicates low cumulative impacts and the red color indicates high cumulative impacts. (HELCOM, 2010)

Toward continuity between Land and Sea and between countries; harmonizing the information:

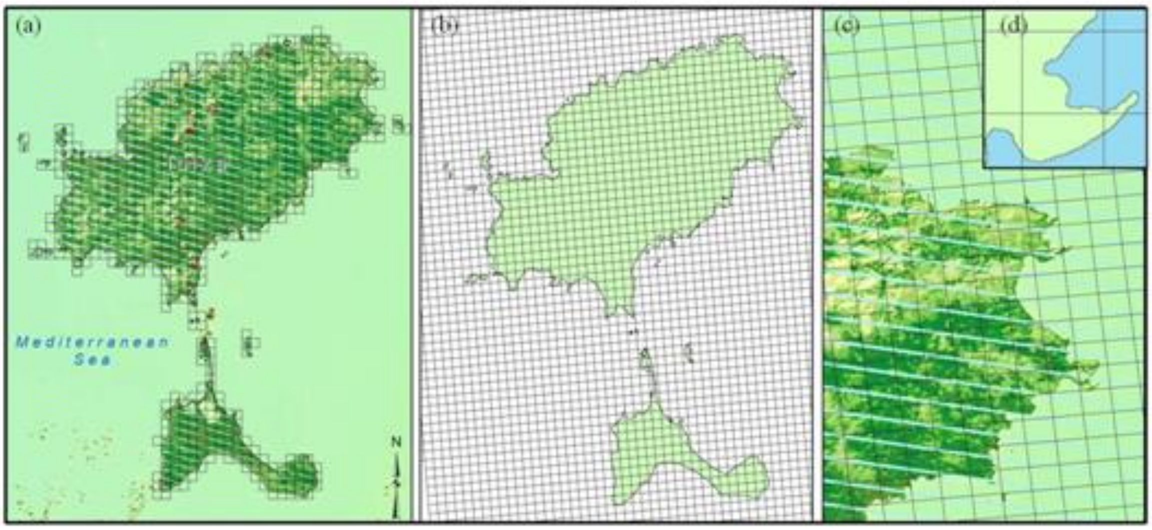



Figure 7: Example of proposed SEAC grid for the island of Ibiza. (a) The current LEAC grid is only available for land. SEAC intends to extend this grid into the sea (b). This will insure continuity and comparable ecosystem accounts for the coastal zone (c) at spatial resolution of 1 $km^2$ grid cells (d)

**The grid approach**

Land-sea continuity in management and planning is greatly facilitated by comparable and continuous data on this interface.

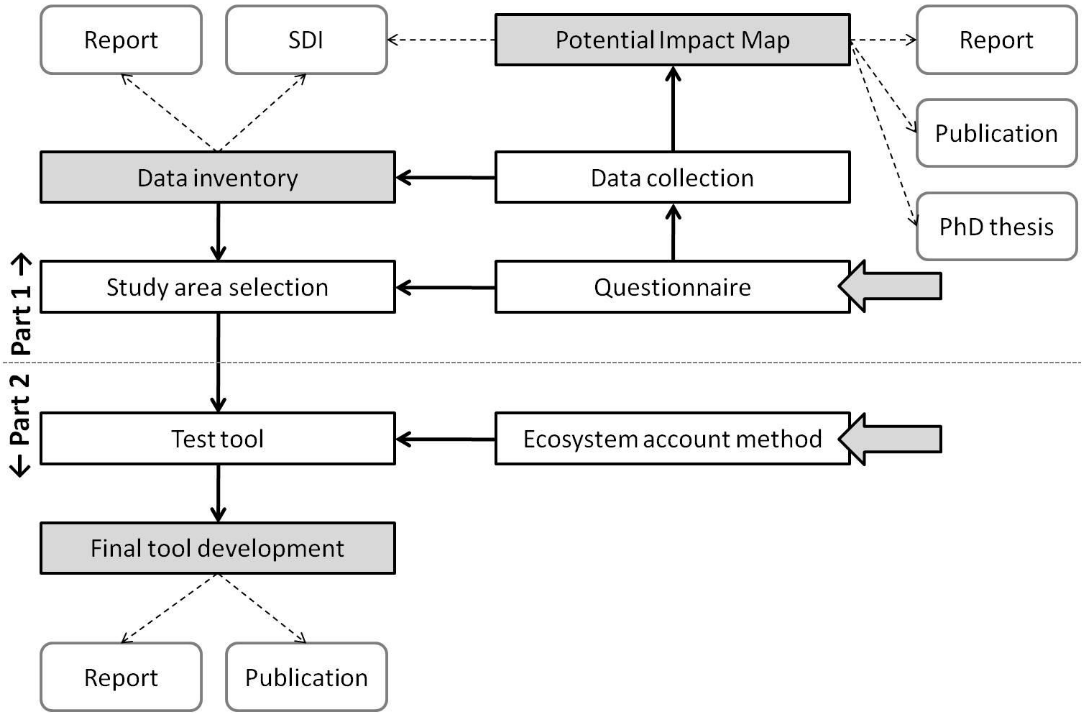
Utilisation and harmonisation of existing data, strengthening the land-sea link will be achieved by extending the 1$km^2$ grid system currently used for LEAC, to cover the Mediterranean and Black Sea (see Figure 2). This Grid system will be coherent with INSPIRE directive.

The grid system allows for data from different times and/or geometries (e.g. NUTS 2003, NUTS 2006) to be combined with continuous (such as CLC) and/or discrete data (e.g.species distribution)(EEA, 2010). In other words, complex spatial, statistical, qualitative and quantitative inputs provide comparable, meaningful outputs.

This gridded approach will serve directly the potential impact and accounts exercises allowing a common data format for analysis and integration both between land and sea and between PEGASO tools.

### 3.2.3 Method

**Study design**




This project will consist of two main complementary parts, namely the 1) data inventory and mapping, and the 2) development of an ecosystem accounting tool. The objective of Part 1 is to identify what data is available at regional, sub-regional, national and local scales. This inventory can be used to identify important areas for marine spatial planning, as well as knowledge gaps. A questionnaire completed with expert judgement methodology will be used to achieve this objective. The results will help to identify data sources for both the SDI and the Potential Impact Map. A report listing the data that is available (and the data sources) will be made available for Mediterranean stakeholders facilitating localization of data or needed research efforts. Additionally, the availability of data is the most important criteria in the selection of study sites needed in Part 2. Part 2 aims to develop an integrative ecosystem accounting tool for coastal zones and their marine interface. Study sites selected in Part 1 will be used to test the tool. The development of this tool is currently underway by Pegaso team at the University of Nottingham. At UAB the methodology will focus on Part 1, even though we participate also in the part 2 discussion on the method elaboration together with UNOTT.

**Data inventory**

Goals:

- Assess what data is available at different scales for both ecosystem and social uses that can affect them.

- Identify knowledge gaps (at all scales)
- Identify study sites for ecosystem accounting tool testing (incl. Regional if feasible)
- Collect data for the Potential Impact Map

Outputs:
- A report listing available data at each scale and data sources
- Potential data layers and geonodes for the Spatial Data Infrastructure (SDI)
- Provide data needed for the Potential Impact Map

**Questionnaire**

A questionnaire will be sent to institutions and entities involved in the management, governance and/or scientific research in the Mediterranean and Black Sea Basins. The main target stakeholders for the questionnaire will be the partners and contacts already established by the Pegaso Project. These stakeholders include regional programs (e.g. IUCN), sub-regional (e.g. INFREMER), national (e.g. government) and local projects (e.g. Pegaso CASEs, MPAs). Other projects, institutions and entities identified in a literature survey will also be contacted. The objective of the questionnaire would be to evaluate what data is available, at what scales and how willing the stakeholder would be to participate in this study. The answers to the questionnaire (both quantitative and qualitative) will be used to select the study sites based on the criteria outlined in the following section.

Several questionnaires and surveys have already been done with the Pegaso partners and stakeholders in the past. The results and types of questions already asked will be assessed to reduce repetition so that questionnaire fatigue can be avoided. Key contact people will be established prior to sending out the questionnaires. These contacts will be fully informed of the objective of the questionnaire and what is expected in terms of a response. Follow-ups will be performed telephonically to ensure that the stakeholders respond and that they understand the questions asked. The questionnaire will be also completed by a number of interviews with experts to assess the best judgment (on data quality if they exist, and on the ecosystem status and changes if no data is available.

**Assessment of available data**

The results of the questionnaire will be used to compile a list of data that is available from the stakeholders.
It will be completed by data search on internet considering:

- Relevant scientific literature
- Ongoing and past projects
- Relevant Database

In addition to the availability of the data, information on the scale, extent and temporal resolution will be recorded.

The list of data for land and sea will be grouped into 3 categories as discussed previously:

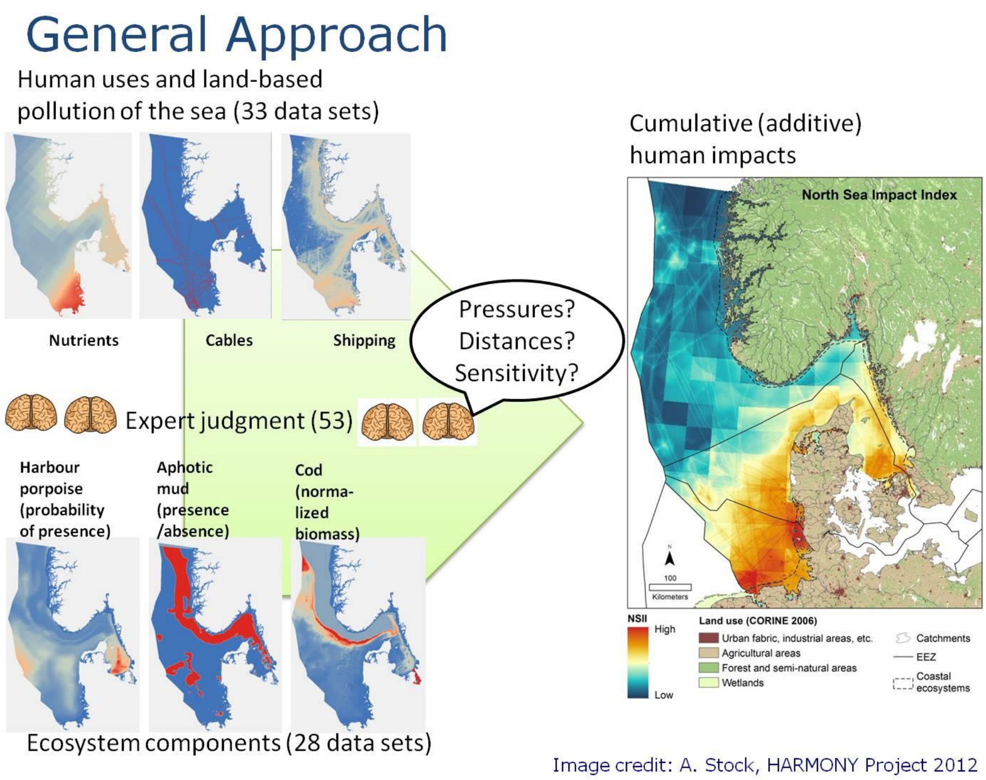
1. Ecological data (biological, geological, oceanographic, etc.), including habitat and ecosystem mapping
2. Coastal and marine levels of protection and legal uses
3. Data on anthropogenic activities

The output of this inventory will be a report listing the data that is available within each category at a regional, sub-regional, national and local scale. The source of the data will also be included. This inventory can be used by stakeholders to identify knowledge gaps where further research is required as well as for marine spatial planning and identifying areas that need to be protected. The inventory will also be useful for the Spatial Data Infrastructure (SDI) to identify potential geonodes for data sharing.

### 3.2.4 Mapping activities

**Potential Impact Map at (sub)regional scale**

The Potential Impact Map will be based on the model designed by Halpern et al. 2008 and 2009 and later developments (Selkoe et al, 2009, Ban et al, 2010, Korpinen et al, 2012). These models are used to evaluate the potential impact of anthropogenic pressures on different marine ecosystems in a systematic way. The resulting impact index value will be indicative of the cumulative impact on a given ecosystem and can be used to identify priority areas for action and conservation as well as predominance of sea based or land based pressures.




The determination of weighting coefficients needed to transform the pressures into potential impacts on a given ecosystem will be done through expert survey, as was done in the study by Korpinen et al. (2012). Due to the specific data requirements, a study area will be selected with the availability of data and presence of environmental experts as the predominant selection criteria.

As explained before data will be obtained from the inventory but also from work of other PEGASO partners (Nutrients input, chlorophyll a, transparency /turbidity, primary production, final scale modeling (ACRI, JRC…). The specific methodology will be taken from the last development in literature and projects and adapted to the specific needs and constrains (e.g. data availability) of the Mediterranean region.
For more information on the methodology please refer to:

- http://www.nceas.ucsb.edu/globalmarine
- http://www.helcom.fi/stc/files/Publications/Proceedings/bsep125.pdf

The main output of this section will be a spatial map of the cumulative impacts on (sub)regional area chosen. This map will be published and represent a section of a UAB /PEGASO PhD thesis. The map will also be made available on the SDI so that stakeholders can include impact information in marine spatial planning and policies process.

### 3.2.5 Concerns and considerations

**About the use of the grid**

The feasibility and relevance of gridded information for looking at stock and flows in the sea is questionable (3-dimensional environment etc.). One of the concerns is how to accommodate the three dimensional character of the sea with the two dimensional land accounting method. The sea has an additional dimension (see Figure 3) that is not present for land ecosystems, namely depth. This means that sea properties and uses may vary at different levels of the water column.

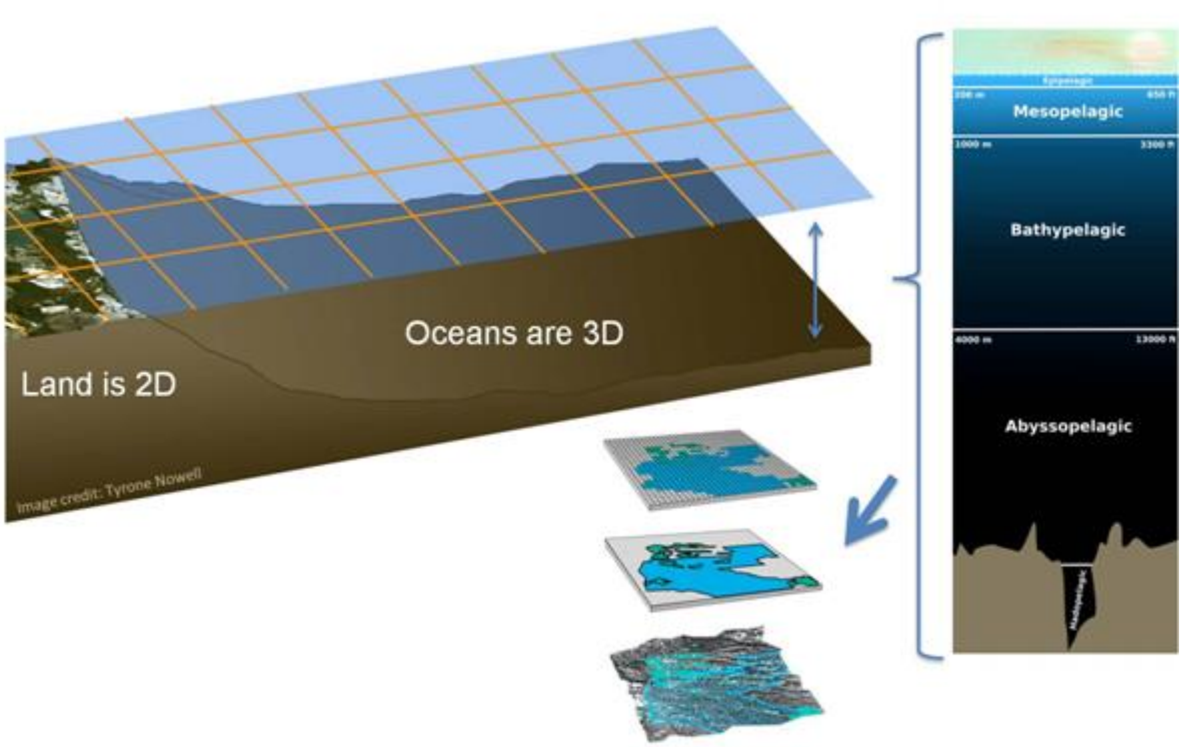



Figure 8: The 3-dimentional nature of oceans can be incorporated into a 2-dimansional grid by dividing the water column into zones and overlaying each zone and a 2-D layer

A way to include this aspect of the sea in the grid system is currently being explored by PEGASO. It has been suggested that ecological thresholds based on depth could be determined to divide the water column into zones (e.g. epipelagic, mesopelagic, bathypelagic, etc.). Information for each zone would be included in the grid as a two dimensional layer.

**Standardization of the method**

In order to enhance data sharing and collaborations, PEGASO will aim to use standardized boundaries, terminology, delineations and other methods and techniques that follow the

Marine Strategy Framework Directive guidelines and other guidelines agreed upon in conjunction with the European Environmental Agency and European Topic Centres involved. These standardized approaches include:

- Standardized regional and sub-regional sea delineation following MSFD boundaries
- Standardized grid using the INSPIRE directive
- Standardized typology for marine and coastal ecosystem services (available at http://transfer.eea.europa.eu/download/13f4de52018e9ca029f22fb391d38d65)
- Delineation of coastal zones is not yet defined, but will be discussed further among the relevant community
- A reference coastline has not yet been decided

## 3.3. Linking land and sea processes in specific applications

A working agreement was reached between UNOTT, JRC and UAB to pursue joint work on modelling and assessing relations between:

- the intensity of land-use (agricultural, urban) at the coastal catchments using the Land and Carbon accounts
- Nutrient loads in major rivers (using JRC data)
- Chlorophyll-a and sediment loads in the river plumes and continuous coastal waters applying the remote sensing data from JRC and ACRI

The input data for this application will include climatological variability of a number of parameters mainly remote sensing products in water as chlorophyll-a concentrations, transparency, backscattering, temperature. On land the data input include land-cover, crops and timber harvest, livestock grazing and net primary production. The analysis will be done for pre-defined units including the terrestrial catchments, the main rivers, delimitation of the river plumes and delimitation of coastal water bodies (an example exist for the Baltic sea).

This application is inspired by the case of the Nile delta, where fisheries have totally collapsed after the construction of the Aswan dam in 1965, due to the cut of the natural flow of nutrients. Research however, uncovered the recovery of fisheries around two decades later and even at rates exceeding the pre-dam times at present times, and explained these changes with the supply of human-origin nutrients when farmers started applying fertilisers which leaked into the river and coastal waters.

# Conclusion

This report presents a revised approach to applying the ecosystem accounting methodology for coast and sea environment in PEGASO. LEAC is a generic tool able to address different needs, but particularly for PEGASO is aims to resolve problems related to the lack of spatial indexes and indicators to measure ecosystem improvements after ICZM policies. Spatial indexes and indicators are needed both for defining ICZM intervention targets and for monitoring of ICZM programmes' success.

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# Annexes

## Annex I. Implementation of LEAC for coast and sea according to PEGASO DoW

Task 4.2.
Land and Ecosystem ACcounts (LEAC) are used to characterise change in the terrestrial environment. They are an effective set of tools that can be used to systematically describe the processes by which land based resources are transformed over time, and as a framework for spatially explicit indicator development and policy appraisal.
The work undertaken in this task will therefore extend the accounting methodologies into the coastal zone using new data for land (e.g. GlobCover 2006 V2), data derived from the mapping of the sea bottom communities, and data on trends in water quality and key species provided by the project participants: IFREMER, IUCN, ACRI-EC and others.

The hierarchical classification frameworks presently employed in LEAC will facilitate a multi-scale approach to the production of statistical data for different parts of the coastal zones and marine areas. The work will proceed in close partnership with T4.1 to evaluate critically the role that accounting methodologies can play in providing operationally effective indicators. It will also link to the work on scenarios (T4.3), participatory methods (T4.4) and valuation (T4.5), to explore how accounts can be used as a framework for modelling plausible futures with stakeholders, and assess marginal change in values for the stocks of natural assets and the benefit flows associated with them.
- Test GlobCorine and its classification system for the dry coast in a buffer of 30 km associated to an elevation model to define coastal areas on land.
- Build consistent km grid for Back Sea and Mediterranean sea.
- Review classification for the marine strip and identify main boundary lines at sea
- Make basic layers with administrative boundaries, river catchments, etc
- Review available satellite images to inform about a number of processes (ecosystem health, fragmentation, HANPP, etc
- Identify attribute to fill the cells of the grid with information (fishing grounds, maritime activities, land and sea uses, sea bottom mapping, quality of water and habitats, data on species, etc)
- Generation of initial accounting fact sheets (tables and maps) and their communication through the portal web
- Presenting result on accounting to the ICZM Platform and discuss them
- Operational training on how to use the tools in general Meetings and CASE Workshop
- Evaluation of testing and validation, implementing next phase from comments and needs

# Annex II. Clarifying main concepts

The following definitions were written to introduce the main themes and subjects, being all very open ones that should be discussed and developed by the whole team

Organizational complexity refers to amount of *social, ecological and economic* capital and number of components per unit area
Each of the three needs to be comparatively assessed across time and space dimensions for the study area, using broadly available spatial indicators; hence a kind of standardized view, method and outcomes should be pursued
Listing the available social, ecological and economic variables, presenting the available indicators and prioritising top, most useful, and critical ones
*Social* – culture, ethics, traditional and historic values on nature, species, landscape also to be explored to understand how much local processes can mitigate global pressures

Examples of *ecological* complexity components – food-chains (predator-prey relations), invasive and expansive species, ecological succession and climax communities

Integrity can be seen as ¨health¨ of ecosystems, implying well ordered landscape (lack fragmentation, pollution, toxicity and other distress syndromes see the box above) also good productivity and vigour of the system. Integrity is based on the existing links between the above mentioned components, the *social, ecological and economic capital*, their tightness and mutual dependences, casual relationships and influences at different scales as well as nature of these relations and trade-offs (for example strong ecological potential might be developing because of lack of economic activity pressures; because of strong existing social potential that prevents external perturbations; or because of strong economic potential that is being developed using external environmental resources thus protecting/sparing the domestic ones …

Resilience refers to the ability to maintain function in periods of stress as well as to recover (original) integrity after stress or even develop higher integrity and organizational complexity…

Many of the parameters referring to ecosystem syndromes, integrity and complexity can be inferred through existing remote sensing, statistics and expert assessment information sources. These inputs allow to start elaborating maps and statistics organized by analytic units with which socio- environmental processes can become more transparent as they are being organized and assessed in environmental accounts.

Production of Environmental accounting tools refers to the process of standardizing information flows as in conventional economic accounting, to allow for scrutinized registry and monitoring of key parameters, subjects and indices aiming to detect and depict changes in ecosystem capital, notably degradation of this capital and the resources needed to restore it after degradation. Ecosystem capital roughly refers to the potential of the ecosystems to maintain a range of ecosystem services to humans as well as to biodiversity. For this work we rely very much on the experience of the EEA, UAB/ETC-LUSI and UNOTT while developing European land and ecosystem accounts, the LEAC approach (EEA, 2006; Weber, 2007).

# Annex III: Applied concepts of holistic and integrated studies and diagnostic assessments of ecosystem 'health'

Odum (1971) introduced the ideas of the holistic nature of Earth's ecosystems. He introduced the ecosystem as an entity normally comprised of six components, e.g. inorganic elements (water, CO2, N, P etc); organic elements (proteins, fats etc); climatic elements (precipitation, temperature etc); primary producers (green vegetation), macro consumers (animals, people etc), micro-consumers (bacteria). Odum explained that the ecosystem as a whole is something more than the sum of its elements and it displays emergent properties such as stability, resilience and adaptability. He also explained that ecosystem change and exhibit dynamics (e.g. seasonal, cyclic changes every few years etc), and described also regular patterns of change termed succession changes. An example of natural succession is the gradual growth of shrubs and later trees on abandoned croplands.

Holling elaborated further the view of the dynamic nature of the ecosystems. He explained observable repeating change in the landscape, summarised in four stages, with a classical example of forest ecosystem evolution (Holling 1978): exploitation (pioneering fast growing trees take over), conservation (establishment of mature climax forest where biomass and energy accumulates), release (forest fire, storm or pest destroys the forest and makes materials and energy available for a new structure to start developing) and reorganization (if the same conditions are preserved, depending on the controlling factors a new forest starts taking over, if resources are depleted then another ecosystem develops, like grassland).

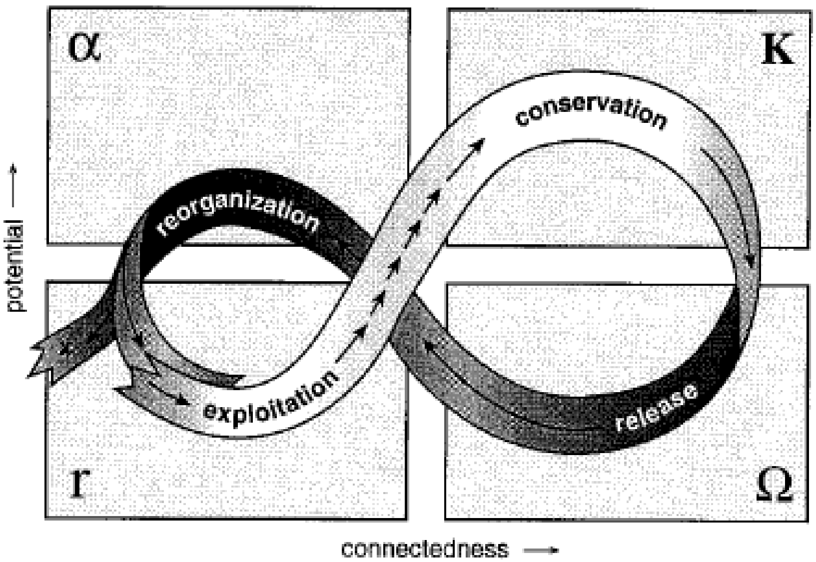



Figure 3. Four stages of ecosystem dynamics (Holling, 2001)

This same model was also extended later (Holling, 2001) to present narratives of evolving and collapsing socio-ecological systems.

Brand and Jax (2007) provide a useful review of the different meanings ascribed to the term resilience. They contrast usage in the ecological literature, with that from the social sciences, and then trace the evolution of a more hybrid concept that deals with problems at the interface between people and nature. Holling (1973) initially proposed the idea as a 'measure of the persistence of systems and of their ability to absorb change and disturbance and still maintain the same relationships between populations or state variables'. Brand and

Jax (2007) suggest that this formulation has been refined by subsequent work, especially that of Gunderson and Holling (2002), Walker and Pearson (2007) and, Folke et al. (2002). Thus the term is now used to refer to two distinct ideas, namely:

- The magnitude of disturbance that can be absorbed before the system changes its structure by changing the variables and processes that control behaviour; and,
- The capacity of a system to experience shocks while retaining essentially the same function, structure, feedbacks, and therefore identity.

The importance of the debate about the resilience has been highlighted by recent initiatives such as the Millennium Ecosystem assessment (MA), which showed how the well-being of people is linked to the well-being of biodiversity (MA, 2005). The MA concluded that globally ecosystems are experiencing growing external pressures from drivers such as climate change, land use change, pollution and invasive species, which will impact on the functioning of ecosystems and on the provision of ecosystem services. In the wider research and policy literatures there is now increased concern that losses in biodiversity may lower resilience to and/or recovery from disturbances (e.g. Loreau et al., 2002; van Ruijven and Berendse, 2010), although the relationship is yet to be confirmed. However the evidence that biodiversity and resilience are closely linked is growing. Thus Isbell et al. (2009) have shown that species richness and more diverse patterns of species interactions can promote ecosystem stability and thus sustain the output of ecosystem services.

Carpenter et al. (2001) and Cummings et al. (2005) they advise that when speaking about ‘ecosystem resilience’ or ‘ecological resilience’ we must be clear about what kind of ecosystem property we are considering by specifying the resilience ‘of what to what’. In this respect accounts have much to offer in terms of helping operationalise the concept. Linked accounts describing changes in stocks and flows and especially the trajectory and sensitivity of the relationships between them, can clearly go a long way to defining the ‘of what’ and ‘to what’ components that need to underpin any analysis of resilience.

Rapport et al. introduced the concept of ecosystem health or ecohealth in the eighties (Rapport et al., 1985), as a way to portrait the strongest concern of impairing the capacity of ecosystems to sustain life while generating human welfare. It is proposed in an analogy with human health considerations. Rapport elaborated the ecohealth perspective by articulating three key indicators of health: vitality (productivity), organization and resilience. The high degree for those three is related to the absence of ecosystem distress syndrome. The ecosystems are viewed as macro-organisms or higher levels of organization that regionally and locally may exhibit great diversity, but show pronounced similarities in the response to stress and disturbance from human actions. The three health indicators are emergent properties of the ecosystem:

- *Vitality* (or vigour) can be measured in terms of activity, metabolism, or primary productivity. It is linked with the capability of the system to make use of the natural elements – light, water, minerals etc to produce biomass, create habitats and regulate favourable living conditions including micro-climate, water cycle regulation etc.
- *Organization* can be assessed in terms of the interactions between biota and their environment. In healthy ecosystems, there are many specialized interactions that link

species together (such as predator–prey relationships, food chain, symbiotic relationships, parasitic relationships, etc.).
- *Resilience* or capacity, is a measure of the capability of ecosystems to recover from disturbance, either human or natural perturbations. If the health of the ecosystem has been compromised owing to anthropogenic stress, recovery from natural perturbations will, in many cases, be slower and less complete (Rapport, 2007).

Common signs of ecosystem distress syndromes (EDS) are:

- *loss of biodiversity* (to which we may also add, in many cases cultural diversity)
- *reduced productivity* (or system ‘‘vitality’’)
- leaching of soil nutrients
- shifts in community composition to favour *smaller life forms*
- *reduced symbiotic relationships* amongst biota
- increased success of *invasive species*
- loss of *endemic species*
- Increased presence of *contaminants* (particularly toxic substances that bio-accumulate in the food web)
- increased *disease* prevalence in various component species (including Homo sapiens)
- reduced efficiencies in *nutrient transport*, and,
- Reduced *productivity/respiration ratios* (Rapport et al., 1985; Rapport and Whitford, 1999).

The focus of ecosystem health practice is twofold, namely to:

(1) ‘‘diagnose’’ through indicators, situations in which ecosystem function (and structure) has become compromised, owing to anthropogenic stress or other causes;
(2) devise diagnostic protocols to assess the causes of dysfunction and propose interventions that may restore ecosystem health.

The framework of ecosystem accounting is largely based on the ideas of ecosystem health or integrity.

# Annex IV: Overview of land accounting methodology and examples

The ¨land¨ component is a central subject of the LEAC framework. Land account is one component that explains the use of the space generally and its resource management resulting in the construction of a landscape. Land (and space, viewed as a resource) can provide some hints on the following issues:

- Where things are happening
- Intensity of changes
- Some proxies on land/nature degradation (e.g. increase of artificial areas near or at cost of forest). i.e. rough ideas on changing the quality of the systems
- Connectivity of land elements,
- Trends and paths
- Drivers of changes and pressures, impacts, responses

## Land cover accounts of Europe

The European land accounts were developed on the basis of the CORINE LC direct applications, as well as definition and extraction of stock and flows. The land cover maps were made in a semi-automated way based on the visual interpretation of remotely sensed satellite imagery to define the land-cover of land cover parcels of a minimum size of 25 hectares. The work covered all the countries affiliated to the EEA. A key point is that for building land accounts all land cover and other inputs are integrated in a 1 $km^2$ grid that covers the whole European territory.

Land cover stock is the area of certain land cover type within a unit of measurement, be it administrative region, river catchment, a country etc. The stocks can also be extracted as a percentage of each land cover class in each cell of the 1 $km^2$ grid and these percentages are used for a number of applications consequently, the product is shortly called 'C0'. The stock derived from the CORINE LC maps can be represented in three hierarchical levels on European scales; level three being the most detailed containing 44 classes (see nomenclature in Annex III).

The CORINE LC maps were so far produced for three years on European scale: 1990, 2000 and 2006. Along with each update e.g. in 2000 and 2006 a change map was also produced. The change map was not simply based on a subtraction of the current from the previous map, but rather was done by overlaying the imagery for the two years to identify change; change units at a 5 ha resolution were identified. The change layer was then used to define land cover flows. All possible combinations between the 44 classes of CORINE LC were grouped into 64 meaningful transitions between them, and labelled as Land-cover flows (see nomenclature in Annex IV)..

### Land cover smoothing - CORILIS

CORILIS, from CORIne and LISsage (smoothing in French), is a methodology developed jointly by the French Environment Institute (IFEN), the Hypercarte Research Group and the French National Institute for Statistics and Economic Studies (INSEE) that provides technical

specifications for the smoothing of CORINE Land Cover Data. The purpose of CORILIS is to calculate "intensities" or "potentials" of a given theme in each point of a territory. A Gaussian type statistical function (called BiWeight) is used to weight this information according to the distance from the considered point in kilometres. CORILIS results into probability surfaces (varying from 0 to 100) for the presence of a certain CLC class within a smoothing radius. Individual CORILIS layers from a given level can be aggregated to upper levels by simple addition.
Smoothed land cover application were calculated to define a probability to find a certain object in neighbourhood. CORILIS method is useful to capture buffering effects. For example the physical boundary of a city is well defined by the CLC but its fuzzy impacts such as mobility, noise, pollution or other inherent processes coming from the city can be well reflected and weighted by CORILIS.

Through smoothing possible pressures can also be mapped, for example from urban, intensive agriculture on surrounding or neighbouring areas, like NATURA2000 or wetlands etc.

Spatial smoothing (applying different radii – 5 km, 10 km) in a 1 $km^2$ grid of selected CORINE LC maps has been developed for facilitating environmental interpretations of the land-cover data. In this way land-cover maps are prepared for expressing:

- Potentials – green background of the landscape (GBLI); connectivity between protected areas – NATURILIS, landscape ecological potential
- Probabilities - dominant land-cover types shown on large-scale i.e EU
- Intensities – urban pressure and intensive agricultural pressure

Smoothed applications of land-cover

1. *Intensities*

The intensities can be interpreted as a positive effect when representing an ecologically favourable element as for example – forest cover; or a negative effect when representing a land use pressure, two examples are provided below.

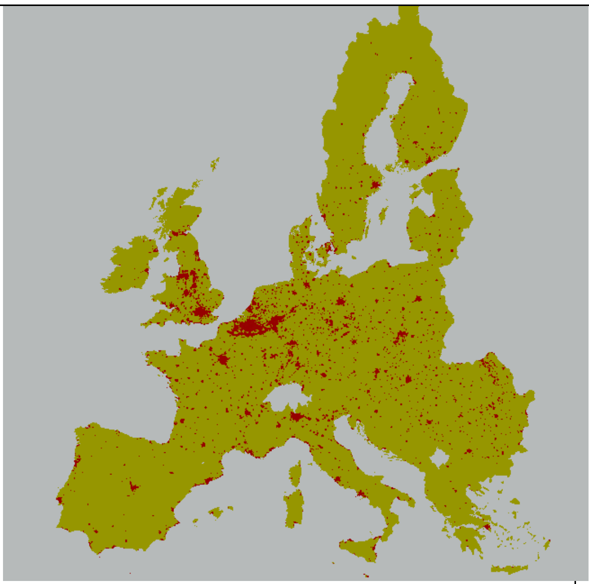
| | |
|---|---|
|  | Smooth map of artificial areas – C1<br>A spatial aggregation of all CORINE LC classes included in the ¨Artificial surfaces¨ category – CLC level 1, class 1It reflects in a general view the total of pressures which the Urban land-uses exert on ecosystems and open space. For definition of the respective land-use classes see CORINE methodology. Note that diffuse urban areas include urbanisation density above a threshold of 30 % sealed land. Exploratory applications have been performed for assessing pressure on NATURA2000 sites. An index of urban "temperature" has been calculated. It reveals that wider radiation of pressures comes from the diffuse urbanizations (not necessarily from dense and most populated areas). |
|  | Smoothed intensive agriculture areas – C2a<br>A spatial aggregation of CLC class 2.1 Arable Land , 2.2 Permanent crops and 2.4.1 Annual crops associated with permanent crops (see Annex I)<br>It reflects in a general view the total of pressures the above-mentioned agricultural land-uses exert on ecosystems and open space. For definition of the respective land-use classes see CORINE methodology. Parcels of croplands under 25 ha are not included even if intensively cultivated. These would be rather included as mixed, mosaic agriculture. |

Figure 7. Land use pressures: from urbanization (above), from intensive agriculture (below)

## 2. *Probabilities*

As mentioned above the smoothing allows the estimation of probability of finding a certain object within a predefined radius around the concrete land cover type, or other element.

Dominant land cover type and dominant landscape type

A map of the European dominant land cover types was constructed by grouping the 44 classes into 7 broader categories defining the following dominant types of cover:

The land cover dominance is then adjusted for relief variations to produce a dominant landscape type

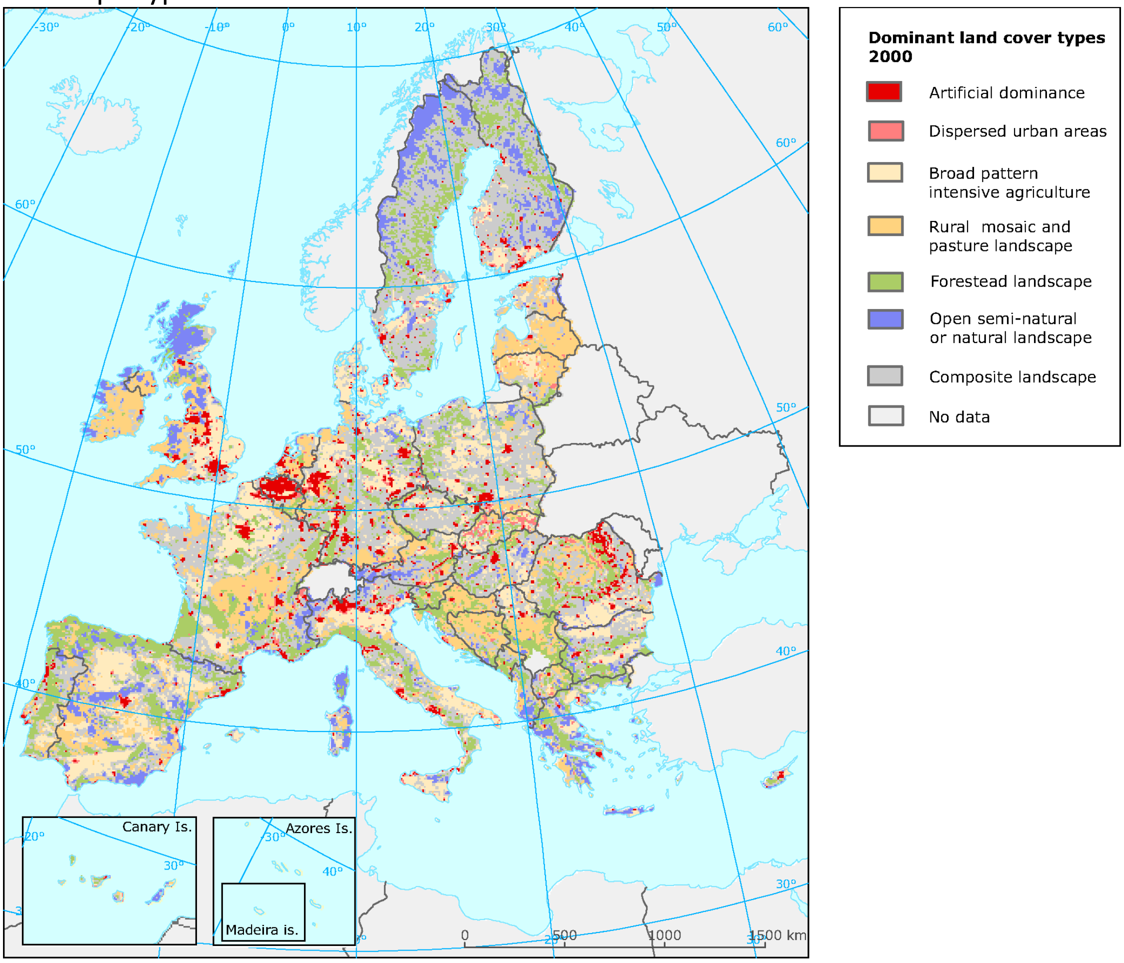



Figure 8. Dominant land cover types

Indexes on favourability of land use

A Green background (GBLI) index was calculated by summing up the classes representing land-use types deemed favourable for supporting ecological functions. These include agro-systems with pastures and/or mosaics of parcels, forests and other semi-natural or natural dry land, wetlands and water bodies.
An index of the *areas of high ecological value*, called NATURILIS index was calculated by merging the map of nationally designated protected areas and the European NATURA2000 network of areas all resampled to the 1 km2 grid. The map was done by applying also smoothing with a 5 km radius. By analogy to CORILIS, the database of smoothed values of designated areas of high ecological value is called NATURILIS.
Effective meshsize or MEFF (Jeager, 2000) was calculated to represent the level of landscape fragmentation in Europe merging a map of the transport network map from Teleatlas with

urban morphological zones map (EEA). The size of meshes is calculated as the Effective Mesh Size (MEFF), a geo-statistical measure, which converts the probability that randomly selected points in an area are connected into the size of an un-fragmented patch. Smaller mesh size means less landscape connectivity and higher landscape fragmentation, which is the inverse of connectivity. Effective mesh density (seff) is the reciprocal value of meff (seff = 1/meff)

Combining the three above inputs produces an index of Net Landscape Ecological potential.

The Making of LNEP:

- GBLI = Aggregation of CLC classes 2B, 3, 4 & 5, smoothed at 5 km. Range [0-100]
- NATURILIS_COMB or COMB = Union of N2K and CDDA, smoothed at 5 km. Range [0-100]
- Gross_LEP or GLEP= GBLI + COMB. Range [0-200]
- GLEPscaled = (GLEP * 255) / max(GLEP). Range [0-255]
- ln(MEFF). Range [0-255]

*and*

NLEP = sqrt(GLEPscaled * lnMEFF ). Range [0-255]

The NLEP is a macro-indicator which allows to outline a range of land-use conditioned ecological states – from most favourable where 3 main factors are at their best – nature respecting land-use, little or no fragmentation from human artefacts, and areas designated for nature conservation (NATURA2000 and other nationally designated protected areas) … to the opposite high fragmentation, no protected area designated and very intensive land-use (urban, agriculture, transport). However at regional scale high intensity of land use and fragmentation are often (partially) compensated with denser network of (smaller) protected areas. Therefore additional indicators are needed, at present ecotones are being extracted by the CORINE LC (A. Oulton and J.-L. Weber, personal communication, 2011).

Land accounting tools

To facilitate the use and exploration of ecosystem accounting outputs, the ETC-LUSI has developed several tools to query land cover data and land cover changes information among other datasets in two different years (1990 and 2000; 2000 and 2006). These tools work with an on line Analytical Processing (OLAP) database, accessible through the Internet. The database is structured in accordance to a multi-dimensional approach for retrieving land cover using different analytical reporting units (LARU). Currently it retrieves land-cover outputs only, however the system it is not closed to other kind of data (population, nature protection, transportation, water assets etc). Main advantage of the LEAC tools are that they allows efficient processing and retrieval of data at a country and continental scale and the implementation of spatial-based queries without needing access to Geographical Information Systems (GIS) software.

# Annex V: CORINE Land Cover Hierarchical Nomenclature

1. Artificial surfaces
1.1. Urban fabric
1.1.1. Continuous urban fabric
1.1.2. Discontinuous urban fabric
1.2. Industrial, commercial
1.2.1. Industrial or commercial units and transport 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
1.3.1. Mineral extraction sites construction sites
1.3.2. Dump sites
1.3.3. Construction sites
1.4. Artificial, non agricultural
1.4.1. Green urban areas vegetated areas
1.4.2. Port and leisure facilities

2. Agricultural areas
2.1. Arable land
2.1.1. Non-irrigated arable land
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 grives
2.3. Pastures
2.3.1. Pastures
2.4. Heterogeneous
2.4.1. Annual crops associated with agricultural areas permanent crops
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. Forest and semi-natural areas
3.1. Forests
3.1.1. Broad-leaved forest
3.1.2. Coniferous forest
3.1.3. Mixed forest
3.2. Scrub and/or herbaceous
3.2.1. Natural grasslands vegetation associations.
3.2.2. Moors and heathland
3.2.3. Sclerophyllous vegetation
3.2.4. Transitional woodland-scrub
3.3. Open spaces with

3.3.1. Beaches, dunes, sands little or no vegetation
3.3.2. Bare rocks
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
4.1.2. Peat bogs
4.2. Maritime wetlands
4.2.1. Salt marshes
4.2.2. Salines
4.2.3. Intertidal flats

5. Water bodies
5.1. Inland waters
5.1.1. Water courses
5.1.2. Water bodies
5.2. Marine waters
5.2.1. Coastal lagoons
5.2.2. Estuaries
5.2.3. Sea and ocean

# Annex VI: DEFINITION OF LAND COVER FLOWS

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

LCF43 Internal conversions between permanent crops: Conversions between vineyards, orchards and/or olive groves
LCF431 Conversion from olives groves to vineyards and orchards: Conversion from olives groves to vineyards and orchards
LCF432 Conversion from vineyards and orchards to olive groves: Conversion from vineyards and orchards to olive groves4
LCF433 Other conversions between vineyards and orchards: Other conversions between vineyards and orchards
LCF44 Conversion from permanent crops to arable land: Conversion from vineyards, orchards and olive groves to irrigated and/or non-irrigated arable land
LCF441 Conversion from permanent crops to permanent irrigation perimeters: Conversion from permanent crops (incl. when associated with arable land — CLC241) to permanent (large) irrigation perimeters and rice fields
LCF442 Conversion from vineyards and orchards to non-irrigated arable land: Conversion from vineyards and orchards to non-irrigated arable land and from associations of annual and permanent crops to uniform arable land
LCF443 Conversion from olive groves to non-irrigated arable land: Conversion from olive groves to non-irrigated arable land, incl. conversions to associations of annual and permanent crops (CLC241) and of crops and pasture (CLC242)
LCF444 Diffuse conversion from permanent crops to arable land: Conversion from vineyards and orchards to associations of annual and permanent crops (CLC241) and of crops and pasture (CLC242: complex cultivation patterns)
LCF45 Conversion from arable land to permanent crops: Plantation of vineyards, orchards and olive groves on arable land
LCF451 Conversion from arable land to vineyards and orchards: Plantation of vineyards, orchards on arable land
LCF452 Conversion from arable land to olive groves: Plantation of olive groves on arable land
LCF453 Diffuse conversion from arable land to permanent crops: Conversion from uniform arable land to associations of permanent crops and annual crops (CLC241)
LCF46 Conversion from pasture to arable and permanent crops: Conversion from pasture to arable and permanent crops
LCF461 Conversion from pasture to permanent irrigation perimeters: Conversion of uniform pasture areas to permanent irrigation perimeters
LCF462 Intensive conversion from pasture to non-irrigated arable land and permanent crops: Conversion of uniform pasture areas to non-irrigated annual and permanent crops
LCF463 Diffuse conversion from pasture to arable and permanent crops: Conversion from complex cultivation patterns including pasture (CLC242) to uniform arable land and permanent crops as well as to associations of the last two (CLC241) and conversion of uniform pasture (CLC231) to complex cultivation patterns
LCF47 Extension of agro-forestry: Conversion of cultivated land and open pasture to agro-forestry systems such as dehesas and montados (note: conversion from 243 to 244, where natural vegetation is important, is recorded under LCF522)
LCF48 Other conversions from agriculture mosaics to arable land and permanent crops: This land cover class is used only when changes are detected from a Corine land cover matrix combing classification of level2 for the initial year and level 3 for the final year. Agriculture mosaic classes being grouped in CLC24 only, it is not possible to differentiate the processes according to the type of land consumed. It includes in particular the sub-class LCF523,

conversions from agriculture-nature mosaics to continuous agriculture, not isolated in this case
LCF481 Other conversions from agriculture mosaics to permanent crops: Used for CLC level 2 x level 3 only. It includes conversion of agriculture-nature mosaics to arable land (see LCF48)
LCF482 Other conversions from agriculture mosaics to arable land (including conversion of agriculture-nature mosaics to permanent crops). Used for CLC level 2 x level 3 only. It includes conversion of agriculture-nature mosaics to arable land (see LCF48)
LCF5 Conversion from forested and natural land to agriculture: Extension of agriculture land use
LCF51 Conversion from forest to agriculture: Deforestation for agriculture purpose, including agricultural conversion of transitional woodland shrub
LCF511 Intensive conversion from forest to agriculture: Deforestation, including agricultural conversion of transitional woodland shrub, for cultivation of annual and permanent crops (incl. in association, CLC241)
LCF512 Diffuse conversion from forest to agriculture: Conversion from uniform forest to complex cultivation patterns, mosaic agricultural landscape and agro-forestry. Due to possible uncertainties in monitoring extension of pasture vs. recent felling, conversion from forests to pasture land (CLC231) is recorded here
LCF52 Conversion from semi-natural land to agriculture: Conversion from dry semi-natural land (except CLC324, grouped with forests) to agriculture
LCF521 Intensive conversion from semi-natural land to agriculture: Conversion from dry semi-natural land (except CLC324, grouped with forests) to annual crops, permanent crops and their association
LCF522 Diffuse conversion from semi-natural land to agriculture: Conversion from dry semi-natural land (except CLC324, grouped with forests) to pasture and mixed agriculture with pasture
LCF523 Conversions from agriculture-nature mosaics to continuous agriculture: Conversion from CLC243, where natural areas are distinctive feature of the land systems to continuous agriculture. This is an over-estimation from an agriculture perspective but is justified in terms of analysis of ecological potentials of complex land systems
LCF53 Conversion from wetlands to agriculture: Conversion of wetlands to any type of farmland (CLC2)
LCF54 Conversion from developed areas to agriculture: Conversion of urban land to any type of farmland (CLC2)
LCF6 Withdrawal of farming: Farmland abandonment and other conversions from agriculture activity in favour of forests or natural land
LCF61 Withdrawal of farming with woodland creation: Forest and woodland creation (incl. transitional woodland shrub) from all CLC agriculture types. Withdrawal of farming with woodland creation is a broader concept than farmland abandonment with woodland creation, which results more from decline of agriculture than afforestation programmes. Additional information is necessary to identify an abandonment process (type of agriculture, landscape type, socio-economic statistics...)
LCF62 Withdrawal of farming without significant woodland creation: Farmland abandonment in favour of natural or semi-natural landscape (except forests and transitional woodland shrub), as long as they are a possible transition. Some odd cases are provisionally recorded as
LCF99 Other changes and unknown

LCF7 Forests creation and management: Creation of forests and management of the forest territory by felling and replanting. Due to the CLC cycle of 10 years, only one part of the shrubs are tall enough to be identified as trees. In order to taking stock of all recent plantations, conversions of semi-natural land to CLC324 are conventionally recorded as afforestation (although some natural colonisation may take place). In the case of conversion from farmland, see LCF61
LCF71 Conversion from transitional woodland to forest: Conversion from transitional woodland to broadleaved, coniferous or mixed forest, taking place when shrubs can be detected as trees
LCF72 Forest creation, afforestation: Forest creation and afforestation take place on all previously non-agricultural landscapes where new forests can be identified. Extension of transitional woodland shrub over non-agricultural land is recorded as afforestation. Conversion from transitional woodland to broadleaved, coniferous or mixed forest are not a creation of forest territory and are therefore registered separately (LCF71)
LCF73 Forests internal conversions: Conversions between broadleaved, coniferous and/or mixed forest (CLC311, 312 and 313)
LCF74 Recent felling and transition: Conversion from broadleaved, coniferous and/or mixed forest to open semi-natural and natural dry land resulting more likely from felling. The main transition is towards CLC324 Transitional woodland shrub, although some other types can be detected. Due to uncertainties, all are provisionally considered as transitional states of forests
LCF8 Water bodies creation and management: Creation of dams and reservoirs and possible consequences of the management of the water resource on the water surface area
LCF81 Water bodies creation: Extension of water surfaces resulting from the creation of dams and reservoirs
LCF82 Water bodies management: Consequences of the management of the water resource on the water surface area of reservoirs
LCF9 Changes of land cover due to natural and multiple causes: Changes in land cover resulting from natural phenomena with or without any
human influence
LCF91 Semi-natural creation and rotation: Changes in natural and semi-natural land cover due to natural factors
LCF911 Semi-natural creation: Natural colonisation of land previously used by human activities. Note that extension of CLC324 is considered as
the result of farmland abandonment or direct afforestation
LCF912 Semi-natural rotation: Rotation between the dry semi-natural and natural land cover types of CLC (except forest and transitional woodland shrub)
LCF913 Extension of water courses: Results from natural erosion and artificial works. Due to the very incomplete detection of rivers with CLC, the LCF913 flow item has to be used very carefully
LCF92 Forests and shrubs fires: Due to the short cycle of recovery of vegetation from fire, burnt areas (which are well identified on satellite images) cannot be compared in a ten-year interval, except for very aggregated statistics
LCF93 Coastal erosion: Conversion of all land cover types to intertidal flats, estuaries or sea and ocean. The tide level when the satellite image is shot being unknown of the photointerpretors, the coastal erosion flow has to be used very carefully

LCF94 Decrease in permanent snow and glaciers cover: Decrease of permanent snow and glaciers due to climate change to semi-natural and natural land covers, mainly to bare rock, sparsely vegetated areas and water systems
LCF99 Other changes and unknown: In this category are recorded land cover changes that are rare or more likely improbable

# ANNEX VII: Main needs identified for PEGASO T4.2 at the start of the project

Task 4.2 Coastal land and marine ecosystem accounting

- Need to extend the Land account to the sea
  - Data need for the 3 dimensions of the sea
    - Bathymetric charts,
    - local maps of benthic communities (ex. Poseidon for part of the Mediterranean),
    - Sediment and nutrients fluxes from the rivers and into the sea
    - fuzzy maps of sea bottom (IFREMER) where a number of parameters are taken into account and then most probable community are mapped
    - Data reported for article 17 HD,
    - IUCN atlases on BD
    - IUCN Red list
    - Maps of coastal and Marine Protected areas
    - Ocean colour maps (ESA, MODIS_NASA, GMES MARCOAST)
    - Pollution data at local/Regional level (UNEP GRID)
    - Species data from birdlife international
    - Data base on alien species
    - Fishery and aquaculture (Eurostat and FAO statistics+ national)
    - Map of the use of the sea (ship routes and volume transported, accidents and oil spills, oleoducts, deep sea cables, platform for gas, oil and wind farms, tidal and wave energy, etc), recreation facilities, metal nodes, mining, dredging, waste disposals, etc
  - Data availability
    - We expect to have lots of data at local and sub regional level in some places but we can have difficulties to get them. We will begin to work in places where data are available through our partners.
    - We can find that for some issues no data exist, or exist partially, at some time and place. So different strategies will be develop for the different issues (ex. The number of monitoring station on water quality is generally localised in some coastal parts, but as we need information on these data for the whole basin, we will have to use remote sensing data as a proxi for example testing ocean colour results and comparability with monitoring stations data, etc to bridge the gap).
    - For issues such as introduced species, expert knowledge, observations from fishermen, etc, can be of high value to get information.

  - Methodology to be developed
    - For all partners, write a conceptual framework on LEAC for land to inform them and have same departure point
    - Make a number of tutorial to build a share knowledge with partners and end users on indicators, spatial indicators, accounts, scenarios and socio-economic valuation, and participative work for valuation.

- Need ontological framework (Mindjet method to structure all sources of knowledge in a systematic way ; ETC-BD)
- Identify the most important issues to be taken into account by LEAC, from different possible inputs and methods.
- Work on stock and flows, comparing land processes with sea bottom processes, processes on the water column and at the
- Identification of stock behaviour and flows at sea, linked with wave and tides, meteorology, etc.
- For time series , stocks and flows at sea can pass by different cycles than on land
- So a standardized framework need to be constructed taking into account listed issues (and probably more).
- A conceptual model is needed to start gathering and developing ideas on how to integrate terrestrial, coastal and marine issues into the same accounting system, incl. 2-dimensional and 3-dimensional issues, following mass-balance, different transitional status, seasonal variability in species, migrations, etc

- From concept to multi-scale implementation
  - We will begin with available data at basin scale and will present general picture on the main issues on the basin (eg. Water quality, community distribution, biodiversity, etc). Results will be first updated by southern and eastern partners, before to be tested on CASES and, therefore, their global/local relevance will be evaluated.
  - When concepts are well understood at local level, then we will work using LEAC for some key activities (e.g. aquaculture, energy…), and on specific issues (eg. water quality, biodiversity, invasive species, etc.
  - At this stage we will develop pilot accounts for Marine Protected Areas and for some islands (focusing towards island metabolism)
  - During 2011 the work on CASE will designed using the inputs of these first results.

- Middle step (mid project):
  - Need to bridge what is done at sea with what is done on land to better integrate the whole system (including rivers, land , water and air)
  - Propose LEAC land-sea for some relevant situations.

- End of project
  - Review the different tools (indicators, LEAC , scenario and economic/social valuation, etc ) to see how they can work in complementarities (Review work done by other EU project such as SENSOR)

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Pegaso Project
People for Ecosystem based Governance
in Assessing Sustainable development of
Ocean and coast

Funded by the European Union
under FP7 – ENV.2009.2.2.1.4
Integrated Coastal Zone Management

Specific Programme FP7
Collaborative Projects
Large scale integrating project

Grant agreement nº: 244170

# LEAC DATA BASE

*(Deliverable ID4.2.3)*

| | |
|---|---|
| Code | Pegaso/ID4.2.3/UNOTT/291212-I-3.0 |
| Date / version | 20 November 2012 (v1) contents<br>02 December 2012 (v2) for circulation to T4.2 partners<br>29 December 2012 (v3) submitted to coordinator |
| Authors | Emil Ivanov (UNOTT)<br>Roy Haines-Young (UNOTT)<br>Marion Potschin (UNOTT)<br>Camino Liquete (JRC)<br>Adolf Stips (JRC)<br>François Morisseau (UAB)<br>Nathalie De Hauwere (VLIZ) |

**Resume**
The aim of this document is to ensemble an overview of the available datasets for producing ecosystem accounts both for land and sea (within the PEGASO SDI) and provide a direct access to PEGASO partners for applying these datasets to calculate ecosystem accounts.

Project coordination
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EU FP7 Project PEGASO Grant agreement nº: 244170.

# 1. Introduction

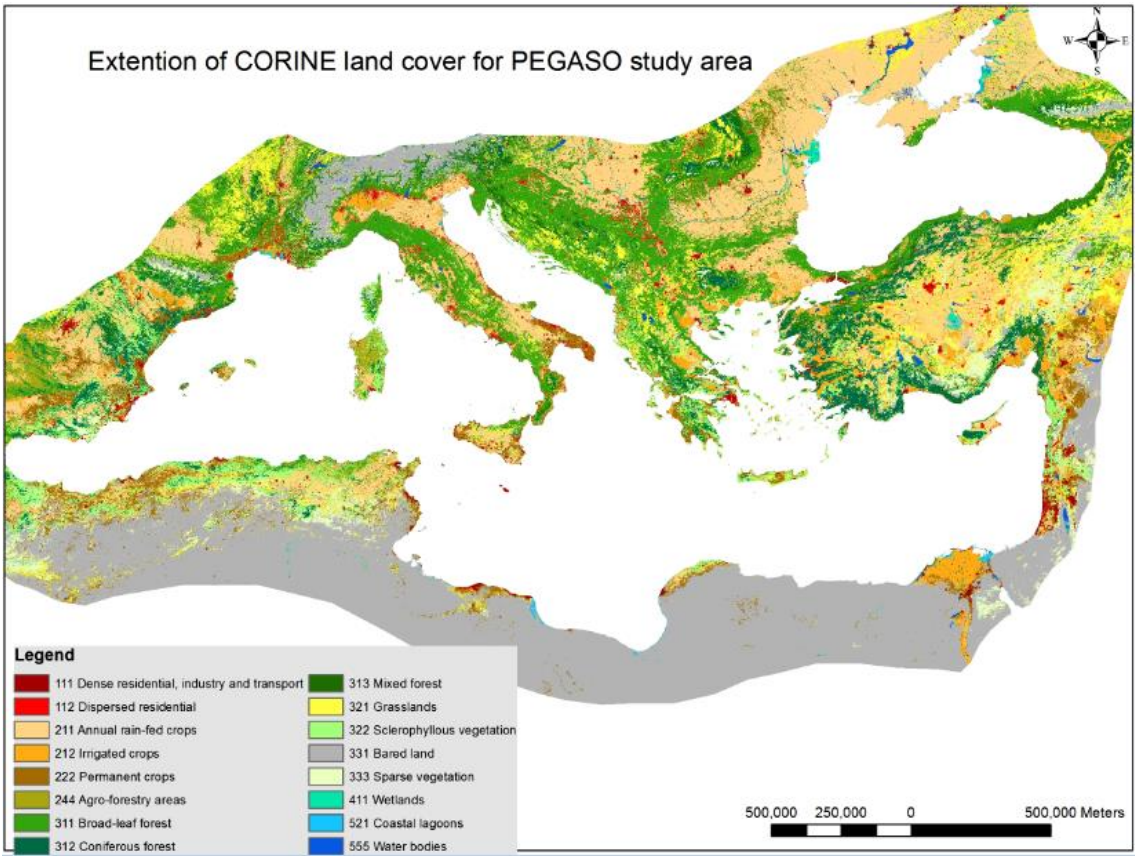
The aim of this document is to ensemble an overview of the available datasets for producing ecosystem accounts both for land and sea and provide a direct access to PEGASO partners for applying these datasets to calculate ecosystem accounts.

The datasets are shortly presented and described, including selected fields from the metadata form in PEGASO's SDI catalogue or a link to external source, in case that the datasets are already available online.
PEGASO SDI catalogue can be accessed at:
http://pegasosdi.uab.es/catalog/srv/en/main.home

# 2. Data overview from UNOTT

## 2.1 Land cover data

Title: PEGASO land cover 2000



Short description (abstract field on metadata form):

Land cover represents an evaluation of the land resource that exist at a certain place and time. The evaluation is expressed in a scale of values, described and mapped as discrete classes or land cover categories, structured in a Land cover nomenclature. PEGASO land cover product is created from MODIS multispectral data following CORINE classification scheme.

Purpose (what is the data useful for?):
The land cover maps are used for calculating and mapping land accounts. The land accounts include stocks, defined as areas of urban land use, agricultural, forest etc. and flows, defined as changes between the above land uses during certain period of time.

Source: Prepared at the Centre for Environmental Management, University of Nottingham using MODIS (NASA) and CORINE land cover (EEA) data

Contact: Emil Ivanov, Emil.Ivanov@nottingham.ac.uk

Thematic keywords: Land cover, PEGASO, MODIS, CORINE

Place (descriptive) keywords: Mediterranean and Black Sea basins

Access constraints/Use constraints/other constraints: (C) CEM University of Nottingham. At this time, this data should only be used by PEGASO partners and not distributed to third parties

Distribution information/transfer options/online resource: not yet uploaded

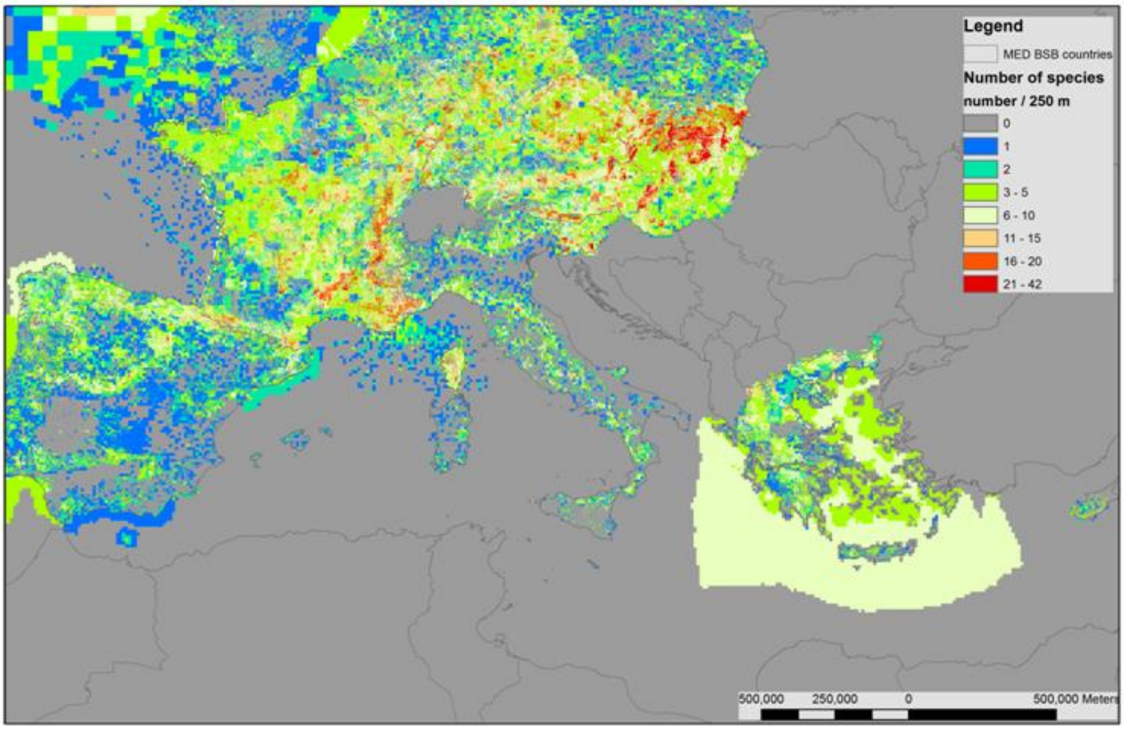
Spatial representation info/resolution: 250 m x 250 m

Reference system information: EPSD, code 3035

Data quality info: dataset, product under development

## 2.2 Species of European conservation importance

Title: Species of European conservation importance: Number of Species




Source: CEM, University of Nottingham, using Art. 17 Habitat Directive (EEC) data

Contact: Emil.Ivanov@nottingham.ac.uk

Short description (abstract field on metadata form):

Number of species of conservation importance were calculated and mapped in a grid of 250 x 250 m using the inputs from Article 17 reports for the Habitat Directive (EEC) and CORINE land cover. The presence of the species of conservation importance characteristic for certain area is perceived to indicate a high degree of ecosystem integrity, interpreted as preserved natural capital. This dataset contains a selection of from all classes except birds.

Purpose (what is the data useful for?):
The species number accounts are useful to track an indicative presence of species per unit area, which may be applied to develop indicators interpreting the state of natural capital maintenance.

Source: Prepared at the Centre for Environmental Management, University of Nottingham using Article 17, Habitat Directive (EEC) data

Contact: Emil Ivanov, Emil.Ivanov@nottingham.ac.uk

Thematic keywords: Biodiversity, species of Conservation Importance, Article 17 Habitat Directive, NATURA 2000

Place (descriptive) keywords: Mediterranean EU countries

Access constraints/Use constraints/other constraints: (C) CEM University of Nottingham. At this time, this data should only be used by PEGASO partners and not distributed to third parties

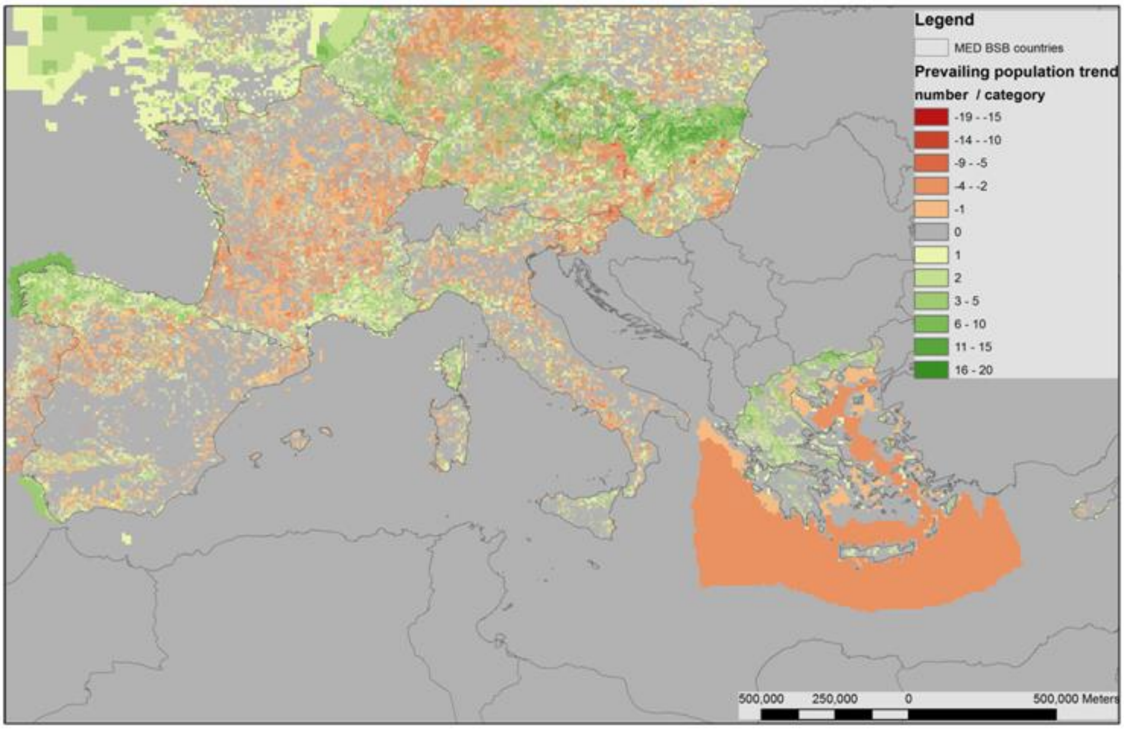
Distribution information/transfer options/online resource: not yet uploaded

Spatial representation info/resolution: 250 m x 250 m

Reference system information: EPSD, code 3035

Data quality info: dataset, product under development

Title: Species of European conservation importance: Prevailing population trend




Source: CEM, University of Nottingham, using Art. 17 Habitat Directive (EEC) data

Contact: Emil.Ivanov@nottingham.ac.uk

Short description (abstract field on metadata form):

Prevailing population trend of the species of conservation importance was calculated and mapped in a grid of 250 x 250 m using the inputs from Article 17 reports for the Habitat Directive (EEC) and CORINE land cover. The stable or increasing population trends indicate that a high value of natural capital has been maintained, while the decreasing trends indicate the reverse, degradation and loss of natural capital. This dataset contains a selection of from all classes except birds.

Purpose (what is the data useful for?):
The species population trend accounts may be applied to develop indicators interpreting the state and change of natural capital maintenance.

Source: Prepared at Centre for Environmental Management, University of Nottingham using Article 17, Habitat Directive (EEC) data

Contact: Emil Ivanov, Emil.Ivanov@nottingham.ac.uk

Thematic keywords: Biodiversity, species of Conservation Importance, Article 17 Habitat Directive, NATURA 2000

Place (descriptive) keywords: Mediterranean EU countries

Access constraints/Use constraints/other constraints: (C) CEM University of Nottingham. At this time, this data should only be used by PEGASO partners and not distributed to third parties

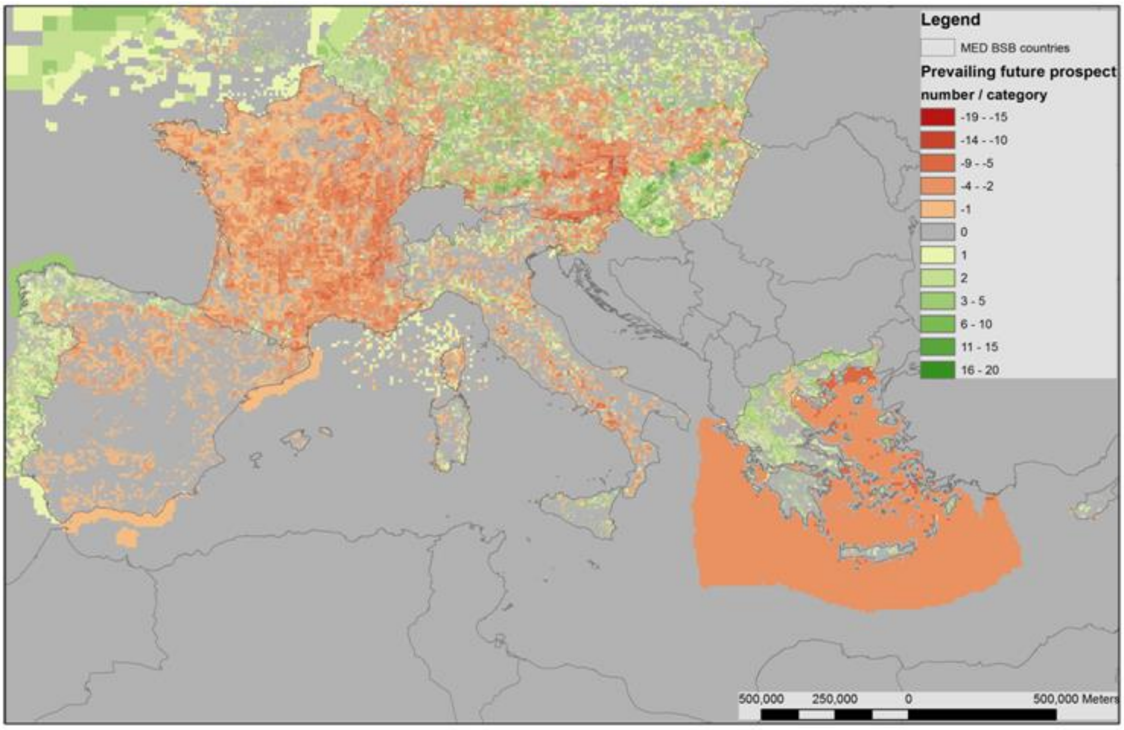
Distribution information/transfer options/online resource: not yet uploaded

Spatial representation info/resolution: 250 m x 250 m

Reference system information: EPSD, code 3035

Data quality info: dataset, product under development

Title: Species of European conservation importance: Prevailing future prospect




Source: CEM, University of Nottingham, using Art. 17 Habitat Directive (EEC) data

Contact: Emil.Ivanov@nottingham.ac.uk

Short description (abstract field on metadata form):

Prevailing future prospect of the species of conservation importance was calculated and mapped in a grid of 250 x 250 m using the inputs from Article 17 reports for the Habitat Directive (EEC) and CORINE land cover. The good future prospects indicate that a high value of natural capital will be maintained in the future, while the bad or poor prospects indicate the reverse, degradation and loss of natural capital. This dataset contains a selection of from all classes except birds.

Purpose (what is the data useful for?):
The species future prospect accounts may be applied to develop indicators interpreting the future state and change of natural capital maintenance.

Source: Prepared at Centre for Environmental Management, University of Nottingham using Article 17, Habitat Directive (EEC) data

Contact: Emil Ivanov, Emil.Ivanov@nottingham.ac.uk

Thematic keywords: Biodiversity, species of Conservation Importance, Article 17 Habitat Directive, NATURA 2000

Place (descriptive) keywords: Mediterranean EU countries

Access constraints/Use constraints/other constraints: (C) CEM University of Nottingham. At this time, this data should only be used by PEGASO partners and not distributed to third parties

Distribution information/transfer options/online resource: not yet uploaded

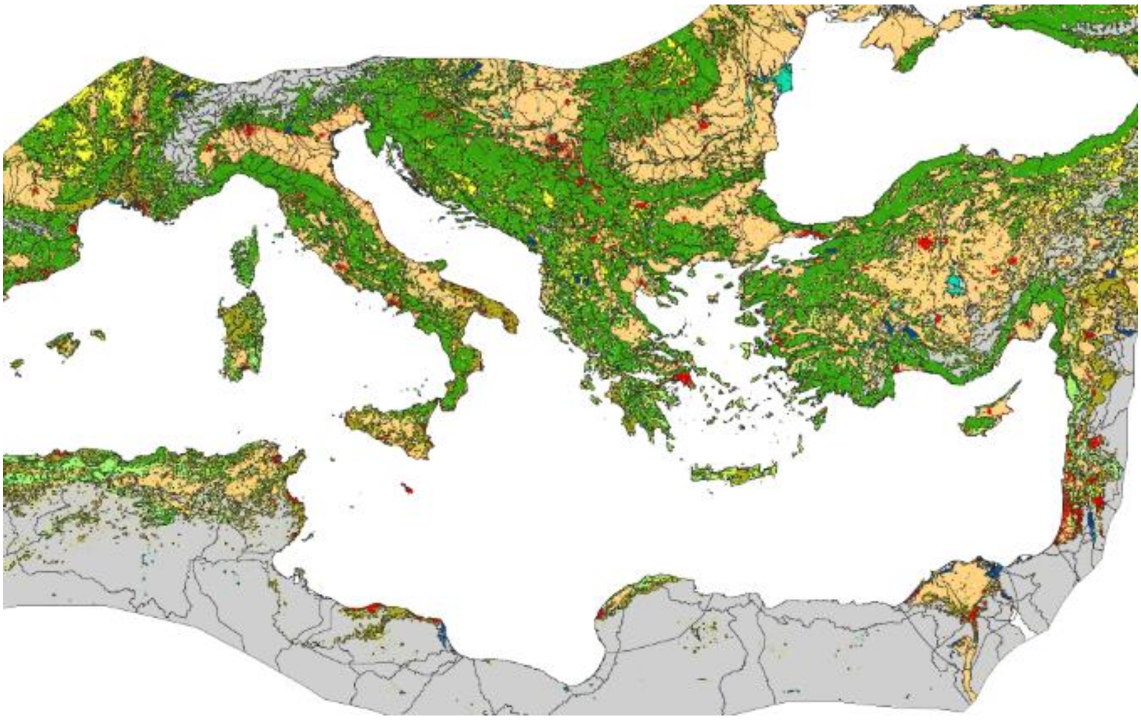
Spatial representation info/resolution: 250 m x 250 m

Reference system information: EPSD, code 3035

Data quality info: dataset, product under development

## 2.3 Ecosystem accounting units

Title: Ecosystem accounting units



Short description (abstract field on metadata form):

The ecosystem accounting units are defined by combining dominant land cover types, administrative divisions and river catchments. Each of the three inputs could be applied independently as an accounting unit. Other divisions may also be applied as accounting units, for example protected areas (currently not included in the combined units).

Purpose (what is the data useful for?):
The accounting units are applied for extracting stock and flow accounts, or other indexes, such as urban pressure, agricultural intensity or green background. Consequently the results can be presented and communicated in the form of graphs, maps or tables.

Source: Prepared at Centre for Environmental Management, University of Nottingham using PEGASO land cover (year 2000), Administrative divisions from DIVA-GIS, and Rivers catchments from FAO.

Contact: Emil Ivanov, Emil.Ivanov@nottingham.ac.uk

Thematic keywords: ecosystem accounting units

Place (descriptive) keywords: Mediterranean and Black Sea basins

Access constraints/Use constraints/other constraints: (C) CEM University of Nottingham. At this time, this data should only be used by PEGASO partners and not distributed to third parties

Distribution information/transfer options/online resource: not yet uploaded

Spatial representation info/resolution: 1 km x 1 km

Reference system information: EPSD, code 3035

Data quality info: dataset, product under development

## 2.4 Protected areas

Title: World database of protected areas

Short description (abstract field on metadata form):

The World Database on Protected Areas is a dataset for conservation information to support decision making. It contains information about all nationally designated areas including boundaries, e.g. designation category both on land and sea.

Purpose (what is the data useful for?):

The data can be used as accounting units...

Source: World Database on Protected Areas, http://www.wdpa.org/

Contact:

Thematic keywords: protected areas

Place (descriptive) keywords: World, Mediterranean and Black Sea basins

Access constraints/Use constraints/other constraints:

Distribution information/transfer options/online resource:
http://www.protectedplanet.net/

Spatial representation info/resolution:

Reference system information:

Data quality info:

# 3. Data overview from JRC

## 3.1 EMIS - Environmental Marine Information System

Title: Environmental Marine Information System

Short description (abstract field on metadata form):

The Environmental Marine Information System (EMIS) relies on biological and physical variables generated from both hydrodynamic models and satellite remote sensing. A number of these variables and advanced products are available to the scientific and environmental managerial community through a GIS tool, which enables the user to create maps and conduct basic regional assessments.

Purpose (what is the data useful for?):

The data can be used to assess the state and trends regarding physical and biological variables of the European regional Seas.

Source: Environmental Marine Information System, http://emis.jrc.ec.europa.eu/

Contact: Nicolas Hoepffner Joint Research Centre (JRC), Email: Nicolas.Hoepffner@jrc.ec.europa.eu

Thematic keywords: Ecosystem, Chlorophyll, Primary Productivity, Sea Surface Temperature, Eutrophication, Mixed Layer Depth, Surface Currents, Salinity

Place (descriptive) keywords: European Regional Seas

Access constraints/Use constraints/other constraints: No conditions apply

Distribution information/transfer options/online resource:
http://emis.jrc.ec.europa.eu/
The EMIS Datasets are available as a Web Map Service (WMS) in accordance with the Open Geospatial Consortium (OGC) specifications (www.opengeospatial.org). The geo-referenced data layers can be displayed in a web browser or Geographic Information System (GIS) and incorporated in your own web application.

Spatial representation info/resolution:
Pan-European scale 4km

Reference system information:
WGS84 bounds: -30,10,42,70
Projection: geographic lat/lon
EPGS: 4326

Data quality info: Regular annual updates are planned

## 3.2 GMIS – Global Marine Information System

Title: Global Marine Information System

Short description (abstract field on metadata form):

The **Global Marine Information System** has been developed to provide the Users community with an appropriate set of bio-physical information (GIS functionalities), of importance to conduct water quality assessment and resource monitoring in the coastal and marine waters. The bulk of environmental analysis in GMIS relies on Earth Observation data, and the provision of continuous, detailed and accurate information on relevant marine biophysical parameters as derived from optical, and infrared satellite sensors.

Purpose (what is the data useful for?):

The data can be used to assess the state and trends regarding physical and biological variables of the global ocean ecosystem.

Source: Global Marine Information System, http://gmis.jrc.ec.europa.eu/

Contact: Nicolas Hoepffner, Joint Research Centre (JRC), Email: Nicolas.Hoepffner@jrc.ec.europa.eu

Thematic keywords: Ecosystem, Chlorophyll, Primary Productivity, Sea Surface Temperature

Place (descriptive) keywords: Global Marine Data

Access constraints/Use constraints/other constraints: No conditions apply

Distribution information/transfer options/online resource:
http://gmis.jrc.ec.europa.eu/
The GMIS Datasets are available as a Web Map Service (WMS) in accordance with the Open Geospatial Consortium (OGC) specifications (www.opengeospatial.org). The geo-referenced data layers can be displayed in a web browser or Geographic Information System (GIS) and incorporated in your own web application.

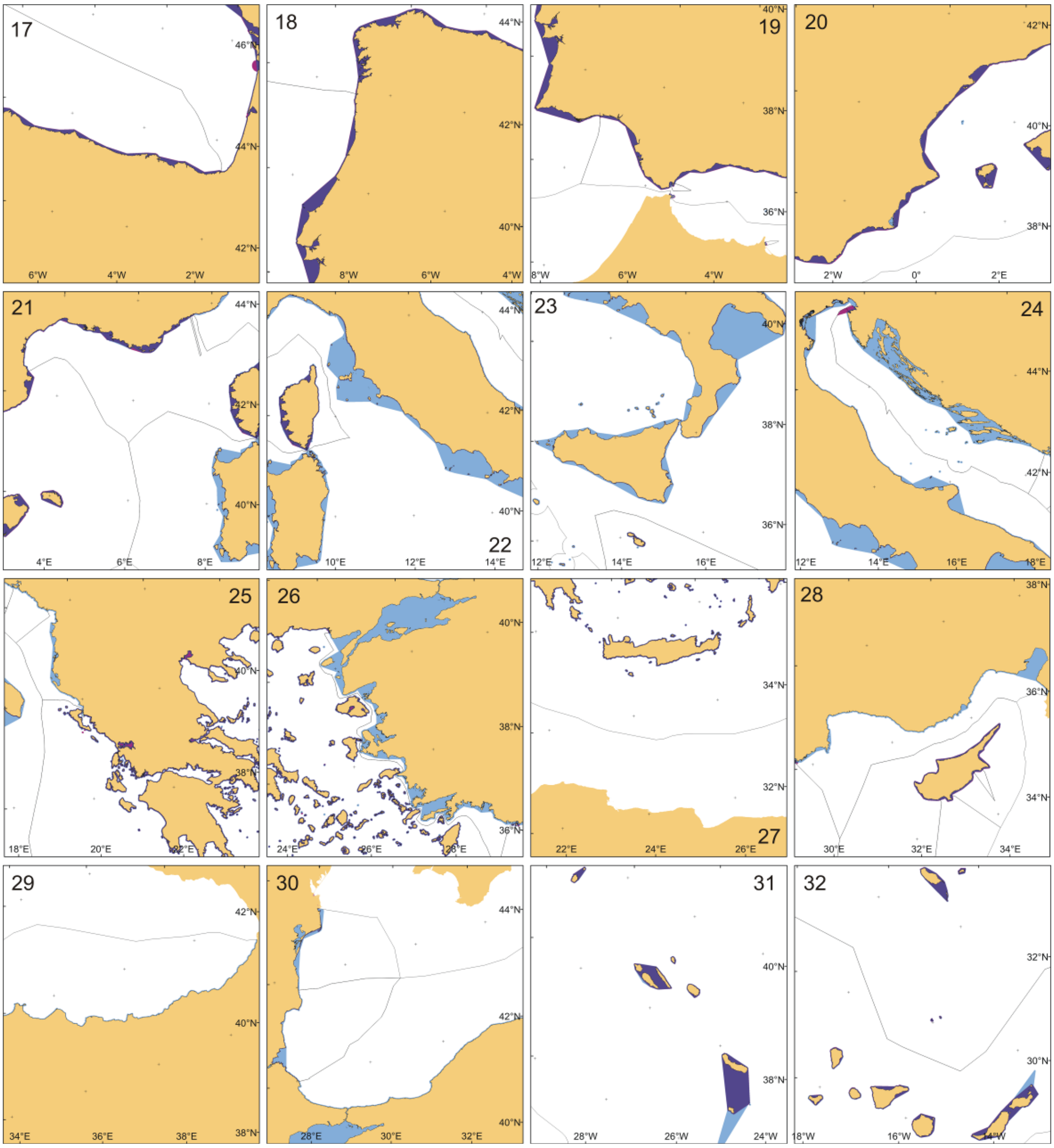
Spatial representation info/resolution:
Global scale 9km

Reference system information:
WGS84 bounds: -180,-90,312,90
Projection: geographic lat/lon
EPGS: 4326

Data quality info: Regular annual updates are planned

## 3.3 Coastal waters delimitation

Title: European coastal waters delimitation




Short description (abstract field on metadata form):

Pan-European delimitation of coastal waters following the definition provided by the Water Framework Directive. More information in: Liquete, C., Somma, F., Maes, J. (2011). A clear delimitation of coastal waters facing the EU environmental legislation: from the Water Framework Directive to the Marine Strategy Framework Directive. Environmental Science & Policy, 14 (4), 432–444.

Purpose (what is the data useful for?):

The purpose of this work is to provide a clear and objective delimitation of the pan-European coastal waters which will facilitate the development of comparable scientific studies and ecological assessments. This delimitation should be compliant with the Water Framework Directive and the Marine Strategy Framework Directive. It can be used in any ICZM assessment that aims to be comparable with the ecological or socio-economic reporting under those Directives.

Source: originator: European Commission - Joint Research Centre (JRC). The views expressed in this document are purely those of the authors and may not in any circumstances be regarded as stating an official position of the European Commission. Input data included the deposits of the United Nations Convention on the Law Of the Sea (UNCLOS) (Division for Ocean Affairs and the Law of the Sea, 2009).

Contact: Francesca Somma, Joint Research Centre (JRC), francesca.somma@jrc.ec.europa.eu

Thematic keywords: coastal water, coastal zone planning, environmental policy, Europe [thesaurus: GEMET v2.4]; administrative units, sea regions [INSPIRE Spatial Data Themes]; Water Framework Directive.

Place (descriptive) keywords: Europe

Access constraints/Use constraints/other constraints: No conditions apply. Please, cite as: Liquete, C., Somma, F., Maes, J. (2011). A clear delimitation of coastal waters facing the EU environmental legislation: from the Water Framework Directive to the Marine Strategy Framework Directive. Environmental Science & Policy, 14 (4), 432–444.

Distribution information/transfer options/online resource: not yet uploaded

Spatial representation info/resolution: ETRS_1989_LAEA

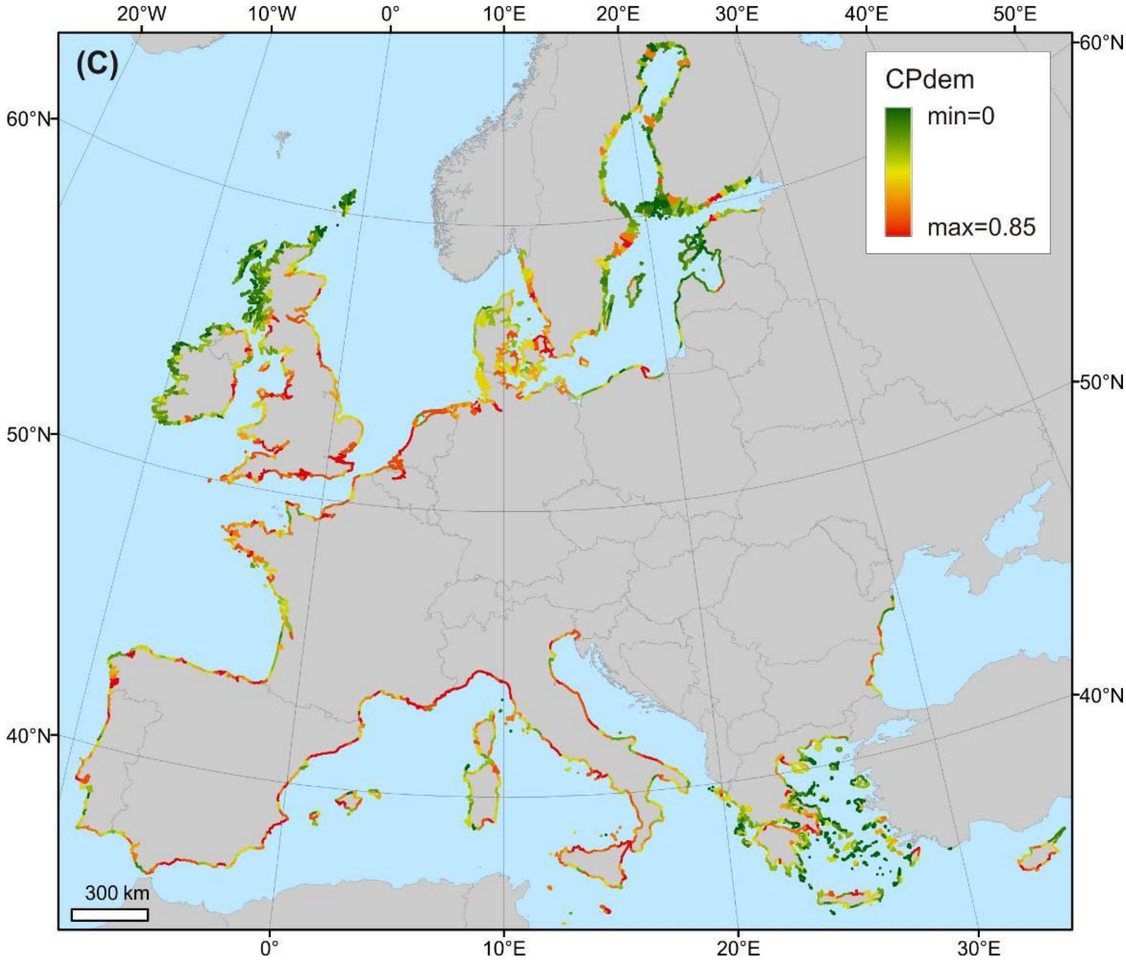
Reference system information: EPSD, code 3035

Data quality info: complete, no updates planned.

ENTITY ATTRIBUTE > Attribute definitions: CNTRY: countries ISO 3166-1-alpha-2 code / Area: Area in square meters
Date of creation: 2010-11-03
Date of last revision: 2011-01-10

## 3.4 Coastal protection

Title: Indicators of the coastal protection ecosystem service in Europe




Short description (abstract field on metadata form):

Assessment of coastal protection as an ecosystem service applied to the EU coastal zone. This assessment incorporates 14 biophysical and socio-economic variables from both terrestrial and marine datasets. Those variables define three indicators: coastal protection capacity (CPcap), coastal exposure (CPexp) and human demand for protection (CPdem). More information in: Liquete, C., Zulian, G., Delgado, I., Stips, A., Maes, J. (2012). Assessment of coastal protection as an ecosystem service in Europe. Ecological Indicators, submitted.

Purpose (what is the data useful for?):

This assessment is thought to assist the comparison between European regions and to inspire national or regional scale studies of ecosystem services. Mapping and assessment of ecosystem services is essential to provide scientific support to international biodiversity policy and to develop environmental accounts. The results of this assessment (the 3 indicators) are comparative and aim to support integrated land and marine spatial planning.

Source: originator: European Commission - Joint Research Centre (JRC). The views expressed in this document are purely those of the authors and may not in any circumstances be regarded as stating an official position of the European Commission.

Contact: Francesca Somma, Joint Research Centre (JRC), francesca.somma@jrc.ec.europa.eu

Thematic keywords: ecosystem service, coastal erosion, coastal inundation, coastal protection, biodiversity, exposure, vulnerability.

Place (descriptive) keywords: Europe

Access constraints/Use constraints/other constraints: Until the data is published, this data will be restricted (available to PEGASO partners on request). Once published, no conditions will apply. Please, cite as: Liquete, C., Zulian, G., Delgado, I., Stips, A., Maes, J. (2012). Assessment of coastal protection as an ecosystem service in Europe. Ecological Indicators, submitted.

Distribution information/transfer options/online resource: not yet uploaded

Spatial representation info/resolution: ETRS_1989_LAEA_L52_M10

Reference system information: EPSD, code 3035

Data quality info: complete, no updates planned.

ENTITY ATTRIBUTE > Attribute definitions: CNTRY: countries ISO 3166-1-alpha-2 code / BID: ID of the blocks or working units / CPcap: dimensionless indicator of coastal protection capacity / CPexp: dimensionless indicator of coastal exposure / CPdem: dimensionless indicator of demand for coastal protection.
Date of creation: 2012-01-25
Date of last revision: 2012-05-15

## 3.5 FATE Data Portal

Title: FATE and impact of nutrients in terrestrial and aquatic ecosystems

Short description (abstract field on metadata form): This portal offers maps, statistics and trends of modelled nutrients (N & P) per catchment unit. More information in: http://fate.jrc.ec.europa.eu/modelling/nutrients.

Purpose (what is the data useful for?): to evaluate human pressure in the coastal zone, river discharge to the sea, risk of eutrophication, etc.

Source: originator: European Commission - Joint Research Centre (JRC)

Contact: fate@jrc.ec.europa.eu, konstantins.bogucarskis@jrc.ec.europa.eu

Thematic keywords: nutrient, pollutant, water quality, impact, nitrogen, phosphorus.

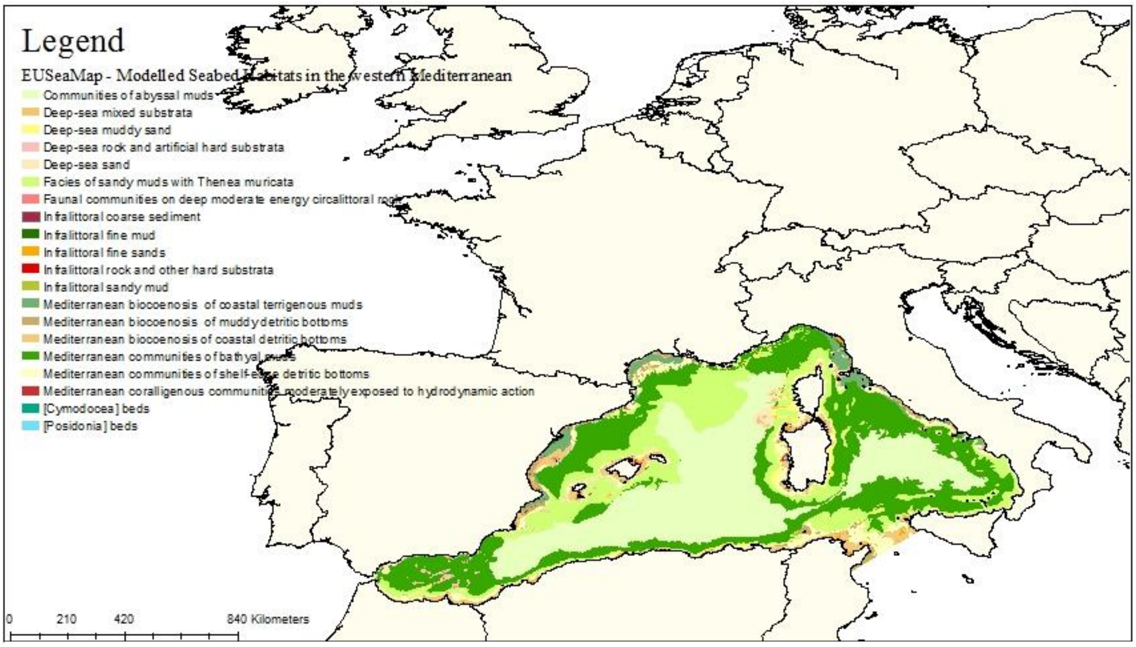
Place (descriptive) keywords: pan-European, including E Mediterranean and N Black Sea.

Access constraints/Use constraints/other constraints: No conditions apply.

Distribution information/transfer options/online resource:
http://fate-gis.jrc.ec.europa.eu

# 4. Data overview from UAB

## 4.1 Euseamap




Source: EUSeaMap: www.jncc.gov.uk/EUSeaMap, webGIS: www.jncc.gov.uk/page-5040

Title: Western Mediterranean modelled seabed habitats

Short description (abstract field on metadata form):

This layer is a predictive seabed habitat map for the Western Mediterranean Sea. The layer has been created using three pre-processed input datasets: substrate, biological zone and energy.

The map follows the EUNIS 2007-11 classification system, and is displayed using (a) the most detailed classifications predicted by the model and (b) simplified classifications that can be compared to the equivalent maps in the Celtic, North and Balic Seas.
The model was created using raster input layers with a cell size of 0.0027dd (~230 x 300m). The model includes the sublittoral zone only; due to the high variability of the littoral zone, the lack of detailed substrate data and the resolution of the model, it is difficult to predict littoral habitats at this scale.

Purpose (what is the data useful for?):

This map can be used for mapping the potential impact of cumulative pressures (land-based and sea-based) over Western Mediterranean benthic habitats.

Source: EUSeaMap: www.jncc.gov.uk/EUSeaMap, webGIS: www.jncc.gov.uk/page-5040

Contact: Marine Ecosystems Team, Joint Nature Conservation Committee.
Monkstone House
City Road
Peterborough
PE1 1JY

Thematic keywords: Seabed habitats

Place (descriptive) keywords: Mediterranean, Western Mediterranean, Seabed habitats, Habitats and biotopes.

Access constraints/Use constraints/other constraints: Public

Distribution information/transfer options/online resource:
www.jncc.gov.uk/page-5040

Spatial representation info/resolution: 0.0027 degrees

Reference system information: WGS84 (urn:ogc:def:crs:EPSG::4326)

Data quality info:

# 5. Data overview from VLIZ

## 5.1 Administrative units

### 5.1.1 Exclusive Economic Zones + Boundaries

Title: Exclusive Economic Zones Boundaries (EEZ), versie 7

Short description (abstract field on metadata form):
This dataset represents Exclusive Economic Zones (EEZ) of the world. Up to now, there was no global public domain cover available. Therefore, the Flanders Marine Institute decided to develop its own database. The database includes two global GIS-layers: one contains polylines that represent the maritime boundaries of the world countries, the other one is a polygon layer representing the Exclusive Economic Zone of countries. The database also contains digital information about treaties.

Purpose (what is the data useful for?):
The data can be used as accounting units

Source: Marine Regions, http://www.marineregions.org

Contact: info@marineregions.org

Thematic keywords: administrative, boundaries, Exclusive Economic Zones, administrative units

Place (descriptive) keywords: World, Mediterranean and Black Sea basins

Access constraints/Use constraints/other constraints:

The Flanders Marine Institute manages Marine Regions, but is aware that it is not complete and undoubtedly contains errors. The Flanders Marine Institute cannot be made responsible for any errors or misuse of data contained in this register. Comments from our users are more than welcome, so if you come across any error or incomplete information or you are willing to contribute to this initiative please contact us.

The data is provided "as is", and no warranty express, implied or otherwise is offered as to the data's accuracy. The developers do not imply any opinion concerning the legal status of any country, territory or area, or concerning the delimitation of its frontiers or boundaries. The data can be used for educational, scientific or research purposes but should not be used for legal, commercial/economical (exploration of natural resources) or navigational purposes.

Anyone can download this data but it is for the sole use of the organisation or individual downloading the data. The geodata may not be redistributed without the permission of the Flanders Marine Institute (VLIZ). The geodata may be used in a Value-Added Software Application (like webservices), on condition that the Flanders Marine Institute is acknowledged as the source of the data. Redistribution rights are granted for hard-copy renditions or static, electronic map images (e.g. jpeg, gif, etc.) that are plotted, printed or publicly displayed with reference to the Flanders Marine Institute. For redistribution rights of derived products, please contact us. You can contact us at info@marineregions.org

The database can be cited as follows: Claus S., De Hauwere N., Vanhoorne B., Hernandez F., Mees J. (Flanders Marine Institute) (2012). Marineregions.org . Accessed at http://www.marineregions.org on 2012-12-17.

Distribution information/transfer options/online resource:
http://www.marineregions.org/downloads.php#eez

Spatial representation info/resolution:

Reference system information:

Data quality info:

### 5.1.2 IHO Sea Areas

Title: IHO Sea Areas

Short description (abstract field on metadata form):
World seas represents the boundaries for the major oceans and seas of the world. The source for the boundaries is the publication 'Limits of Oceans & Seas, Special Publication No. 23' published by the IHO in 1953. (http://www.iho-ohi.net/iho_pubs/standard/S-23/S23_1953.pdf).

Purpose (what is the data useful for?):
The data can be used as accounting units

Source: Marine Regions, http://www.marineregions.org

Contact: info@marineregions.org

Thematic keywords: administrative, boundaries, seas, oceans

Place (descriptive) keywords: World, Mediterranean and Black Sea basins, Oceans

Access constraints/Use constraints/other constraints:

Distribution information/transfer options/online resource:
http://www.marineregions.org/downloads.php#iho

Spatial representation info/resolution:

Reference system information:

Data quality info:

## 5.2 Marine Regions (in general)

Title: Marine Regions

Short description (abstract field on metadata form):

Geographic Information Systems have become indispensable tools in managing and displaying marine data and information. However, a unique georeferenced standard of marine place names and areas was not available, hampering several marine geographic applications, for example the linking of these locations to databases to integrate data. The purpose of Marine Regions is therefore to create a standard, relational list of geographic names, coupled with information and maps of the geographic location of these features. This will improve access and clarity of the different geographic, marine names such as seas, sandbanks, ridges and bays and display univocally the boundaries of marine biogeographic or managerial marine areas.

Marine Regions is an integration of the VLIMAR Gazetteer and the VLIZ Maritime Boundaries Geodatabase. The VLIMAR Gazetteer is a database with geographic, mainly marine names such as seas, sandbanks, seamounts, ridges, bays or even standard sampling stations used in marine research. The geographic cover of the VLIMAR gazetteer is global but initially focused on the Belgian Continental Shelf and the Scheldt Estuary and the Southern Bight of the North Sea. Gradually more regional and global geographic information was added to VLIMAR and combining this information with the Maritime Boundaries database, representing the Exclusive Economic Zone (EEZ) of the world, led to the creation of marineregions.org.

Marine Regions is managed by the Flanders Marine Institute. Funding for the creation of the VLIMAR gazetteer was provided initially through the EU Network of Excellence MarBEF, but also other European initiative such as EMODnet and Lifewatch provide the necessary funding for the maintenance and management of Marine Regions.

With the launch of marineregions.org, we are also aiming at the establishment of an international editorial board, responsible for the content, quality control and promotion of Marine Regions. You can apply for membership by sending your contact details, interest and proposed contribution to info@marineregions.org

Purpose (what is the data useful for?):
The data can be used as accounting units

Source: Marine Regions, http://www.marineregions.org

Contact: info@marineregions.org

Thematic keywords: administrative, boundaries, seas, oceans

Place (descriptive) keywords: World, Mediterranean and Black Sea basins, Oceans

Access constraints/Use constraints/other constraints:

Distribution information/transfer options/online resource:
http://www.marineregions.org/downloads.php

Spatial representation info/resolution:

Reference system information:

Data quality info:

## 5.3 Background information

### 5.3.1 Salinity per season

Title: Salinity for the European Marine waters, based on WOA 2005

Short description (abstract field on metadata form):
Created by VLIZ, based on WOD

Purpose (what is the data useful for?):
The data can be used as background

Source: EMODNet, http://bio.emodnet.eu/portal/

Contact: bio@emodnet.eu

Thematic keywords: salinity, seas, oceans

Place (descriptive) keywords: Europe, Mediterranean, seas

Access constraints/Use constraints/other constraints:

Distribution information/transfer options/online resource:
http://bio.emodnet.eu/portal/

Spatial representation info/resolution:

Reference system information:

Data quality info:

### 5.3.2 Temperature per season

Title: Temperature for the European Marine waters, based on WOA 2005

Short description (abstract field on metadata form):
Created by VLIZ, based on WOD

Purpose (what is the data useful for?):
The data can be used as background

Source: EMODNet, http://bio.emodnet.eu/portal/

Contact: bio@emodnet.eu

Thematic keywords: temperature, seas, oceans

Place (descriptive) keywords: Europe, Mediterranean, seas

Access constraints/Use constraints/other constraints:

Distribution information/transfer options/online resource:
http://bio.emodnet.eu/portal/

Spatial representation info/resolution:

Reference system information:

Data quality info:

### 5.3.3 Number of Unique species

Title: Number of unique species of mammals / macroalgae / cnidaria / chromista / birds / echinoderms / mollusc / annelids / reptiles / crustaceans / fish on a 3x3 degrees grid for the European Marine Waters, based on EurOBIS data (september 2009)

Short description (abstract field on metadata form):
Number of unique species of

- Mammals
- Macroalgae
- Cnidaria
- Chromista
- Birds
- Echinoderms
- Mollusc
- Annelids
- Reptiles

- Crustaceans
- fish

on a 3x3 degrees grid for the European Marine Waters, based on EurOBIS data (September 2009)

Purpose (what is the data useful for?):
The data can be used as background

Source: EMODNet, http://bio.emodnet.eu/portal/

Contact: bio@emodnet.eu

Thematic keywords: temperature, seas, oceans

Place (descriptive) keywords: Europe, Mediterranean, seas

Access constraints/Use constraints/other constraints:

Distribution information/transfer options/online resource:
http://bio.emodnet.eu/portal/

Spatial representation info/resolution:

Reference system information:

Data quality info:

### 5.3.4 Sampling effort

Title: Sampling effort for plants / echinoderms / reptiles / birds / mollusc / fish on a 3x3 degrees grid for the European Marine Waters, based on EurOBIS data (september 2009)

Short description (abstract field on metadata form):
Sampling effort for

- Plants
- Echinoderms
- Reptiles
- Birds
- Mollusc
- Fish

on a 3x3 degrees grid for the European Marine Waters, based on EurOBIS data (september 2009)

Purpose (what is the data useful for?):
The data can be used as background

Source: EMODNet, http://bio.emodnet.eu/portal/

Contact: bio@emodnet.eu

Thematic keywords: temperature, seas, oceans

Place (descriptive) keywords: Europe, Mediterranean, seas

Access constraints/Use constraints/other constraints:

Distribution information/transfer options/online resource:
http://bio.emodnet.eu/portal/

Spatial representation info/resolution:

Reference system information:

Data quality info:

### 5.3.5 Biodiversity Index ES50

Title: Biodiversity index ES50 for birds on a 3x3 degrees grid for the European Marine Waters, based on EurOBIS data (september 2009)

Short description (abstract field on metadata form):
Biodiversity index ES50 for birds on a 3x3 degrees grid for the European Marine Waters, based on EurOBIS data (september 2009)

Purpose (what is the data useful for?):
The data can be used as background

Source: EMODNet, http://bio.emodnet.eu/portal/

Contact: bio@emodnet.eu

Thematic keywords: temperature, seas, oceans

Place (descriptive) keywords: Europe, Mediterranean, seas

Access constraints/Use constraints/other constraints:

Distribution information/transfer options/online resource:
http://bio.emodnet.eu/portal/

Spatial representation info/resolution:

Reference system information:

Data quality info:

### 5.3.6 Number of species and observations per sea based on EurOBIS data

Title: Number of species and observations per sea based on EurOBIS data

Short description (abstract field on metadata form):
Created by VLIZ, based on WOD

Purpose (what is the data useful for?):
The data can be used as background

Source: EMODNet, http://bio.emodnet.eu/portal/

Contact: bio@emodnet.eu

Thematic keywords: temperature, seas, oceans

Place (descriptive) keywords: Europe, Mediterranean, seas

Access constraints/Use constraints/other constraints:

Distribution information/transfer options/online resource:
http://bio.emodnet.eu/portal/

Spatial representation info/resolution:

Reference system information:

Data quality info:

### 5.3.7 Chlorophyll

Title:

- Chlorophyll data points for all seasons from 1980 to 2008, based on chlorophyll data from Waterbase (EEA)
- Extrapolated chlorophyll values for all seasons from 1980 to 2008 on a 1x1 degree grid for Europe, based on distinct surface chlorophyll data from Waterbase (EEA)

Short description (abstract field on metadata form):

Purpose (what is the data useful for?):
The data can be used as background

Source: EMODNet, http://bio.emodnet.eu/portal/

Contact: bio@emodnet.eu

Thematic keywords: temperature, seas, oceans

Place (descriptive) keywords: Europe, Mediterranean, seas

Access constraints/Use constraints/other constraints:

Distribution information/transfer options/online resource:
http://bio.emodnet.eu/portal/

Spatial representation info/resolution:

Reference system information:

Data quality info:

# References

Division for Ocean Affairs and the Law of the Sea, 2009. Maritime Space: Maritime Zones and Maritime Delimitation. Available online at http://www.un.org/Depts/los/LEGISLATIONANDTREATIES/index.htm. Last update: 20.07.2010.

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Pegaso Project
People for Ecosystem based Governance
in Assessing Sustainable development of
Ocean and coast

Funded by the European Union
under FP7 – ENV.2009.2.2.1.4
Integrated Coastal Zone Management

Specific Programme FP7
Collaborative Projects
Large scale integrating project

Grant agreement nº: 244170

# ID4.2.4 Modelling Framework report

## Development of Spatial Indicator and modelling

| | |
|---|---|
| Code | Pegaso/ID4.2.4/UNOTT/211112-I-2.0 |
| Date / version | 01 December 2012 (v1) contents<br>30 December 2012 (v2) submitted to coordinator |
| Authors | Emil Ivanov (UNOTT)<br>Roy Haines-Young (UNOTT)<br>Marion Potschin (UNOTT)<br>Camino Liquete (JRC)<br>Adolf Stips (JRC)<br>François Morisseau (UAB) |

**Resume**

This is an internal document, written for the PEGASO team only.

The aim of this document is to present an overview of the modelling methods and spatial data processing for producing indexes and indicators, within the ecosystem accounting framework covering both land and sea (within WP4 of PEGASO).

Project coordination
Universitat Autònoma de Barcelona
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Notes:

If you use this document please quote as:

Ivanov, E.; Haines-Young, R.; Potschin, M.; Liquete , C.; Morisseau, F. and A. Stips (2012): Development of Spatial Indicator and modelling. ID4.2.4 Modelling Framework Report. V2.0 (December 2012), 24 pp.

EU FP7 Project PEGASO Grant agreement nº: 244170.

# Contents

# 1. Introduction

This report introduces the accounting framework, with method, models and data inputs used to estimate ecosystem accounts.

# 2. Land accounting framework

Land accounting refers to a method designed to detect, depict and register the main types of land-cover and their related human uses and functions in the landscape. It is a part of a bigger framework of environmental accounting, called Land and Ecosystem ACcounts (LEAC, Weber, 2007), an innovative framework promoted by the European Environmental Agency (EEA) along the development of the United Nation's System of integrated Environmental and Economic Accounts (SEEA1). The method produces quantitative estimates following specially designed mapping procedures, analysing the quality and quantity (area) of land resources and their changes in time. The results are presented per unit area of interest, be it an administrative region, a country, a coastal area or a protected area, in the form of statistics and maps. For this, the method was included in PEGASO's toolbox (WP4), to be explored and tested as a decision support tool relevant in Mediterranean and Black sea coastal management context. It is expected to contribute with information relevant for two points of policy importance: characterizing the state and change in natural capital and its damage from urban sprawl in the coastal regions.

## 2.1 Land accounting model

The land accounts produce two estimates generally: a quantity (area in hectares) of a natural capital represented by the categories of land cover (such as forest, wetland, grassland, arable land) and a change in this quantity, or changes in certain quality features of the capital when identified, during a relevant period of time (Weber, 2007). The land accounting method was developed by the EEA and its Topic Centre on Terrestrial Environment (ETC-TE) using the European CORINE land cover product (EEA, 2006).

A simplified version of the land accounting scheme is developed for an application in the Mediterranean and the Black sea basins, the study area of PEGASO (Ivanov et al. 2012) Simplified land accounts include a clear description of what the minimum application needs: land cover dataset for time 1; land cover dataset for time 2 (each with explained legend nomenclature specifying how the value of natural capital is interpreted and encoded in distinct classes); changed land-cover (detecting where changes happened, specifying the nature of the changes and the system defining values to judge whether there is loss or gain in natural capital).

[1] http://unstats.un.org/unsd/envaccounting/seearev/

## 2.2 Dataset for the Mediterranean and Black Sea basins

An extension of CORINE Land cover over the Mediterranean and Black Sea basins was developed using a set of data-sources: the European CORINE land cover for training a supervised maximum likelihood classification of MODIS multispectral and other geographic data.

**Remote sensing data:**

- MODIS land products2 cover the whole globe with freely accessible data (highest detail at 250 m2 resolution) since 2000. It includes classified land cover maps (annual, at 500 m2 but not suitable for multi-temporal analysis); vegetation indices and multispectral reflectance data (at 250 m, every 14 days). These products were chosen for testing the possibility to reproduce a selection of classes from CORINE land cover, at a medium resolution and compatible with the original CORINE land
- DMSP-OLS Night-time Lights Time Series3 contains global annual images of nightlight intensity at 1 km resolution. The images are composites of cloud-free scenes using all available smooth resolution data acquired during each calendar year since 1992.

**Classified land cover/land use data:**
CORINE4 is a standardised land cover inventory (at 100x100 m2 spatial resolution) derived from satellite imagery for three dates (1990, 2000 and 2006) for the EU and EEA associated countries.

**Other geographic data:**
SRTM 90m Digital Elevation Data5(DEM) was produced originally by NASA in 90 m resolution at the equator. For the current application a resampled version was used at 250 m resolution. Slope and aspect layers were derived from the DEM.

The method has allowed reproducing the European CORINE land cover product, in a modified way, over the African and Near-east Mediterranean areas and East European temperate areas for the years 2000 and 2011.

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[2] MODIS land products can be accessed and downloaded from NASA's data centre: http://reverb.echo.nasa.gov/reverb/#utf8=%E2%9C%93&spatial_map=satellite&spatial_type=rectangle

[3] http://www.ngdc.noaa.gov/dmsp/downloadV4composites.html

[4] CORINE Land cover can be downloaded from EEA's data centre: http://www.eea.europa.eu/data-and-maps/data/corine-land-cover-2000-raster-2

[5] http://srtm.csi.cgiar.org/

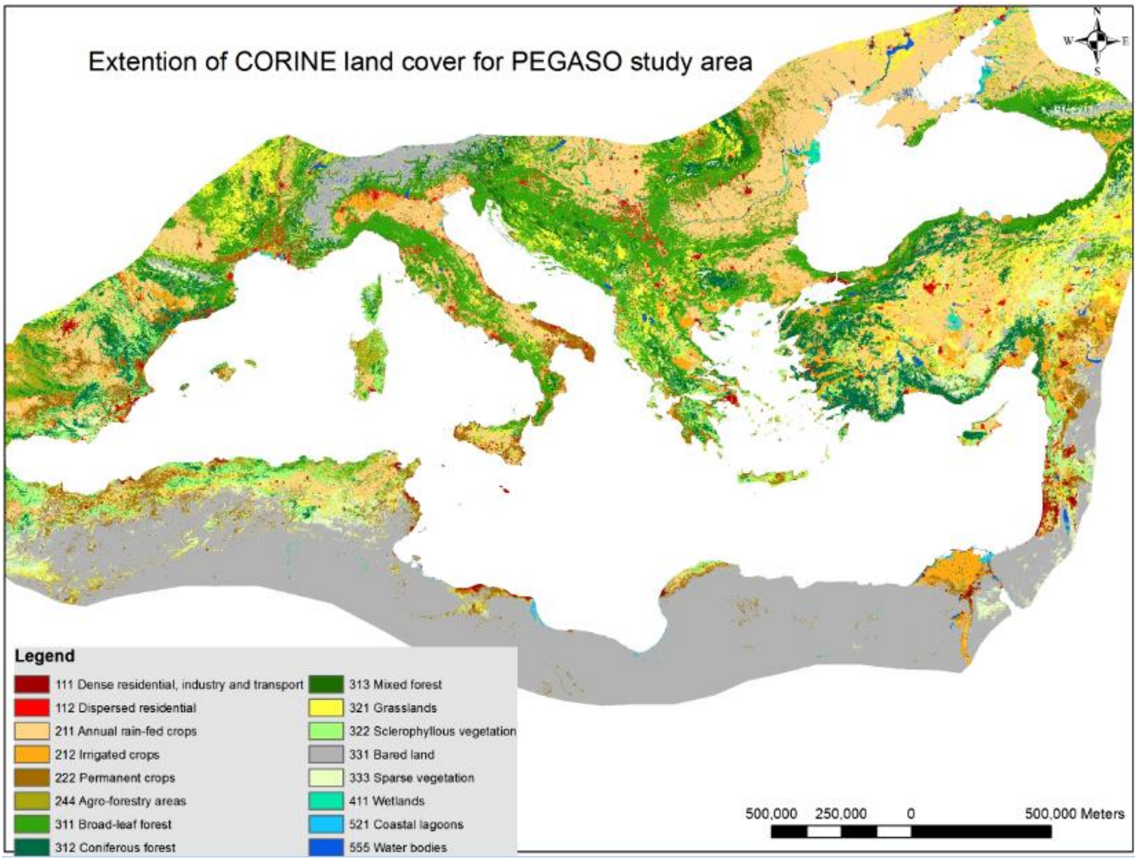



**Figure 1**. PEGASO Land cover for year 2000

18 out of the 44 classes of the CORINE nomenclature could be reproduced in this way. The nomenclature was modified by merging some classes and excluding others in order to ensure relative separability of the retained classes using the MODIS multispectral and other inputs at 250 m spatial resolution. For example all the classes characterised my continuous hard or paved surface were merged in a single class '111', while the class of discontinuous urban land, including open spaces (agriculture, parks, green areas) is kept separate '112'.

## 2.3 Validation and application of land accounts

This product is still under development, and therefore the current results are presented in a way to emphasize the options available for improvement, rather than the possible highest quality output, as defined by the accuracy assessment, which shows 70 % agreement between CORINE land cover and PEGASO land cover at level 1, for the five major classes: urban land, agricultural, natural and semi-natural, wetland and water. Further validation work is needed for the areas out of the coverage of the European Corine Land cover, e.g. over the north-African, Near-east and East Europe areas.

# 3. Species accounting framework

This section describes the development of a species accounting method (Ivanov et al., 2012) part of the ecosystem accounting framework led by the EEA (EEA, 2011). The approach and results are used for producing ecosystem accounts, to supporting ICZM relevant assessments at regional level for the North Mediterranean, EU countries and also to extend the method along the North-African, Near-East and the Black Sea coastal areas.

## 3.1 Species accounting model

The ecosystem accounts provide two general estimates: (i) a measure of the 'volume' or stock of natural capital for defined units of ecosystem types; and, (ii) measures of the quality functional integrity/performance of that stock. Ideally, in keeping with the idea of accounts both sets of measures should also give a picture of how stock and quality are changing over time (Weber, 2007). Thus any species account should follow the same format, and provide information on changes in either species number and conservation status at a certain location, between two given times. The count of number of species present in given area is represents the 'volume' of natural capital; the species conservation status – is a measure of its quality. Changes in the conservation status over a period of time, may affect the original species number, if some initially extant species become extinct.

The accounting method devised here was designed to produce estimates for the entire territory of the EU countries in spatially explicit form, using a 1km x 1km grid. A major challenge for the work has been to extract and harmonise the available data, and report them spatially so that comparable results could be published across all the European countries for at least two time periods. The work has focussed on three elements of the species account:

- a number of species of European conservation importance present in a given area (representative for the time when the countries carried out their assessments for the period 2001 - 2006);
- a prevailing trend of the population sizes of the species present in a given area, which indicates whether the conservation status of the species improved or worsened since their designation in the 90-ies; and,
- the species' prevailing future prospects, which can help to assess whether the current trend in conservation success may continue or change in the near future.

For the fast track implementation of European ecosystem capital accounts it was decided to explore the information available for a preselected subset of just above a 1000 species (plants, mammals, amphibians, reptiles, arthropods) included in the

Annexes of the Habitat Directive (Council Directive 92/43/EEC), which have been considered through a policy processes as having European conservation importance (see list). Although progress can be made using these sources, data availability and data quality are identified as the main constraints for constructing a complete set of accounts. In the future other species data can be explored to extending and improving the method, and for its application in other areas, including: the IUCN red-list species; and the Protocol concerning Specially Protected Areas and Biological Diversity in the Mediterranean. The latter identifies species of 'Mediterranean conservation importance' (Annex II: List of Endangered or Threatened Species) and commits the countries that have signed the Barcelona Convention to fulfil monitor and report their of conservation status, in a similar way as done for the European Article 17 Habitats Directive.

## 3.2 Dataset for the EU Mediterranean countries

The method described here uses as input spatially explicit land cover and distribution data for species and habitats, together with their conservation status, to produce an estimate of the species number and prevailing conservation trends (negative or positive) at a landscape scale.

The source for the land cover data is the European CORINE Land Cover product (EEA, 2006). It standardised land cover inventory derived from satellite imagery for all the EU and EEA associated countries for three dates: 1990, 2000 and 2006 .

The species distribution data includes an expert judgements on conservation status is derived from the 'Article 17' assessment database. These data are reported by the EU member states, and harmonized by the European Topic Centre on Biodiversity as part of the implementation of the European NATURA2000 network, which was set up in response to the Convention in Biological Diversity and the political commitment of 'significantly reducing the current rate of biodiversity loss by 2010' (European Commission, 2009)[6].

The species numbers, prevailing population trends and the prevailing future prospects were calculated and mapped for eight broad ecosystem types:

[6] This commitment has now been updated: ec.europa.eu/environment/nature/biodiversity/comm2006/2020.htm

| | Ecosystem type |
|---|---|
| 1 | agro-ecosystems |
| 2 | grasslands |
| 3 | heaths and scrubs |
| 4 | forest ecosystems |
| 5 | wetland ecosystems |
| 6 | lakes and rivers |
| 7 | coastal ecosystems |
| 8 | marine ecosystems |

Aggregated layers combining the eight types in a single map were estimated too (see Figure2).

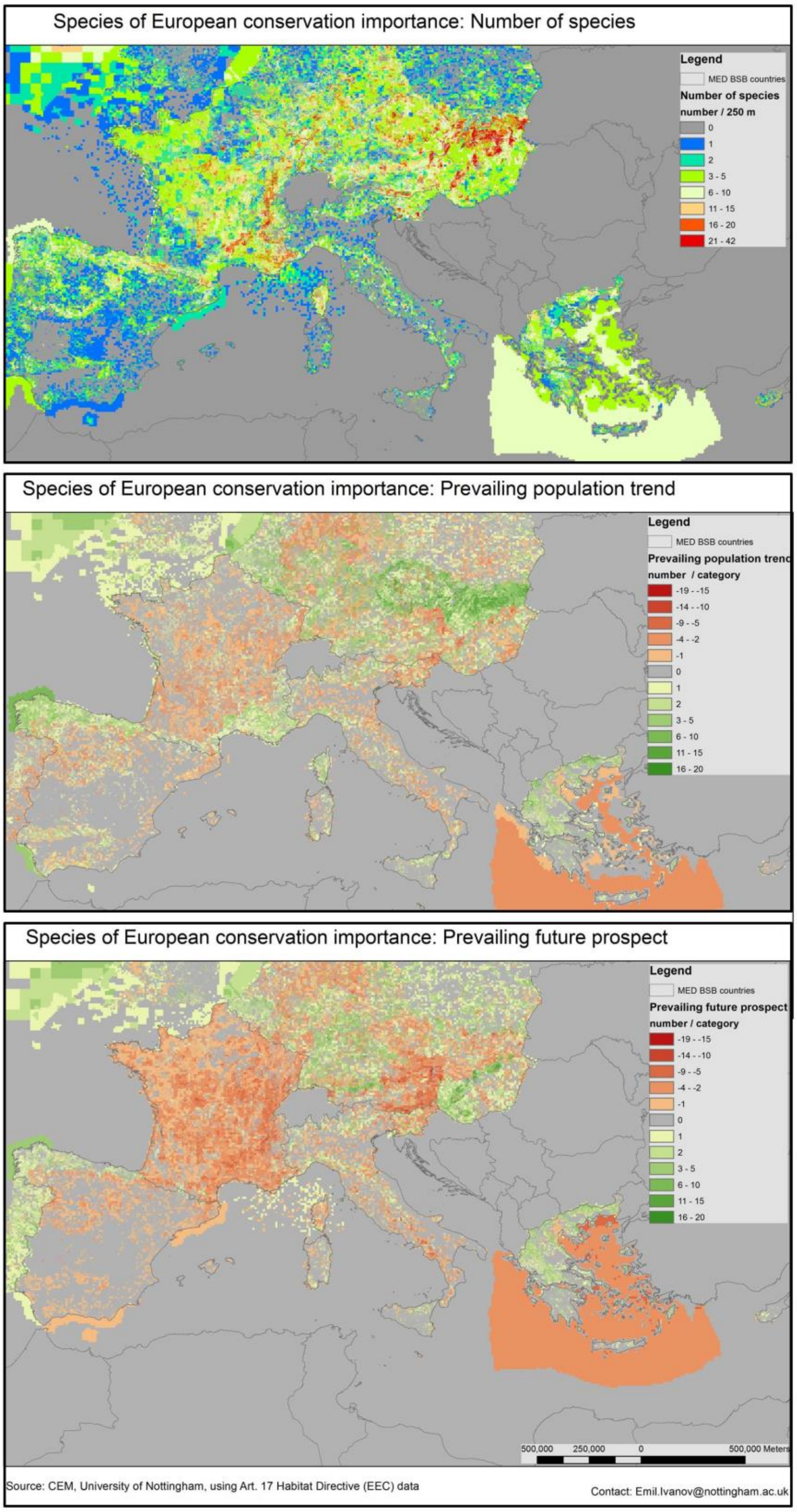



**Figure 2**. Species accounts for the Mediterranean EU countries

The purpose of this explorative work was to develop a biodiversity accounting method. The major conclusion is that given the data limitations a complete biodiversity account is unfeasible, especially when targeting a wide and diverse area like the Mediterranean coastal regions of the EU countries. The spatial patterns of these preliminary results, indicative of species present and their prevailing conservation trends, relate to patterns of land-use change occurred in the last 2 decades.

## 3.3 Validation and application of species accounts

Further analysis and validation of the current elements of the account should improve the understanding of the extent to which this subset can be considered a proxy for biodiversity richness and conservation success for the EU Mediterranean regions. It may also be used to examine the extent that it captures changes of major concern to decision makers, such as those leading to habitat loss and (local) species extinction.

The method was presented to the team for developing coastal ecosystem accounts in the FP7 project PEGASO with a view of extending the accounts over the north-African, near-East and Black Sea coasts using datasets from IUCN and other sources. First the list of species of European and Mediterranean conservation importance (species listed in Annex II of the Protocol concerning Specially Protected Areas and Biological Diversity in the Mediterranean) were compared. The latter includes 105 species, of which 32 are also of European conservation importance (and hence already processed in the current accounts). The Mediterranean list targets only marine species and they are not the only ones relevant to coastal management, when considered at a wider context and scale. Therefore more species characteristic of the terrestrial and wetland parts of the coastal areas need to be included in the accounts to be prepared for the South and East Mediterranean and the Black sea basin.

Further the available accounts can be refined for areas where more detailed and accurate biodiversity data exists, in spatial quality terms, as well as more certain conservation status changes.

# 4. Carbon accounting framework

The carbon accounting method is also part of the ecosystem accounting framework led by the EEA. Carbon accounts to produce a number of estimates used to assess the ecosystems' primary production status and changes related to human use and impacts, on large international scale, to link with international environmental policy making, and specifically the policies of the European Union. The need was to create a method for spatially explicit mapping of the relations between ecosystems biomass production (carbon fixing, ecosystem vigour) and the human use of biomass (for food, fibre, materials). Once having these key parameters mapped separately, then a set of indexes were extracted to represent key relationships between the human uses and the ecosystem parameters. The carbon accounts are used to assess whether countries (or other administrative units) overuse their own or other countries' ecosystem resources, also which ecosystems are under threat of degradation and where they are located.

## 4.1 Carbon accounting model

The carbon accounting model includes the 'standard' accounting estimates of stocks and flows. The stocks are sub-divided into annual stock and multi-annual stock due to the need to distinguish between annual and longer-term processes in 'ecosystem resource supply' and the human use of it. The annual carbon stocks are 'supplied' as a result of the process of carbon sequestration. Green plants use sun-light, $CO_2$ and water to fix carbon and produce organic matter (sugars) which are consequently used to build plant biomass and to maintain it (autotrophic respiration). The process is called Net primary production (NPP). The plant biomass can then be harvested/used by people or other components of the ecosystem (animals, fungi etc) or stored/accumulated in carbon pools. Carbon accumulation in woody biomass and dead material is a multi-annual process considered a major mechanism for abatement of $CO_2$ emissions. Carbon accumulation in soils (organic carbon stored in the soils as a result of decomposition of the biomass) is the other important mechanism. These two carbon pools are of special interest in carbon accounting. Therefore the carbon accounting model estimates three parameters:

- **Carbon resource** (or annual carbon stock): annual sum of carbon sequestered as a result of NPP;
- **Carbon resource**: multiannual sum of carbon stored in woody plant material and soils; and,
- **Carbon use**: annual sum of carbon removed from the ecosystems in the form of crop harvest, timber extraction and grazed biomass (by domestic livestock).

The four parameters are calculated and mapped in 1 km grid using remote sensing products (GEOSUCCESS NPP product and Spot-vegetation NDVI); CORINE land cover and national statistics on crops, timber and livestock from FAO. All outputs are presented as tons of carbon per km2 and per year (where relevant). Only exchanges related to living processes are considered (at this stage), carbon sequestration in the ocean or processes related to fossil fuels are not considered.

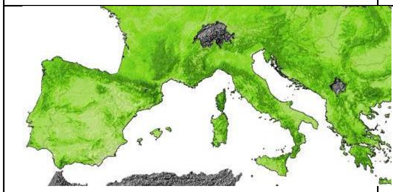
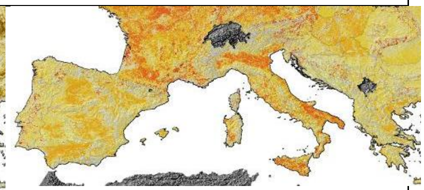
| Carbon resource | Carbon resource | Carbon use |
|---|---|---|
|  |  |  |

**Figure 3.** Components of the carbon accounting model estimated for year 2000

An index of ecosystem carbon balance can be estimated too, as the difference between carbon stocks (annual and multiannual) and carbon use. Therefore it can be applied to assess whether the annual resources produced by the ecosystems, as well as the multiannual stock accumulations are used sustainably by people, e.g. when the balance is positive; and the reverse – assess if the ecosystems might be under risk of continuous degradation indicated by multi-annual trends of negative carbon balance.

The relevance and necessity to develop carbon accounts for PEGASO was discussed earlier but not concluded yet. With the new Land cover source these estimates can easily be extended over the whole Mediterranean and Black sea basins.

# 5. Western Mediterranean Impact Index

Transnational, national, and local management of coastal areas requires spatial data on the intensity of human pressures and the potential impact that they have on surrounding ecosystems components.

There is a recent effort to estimate and map in a transparent and systematic way the cumulative impact of pressures on each ecosystem. Halpern et al. (2008), applying a method eliciting expert judgments on the vulnerability of ecosystems to anthropogenic threats, gave one of the first spatial visualization of cumulative impact (from land-sea) at global level and was followed by other papers at smaller scale with refined data (Korpinen et al., 2012; Andersen et al., 2012).

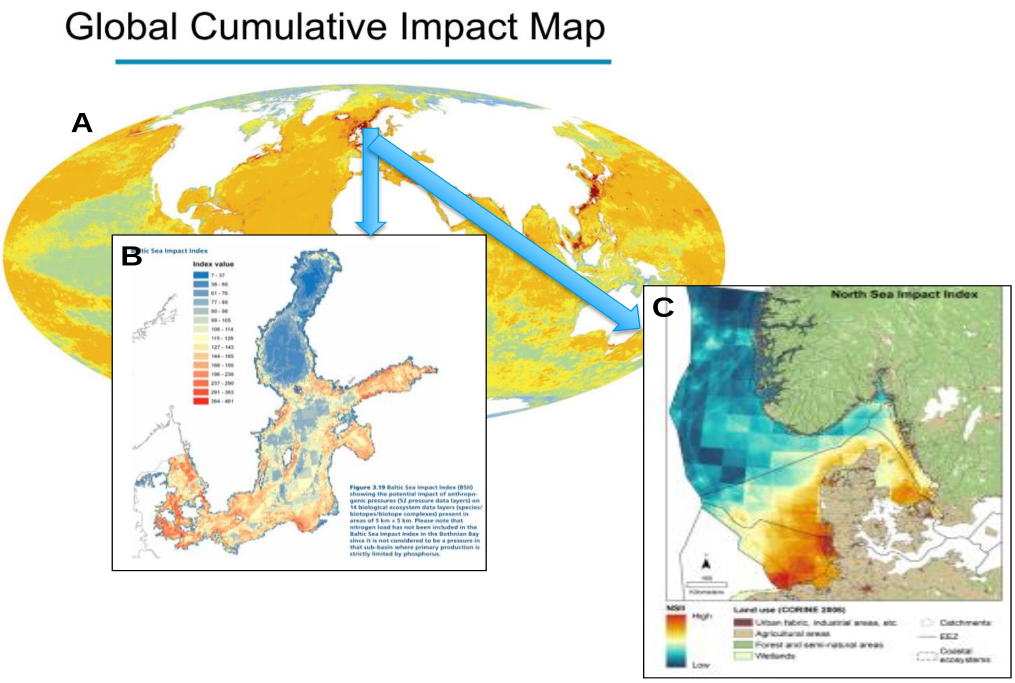



**Figure 4.** Example of work done on cumulative impact using similar methodologies. A: A Global Map of Human Impact on Marine Ecosystems (Halpern et al., 2008); B: Human pressures and their potential impact on the Baltic Sea ecosystem (Korpinen et al., 2012); C: North Sea Impact Index (Andersen et al, 2012).

In the framework of the European FP7 project PEGASO (www.pegasoproject.eu), this methodology will be applied to the Western Mediterranean sea as presented above.

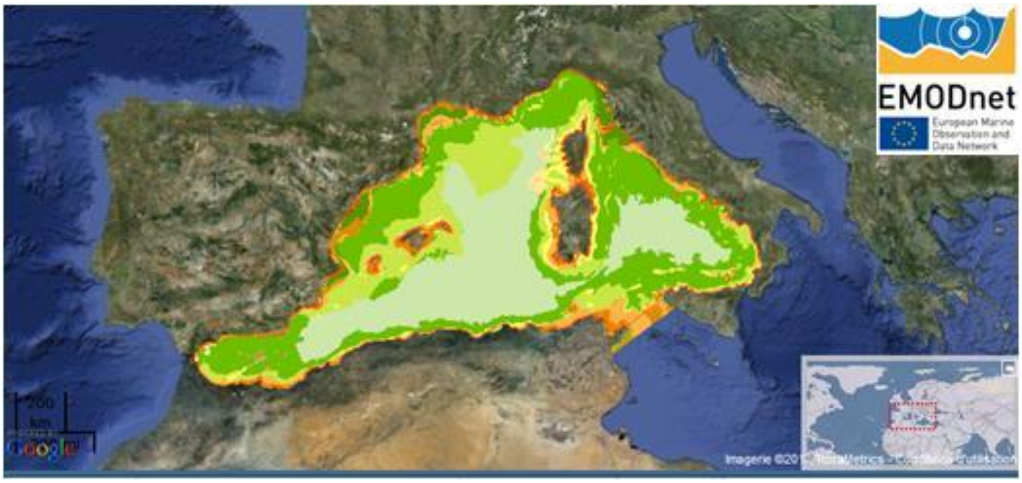



**Figure 5.** Modelled marine habitat map of the western Mediterranean sea (EUSeaMap: www.jncc.gov.uk/EUSeaMap, webGIS: www.jncc.gov.uk/page-5040).

This kind of model needs spatial explicit data on both human activities and ecological features that are harmonized for the entire area of study.

The collaboration between PEGASO partners and other projects will be maximized in order in order to apply this methodology with the best datasets available.

This methodology still supposes important hypothesis with associated uncertainties but should be seen as the first step towards more comprehensive impact assessments and better validated quantification of impacts.

This work has three underlying objectives in the framework of PEGASO project:

- Assess spatial explicit data availability on anthropogenic and ecosystem features for the Mediterranean Sea;
- Obtain through the expert survey, vulnerability scores that are specific for Mediterranean Ecosystems; and,
- Use existing data and make them useful and easily understandable by stakeholders and policy makers.

## 5.1 Conceptual framework

The cumulative impact index will be based on the model developed by Halpern et al. (2007, 2008) and later developments (Selkoe et al., 2009: Ban et al., 2010, Korpinen et al., 2012). This methodology is used to evaluate in a systematic way the potential impact of anthropogenic pressures here after called “**stressors”** on different marine ecosystems. **Human uses and land-based pollution** data are considered as proxies for stressors and **Expert judgment** allows estimating the cumulative impact they have on **Ecosystem components for each** 1km$^2$ as showed in the figure above.

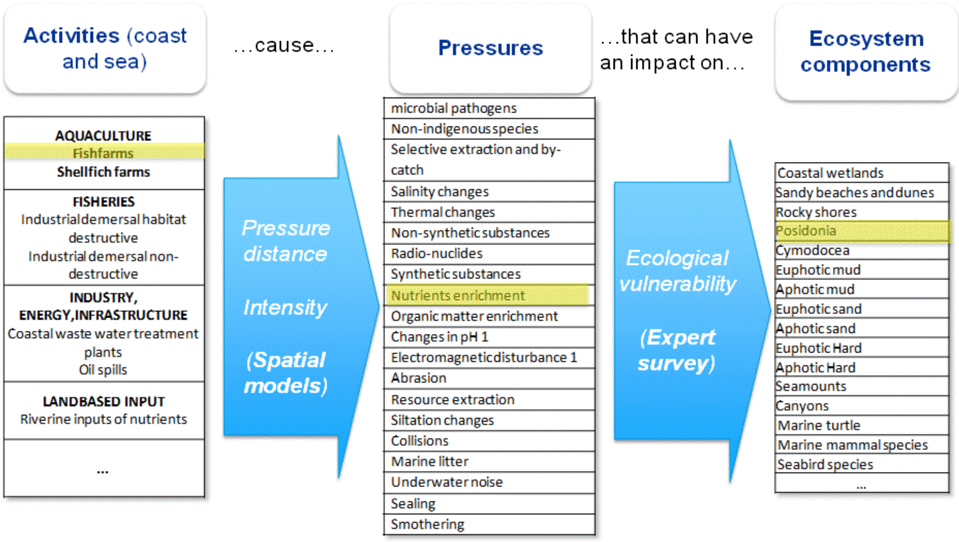



**Figure 6.** Conceptual framework for the impact index development.

Following methodology of Halpern et al. (2008), predictive cumulative impact score will be calculated for each cell as follows:

$$I_c = \sum_{i=1}^{n} \sum_{j=1}^{m} D_i * E_j * \mu_{i,j}$$

Where $D_i$ is the log-transformed and normalised value of a stressor at location *i*, $E_j$ is the presence or absence of ecosystem *j* (0 or 1) and $\mu_{i,j}$ is the impact of stressor *i* on ecosystem *j*.

The resulting map with impact index value will be indicative of the cumulative impact of these stressors on a given ecosystem for each $1km^2$ cells and can be used to identify priority areas for action and conservation as well as predominance of sea based or land based pressures.

## 5.2 Expert Survey

The online expert survey will ask more than 200 Mediterranean experts to estimate the “ecological vulnerability” of each ecosystem component to each stressor in the particular context of the Mediterranean Sea.

This survey has been inspired by the NCEAS Marine Ecosystem Threats Survey, described by Halpern et al. (2007) and the North Sea Impact Index survey, described by Andersen et al. (2012).
This ecological vulnerability will be defined in the questionnaire by 4 parameters that the experts will have to rate:

- **Pressure distance (that will give us the spatial model)**
- **Functional impact (individual to community level)**
- **Resistance of the ecosystem against the pressure**
- **Recovery time after pressure ceased**
- **Confidence in their judgment**

Before to rate vulnerability, the experts will be asked to associate each human activity (e.g. aquaculture) to the main pressure that it generates in one given ecosystem component (e.g. the main pressure that *aquaculture* exert on benthic ecosystem above may be *organic matter enrichment*) as in the picture above.

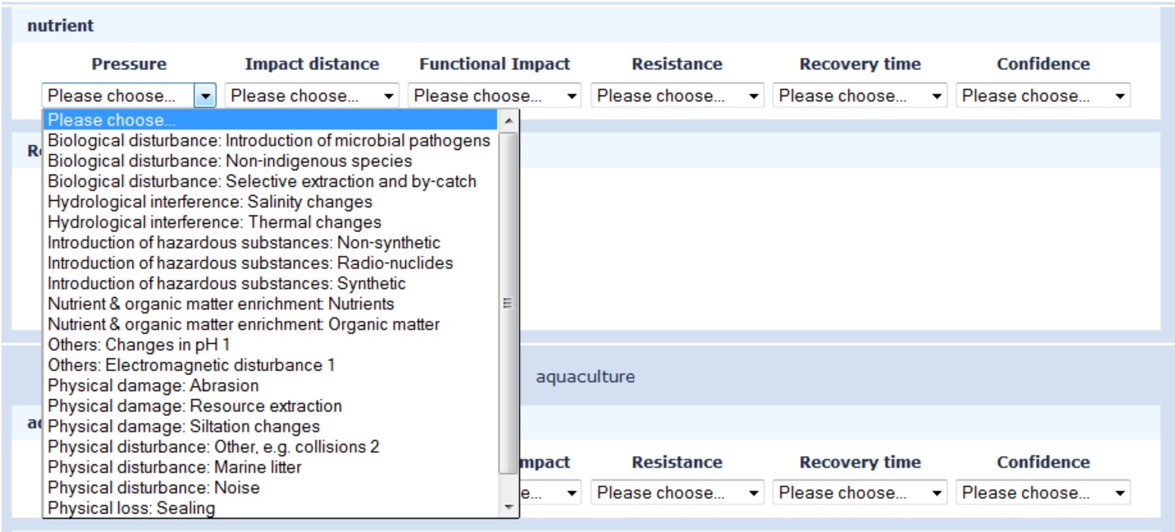



**Figure 7.** Example of the online expert survey done for the western Mediterranean impact index. The list of pressures that Expert can choose from. Taken from the Marine Strategy Framework Directive with some additional pressures.

**Table 1**. List of considered pressures/proxies for pressures and their source for the Western Mediterranean sea.

| <u>**Human activities**</u> | **Source of data (checked or foreseen)** |
|---|---|
| **Land and atmospheric inputs** | |
| • Water clarity changes (secchi depth change: important mostly for seagrass,) | ACRI |
| • Riverine inputs of nutrients (Ludwig) | UAB/ Published material |
| • Riverine inputs of heavy metals (if available) | ??? |
| • Riverine inputs of synthetic pollutants | UAB/ Published material |
| • Riverine inputs of organic matter | UAB/ Published material |
| • Atmospheric deposition of nutrients | Published material |
| • Atmospheric deposition of heavy metals | *European Monitoring and Evaluation Programme (EMEP)* |
| **Aquaculture** | |
| • Fish farms | Published material |
| • Shell fish farms | To be checked |
| **Fisheries** | |
| • Benthic disturbance from fishing (historical disturbance) | Published material |
| • Industrial demersal habitat destructive | Published material |
| • Industrial demersal non-destructive low bycatch | Published material |

| | |
|---|---|
| • Industrial demersal non-destructive high bycatch | Published material |
| • Industrial pelagic (high bycatch) | Published material |
| • Artisanal | Published material |
| **Population** | |
| • Coastal population | UAB/Plan bleu |
| • Urbanization | UAB |
| • Tourism | To be checked |
| **Industry, energy infrastructures** | |
| • Shipping | To be checked |
| • Underwater cables and pipelines (data availability to be confirmed) | To be checked |
| • Oil spills | To be checked |
| • Coastal waste water treatment plants | To be checked |
| • Desalination plants | To be checked |
| • Coastal engineering | To be checked |
| **Global change** | |
| • Acidification | Published material |
| • UV Radiation | Published material |
| • Changes in sea surface temperatura (SST) | Published material |
| **Other** | |
| • Invasive species | Published material |

**Table 2**. List of considered ecosystem components and their source for the Western Mediterranean sea.

| **Ecosystem components** | **Source of data (checked or foreseen)** |
|---|---|
| **Littoral & shallow water ecosystems** | |
| • Coastal wetlands | UNOTT material |
| • Sandy beaches and dunes | UNOTT material |
| • Rocky shores | UNOTT material/Euseamap |
| • Posidonia beds | Euseamap |
| • Cymodocea beds | Euseamap |
| **Specific seabed ecosystems** | |
| • Submarines canyons | RacSpa |
| • Sandbanks | RacSpa |
| • Seamounts | RacSpa |
| • *Deep sea corals (if available)* | To be checked |
| **Broad scale benthic habitats and their communities** | Eusemap |
| **Species** | |
| • Marine turtles (3 species) | To be checked |
| • Important marine mammal species | Published material + development |
| • Seabirds | RacSpa |

# 6. Coastal protection framework

The international policies to conserve biodiversity have adopted, as a complement to the protection of designated habitats and species, the arguments of protecting and maintaining ecosystem services. Coastal ecosystems may contribute between 36% (Costanza, 1999) and 77% (Martínez et al., 2007) of global ecosystem services value. However, given the complexity of coastal systems and the lack of precise economic valuations, both land and marine spatial planning usually neglect natural coastal protection and other important ecosystem services. This study provides a practical example to assess and map the ecosystem service coastal protection. It proposes a conceptual framework and specific metrics that can be replicated and compared across different areas or spatial-temporal scales. For more information, please go to Liquete et al. (2012).

This method is expected to contribute as a decision support tool for the ICZM implementation in the Mediterranean and Black seas. In particular, it links with and provides relevant information for four of the policy objectives:

- To preserve the wealth of natural capital in coastal zone;
- To formulate land-use strategies, plans, and programmes covering all coastal and marine uses;
- To have a balanced use of coastal zone, and avoid urban sprawl; and,
- To prevent damage to coastal environment, and appropriate restoration if damage already occurred.

## 6.1 Coastal protection model

Coastal protection as an ecosystem service is defined as the natural defence of the coastal zone against inundation and erosion from waves, storms or sea level rise. Thus, human-made structures (e.g. coastal works, ports) are extracted from the analysis and their eventual protection is not considered herein. The coastal zone considered in this model embraces the area potentially affected by extreme hydrodynamic conditions. This area is delimited in general by the 50 m depth isobath and the 50 m height contour line. Once the coastal zone was delimited, operational units of a length of approximately 30 km were delineated perpendicular to the coast and the main topographic and bathymetry trends.

The main variables affecting coastal protection in Europe were identified (see table 3). The number of variables to be included in the analysis and their resolution depend to some extent on the scale of the study (continental-scale) and on data availability. Many of the variables are indeed the output from a previous model. The relevance and weight of these variables were estimated thanks to expert opinion. Finally, all the results (the average value per operational unit for each variable) were normalised and were used to create three novel indicators for coastal protection (see below).

**Table 3.** List of variables and data sources considered in this study and their corresponding use for building indicators and for assessing the coastal protection ecosystem service.

| Variable | Data source | Reference | Use for indicators |
|---|---|---|---|
| Bathymetry | GEBCO global bathymetric data with a resolution of 30 arc-seconds | BODC (2009) | |
| Topography | Global digital elevation data based on the NASA Shuttle Radar Topographic Mission (SRTM) of 3 arc-second resolution | Farr et al. (2007), Jarvis et al. (2008) | Delimitation of the study area |
| | Digital topographic maps for Scandinavian countries at different resolutions | de Ferranti (2009) | |
| Slope | Same as Topography | Same as above | |
| Geomorphology | EU coastal geomorphology data and defence works at aprox. 1:100 000 resolution | Eurosion (2005) | |
| Submarine habitats | Modelled seabed habitat maps from the Baltic Sea, the Celtic Sea, the North Sea, and the Western Mediterranean from the EUSeaMap | JNCC (2010) | Capacity |
| | Modelled seabed habitat maps from the Brittany and Pays de la Loire French regions | MESH (2010) | |
| Emerged habitats | EU Corine Land Cover (CLC) dataset v.15 from the year 2000 with a resolution of 100 m | EEA (2011) | |
| Wave regime | Modelled data of maximum significant wave height estimated with the WAM 'WAve prediction Model' cycle 4.5 as implemented at the European Centre for Medium range Weather Forecasting. WAM is a continually updated spectral wave model specifically designed for global and shelf sea applications (for deep or shallow waters). It predicts directional spectra and wave characteristics of both wind sea and swell. The values used in this study represent the average of 10 years model run. | WAM model from WAMDI Group (1988) and Komen et al. (1994) | |
| Tidal range | Tidal amplitude from the principal constituent of tide, in this case the M2 or lunar semi-diurnal wave at 1/8 of a degree resolution extracted from the FES2004 global tidal atlas | Lyard et al. (2006) | Exposure |
| Relative sea level | Global grid of mean sea level trends measured from satellite altimetry between 1992 and 2010 with a resolution of 1/3 of a degree. The altimeter products are produced by Ssalto/Duacs and distributed by Aviso with support from Cnes (http://www.aviso.oceanobs.com/duacs/) | CNES (2010) | |
| Storm surge | Global storm surge height data extracted from the Dynamic Interactive Vulnerability Assessment (DIVA) database (http://www.diva-model.net/), which collects the output data from the Storm Surge Model Systems of Delft Hydraulics. The variable used in this study is the surge height for a 1:100 year return period | Vafeidis et al. (2008) | |
| Population density | EU population density disaggregated with CLC 2000 at 100 m resolution | Gallego (2010) | |
| Infrastructures | Main infrastructures in the coastal zone represented here by the road network | MapCruzin (2011) dataset | Demand |
| Artificial surface | Presence of artificial surface (land dedicated to urban and industrial areas) in the coastal zone extracted from CLC | EEA (2011) | |

| | | | |
|---|---|---|---|
| | 2000 | | |
| Main cultural sites | Main historical, religious and cultural sites broadly represented by the UNESCO World Heritage List | UNESCO-WHC (2011) | |

## 6.2 Indicators

This model proposes a set of indicators and their metrics to assess the regulating service coastal protection. These indicators were estimated at a European scale, but their structure is flexible to allow for replication at different scales or locations.

- Capacity ($CP_{cap}$): The natural potential that coastal ecosystems possess to protect the coast against inundation or erosion. This is based on geological and ecological characteristics.
- Natural exposure ($CP_{exp}$): The predicted need of coastal protection based on the climatic and oceanographic conditions of each area.
- Human demand ($CP_{dem}$): The estimated necessity of protection of the coastal populations based on the presence of residents and assets in the coastal zone.

These indicators are calculated as follows:
$CP_{cap} = 0.33 \bullet geo + 0.25 \bullet slo + 0.21 \bullet sea + 0.21 \bullet lan$
$CP_{exp} = 0.29 \bullet wav + 0.29 \bullet sur + 0.23 \bullet lev - 0.19 \bullet tid$
$CP_{dem} = 0.35 \bullet pop + 0.30 \bullet inf + 0.20 \bullet art + 0.15 \bullet cul$
Where *geo* refers to geomorphology, *slo* to slope, *sea* to seabed habitats, *lan* to land cover, *wav* to wave regime, *sur* to storm surge, *lev* to relative sea level change, *tid* to tidal amplitude, *pop* to population density, *inf* to infrastructures, *art* to artificial surface, and *cul* to cultural sites.

The indicators are dimensionless and have no meaning in absolute terms, they are applied to comparative studies along EU, although this methodology can be replicated at other scales to highlight optimal areas for conservation or restoration, most vulnerable zones, etc.

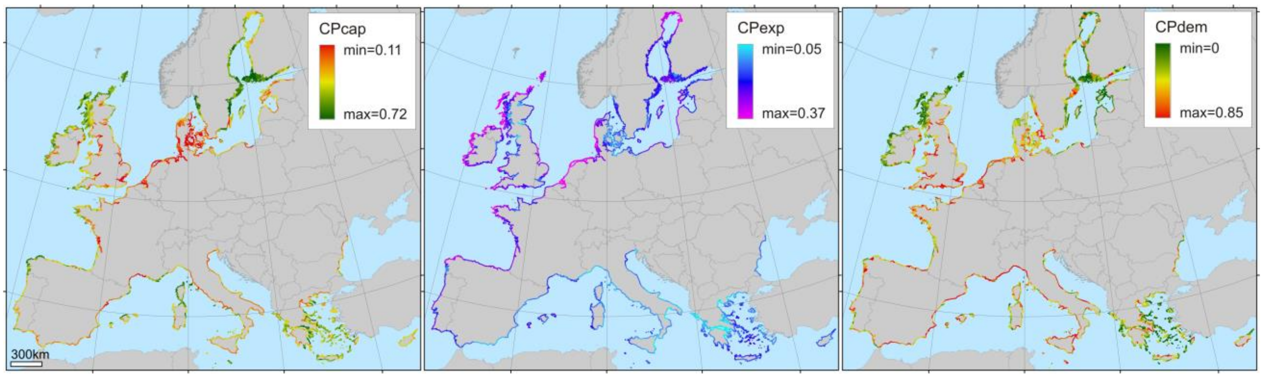



**Figure 8**. Estimation of the set of indicators proposed in this study along the European shoreline: coastal protection capacity ($CP_{cap}$); coastal exposure ($CP_{exp}$); and demand for coastal protection ($CP_{dem}$).

# 7. Eutrophication modelling framework

Following the Marine Strategy Framework Directive (MSFD) adopted by the European Council in May 2008, EU Member States must achieve or maintain Good Environmental Status (GES) of their marine and coastal waters by 2020 according to 11 descriptors. Eutrophication is one of these descriptors, reported in Annex 1 of the Directive as: “Human-induced eutrophication is minimised, especially adverse effects thereof, such as losses in biodiversity, ecosystem degradation, harmful algae blooms and oxygen deficiency in bottom waters.”

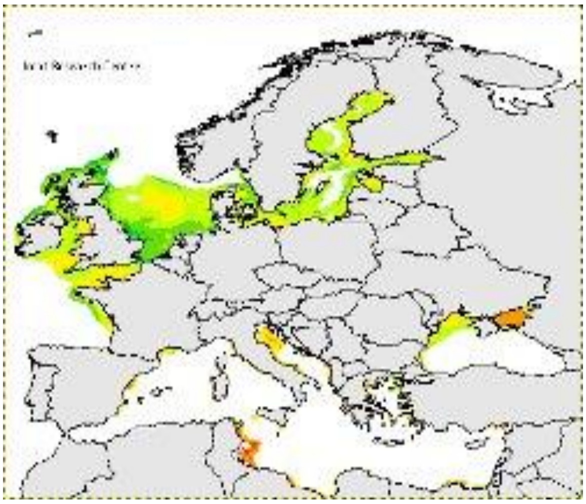
In this context, a panel of international experts provided guidance for the interpretation and application of the Eutrophication Quality Descriptor, defining eutrophication as: “A process driven by enrichment of water nutrients, especially nitrogen and/or phosphorus compounds, leading to: increased growth, primary production and biomass of algae; changes in the balance of organisms; and water quality degradation. The consequences of eutrophication are undesirable if they appreciably degrade ecosystem health and/or the sustainable provision of goods and services.”

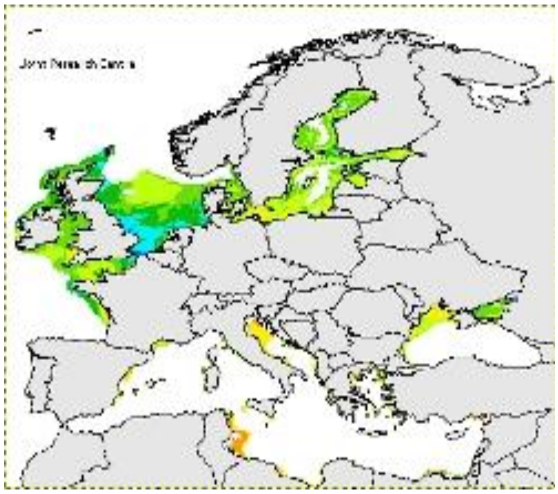
## 7.1 Eutrophication model

Marine eutrophication is considered to be a major issue in Europe (EEA, 2010) causing various environmental effects such as anomalous blooms, changes in the composition and abundance of organisms, and anoxia. To better assess this process, there is a need to identify an objective, cost-effective, and straightforward indicator system that can be applied serially and operationally to compare the status and trends of eutrophication over different coastal areas. The Water Research Unit at JRC developed a complementary pair of advanced eutrophication indices for the coastal and marine areas, for application at the European scale (Druon et al., 2004). The basic principles of the PSA and OXYRISK indices are to use known, deduced or easily observable and non-correlated parameters with an adequate temporal and spatial resolution.

## 7.2 Eutrophication indices

The ‘**Physically Sensitive Area Index'** (‘**PSA**') integrates the various supporting factors of eutrophication to locate areas that are sensitive to oxygen deficiencies assuming primary production and nutrients are evenly distributed. The aim of the PSA is to assess the effect of the physical environment on the production and assimilation of the organic matter from coastal and shelf ecosystems, assuming the nutrient distribution is homogenous. It provides a comparable measurement of the **physical resistance** to eutrophication, hence oxygen deficiency, on a simple scale from 0 [high resistance] to 1 [low resistance].





PSA (Climatology) July

PSA (Climatology) October


**Figure 9**: Monthly maps of the modelled Physical Sensitive Area (PSA) index for European seas (<100m water depth) from 10 years' climatology data (1998-2008). The index, ranging from 0 to 1, reflects the vulnerability of the coastal waters to eutrophication based on the dominant physical processes. An additional data layer on land illustrates the catchment basins. Figures generated by JRC using http://emis.jrc.ec.europa.eu/)

The '**OXYgen depletion RISK index**' ('**OXYRISK**') characterises the spatial distribution of potential hypoxia for a given month, by performing an oxygen budget between the physical supporting factors (source term) and the flux of organic matter (sink term), which are estimated primarily from satellite-derived 'Chlorophyll-a' or 'Primary Production' data. In the index calculation, phytoplankton is assumed to be the main source of production and export of organic matter to the seabed in coastal and shelf areas (<100m depth). **Satellite-derived optical radiometry data** are used to estimate phytoplankton biomass and primary production (PP), whereas **numerical modelling** provides data on the physical capacity of oxygen renewal near the seabed and the oxygen reserve below the mixed layer.

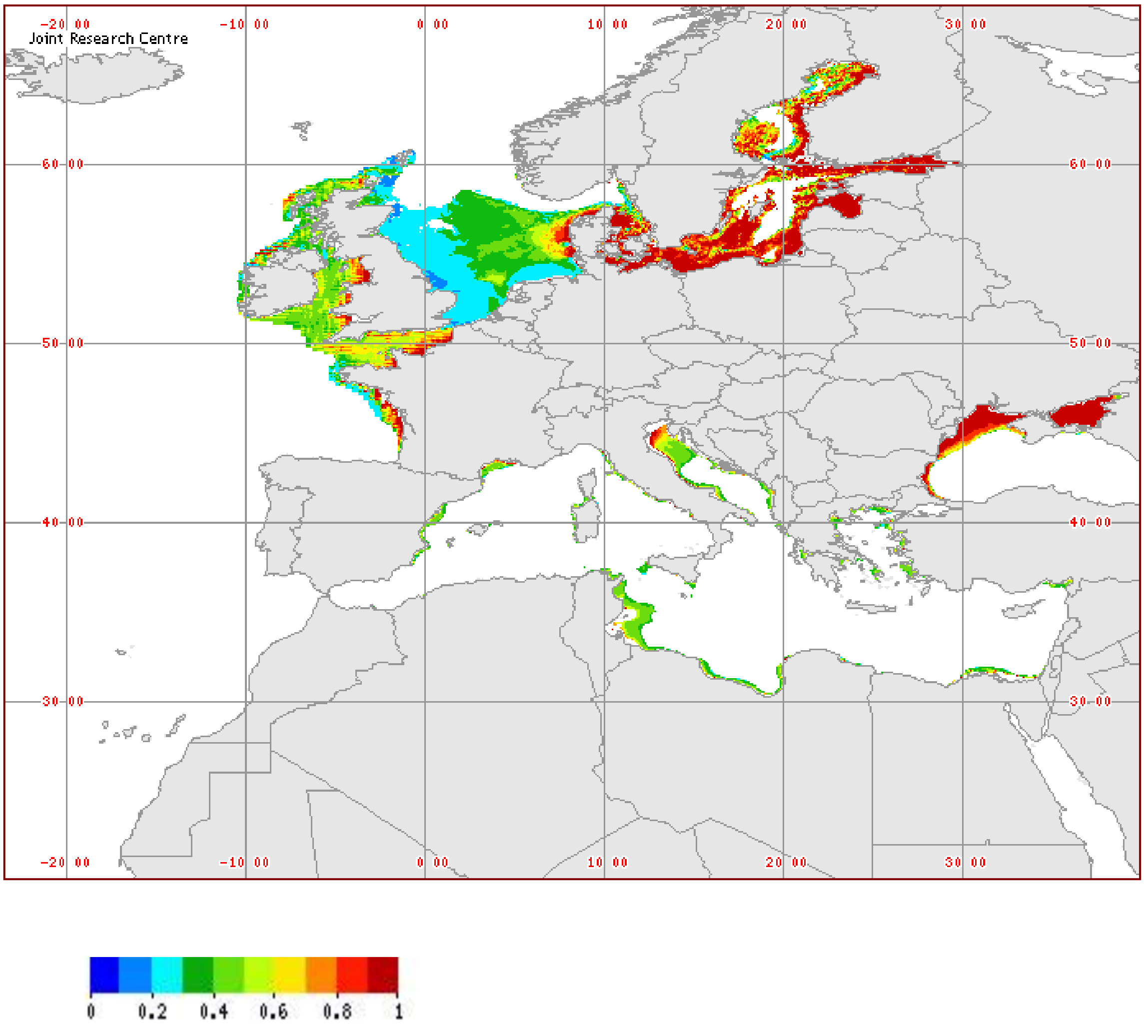



**Figure 10.** Oxygen depletion risk index for European seas (<100m water depth) from 10 years' climatology data (1998-2008). The index, ranging from 0 to 1, reflects the vulnerability of the coastal waters to eutrophication based oxygen deficiency. (Figures generated by JRC using http://emis.jrc.ec.europa.eu/)

# 8. Outlook

This report presented a compilation of frameworks and quantitative methods suitable for producing inputs to estimate ecosystem accounts for the Mediterranean and the Black sea basins covering both land and sea.

The six thematic areas: land use, species of conservation importance, primary production, cumulative impacts, coastal protection and eutrophication have been selected to support comprehensive analysis and assessments of major ecosystem properties over wide and diverse geographic extents. Therefore the outputs are expected to feed in a number of applications and tasks within the project, including the regional assessments and construction of future scenarios.

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# D4.2A

# Report on Application and Testing of Accounting Tools for IZCM

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## Table of Contents

## Executive Summary

The aim of this document is to develop a set of evaluation criteria to test the robustness of the land and ecosystem accounts developed within PEGASO, and to apply them to evaluate the accuracy and adequacy of the accounting outputs created within the Project. The work considered the PEGASO data in those regions within the study area for which independent sources are available. The analysis showed that the PEGASO data for Europe showed a good correspondence to CORINE and JRC data sources, especially at broader spatial scales. The data can also be used at the local CASE scale with caution. The work concludes that we can be confident in using the PEGASO accounts data across the whole of the Mediterranean and Black Sea Basins, for the purposes of comparison, given the lack of other data sources for these areas.

To be extended for the final version

# Part A. Introduction

Integrated Coastal Zone Management (ICZM) has been promoted as a set of principles to support decisions and policies aiming to resolve conflicts over multiple resource use demands which are often found competing in limited coastal zone spaces. The Mediterranean and Black Sea coasts exhibit a diverse range of ICZM practices that address a number of complex resource issues. In recent decades, the fast-growing demands for mass tourism, intensive agriculture, fisheries, transport and energy supply have brought wide-spread concerns of environmental degradation and generated conflicts over resource access and use. To help address these problems an Ecosystem Accounting methodology was developed in Europe (EEA, 2011) with the goal of assessing major environmental assets including land and water resources and their use and also primary ecosystem functions such as carbon sequestration, production of biomass and habitats for biodiversity. A short overview on the LEAC methodology as applied in PEGASO is given by Ivanov et al. (2013) or can be found on the PEGASO WIKI[1].

The European methodology was adapted in PEGASO for developing ecosystem accounts for land, coast and sea in the Mediterranean and the Black Sea Basins, to support the implementation of the ICZM policies established by UNEP and the EU. The work programme developed inputs that allowed the methodology to be used for performing spatial analysis at distinct scales: from broad regional assessments to decision-support for specific issues, in the context of cases such as the Nile Delta in Egypt and the Camargue Delta in France. The methodology has also been considered and applied in other areas within PEGASO to provide input for the application of other tools, indicators and scenarios; the experiences from all these activities are the subject of this review which aims to text the robustness of the accounting methods and data sources that are now becoming made available.

## A.1 Framework for assessing effectiveness of a decision support tool and information

The lack of adequate information and standardized methodologies for meeting the needs of decision-makers is often emphasized in different environmental fields, e.g. biodiversity conservation (e.g., Müssner, 2005; Certain et al., 2011); water quality management (Von Der Ohe, 2009), and land use planning. The gaps between science and policy applications, and also the mismatch between different scale and thematic fields have obstructed the development proven effective and widely-applicable tools for monitoring success of implemented projects. To address these gaps evidence based approaches have been promoted in environmental policies (Faludi and Waterhout, 2006). Sutherland et al. (2004), for example, proposed the *Evidence-based conservation approach*, promoting learning from the success and mistakes of management measures applied throughout the UK's protected areas. This approach draws on the lessons from the Medicine's revolution in improving public health, some 30 years ago.

The need for developing a standardized approach to evaluation of environmental projects, and specifically ICZM in the UK was addressed by Gallagher (2010) who proposed and tested a 'coastal sustainability standard' (CoSS), drawing on experiences of environmental management systems approaches, such as the EU's Eco-Management and Audit Scheme (EMAS). It comprises six principles for ICZM implementation monitoring: planning; participation; communication; integration; responsibility and balance; and each with a set of criteria and performance indicators. The latter are

[1] http://www.pegasoproject.eu/wiki/Application_of_LEAC_in_PEGASO

expressed and assessed at a 10 point scale, with a threshold above seven defining 'success', which can be used to assess and compare the performance of different projects. There are other similar examples, such as that of Kapos et al. (2008), who introduced a new tool for assessing success of biodiversity conservation projects by considering somewhat similar issues and principles, including threats, species management, site management, livelihoods, policy and legislation, education and awareness; capacity building and research.

These examples are useful as they provide practical guidance on assessing the effectiveness of informing decision-making actions through research and information supply. There are also more common practices where data and information is provided and updated regularly, for estimating official environmental statistics. National or official statistics production can be viewed as the formal, comprehensive and regular information supply reflecting on the most 'key' processes concerning a nation's socio-economic and resource-use processes, structured as statistical indicators or items. Officially issued statistics implies high degree of quality and reliability of the presented information, as compared to other (informal, alternative) sources of information. In part due to the fact that national statistics have become a subject of an international standard development for long time; including many methods and stages of improvement, adjustments etc. The quality of official statistics is ensured by conforming to a number of criteria (covered by the international standard) such as relevance (to different users), accuracy, comparability, transparency, coherence etc. Complying with these standards has ensured a high degree of consistency across thematic, temporal and spatial domains, or in other words the statistics are comparable between countries and between different points in time.

## A.2 Data quality and data requirements

Minimum data requirements for producing ecosystem accounts are shown in comparison with the needs identified for FAO statistics.

| | **FASTAT example (FAO, 2005)** | **PEGASO LEAC** |
|---|---|---|
| Spatial coverage | Global coverage | Mediterranean and Black Sea coastal areas (at least 50 km from coastline) |
| Data production | Regular, committed sustainable data collection activities by the countries | Committed partners (contributions to SDI) |
| Temporal coverage | Time-series data | At least two points in time (years 2000 and 2011 |
| Quality assessment | Data quality assessment performed | Data quality assessment performed |
| Metadata for users | Statistical metadata available | Statistical metadata available |
| Data release | Data is edited and validated | Data is edited and validated |

More extensive quality guidelines for the statistics that underpin accounts can be found at national scales. For example, the UK Office for National Statistics issued detailed guidelines on measuring and reporting the quality of official statistics (ONS, 2007). The guidelines were designed to address comprehensively all issues that need to be communicated to the users, to help them to understand and define how reliable the statistics are for their purposes. The quality measures aim to support the users by clarifying the context of data generation; the methods used and their limitations; better understanding of the values and figures derived from the data and other sources which relate or proof the statistical outputs. It is stated that first of all national statistics are built in a way to ensure that they meet customer needs and that they are free from any political influence. The guidelines are structured as a 'best practice framework' for quality control throughout the processes of producing official statistics. The quality of statistics is regarded as a measure of how well statistical outputs meet user needs, and whether they are 'fit for purpose'. The quality measurements are concerned with providing the user with full range of information, called indicators, to judge whether or not the data are of sufficient quality for their intended use.

A similar approach is followed within Europe. The guidelines promoted by the European Statistical System, for example, address *the Six Quality Dimensions* (http://epp.eurostat.ec.europa.eu): 1. Relevance; 2. Accuracy and precision; 3. Timelines and punctuality; 4. Accessibility and clarity; 5. Comparability; 6. Coherence. The first three have a more decisive influence on the ecosystem accounts applicability as they address data quality explicitly. If the outputs are not relevant, accurate or timely then further usefulness assessment maybe irrelevant (for example clarity for metadata in criterion 4). The applicability assessment and results review that is presented here follow these criteria, and are organized according to scale (from local cases to PEGASO regional) and tool's component (concept, method, results). Thus for the purposes of the present analysis the criteria have been interpreted as follows:

1. Relevance: involves consideration of the coverage and content of the information. The ecosystem accounting approach is intended as a policy-support tool providing a link between bio-physical and socio-economic information for the reporting units across which strategic decisions are discussed, for example decisions addressing spatial development versus nature conservation needs. Therefore, the accounting tool must allow the extraction of spatial statistics for policy or management relevant units, such as municipalities or NATURA2000 sites. The system should allow ecosystem stocks and flows (such as biomass, productivity; species and habitats numbers and conservation status) to be viewed in comparison with local GDP, population, industrial sector outputs and other quantitative indicators.

   The relevance of on-going accounting applications can be assessed in terms of its adequacy to meet the interest and intents of stakeholders. For ICZM in particular – the ability to respond to the needs of coastal area management practices.

2. Accuracy: concerns 'The closeness between an estimated result and the (unknown) true value'; and precision, the repeatability of the estimates being able to deliver same result under unchanged conditions. Ecosystem accounts are based on spatially explicit inputs, such as medium resolution remote-sensing products (land cover, vegetation indices etc.) which are able to reflect on spatial and temporal variability of the accounted items. The wide-area mapping and estimates needs to be assessed in terms of spatial and quantitative accuracy of the produced accounts.
3. Timelines and punctuality, concerns the time-lapse between the publication of data and referred period. The accounts can be updated using near-real-time remote sensing data in conjunction with other inputs. Supply of timely information is critical for supporting informed decision-making processes. The precision aspects are related to this criterion and needs to be defined in accordance with the phenomena being addressed. For example land cover changes need an update once every 3 to 5 years. Other processes, such as desertification and species extinction may take longer time for detecting significant trends of change. The timeliness needs to be assess in terms of how easily updatable the outputs could be for concrete accounting items; how frequent the update of accounts need to be done and finally how recent the accounts need to be in order to apply for effective decision-making.

4. Accessibility and clarity, concerns the clarity of metadata, and the ease of understanding of the data by users. Structuring accounts in simple and real-world, well-known expressions (rather than new and very specific terms), facilitates the communication to wider circle of users and stake-holders. The methods of estimating the accounts are kept simple, transparent and easily reproducible. The accounting inputs for land and species/habitats accounts are available on the SDI and all methodological and metadata details are explained in the internal deliverables (D4.2.3 and D4.2.4). The metadata are structured and reported in accordance with PEGASO SDI guidelines.
5. Comparability, is 'the degree to which data can be compared over time and domain', spatial domains include sub-national, national and international. Comparability between the results across spatial and temporal scales is a main criterion to assess whether the tool can be deemed operational or not.
6. Coherence, is 'the degree to which data derived from different sources or methods produce similar output. For ecosystem accounts which address issues at broad geographical scales, such as land cover, biodiversity and habitats distribution, the accounting outputs need to agree with other broad area mapping methods and assessments. The agreement needs to be assessed in terms of conceptual, methodological aspects as well as results. The results originating from different work would be regarded as coherent if they showed consistent spatial and temporal patterns. The frequent application of certain methodological elements such as selected dominant land types or broad ecosystem types would be indicative of coherence and ultimately such applications should evolve as a standard method which guarantees robust applicability.

At this stage the developed accounts for regional and CASEs application were evaluated in terms of spatial and quantitate accuracy.

# B. Evaluation of the accuracy of the accounts

The aim of this work was to assess the spatial and quantitative accuracy of the accounts on natural and urban areas, using independent and high resolution reference data sources. The accuracy was judged on the bases of linear correlation coefficients ($R^2$) estimated between the reference data and the evaluated data (either CORINE or PEGASO version).  For this purpose all the three datasets had to be processed to express the quantities of area estimates (in hectares) in comparable way. This was done by converting the discrete classes into continuous quantitative measure expressing number of hectares of either natural or urban land per one km grid cell. Consequently, the numbers of hectares were 'sampled' for around 500000 centroid points. Each centroid represented each of the 1 km cells, and could be linked with different spatial reporting units. The geographical units considered were countries, buffers around the coast and dominant land types. The correlations were analysed by comparing the average values for these spatial units.

The evaluation was made at two levels: (a) the 'regional', covering the entire 50 km coastal zone for the EU countries in which the three sources overlap completely in terms of areal coverage (Fig. 1). It includes all the EU and associated countries; and, (b) the CASEs scale, for which the equivalent sources could be applied at local levels (Fig. 2). The CASEs considered were Bouches-du-Rhone, North Adriatic, Cyclades, Danube delta and Nile delta.

The reference data used for the two themes, natural and urban land originates from different sources and needed separate processing procedures aiming to derive comparable results.

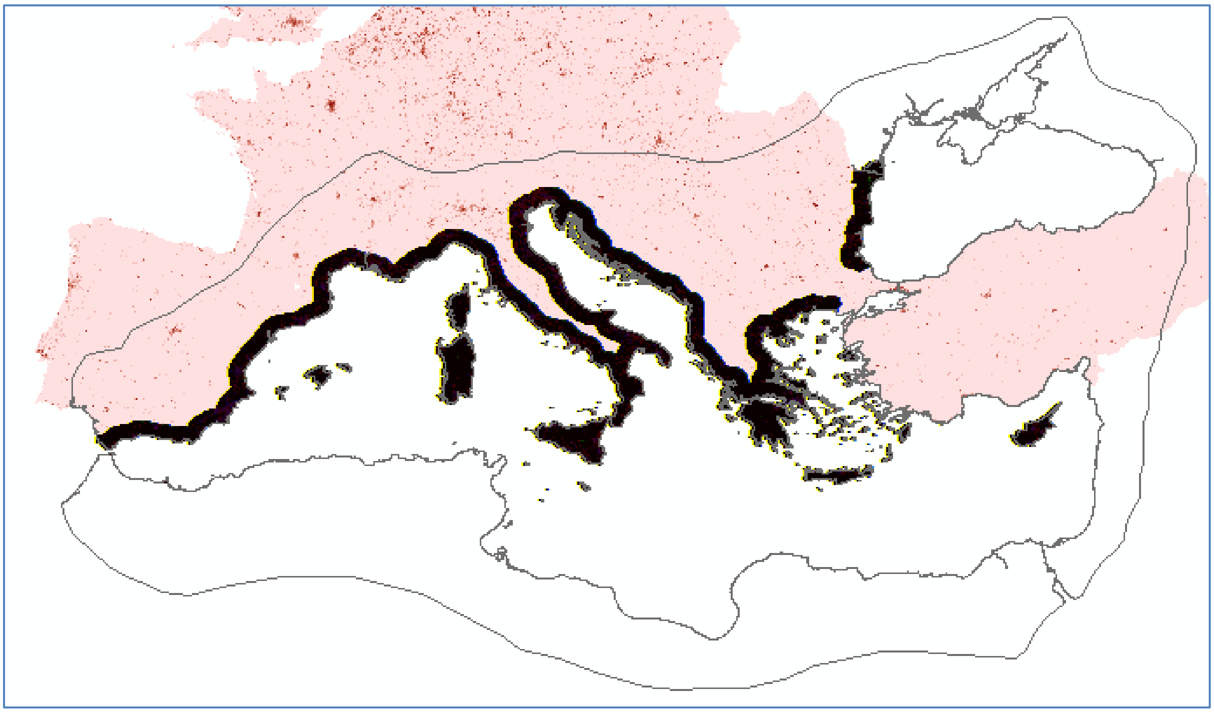

Fig. 1: Evaluation data extends at regional level. The black dots are the 1 km centroids of the grid-cells used to 'sample' the three data inputs for evaluation

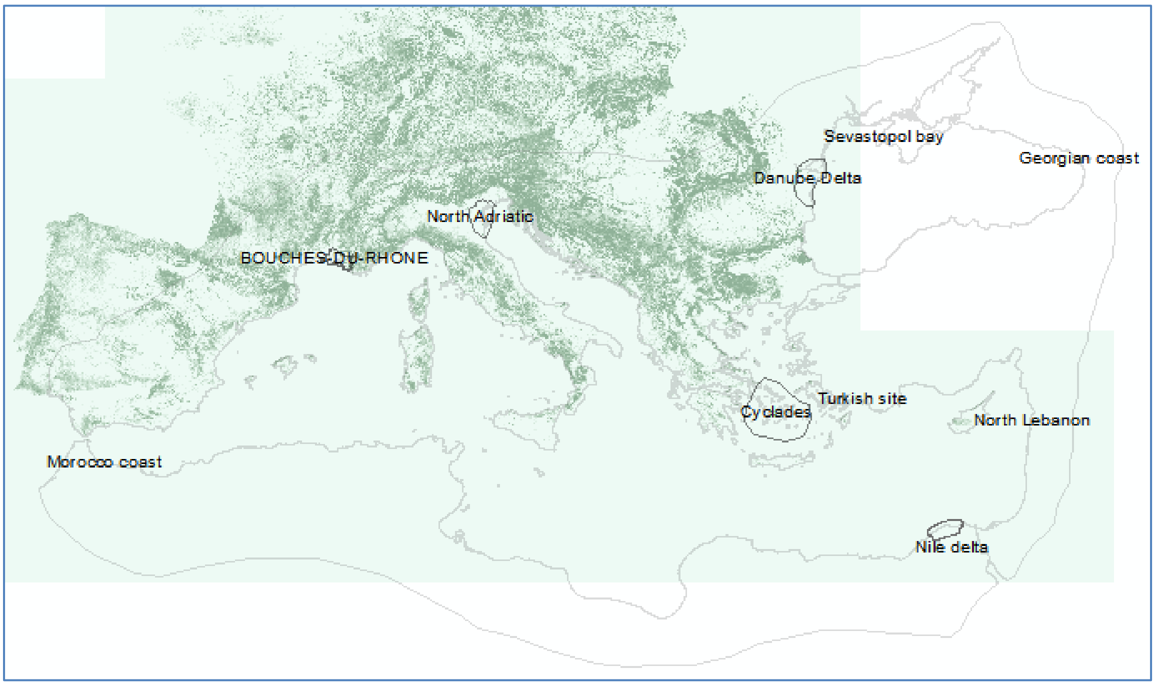


Fig 2: Evaluation data extents at CASEs level

## B.1 Evaluation of the accounts on natural areas

For natural areas, the accounts from PEGASO and CORINE land cover were compared with the JRC product of forest cover in year 2000[2]. The JRC map was produced at 25m spatial resolution using LANDSAT imagery. For the evaluation purposes, the input from PEGASO and CORINE had to be processed and harmonised to match the semantic definitions of the JRC product. In this regard, the natural areas of forests and shrublands were grouped to express the total coverage of woody vegetation from PEGASO and CORINE Land cover, which was then compared to the JRC Forest areas map. The three products were compared after being converted to area coverage registering number of hectares woody vegetation per 1 km grid cell. At regional level, the average number of hectares of woody vegetation of the coasts per country is shown below.

| | mean JRC forest | mean PLC forest | mean CLC forest |
|---|---|---|---|
| Albania | 18.44 | 52.00 | 46.54 |
| Bosnia and Herzegovina | 24.70 | 70.18 | 63.35 |
| Bulgaria | 32.75 | 35.89 | 34.12 |
| Croatia | 42.64 | 71.66 | 59.62 |
| Cyprus | 11.05 | 44.12 | 37.11 |
| France | 33.83 | 54.85 | 50.25 |
| Greece | 14.46 | 52.74 | 43.83 |
| Italy | 23.52 | 35.38 | 30.07 |
| Malta | 0.49 | 0.37 | 12.17 |
| Montenegro | 40.50 | 76.96 | 62.24 |
| Romania | 4.11 | 6.91 | 9.09 |
| Slovenia | 79.65 | 85.92 | 72.12 |
| Spain | 20.47 | 53.51 | 40.43 |

Table 1: Forested areas from JRC, PEGASO and CORINE land cover per country

[2] http://forest.jrc.ec.europa.eu/download/data/forest-data-download/

The average per country were analysed considering the JRC as the 'most precise' estimate. In comparison to it, PEGASO LC averages are generally higher than the other two sources which imply an over-estimation of woody vegetation in the latter. The correlation coefficient for CLC is slightly higher, as shown on the Fig. 3.

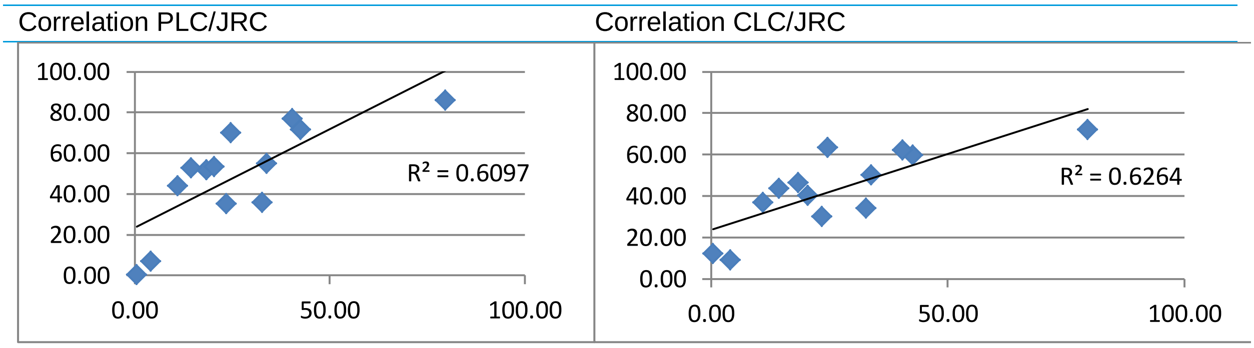


Fig. 3 Scatterplots and linear correlation coefficients for woody vegetation from PEGASO land cover (left) and CORINE land cover (right) for average country areas

Similar coefficients are estimated when considering the much higher spatial variation when comparing the averages per coastal accounting units (defined by intersecting the three buffers around the coast and the administrative divisions).

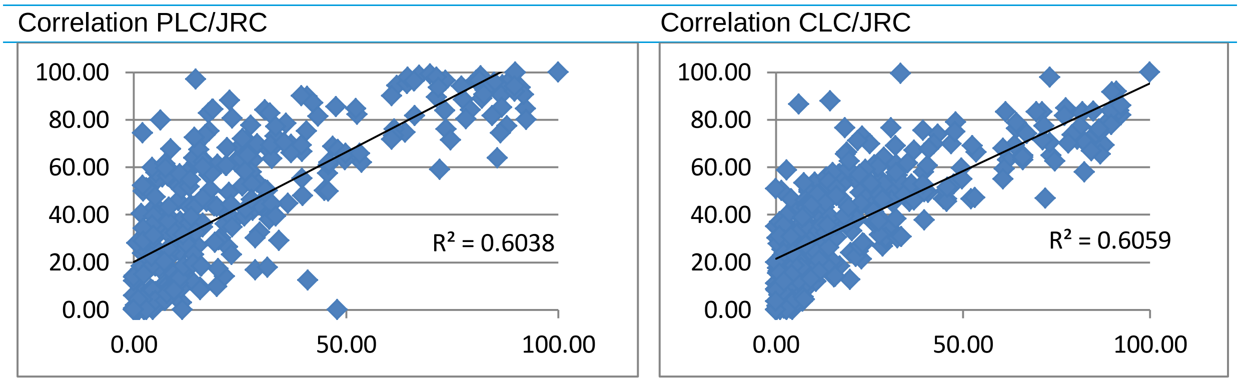


Fig 4. Scatterplots and linear correlation coefficients for woody vegetation from PEGASO land cover (left) and CORINE land cover (right) for average areas per ecosystem accounting unit

At the CASEs level, the same reference data for applied for the four EU cases, and another product was applied for the Nile delta case. It is the land cover map developed by NARSS at very high spatial resolution, specifically for the purposes of PEGASO. The average areas per case and buffer from coast are shown in Table 2.

| cases | buffers | mean JRC forest | mean PLC forest | mean CLC forest |
|---|---|---|---|---|
| Bouches-du-Rhone | 10000 | 13.14 | 20.40 | 22.18 |
| | 50000 | 28.44 | 42.05 | 41.59 |
| Cyclades | 1000 | 0.91 | 27.68 | 24.72 |
| | 10000 | 3.69 | 57.05 | 37.51 |
| Danube Delta | 1000 | 0.93 | 3.75 | 13.05 |
| | 10000 | 1.70 | 3.52 | 6.09 |
| | 50000 | 6.38 | 10.12 | 11.79 |
| North Adriatic | 1000 | 4.09 | 3.01 | 3.60 |
| | 10000 | 2.67 | 1.81 | 1.86 |
| | 50000 | 1.64 | 3.06 | 1.37 |
| Nile delta | all | 3.35[3] | 4.45 | |

Table 2: Forested areas and difference between CORINE, PEGASO and JRC forest map for the 5 CASEs

The correlations for woody/natural vegetation for these five cases are rather low for the two sources (R2=0.22 for PEGASEO land cover and R2=0.39 for CORINE land cover). The two sources show quite similar averages for most units. Therefore, it can be confirmed that more accurate data sources are needed to analyse natural areas at case level. Higher correlations were registered, however when analysing the spatial variation as averaged per case and dominant land type, as shown on Fig. 5.

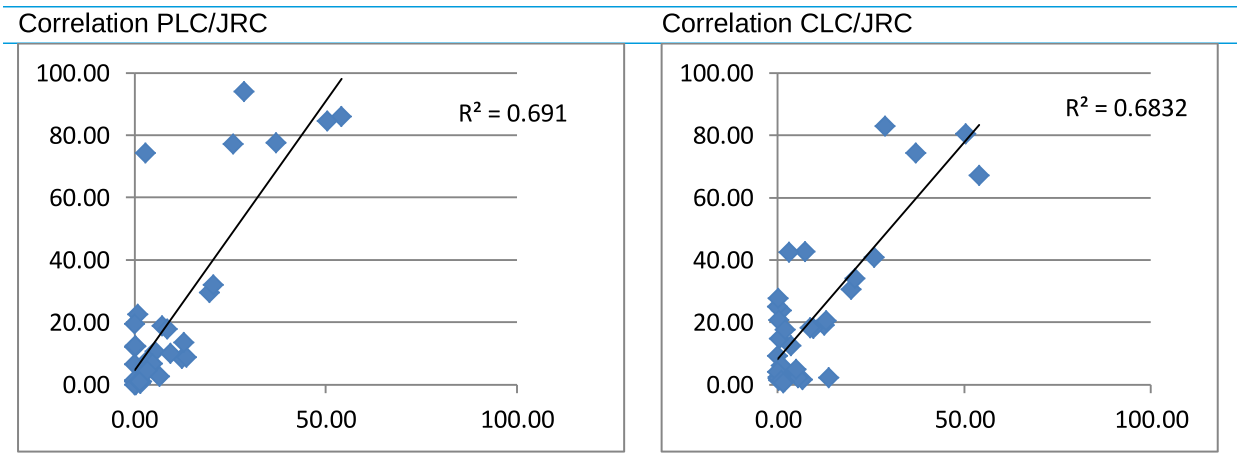


Fig 5. Scatterplots and linear correlation coefficients for woody/natural vegetation from PEGASO land cover (left) and CORINE land cover (right) per DLT and CASEs

[3] The source of reference for the Nile Delta case is NARSS land cover classification

A possible reason, for obtaining higher correlation when considering DLT, rather than coastal buffers could be that much of the land within the first coastal buffer, of 1 km may be affected by differences in the coast definition and detection by the three sources. In the case of PEGASO land cover, it was observed that most mountainous coasts facing west are obscured by 'shadowing' effects.

## B.2 Evaluation of accounts on urban areas

Urban areas from PEGASO and CORINE Land cover were compared to high resolution map of per cent sealed soil (downloaded from EEA[4] website), representing artificialized surfaced in year 2006. Artificial cover was consequently considered equivalent to urban land cover and the corresponding classes from CORINE and PEGASO land cover, grouped at level 1. The artificial cover was mapped at 20m spatial resolution using SPOT imagery. For the purpose of comparing the three sources, the area coverage was sampled in the same way as for woody vegetation, and in addition a temporal adjustment had to be done for the PEGASO land cover product. The adjustment was done by estimating the difference between 2000 and 2011, deriving the annual rate of change, and applying 6-year increment to the value in year 2000. The mean areas of urban coverage per country and buffer zones is shown in Table 3.

| country | buffer | mean EEA sealed soil | mean PLC urban | mean CLC urban |
|---|---|---|---|---|
| Albania | 1000 | 3.03 | 4.64 | 8.27 |
| Albania | 10000 | 1.64 | 1.94 | 6.67 |
| Albania | 50000 | 0.76 | 1.67 | 3.31 |
| Bosnia and Herzegovina | 1000 | 6.64 | 3.82 | 7.64 |
| Bosnia and Herzegovina | 10000 | 0.69 | 0.55 | 0.79 |
| Bosnia and Herzegovina | 50000 | 1.19 | 1.55 | 1.38 |
| Bulgaria | 1000 | 11.72 | 13.86 | 21.64 |
| Bulgaria | 10000 | 3.09 | 3.86 | 6.69 |
| Bulgaria | 50000 | 1.12 | 1.68 | 4.24 |
| Croatia | 1000 | 4.98 | 4.73 | 8.03 |
| Croatia | 10000 | 2.30 | 1.82 | 2.90 |
| Croatia | 50000 | 0.93 | 0.44 | 1.09 |
| Cyprus | 1000 | 6.58 | 13.35 | 16.37 |
| Cyprus | 10000 | 3.65 | 6.27 | 8.62 |
| Cyprus | 50000 | 3.05 | 5.06 | 6.76 |
| France | 1000 | 11.13 | 17.96 | 22.44 |
| France | 10000 | 5.73 | 10.91 | 10.39 |
| France | 50000 | 2.08 | 3.88 | 4.34 |
| Greece | 1000 | 2.79 | 6.81 | |
| Greece | 10000 | 1.68 | 4.62 | |
| Greece | 50000 | 1.01 | 1.28 | |
| Italy | 1000 | 11.21 | 20.20 | 20.13 |
| Italy | 10000 | 4.12 | 9.22 | 6.28 |
| Italy | 50000 | 1.91 | 3.78 | 3.44 |
| Malta | 1000 | 10.27 | 56.04 | 18.94 |

[4] http://www.eea.europa.eu/data-and-maps/explore-interactive-maps/european-soil-sealing-v2

| | | | | |
|---|---|---|---|---|
| Malta | 10000 | 14.74 | 85.63 | 30.54 |
| Montenegro | 1000 | 7.66 | 5.12 | 15.25 |
| Montenegro | 10000 | 1.29 | 0.43 | 1.35 |
| Montenegro | 50000 | 1.17 | 1.75 | 1.60 |
| Romania | 1000 | 4.90 | 3.41 | 10.12 |
| Romania | 10000 | 1.85 | 3.07 | 4.22 |
| Romania | 50000 | 1.26 | 1.15 | 4.70 |
| Slovenia | 1000 | 20.66 | 31.75 | 23.69 |
| Slovenia | 10000 | 4.47 | 8.89 | 3.66 |
| Slovenia | 50000 | 1.29 | 1.41 | 1.39 |
| Spain | 1000 | 14.67 | 22.38 | 25.63 |
| Spain | 10000 | 6.63 | 11.58 | 8.95 |
| Spain | 50000 | 2.04 | 4.75 | 3.08 |

Table 3: Urban areas from CORINE, PEGASO and EEA soil sealing map per country and buffer zones.

The mean values from the three sources show lowest values from the highest precision source, the EEA's sealed soil; higher averages from the PEGASO land cover and generally highest from CORINE land cover, which implies that CORINE estimates are mostly exaggerated.  The correlation coefficients however shows that CORINE's estimates ($R^2$ = 0.87) with the reference source are higher than PEGASO estimates ($R^2$=0.53).

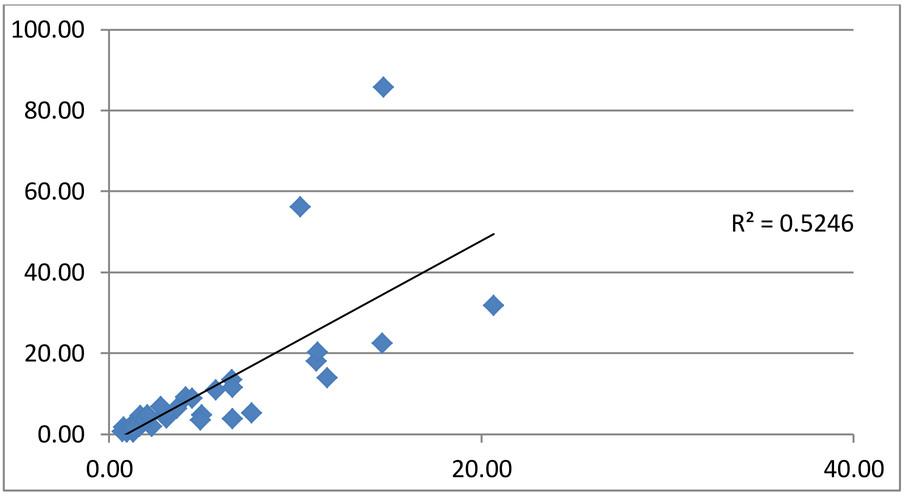


Fig  6. Scatterplot of mean urban area coverage per country and buffer zone from PEGASO land cover

On the scatterplot (Fig. 6), several distinct outliers can be observed, which show exceptionally high of urban land in PEGASO land cover, e.g. for Malta. If these outliers are cleared the correlation coefficients will be $R^2$ = 0.89 for PEGASO land cover and $R^2$ = 0.86 for CORINE land cover. At the level of coastal accounting units, CORINE preserves very high correlation while PEGASO land cover diminishes.

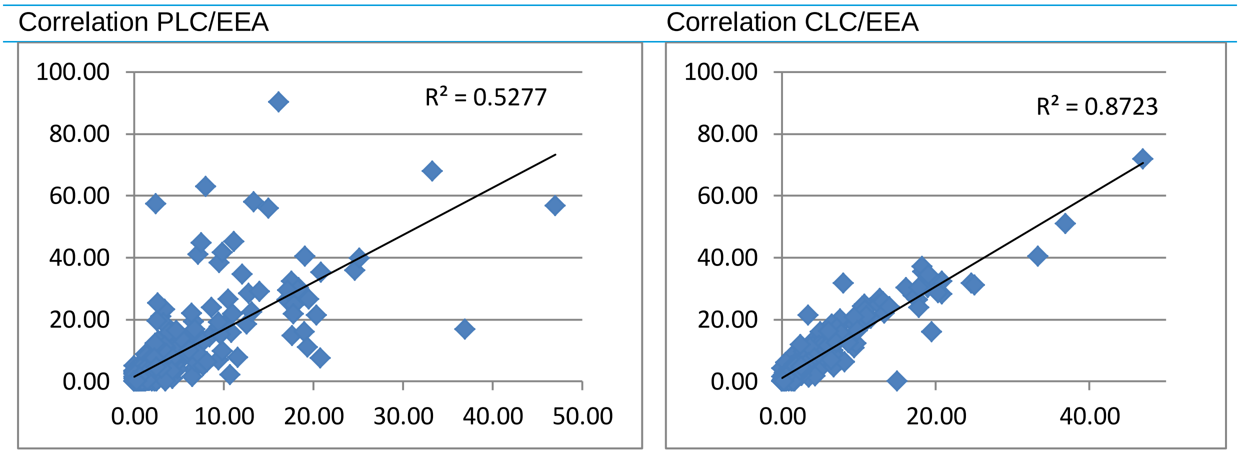


Figure 7. Scatterplots and linear correlation coefficients for urban/artificialized land from PEGASO land cover (left) and CORINE land cover (right) for average areas per ecosystem accounting unit

At CASEs level, average coverage of urban area is shown for the coastal stripes of the cases in table 4.

| Case | buffer | mean EEA sealed soil | mean PLC urban | mean CLC urban |
|---|---|---|---|---|
| Bouches-du-Rhone | 1000 | 15.77 | 26.45 | 24.80 |
| Bouches-du-Rhone | 10000 | 8.62 | 21.29 | 15.00 |
| Bouches-du-Rhone | 50000 | 4.55 | 15.05 | 8.98 |
| Cyclades | 1000 | 1.32 | 5.23 | |
| Cyclades | 10000 | 0.58 | 3.66 | |
| Danube Delta | 1000 | 4.27 | 2.60 | 9.07 |
| Danube Delta | 10000 | 1.84 | 3.08 | 4.17 |
| Danube Delta | 50000 | 1.36 | 1.34 | 4.77 |
| North Adriatic | 1000 | 6.04 | 15.54 | 13.46 |
| North Adriatic | 10000 | 3.53 | 11.42 | 8.10 |
| North Adriatic | 50000 | 4.19 | 11.03 | 9.06 |
| Nile delta | all | 3.80[5] | 2.00 | |

Table 4. Mean coverage of urban/artificialized areas from CORINE, PEGASO and EEA soil sealing map per case and buffer zones.

At CASEs level the average coverage of urban land exaggerated by the two sources, as shown on regional level, however for the French and Italian cases, the exaggeration is higher for PEGASO land cover. The correlation coefficients (Figu. 8) are very high for CORINE land cover, but also high for the PEGASO product.

[5] The source of reference for the Nile Delta case is NARSS land cover classification

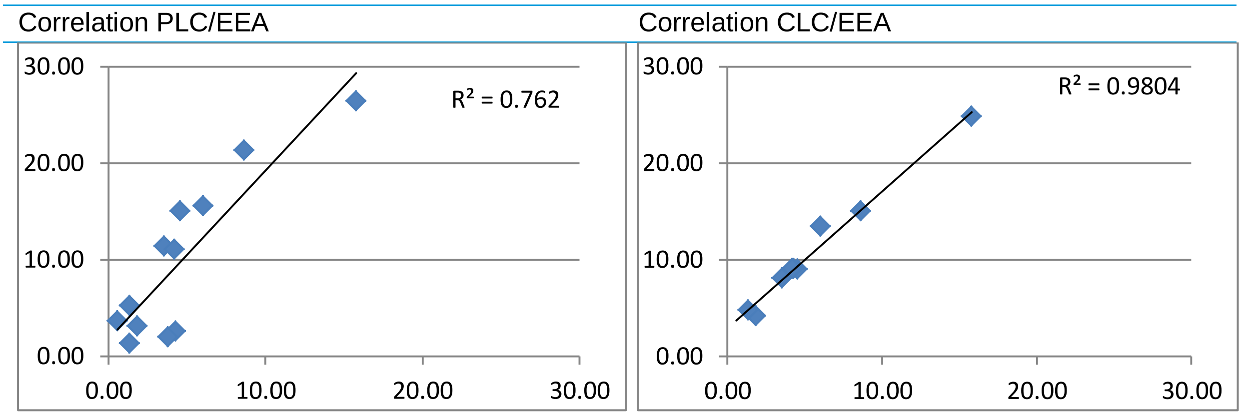

Fig 8. Scatterplot and correlation coefficients for cases with three coastal buffers

The correlation coefficient for PEGASO land cover increases to $R^2$= 0.83 when estimated for averages per DLT, possibly due to the same effects commented above, for woody and natural vegetation.

# C Conclusions

According to the evaluation results, both sources of accounting inputs CORINE land cover and PEGASO land cover compare well with independent and high precision reference data on forested and artificialized land in Europe. PEGASO land cover is more appropriate for assessments at wide regional level across the entire Mediterranean and Black Sea basins, while CORINE land cover performs better at higher spatial detail level. Both sources, show deficiencies of accuracy when assessed at local, CASEs level, although to a lesser extent for urban/artificialized areas.

According to the evaluation methodology, more criteria need to be satisfied before assessing the accounting outputs as effective for decision support purposes. Namely, the criteria of accessibility/user-friendliness, coherence and comparability, but the latter can be clearly evaluated once the accounting outputs get actually applied in decision-making processes.

The criteria of accuracy and precision for the purposes of regional and CASEs level analysis are of highest importance at this stage, because if the data was proven inaccurate, then no application could be recommended.

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| WP4. Multi-scale tools, methods and models for integrated assessment<br>Task 4.2. LEAC | Tool Fact Sheet |
|---|---|

# Tool: Land and Ecosystem Accounts (LEAC)

The University of Nottingham

**Authors**: Emil Ivanov, Roy Haines-Young and Marion Potschin University of Nottingham (UNOTT)

Land and Ecosystem Accounts (LEAC) have been recognized as an important tool for decision makers. Such accounting covers a broad range of environmental issues. In PEGASO the application of Land and Ecosystem Accounts to coastal issues is developed in the context of the goals of Integrated Coastal Zone Management (ICZM).

## What are ecosystem accounts?

Land and Ecosystem Accounts can support different aspects of spatially explicit environmental assessments and monitoring. In particular it can provide spatial indicators for regional assessments on the status and change (gain or loss) of natural capital due to human actions.

These Accounts are based on the following type of measurements:

- Stocks (or resource) levels expressed as a mass (e.g. biomass) or volume (e.g. water per area of forest, arable land etc.);
- Flows (expressing temporal changes that can be interpreted as benefits or losses), measured in terms of a rate of some kind (for example the change in agricultural to developed land, annual consumption of water, or the harvest of crop, or number of tourists visits/yr); and,
- Balances are calculated to account for the relations between stock and flows and their changes for a given period of time, e.g. annual or five-year period etc.

## What role do Accounts play in PEGASO?

The LEAC methodology (EEA, 2006) provides multi-scale (hierarchical) outputs, designed to facilitate the assessment of processes that take place at different spatial scales e.g. continental, country, region and local levels. By applying LEAC to the different scales, the following outputs can be generated:

- Assessment of the quantity and quality of the existing ecosystem capital (such as arable land, biodiversity, wood biomass);
- Assessment of the quality and quantity of the derived annual flows of related ecosystem services or functions (such as crops harvest, carbon sequestration etc.) according to the volume of the opening stocks and according to the conditions of use (pollution and degradation, or restoration and enhancement of ecosystem capital); and,
- Assessment of the ‘balances’ of remaining natural capital in a given year and also the potentials or trends in longer term.

Understanding the trends in terms of what is required to maintain or improve major ecological functions, or the impacts of the simplification of ecological systems, or the degradation of the ecosystems, and hence the future potential of natural capital is the main objective of the accounting exercise.

The accounts can be used to assess of the general integrity or ‘health’ of ecosystems and issues like the quality of the landscape, and also to identify hotspots, trends and patterns of changes of major concern. Such outputs are therefore designed to support more informed decision-making.

In PEGASO the accounts provide inputs to the work on scenarios, indicators, and also inputs for the cases and the regional assessments. All of the accounting elements are expressed in physical terms.

## How can we test/apply them?

LEAC uses bio-physical assessments for the calculation and mapping of major ecosystem properties, with the aim of diagnosing ecosystem integrity or health. The following methods are applied for this purpose:

- Continuous interactive mapping and estimation of accounts, validation and improvements on at least two levels – regional and case-study level;
- Designing a diagnostic accounting framework to support specific subjects or themes;
- Bringing multiple sources of evidence on complex socio-ecological problems and performing multi-criteria assessments to derive consistent conclusions; and,
- Assessing the effectiveness of this new information for supporting decisions and solving practical problems.

## What do we need to do to implement accounts?

For implementing the accounts the following steps are required:

- Identify main issues at regional scale and the cases where LEAC can be applied for improved understanding of the issues;
- Agree on working concepts for coastal and marine zones;
- Collect, process (harmonize) LEAC input data in cooperation with the PEGASO SDI;
- Prepare first version of the relevant LEAC tools and accounts;
- Present to partners first results and collect feedback;
- Improve the LEAC tools and the accounts.

Key References

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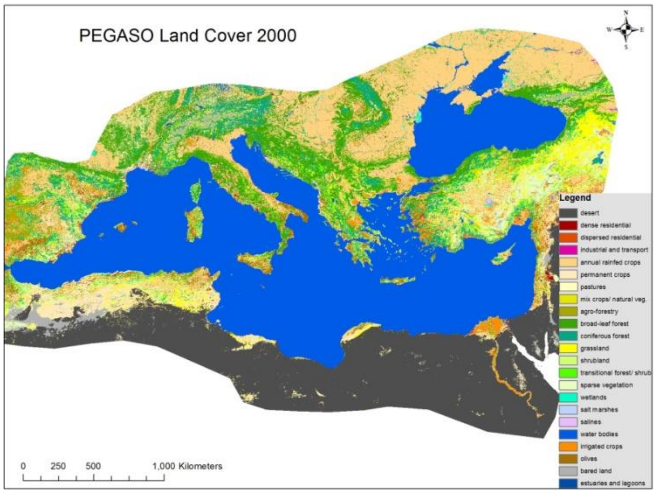
For more information on LEAC as part of PEGASO see CEM working papers no 10 and no 11

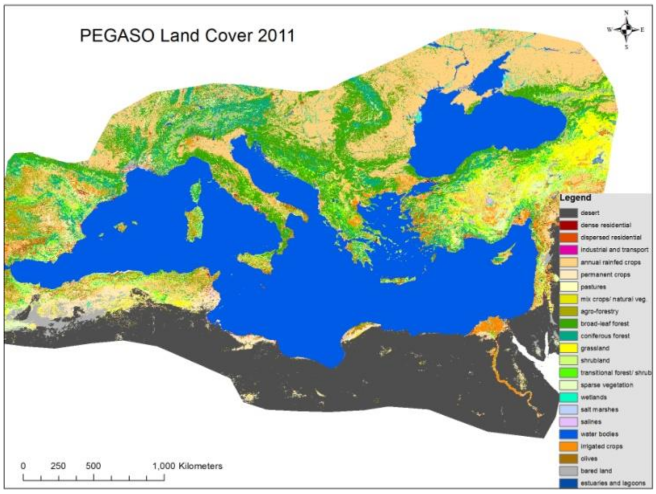
visit: http://www.nottingham.ac.uk/cem/WorkingPapers.html

## Example of accounting inputs and outputs

**Land cover inputs**

An extension of CORINE Land cover over the Mediterranean and Black Sea basins was developed using a set of data-sources: the European CORINE land cover for training a supervised maximum likelihood classification of MODIS multispectral and other geographic data.



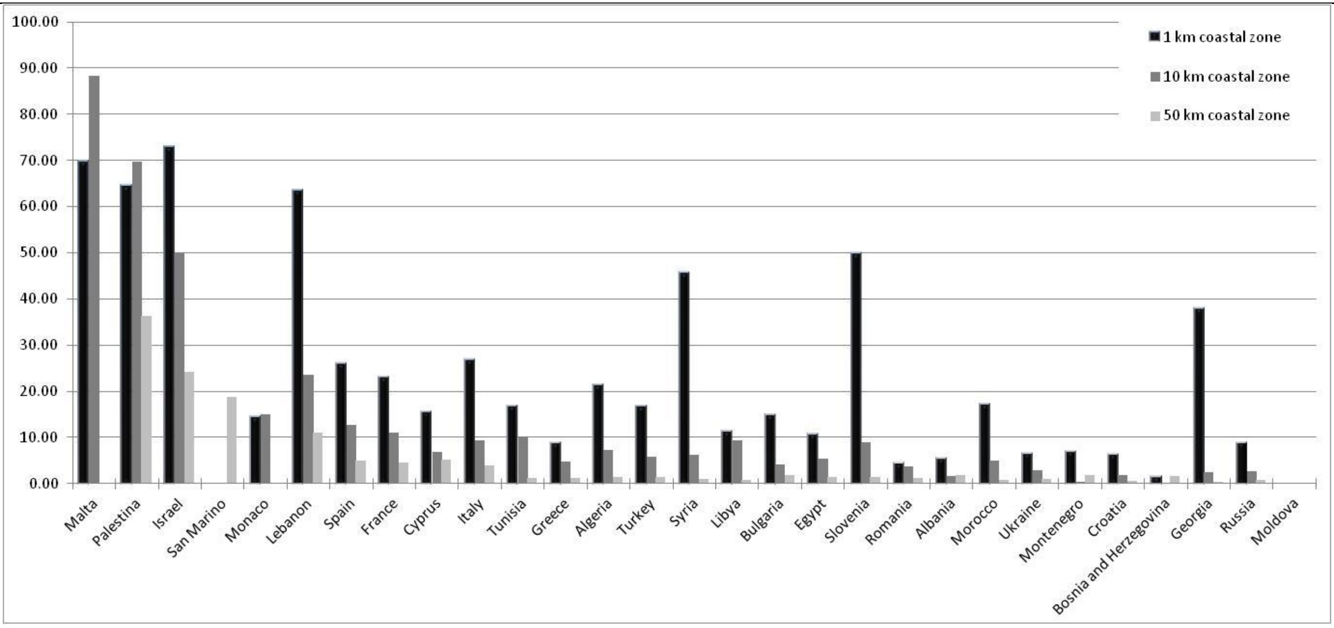

Extension of CORINE land cover in the Mediterranean and Black Sea Basins (Ivanov E., 2013)

**Land accounts outputs**

The outputs are extracted by deriving the number of hectares of each land class per unit area of interest. An example of urban land 'stocks' (Ivanov E., 2013) within three coastal buffers in the Mediterranean and Black sea countries is shown below:

| Opening 'stock' of Urban area (ha) in year 2000 and closing 'stock' in year 2011 | | | | | | |
|---|---|---|---|---|---|---|
| Buffer (km) from coast | 1 km | | 10 km | | 50 km | |
| Year | 2000 | 2011 | 2000 | 2011 | 2000 | 2011 |
| Mediterranean basin | 433894 | 446519 | 1678125 | 1735475 | 1695056 | 1805063 |
| Black Sea basin | 30969 | 32988 | 86681 | 92694 | 89025 | 92419 |

At such an aggregated level the 'stocks' reveal similar trends of expanding urban areas in both basins and in the three buffers around the coastline. Spatial disaggregation by country highlights where most of the changes occurred. The next figure shows percentages of urban and artificial area in 2011 for units defined by the countries and the three buffers' boundaries:




The percentages of urban and artificial land cover in 2011 (Ivanov E., 2013) show there is generally a high concentration of urban areas within the first km of the coast throughout the study region.