Pilot project in the Adriatic on testing the candidate common indicator 'Land use change' in the Mediterranean

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Content

1. Introduction

Coastal areas are very dynamic domains as a result of its particular position at the interface between the land and the see. Coast areas receive pressures and impacts accumulated through the river basin and, at the same time, exert a certain pressure on the marine side. All these interactions are interconnected with the human activity which has been shaping the coastal landscape for centuries in the Mediterranean. Therefore the monitoring and assessment of land use changes has been largely used to identify hot spots and critical areas where to prioritise actions to ensure the preservation of the biodiversity (EEA, 2015).

In fact the Mediterranean EcAp has already proposed a coastal indicator on “Land use change” within the Ecological Objective 8 (EO8) “Coastal ecosystems and landscapes”, in line with the ICZM Protocol requirements, particularly the ecosystem approach and balanced allocation of uses, with the aim to avoid urban sprawl (Article 5 and 6) and limitation of linear extension of urban development including transport infrastructure along the coast (Article 8).

One particularity of this EO8 of the Mediterranean EcAp (compared to the EU MSFD, or other regional ecosystem approach initiatives such as HELCOM or OSPAR) is the focus on the coast, which implies a strong terrestrial component. While the EU MSFD is fully oriented towards marine environment, this EO is based on the requirements originating from the geographic coverage of the revised Barcelona Convention and the ICZM Protocol, as well as the LBS Protocol. In all these documents, the spatial coverage extends to the terrestrial part of the coastal zone.

International standards methodologies and guidelines exist for the assessment and monitoring of some indicators relevant for Ecological Objectives of GES, such as in EO9 Contaminants or EO5 Eutrophication (subject to adaptation according to local and regional specifics) (European Commission, 2011a). This is not the case of those indicators related to EO8 Coastal Ecosystems; indeed, there is a general lack of technical guidelines and agreed methodologies adequate for the purpose of the ecosystem approach. Accordingly, there is a need to establish the baselines that constitute the EcAp coastal indicators.

Because the coastal ecosystem is such an important element of the regional Mediterranean space, the introduction of this EO is fully justified. However, the “coastal land use change” indicator was not found mature enough to be included in the list submitted for decision at CoP18 (Istanbul, December 2013).

Most of the guidance documents distributed by the UNEPMAP to support the EcAp process are based on previous works produced in the framework of the MSFD, as well as by the experience gained throw other regional Conventions. The genuine character of this coastal EO exclusive from the UNEPMAP explains the general lack of support material available. Moreover, the spatial framework of EO8’ indicators is quite different from those proposed by the rest of EOs which are fully oriented towards marine environment. Therefore, the coastal approach introduced by the EcAp represents a distinctive character and a challenging task for the Mediterranean regional ecosystem status assessment.

The objective of this report is to develop the conceptual basis and define the methodology for the EcAp coastal indicator “Land use change”. The proposed methodology is further tested on the Adriatic region to evaluate its feasibility and usefulness. The test takes into account its further extension to the complete Mediterranean area.

It should be noted that the indicator is not intended to provide the basis for land planning. The purpose is to identify where the higher pressures in terms of land use are, and in particular land take, since this is one of the major threats to biodiversity (EEA, 2015).

The report is organised in three main sections:

- Chapter 2 provides the background and the conceptual basis for the indicator.
- Chapter 3 provides the results of the indicator test on the Adriatic region.
- Annexes provide the details on the methodologies.

EO8 is divided in three indicators (Table 1:1). The indicator *8.1 Change of land use* is the main focus of this report, since this is the candidate indicator. However, indicators *8.2 Change of landscape types* and *8.3 Share of non-fragmented coastal habitats* are also introduced as complementary information that may provide further insight on the candidate indicator.

Table 1:1. Organisation of the relevant information related to the indicators in the report. The candidate indicator is *8.1 Change of land use*. Description and examples are also provided for complementary indicators to illustrate additional analysis that provide a further insight on coastal landscapes.

	Indicator	Concept	Methodology	Results of pilot test
EO8 Coastal landscapes	**8.1 Change of land use**	Page 6	Page 11 Annex III	23
	Complementary indicators			
	8.2. Change of landscape types	Page 18	Page 18 Annex III	35
	8.3 Share of non-fragmented coastal habitats	Page 21	Page 21 Annex III	n.a.

2. EO8 indicators: concept and approach

2.1. Overview

Mediterranean coastal areas are particularity threatened by coastal development that modifies the coastline through the construction of buildings and infrastructures (Cori, 1999; EEA, 2006; Serra et al, 2008; EEA, 2011). However, there has not been systematic monitoring, in particular not quantitatively based monitoring or any major attempt to systematize characteristics of coastal ecosystems at the scale of Mediterranean basis. The status assessment of EO8 aims at filling this gap.

The operational objectives and indicators adopted by the Contracting Parties for EO8 are presented in the Table 2:1., extracted from the Decision 20/4 of the 17th Contracting Parties Meeting in Paris in 2012.

The complexity of coastal ecosystems makes very difficult their assessment at all levels and in all areas. The two operational objectives of this EO (8.1. and 8.2.) refer to several important components of coastal ecosystems (see Table 2:1). The first operational objective (*8.1 The natural dynamic of coastlines is respected and coastal areas are in good condition*) referring to the "natural dynamics", essentially reduces itself to the issue of **coastal erosion**. The second operational objective (*8.2 Integrity and diversity of coastal ecosystems, landscapes and their geomorphology are preserved*) refers to the integrity of coastal ecosystems, which is, essentially, expressed through the issue **of coastal landscapes**(UNEP/MAP, 2013).

Table 2:1. Operational Objectives and Indicators defined by the UNEP/MAP-EcAp for Ecological Objective 8 (Coastal ecosystems and dynamics). The position of the candidate indicator*8.1 change of land use* has been highlighted. Complementary indicators are in italics.

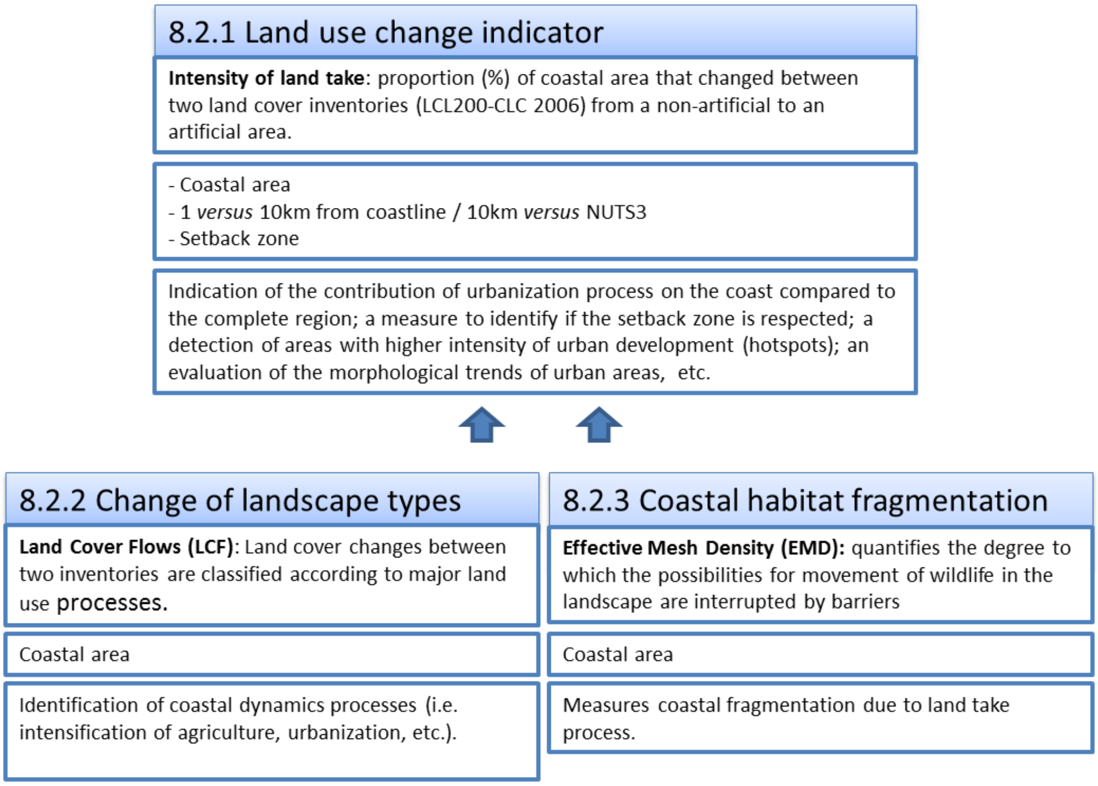
Ecological Objective (EO)	Operational Objectives (OO)	Indicators
Coastal ecosystems	8.1 Coastline natural dynamic	8.1.1 Areal extent of coastline erosion and coastline instability
		8.1.2 Change in sediment dynamics along the coastline
		8.1.3 Areal extent of sandy areas subject to physical disturbance
		8.1.4 Length of coastline subject to physical disturbance due to the influence of manmade structures
	8.2 Coastal landscapes	**8.2.1 Change of land-use**
		8.2.2 Change of landscape types
		8.2.3 Share of non-fragmented coastal habitats

Coastal erosion is a phenomenon that concerns coastal regions due to its negative effects on coastal development and economic costs to mitigate related impacts. This can explains why coastal regions engage more efforts to address (i.e. monitor, analyse, etc.) and to reduce negative impacts of coastal erosion dynamics (or OO 8.1) than to address efforts to monitor and preserve coastal landscapes (or OO 8.2). In fact, while at short term coastal erosion cause negative economic impacts, coastal development (e.g. driven by tourism) at short term generates economic benefits (often at the expense of preserving the integrity and health of coastal ecosystems).

Historically, the coastal zone has been a major focus for the development of human society and it continues to be an area of rich potential for the future where several competitive uses are pressing the state of this dynamic and transitional system.

Change of land uses embraces many concepts that can be derived from this indicator such as land take, the percentage of built up areas, the trends in the evolution of urban areas and detection of urban sprawl areas, continuation of linear development of urban areas along the coast, as well as fragmentation of coastal habitats or change of landscape types, and so on. Moreover, the sets of data needed for the land use change can be used also for two other indicators, the latter two mentioned above in particular. Therefore it is proposed the structure as depicted in Figure 2:1

Figure 2:1. Structure of the candidate indicator and links with the complementary ones.



2.2. Interlinkages between land use and biodiversity

Coastal landscapes are expressions of anthropogenic (cultural) and natural processes in the coastal zone, as well as home to considerable biodiversity wealth. Well preserved coastal landscape is an indicator of good environmental status, but also a basis for sustainable socio-economic development (UNEP/MAP, 2013).

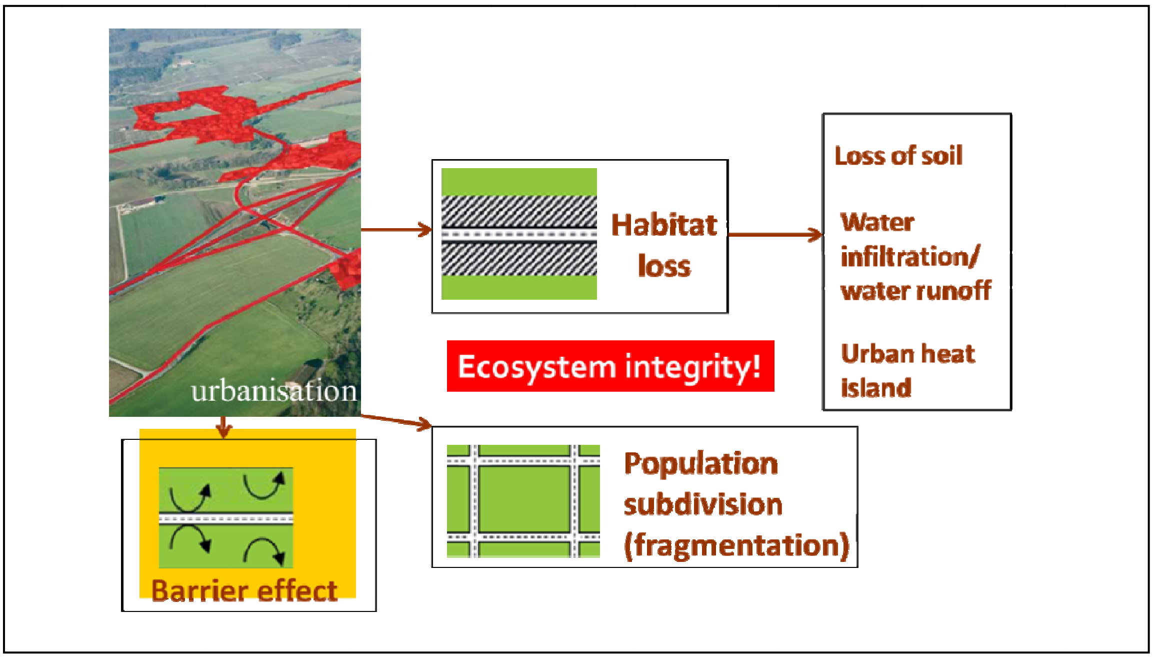
Especially relevant for critical areas like the coastal ones, where several competitive uses are pressing, is to identify and to understand processes of land use changes, how land cover has been changed by humans and the processes that result in landscape transformation.

Changes on land use have impact on land cover, the biophysical state of the land surface. Several studies have further investigated the close relationship between coastal land use changes and specific impacts on coastal ecosystems:

- Shoreline Dynamics. Lo and Gunasiri (2014) have demonstrated a strong correlation between the degree of construction and shoreline area changes.
- Biodiversity loss. Falcucci et al. (2007) relate land-use/land-cover change to habitat loss as causing biodiversity loss.
- Land degradation. Several authors study how different land use/cover changes, and under which regional conditions, lead to land degradation and desertification(Drake and Vafeidis 2004; Wainwright, 2004, Bajocco et al., 2012; Thornes JB, 2005).
- Fragmentation. There is an extensive literature on the impact on biodiversity caused by transport networks and urban development (EEA, 2011).

All these impacts are summarised in Figure 2:2.

Figure 2:2. Overview of major impacts of land take. The picture on the left shows the different types of built-up structures (in red) observed in a certain landscape.



All these references demonstrate that the impact of land use on the coastal zone is significantly high and justify the close relationship between land use change and the state of coastal integrity. However, all these evidences do not provide enough information, or sometimes require a lot of detailed data, to operationalise in a meaningful indicator. Therefore we need to know more about the mechanisms that relate land use changes to the corresponding impact.

Dale et al (2000) in an extensive review provide some guiding principles to understand the key elements of the land use that explain the corresponding ecological impact:

- Time
- Species
- Place
- Disturbance
- Landscape

From this list, and assuming that we will analyse land use changes using information derived from remote sensing (see 2.3.2, page 12), we know time (time lapse between two observations) and place. Species can only be inferred with additional information coming from biodiversity monitoring for example. However, considering the coverage of the indicator and the guiding principle on the easiness, we don't consider to look for additional information.

The remaining items from the previous list are: disturbance and landscape. Both could be derived from the same source data used to derive land use changes. In fact we can relate land use changes to the type of disturbance (Gibbs et al., 2005). For example urbanisation (or land take) results in a net loss of habitats and ecosystem functions, while afforestation may have a positive impact on reducing erosion, increasing C sequestration and increase of connectivity. Finally, landscape, could be simplified by taking the current land use before the change (land use at time 0). This component could be further refined as presented on section 2.4.2 (page 18), where the complementary indicators are described.

Köhler et al. (2006) corroborate this approach as a result of an extensive analysis of long time series of land use changes and biodiversity. They describe the following elements as key to determine the ecological impact:

- Magnitude of the changes
- Type of changes. Not all changes have the same impact. They provide some guidance on the level of severity
    - Most extreme severity is caused by net loss (e.g. urbanisation or erosion)
    - Intensification. Mainly related to agriculture and high input of energy in form of fertilisers or machinery.
    - Extensification. As opposite to the previous case.
- Where those changes are happening. The context is relevant since the impact is modulated by the landscape. Logging 1 ha of forest in a large forest area does not have the same impact than logging 1 ha of a rural mosaic composed by agricultural land and small patches of forest.

From the information provided by remote sensing, the magnitude of change can be related to the amount of land use/land cover change. Type of change is in line with what has been described above related to disturbance. Finally, the context is similar to the concept of landscape just discussed above.

All in all this provides a basis to produce a systematic qualitative assessment on potential impacts of the identified land use changes. However, this approach does not provide a clear indication of the status at certain point in time. Given the cumulative effect of land use over time, it is very difficult to assess the ecosystem condition at certain point, purely from remote sensing. It still can provide some hint on the patch diversity, habitat fragmentation or spatial patterns. On the other side, the objective is not to come back to a pristine environment, so the consideration of the status at certain point could alternatively be looked as distance to certain objective at mid-long term (for example restoration of certain % of degraded areas, or establishing a certain threshold for land take) according to regional, national or local plans.

As stated in the UNEP-EcAp guidelines (UNEP/MAP, 2012a), targets should establish desired conditions, be measurable with associated indicators allowing for monitoring and assessment and be operational relating to concrete implementation of measures to support their achievement and move towards Good Environmental Status (GES[1]).

1**GES** refers to the desired status of the marine and coastal environment and its components. It involves protecting the marine and coastal environment, preventing its deterioration and restoring it where practical, while using marine and coastal resources sustainably. Considering that the Mediterranean coastal ecosystems are providing services in support to diverse human activities, GES should not refer to a pristine state, as that would be an

In other words, targets represent defined objectives to be achieved within a defined period of time with the aim to improve the Environmental Status.

Table 2:2provides the proposed GES description and targets. These objectives and targets are developed for each indicator. It should be noted that the proposed targets are only examples since the local component is highly relevant and it is not fully captured with the indicator. Therefore, the targets should be finally established by each Member State.

Table 2:2. Proposed GES description and targets for Operational Objective 8.2

Indicator	Proposed GES description	Proposed targets[2]
8.2.1. Change of land use	Perpendicular coastal development, with linear development minimised Mixed land-use structure achieved [in coastal spatial units, to be established]	No further construction within 100 m width setback zone; established in majority of countries Change of coastal land use structure, dominance of urban land use reversed Adaptive carrying capacity established and implemented
Complementary indicators		
8.2. 2. Change of landscape types	Coastal landscape becomes strategic element of local identity Different landscape types form a harmonious and balanced whole	Expand network of protected coastal landscapes Limited extent of mono- type coastal landscapes Mixed landscape structure maintained
8.2.3. Share of non-fragmented coastal habitats	Coastal habitats are not fragmented to a level that prevents them from providing ecological functions and environmental services	Share of non-fragmented coastal habitats higher than [60%] within a coastal landscape unit

These criteria could be contextualised by more general principles as examples:

- Limit urban development where is causing major impact on ecosystems. This can be identified either by the **intensity** of the urban development (hot spots) and/or development on **more sensitive areas**:
    - Identification of **hot spots**, which could be characterised by some of these elements:
        - Areas of high rate of urban development
        - Persistence over time
    - More sensitive areas
        - Setback zone (already defined on ICZM and many national legislations)

idealistic objective almost impossible to reach. Instead, it should relate to a state that accommodates the use of the marine and coastal environment with a high level of resilience of the ecosystems to the impacts of human activities and of predicted Global Changes

[2]**GES Target** is a "qualitative or quantitative statement on the desired condition of the different components of, and pressures and impacts on, marine water (and coastal ecosystem)..." (MSFD). It also relates to an objective indicator corresponding to the required conditions for maintaining or reaching the desired Good Environmental Status

        - Natural areas, which extend beyond the protected areas. There is a need to consider the complete picture of protected and non-protected areas in order to ensure habitats connectivity. Furthermore the exclusion of natural areas (or limitation of development)
- Regarding the urban development itself, which is needed for housing and economic activities, some objectives could be highlighted regarding the **form** and where is it happening:
    - Prioritise the recycling and reusing of abandoned urban land.
    - Promote more compact urban development, while keeping the quality of place on those areas. . This may be easier in cities than on second homes or residential areas where the value is the single detached home.
    - Do not compromise further ecological improvement of marginal areas.
    - Promote mixed land uses on rural areas in order to maintain characteristic landscape diversity on those regions.

2.3. Definition of the candidate indicator change of land use

2.3.1. Definitions

The OE8 refers to coastal landscapes. "Landscape" is generally defined as mosaic of "interacting ecosystems". The term has many components including visual, political, socio-economic and cultural. Moreover, the term coastal landscape implies a relationship between land and sea. Some units in these landscapes such as beaches or rocky islands are defined by both sea and land while others such as mud flats and salt marshes exist somewhere between land and sea. In this proposal we take the approach of considering the landscape as the mosaic of land uses and their patterns.

In addition, there are several concepts used on the indicator and along the document which are defined on Table 4. As it can be seen land use and land cover are different concepts, although very often they are used as if they interchangeable concepts.

Table 2:3.Definition of concepts related to the indicators.

Concept	Definition
Land cover	The ecological state and physical appearance of land surface (e.g., closed forests, open forests, grasslands).
Land use	The purpose to which land is profited by humans (e.g., protected areas, forestry for timber products, plantations, row-crop agriculture, pastures, or human settlements)
Land take	Urbanisation on previous undeveloped land. Land take represents a proportion (%) of a specific area that changed between two land cover inventories from a non-artificial to an artificial area

Ecosystem management	The process of land use decision-making and land management practice that takes into account the best available understanding of the ecosystem's full suite of organisms and natural processes
Land management	The way a given land use is administered by humans
Biodiversity	The variety of life and ecological systems at scales ranging from populations to landscapes
Habitat fragmentation	The alteration of previously continuous habitat into spatially separate, smaller patches

2.3.2. Data sources and definition of land use/land cover classes

Land use data can be obtained from two types of sources

- Remote sensing
- In situ monitoring

Processing satellite images to derive land use information is the most widely used approach given the broad range of satellite images (some for free), compared to in situ monitoring which tend to be more expensive. However, in situ monitoring can provide valuable complementary information which is not possible to identify by remote sensing (e.g. agricultural practices, identification of relevant landscape components at different scales).

For the current indicator it is proposed to obtain the land use data from satellite images since this ensures a more coherent and comparable results, without the need to implement additional specific monitoring schemes.

One critical issue is the definition of the land use classes, since they should be comparable through the complete Mediterranean coast. Usually, land use inventories are organised in a hierarchical structure (up to 3-5 levels), from more general classes to a high level of detail. Consequently, the first level of the land use nomenclature is very similar in different systems identifying key elements such:

- Constructed areas (there are similar concepts like artificial or built-up areas)
- Agriculture
- Forest and other natural areas

At that level, this nomenclature combines degree of naturalness with degree of humanisation of landscape.

We propose to adopt a two level land use classification (Table 2:4). It intends to capture the variety of landscapes existing on the Mediterranean region and it corresponds to a simplified version of the classification developed in the PEGASO project for the complete area (Breton, 2014). This classification is also compatible with CORINE Land Cover which is available for the European part of the Mediterranean.

Table 2:4. Proposed classification of land use classes at two levels.

1 Artificial surfaces	
	1.1 Urban fabric
	1.2 Industrial, commercial and transport units
	1.3 Mines, dump and construction sites
	1.4 Artificial non-agricultural vegetated areas
2 Agricultural areas	
	2.1 Arable Land
	2.2 Permanent Crops
	2.3 Pastures
	2.4 Heterogeneous agricultural areas
3 Forests and semi-natural areas	
	3.1 Forests
	3.2 Shrub and/or herbaceous vegetation associations
	3.3 Open spaces with little or no vegetation
4 Wetlands	
5 Water bodies	

For the test of the indicator on the Adriatic we have used CORINE Land Cover 2000 and 2006 as the latest available data. It is expected that CORINE Land Cover 2012 would be available by mid-2015.

2.3.3. Definition of analytical units of the terrestrial part of the coastal zone

Given the nature of the coast as a transition and dynamic system, with an often intensive human activity, it is proposed to divide the coastal zone in several analytical units in order to better understand the dynamics and processes linked to land use changes. Annex II provides a detailed analysis of the different options and criteria tested for the analytical units of the terrestrial part of the coastal zone.

The final criteria have taken into consideration:

- Coastal zone is characterized by proximity to the see
- Inclusion of characteristic coastal ecosystems
- Balance between complexity and easiness to fully implement on the Mediterranean

Land use changes, in particular land take, are better understood by considering the following components (see Figure 2:3 for a schematic representation of the analytical units):

- 10 km buffer from the shoreline
- Segmentation by the following bands to the coastline in order to better understand the land use changes
  - < 300 m. This includes the setback zone. Given the limitations on the source data (resolution and definition of coastal line), this is the minimum distance that is feasible to delineate.
  - 300 m – 1 km
  - 1 – 10 km
- Inclusion of the elevation component. It has been observed that the Adriatic coast has a quite diverse topography (see Figure 2:4), which could be replicated on the complete

Mediterranean region. Therefore the following elevation breakdown has been considered for further analysis of land use changes:

- < 50 m masl
- 50 – 300 m
- >300 m

Given the complexity of coastal landscape and related ecosystems, which not always follow sharp transitions, any delineation based on fixed distances has its inherent limitations. In particular the elevation breakdown could be further improved by looking closer to altitudinal zonation, i.e. to identify relevant altitudes linked to potential habitat transitions. However, this is not homogenous through the Mediterranean coast and probably would require different thresholds for each sub-region.

Figure 2:3. Schematic representation of the different analytical units considered within the coastal zone as

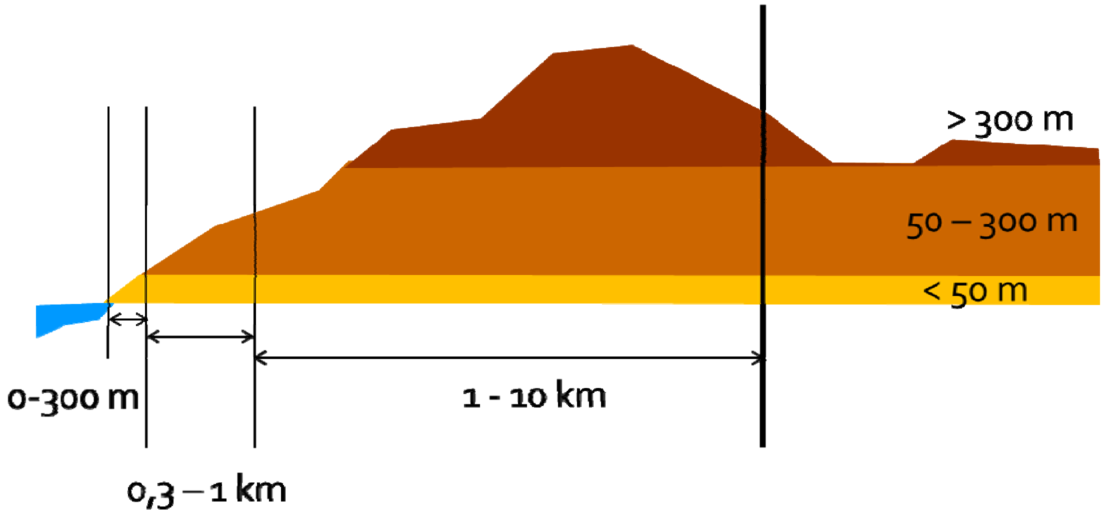
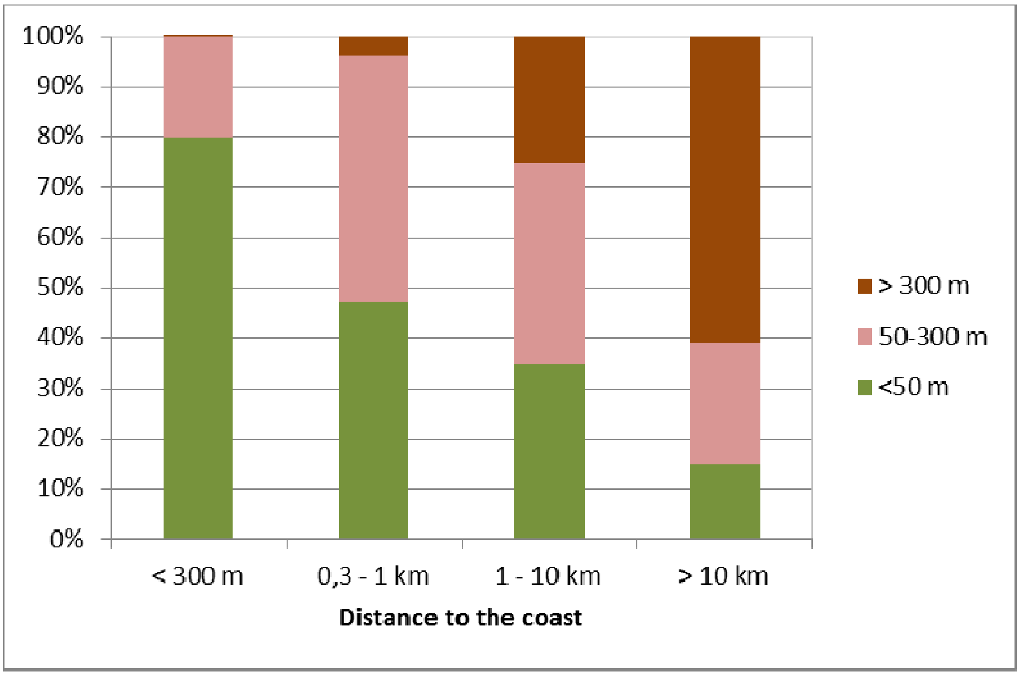


Figure 2:4. Distribution of elevation ranges (in colours) by coastal bands from the coastline on the Adriatic area.



2.3.4. Indicator 8.2.1: Land use change

<u>Overview</u>

Land use change is a broad concept to define a concrete EcAp indicator and its metrics. Different analysis can be conducted under the term land use and land cover change (LUCC). However, based on the official documents related to this indicator (UNEP(DEPI)/MED WG.395/Inf.3, 2014; UNEP/MAP, 2013), we can determine *that 8.2.1 Land use change* actually focuses on the analysis of the state and trends of built-up areas in coastal areas.

The objective is to know the extent to which the coastal zone has been built-up over the past several years because this will indicate the degree of pressure on the coast and the likelihood of further changes in the future (UNEP(DEPI)/MED WG.395/inf.3).

Therefore, this indicator measures the intensity of land take in coastal zones. Land take represents a proportion (%) of a specific area that changed between two land cover inventories from a non-artificial to an artificial area.

To quantitatively analyse the correlation between land take and the proximity to the coastline, compared analysis will be performed at 1 km buffer *versus* 10 km buffer from the coastline. Moreover, to better understand the coast influence, coastal land take (10 km) will be contrasted with inland land take (NUTS 3).

Additionally, the two remaining EO 8.2 indicators will provide complementary information on main coastal process and landscape dynamics (i.e. *8.2.2 Change of landscape)* and a quantification of a relevant impact of land take (i.e. *8.2.3 Coastal habitats fragmentation*).

<u>Temporal scale</u>

Since urbanisation is one of the most dynamic processes, the temporal scale to analysed changes should not be more than 5 years in order to be effective on the counteracting negative effects and taking early actions on hot spots. It could also be considered to have different time lapse for monitoring all land cover changes (5 to 10 years), and a shorter one to just analyse land take (e.g. every 3 years).

Spatial scale and reporting units

The resolution of the source data is a compromise between precision and efforts needed in processing the satellite images. The following indications could be tentatively considered minimum requirements

- Minimum mapping unit of 25 ha and 100 m of linear elements
- Minimum change detection 5 ha.

This information will be processed and mapped in a grid of 1 ha. Later on, the parameters will be aggregated at different units, namely:

- Administrative area (equivalent to NUTS3)
- Coastal zone, as defined on the ICZM protocol. In addition, differentiated in three bands as distance to the shoreline
  - < 300 m
  - 0,3 to 1 km
  - 1 to 10 km
- Elevation
  - < 50 m
  - 50 to 300 m
  - > 300 m

Basic steps

In order to obtain the final parameters for the indicator the following processes are required

- Obtain the land use for the different time shots (t_0, t_1, t_2,…)
- Calculate land use changes related to urbanisation between t_n (initial time) and t_{n+1} (selected time lapse) as follows:
  - Select all areas that correspond to artificial classes at t_{n+1}
  - Identify the land use classes on the areas selected in the previous step, at t_n (initial time)
  - For each reporting unit (e.g. administrative area, coastal segment) calculate the changes of artificial areas as difference between the two times $t_{n+1} - t_n$
  - For each reporting unit (e.g. administrative area, coastal segment) calculate the percentages of different land uses at the starting time (t_n).

Parameters

The following table provides a comprehensive overview on the parameters used on the indicator.

Table 2:5. Description of the parameters calculated for the indicator land use change.

Parameter	Units	Data required	Reporting units	Meaning
Area of built-up land in coastal zone as a proportion of the total area in the same unit	% of artificial areas	Artificial areas (land use class 1) at a single time shot	Coastal strips (<300m, 0,3-1 km, 1-10 km) Elevation breakdown (<50 m, 50-300 m, > 300 m)	State of urban areas at a particular time. This is used as a baseline, i.e. initial condition for the analysis of changes. It is of particular relevance the parameter reported on the first 300 m of the coast, since this is used as a proxy for the state of urbanisation on the setback zone.
Area of built-up land in coastal units as a proportion of the area of built-up land in the wider reference region	% of artificial areas	Artificial areas (land use class 1) at a single time shot	Wider administrative region (equivalent to NUTS3)	This parameter shows to what extent the process of urbanisation has been more intense on the coast than on the inland. It also reflects the relevance of economic activities on the coast as a driver of urban development.
Land take as % initial urban area on the coastal zone	% of increase of urban areas	Artificial areas (land use class 1) at t_0 and t_1	Coastal strips (<300m, 0,3-1 km, 1-10 km) Elevation breakdown (<50 m, 50-300 m, > 300 m)	Intensity of the process of urbanisation in a given period of time.

2.3.5. Limitations to the proposed approach

The taken approach is intended to be applied to the complete Mediterranean coast minimising additional data collection. Therefore, it has its own drawbacks.

The definition of the analytical units of the coastal zone, as described in section 2.3.3 could be revised in view of more detailed data on habitats distribution, or input from national experts. In any case it is important to take into account the implications of the different delineations on the interpretation of the results.

The use of remote sensing and the selected resolution is the main constrain when analysing the outcomes

- Not all changes are observed since there is minimum change detection. Therefore the patterns observed indicate that changes are underestimated. In any case the proposed approach is still relevant since it provides an idea of the magnitude of the processes of urbanisation.
- Given the resolution and processing, linear elements are not well captured; therefore linear elements perpendicular to the coast, for example, are not detected.
- The information currently available does not allow identifying built-up on the territorial waters.

Since these limitations arise from the definition of the resolution, there is space for improvement if it is needed. However, there is always a trade-off between resolution and efforts required to obtain the information.

It should also be highlighted that increasing awareness of the importance of coastal areas is leading to new developments regarding specific land use methodological development from remote sensing. Therefore some of these improvements could be integrated at later stages.

Finally this proposal is intended to use the minimum requirements in terms of monitoring to still provide meaningful understanding of the land use changes on the coast.

2.4. Complementary indicators

2.4.1. Overview

In addition to the indicator on land use changes, two complementary indicators have been proposed to provide additional information and better insight on the coastal landscapes. Although the purpose of the current report is to focus on the candidate indicator, a methodological basis on how this could be further developed is described on the following section.

2.4.2. Indicator 8.2.2 Change of landscape types

Overview

The aim of this indicator is to quantify main flows of coastal landscapes, thus it complements the candidate common indicator by providing a general picture of main process affecting coastal process. Preserving coastal ecosystems and landscapes involve addressing not only the issues related to the geographical settings per se, but also the processes influencing the dynamics of these physical settings. (UNEP/MAP, 2013).

As land cover is an indivisible part of the landscape, it reflects its states in different stages of development. This is the reason why land cover changes can be considered the relevant information source about processes (flows) in the landscape (Feranec et al., 2010).

Temporal scale

Considering broad landscape changes, it is proposed a minimum time lapse of 5 years to find a good balance between detection of relevant changes and efforts required to obtain the data.

Spatial scale and reporting units

The resolution of the source data is a compromise between precision and efforts needed in processing the satellite images. The following indications could be tentatively considered minimum requirements

- Minimum mapping unit of 25 ha and 100 m of linear elements
- Minimum change detection 5 ha.

This information will be processed and mapped in a grid of 1 ha. Later on, the parameters will be aggregated at different units, namely:

- Administrative area (equivalent to NUTS3)
- Coastal zone, differentiated in three bands as distance to the shoreline
    - < 300 m
    - 0,3 to 1 km
    - 1 to 10 km
- Elevation
    - < 50 m
    - 50 to 300 m

o > 300 m

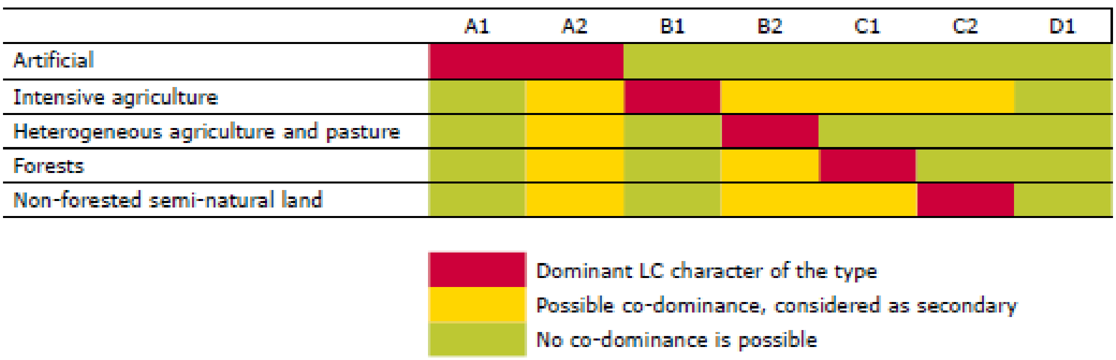
Definition of landscapes

One important element when identifying the impact of land use changes is the context, where this is happening, in other words the landscape. "Landscape" is generally defined as mosaic of "interacting ecosystems". The term has many components including visual, political, socio-economic and cultural. In order to operationalise we have used the concept of dominant landscape type (Weber, 2006). This concept is based on considering the dominant land uses within a radius of 5 km. Although this is a simplification of the concept of landscape, it is relevant since it integrates the context for specific land use in a single point.

Figure 2:5 provides the description of the dominant landscape type and the corresponding land use classes that define the dominance. Also Figure 2:6 illustrates the difference between land use map (left) and the result of applying the methodology of dominant landscape type (right).

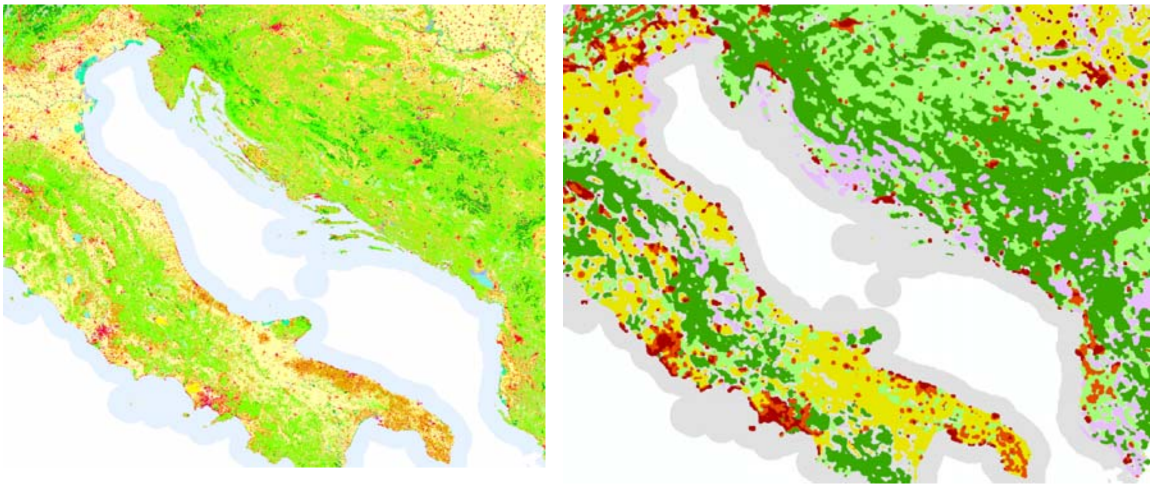
The development of the dominant landscape type is also useful to analyse where land use changes are happening. The most simple land use analysis indicates that between time 0 and time 1, land use x has been transformed into land use y. However, if we take into account in which dominant landscape type we have a better understanding on which context this change is happening. For example is land take happening on an intensive agriculture or in a semi-natural land?

Figure 2:5. Definition of dominant landscape types and their relationship to broad land use classes



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

Figure 2:6. Land use (left) and corresponding dominant landscape types (right) on the Adriatic area (2006).



<u>Land use changes</u>

From the land use classes described on section 2.3.2 (page 12), one could compute all possible changes between two time shots. Considering that the proposed land use classification at level two has 13 classes, it results in 169 possible combinations. In order to digest this amount of information the EEA developed the methodology of land cover flows, which aggregates al possible changes according to meaningful processes, allowing to identifying changes and land use flows (source, destination, gains and losses). With such approach it is also possible to identify changes in the quality of the landscape. The changes, which are grouped into what is referred as LCFs, are classified according to 9 major land use processes (Table 2:6).

Table 2:6. Land cover flows and description of related process. Land cover flows represent certain level of aggregation of land use/cover changes.

Land cover flows	Description of the process implied
lcf1 Urban land management.	Internal transformation of urban areas.
lcf2 Urban residential sprawl.	Land uptake by residential buildings altogether with associated services and urban infrastructure 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.
lcf4 Agriculture internal conversions	Conversion between farming types.
lcf5 Conversion from other land cover to agriculture	Extension of agriculture land use
lcf6 Withdrawal of farming	Farmland abandonment and other type of withdrawal of agriculture activity in favour of forests or natural land
lcf7 Forests creation and management	Creation of forests and management of the forest territory by felling and replanting
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.
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.

2.4.3. Indicator 8.2.3: Share of non-fragmented coastal habitats indicator

Overview

The calculation of the coastal habitat fragmentation provides complementary information to the built-up index (as one of its direct ecosystem impact).

Landscape fragmentation caused by transportation infrastructure and built-up areas has a number of ecological effects. It contributes significantly to the decline and loss of wildlife populations and to the increasing endangerment of species in Europe, for example through the dissection and isolation of populations, and affects the water regime and the recreational quality of landscapes. Therefore, data on the degree of landscape fragmentation are needed that are suitable for comparing different regions, especially in relation to different natural landscape types and different socioeconomic conditions. Therefore fragmentation could be seen as a consequence of the increase of the built-up.

Calculating habitat fragmentation

The indicator shows the change on the average size of patches of natural and semi natural areas, on the basis of land cover maps produced by photo-interpretation of satellite imagery.

Natural and semi-natural areas are represented by selected land cover categories which are forests, pasture, agricultural mosaics, semi-natural land, inland waters and wetlands. For a given region/ country, the change in average patch size of the selected land cover categories is the difference between two dates in their mean value, calculated as their quadratic mean.

The indicator is produced by using a simple mathematical calculation, the quadratic mean between the mean values of the patch size of a given area between two dates. By using the quadratic mean, the size of the individual objects matters as much as their number; in most cases, strong fragmentation of the larger areas matters more than fragmentation of small ones. At the same time, when a small patch in an area disappears completely (in time 2), the mean value for that area will be greater than at the time it was still present (time 1), unless the number of patches (n) in time 2 cannot be less than in time 1. That means that patches with size = 0 have to be taken into account too.

The Quadratic Mean or Root Mean Square (RMS) is the square root of the mean square value of a variable so it is a statistical measure of the magnitude of a varying quantity. It can be calculated for a series of discrete values or for a continuously varying function, using the following formula:

Quadratic Mean or Root Mean Square = SQRT (1/n ((X1)2 + (X2)2 + (X3)2 +........+ (Xn)2)

where X = Individual score and n = Sample size (number of scores or units)

Calculation can be done by NUTS level 2 or 3, or by river basin, as well as by country and biogeographical zone. The analysis can be done separately for different classes of patch size (e.g. large, medium and small), in order to capture specific trends and avoid some bias mentioned previously.

3. Results of the implementation of the indicators on the Adriatic

3.1. Definition of the geographic extent

The Adriatic Sea is a semi-enclosed sea connected to the Ionian extending northwards to the Po Valley. A variety of habitats from alluvial shallow waters on the north to the eastern steep karst habitats, are hosting a wide variety of habitats and endemic species.

The relevance of this area as a functional entity has been recognised in the context of the EU Macro Regional strategies. The EC adopted on 2014 a Communication on the EU Strategy for the Adriatic and Ionian region with corresponding Action Plan. This strategy recognises the importance to integrate the marine, coastal and terrestrial areas as interconnected systems.

In this regional context it should also be mentioned the IPA Adriatic Cross-border Cooperation Programme with special focus for the pre-accession assistance to which most of the countries belong.

Therefore the Adriatic Sea region is defined by the south-western and northern boundaries covered by Italy while the eastern waters are limiting with Slovenia, Croatia, Bosnia and Herzegovina, Montenegro and Albania (Figure 3:1). These 6 countries bordering the Sea define the geographic extent of the Adriatic region considered in this study.

Figure 3:1. Sea regional context for the Adriatic Sea

Source: MSFD Sea Regions and sub-regions (EEA, 2013)

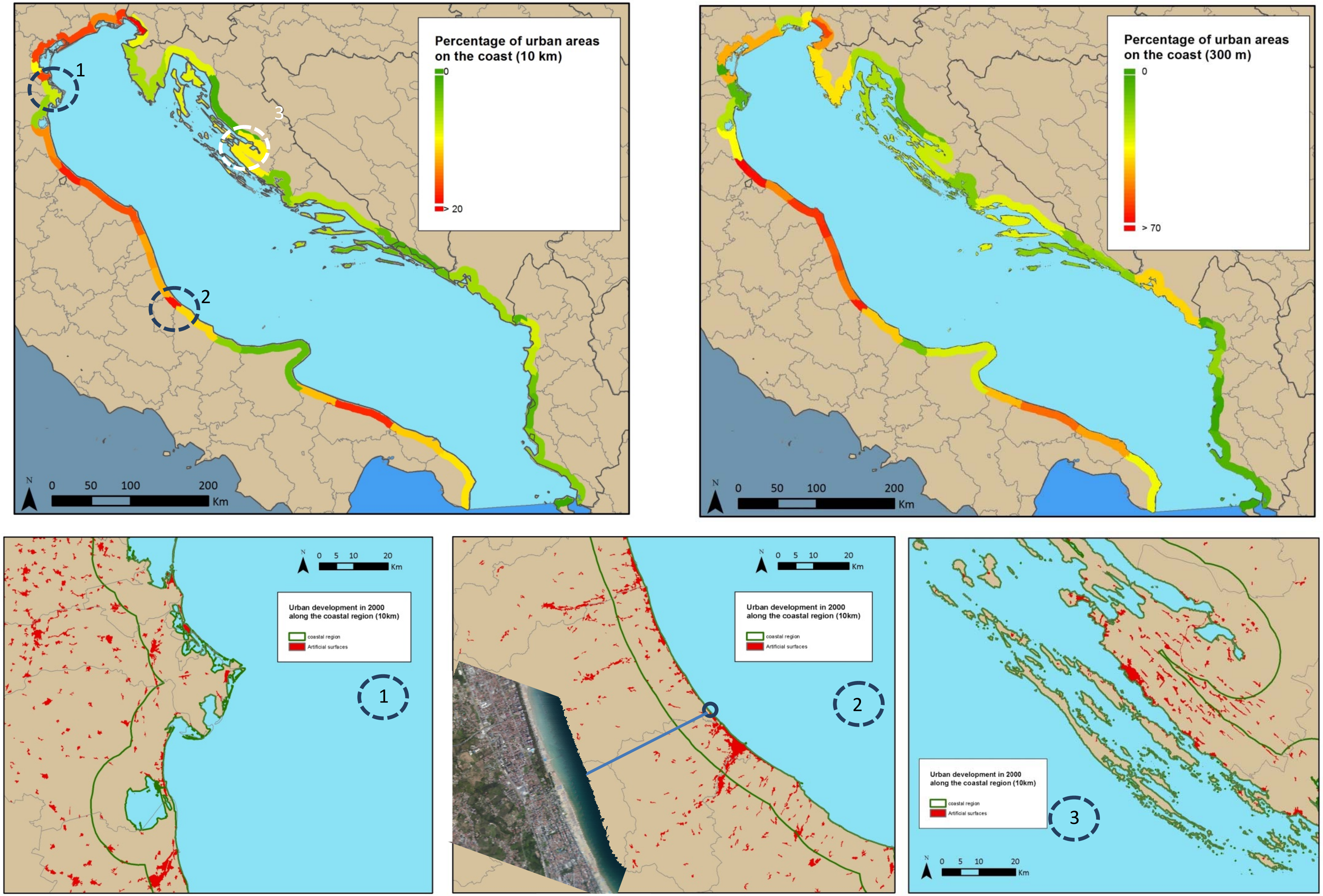
3.2. Candidate indicator Land use change

3.2.1. Reference to initial state: % built-up on the coast in 2000

<u>State of urbanisation on the coastal zone (10 km)</u>

About 6 % of the coastal zone is urbanised on the Adriatic region. However, there is not a homogenous distribution of built-up areas along the coast, which is logical considering the diverse topography and history of the region: the less urbanised coast is found in some parts of Croatia and Bosnia and Herzegovina, while Italy has urban spots where the percentage of built-up goes up to 20% of the coastal zone (Figure 6).

Figure 3:2. Share of built-up area in the first 10 km of the coast (left) and share of built-up in the first 300 m (right) in 2000. The zoomed areas show the details of the built-up areas where different patterns emerge: in the region of Ravenna (1), urban areas tend to be more compact and extend beyond the 10 km of the coastal zone; on the region of Pescara (2) there is a strong urban linear development on the first 300 m of the coast. In addition, urban development is also observed developing landwards following natural and transport corridors (2). In Croatia (3) the development is also more concentrated in certain areas following the valleys. Green line on zoomed areas marks the 10 km coastal zone



State of urbanisation on the setback zone (300 m)

The share of built-up areas on the first 300 m of the coastal zone, which includes the setback zone, is about 18% (three times of the built-up observed on the complete coastal area -10 km).

In that case the urbanisation is more dispersed through the complete Adriatic region (Figure 6). As a result only few areas have a share of urbanisation below 5%.

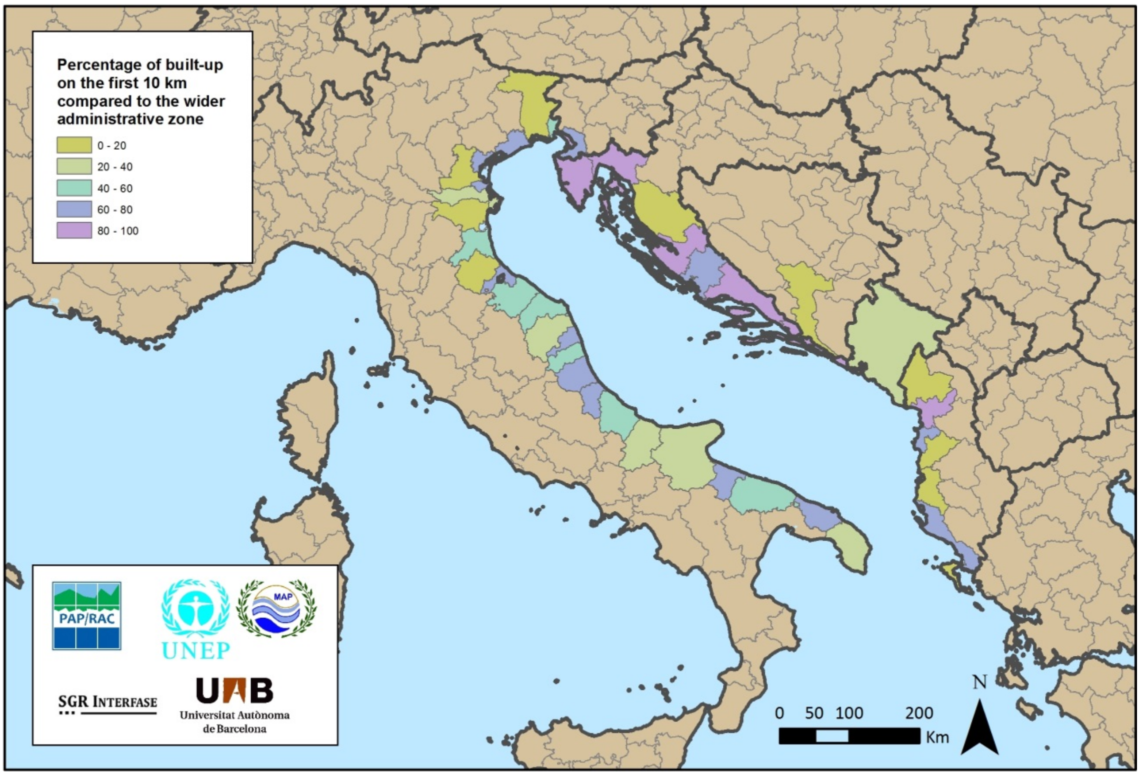
The urbanisation in this part of the coast is characterised by a linear urban development following the coastline (see zoom 2 on Figure 6) which implies the disruption of the connection between the land and the marine component of the coast. Moreover, these developments are also at higher risk of coastal floods.

Share of built-up on the coastal zone as a proportion of the built-up in the wider administrative area

Figure 3:3 illustrates to what extent built-up areas are concentrated on the coast for a given administrative area. The higher the value, the higher the concentration of urban areas along the coast, which may integrate two components:

- Availability of space for development. This is the case of some parts of the Balkan coast, with high share of urban on the first 10km of the coastal zone. Here, the topography is a major constrain for urban development landwards.
- Economic activities on the coast as a major driver for development. This would be the case in some regions in Italy where not topographic constrain was observed.

Figure 3:3. Built-up in the 0-10 km coastal strip versus the entire administrative area (2000).



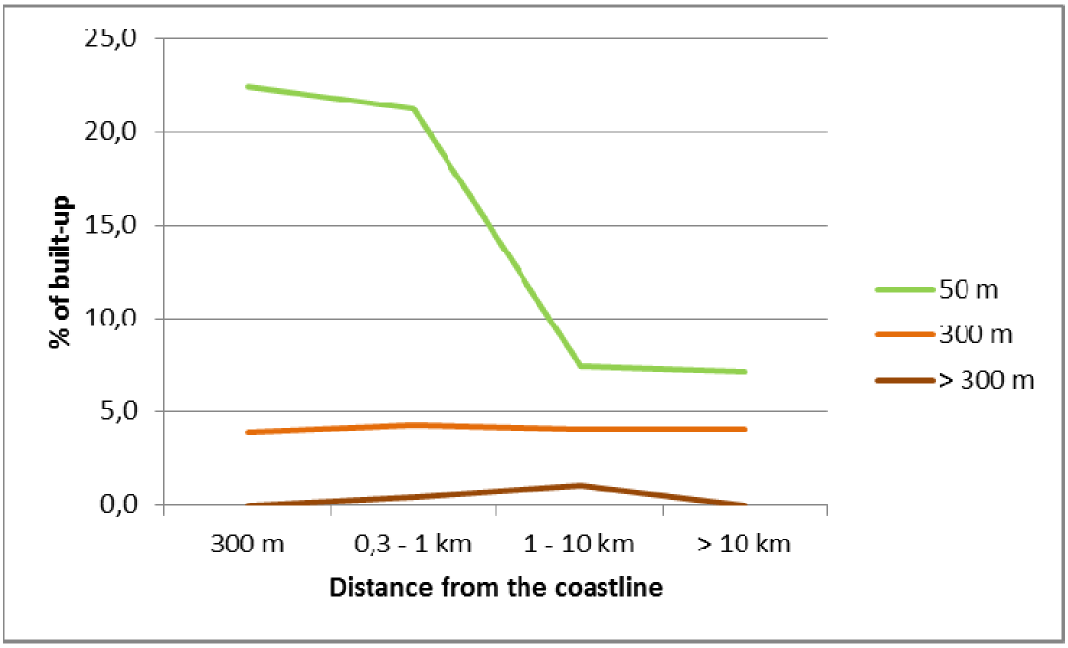
Patterns of built-up areas along the coast and elevation

So far we have seen the different patterns of built-up areas depending on the distance to the coastline and we have also identified a potential effect of the elevation on these patterns. Figure 3:4 corroborates this interlinkage:

- Degree of urbanisation is relatively high at low elevation.
- Degree of urbanisation is higher on the first 300 m, which includes the setback zone, and sharply decrease at the 1-10 km buffer.

This pattern is likely related to the fact that urbanisation in the past took place on the most suitable areas (flat, low elevation and closer to the coast).Therefore local conditions determined to a great extent the built-up patterns that we currently observe.

Figure 3:4. Share of built-up areas by buffer strips from the coastline and elevation on the Adriatic area (2000). For example 20% of the land is occupied by built-up areas on the 300 m buffer and below 50 m.



3.2.2. Land take (change 2000-2006)

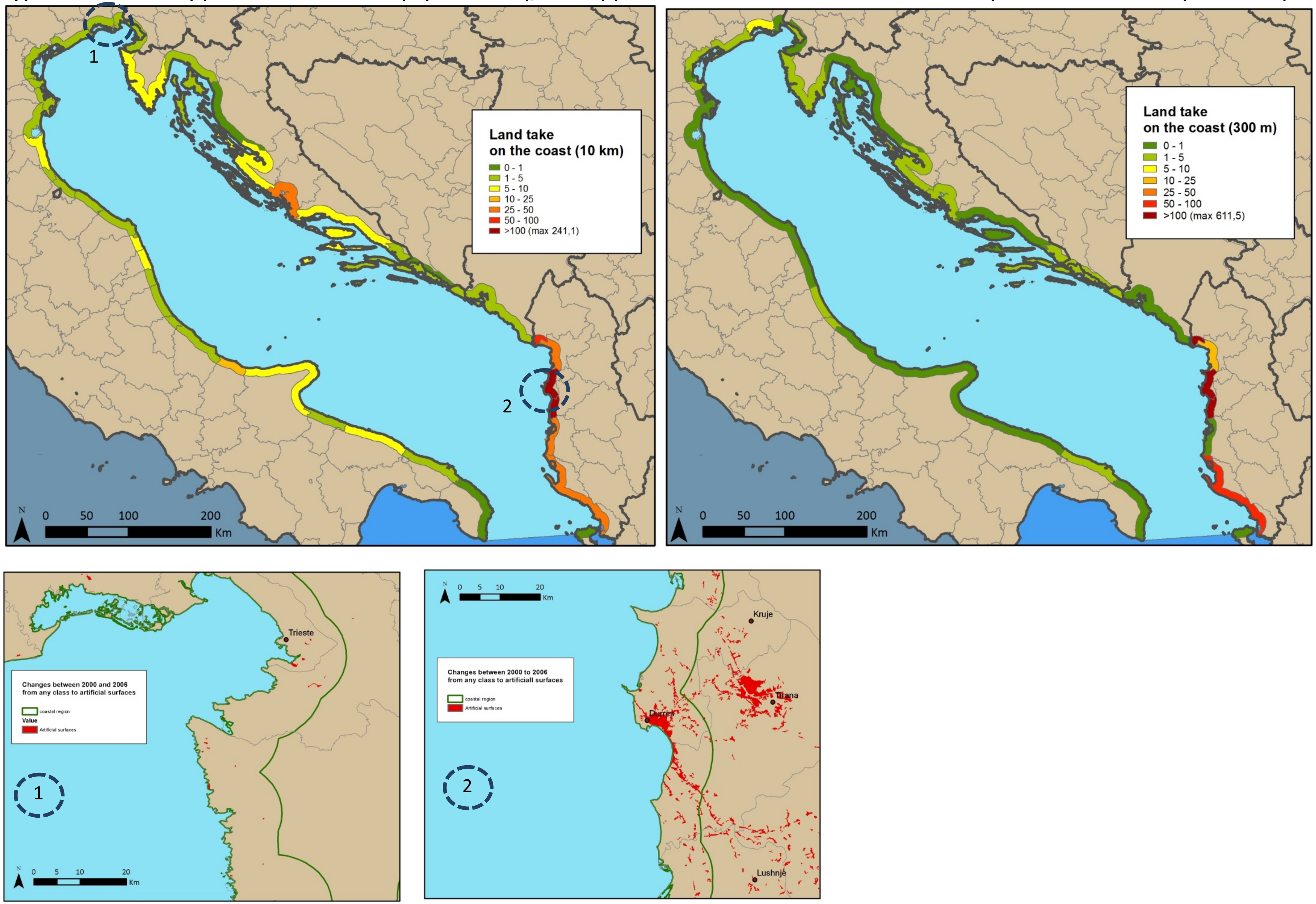
How much land has been urbanised in the period 2000-2006?

The process of urbanisationon the region has taken place at an average rate of 4600 ha/year (2000-2006) on the first 10 km of the coast. In general the land take rate could be considered medium to high: most of the areas are on the range of 5-10 % increase, with a clear hot spot on Albania (Figure 3:5, left and zoomed areas).

The situation slightly improve on the first 300 m (Figure 3:5, right): the rate of development is below 1% in most areas. However, some hot spots are still found in Albania, and some other areas are still on the range of 5-10% of increase of built-up.

In any case it is also interesting to relate the land take with the previous degree of urbanisation since it provides additional insight on the persistence (existing previous urban areas) with increased impact (new land take). In that sense the rapid land take in Albania is taking place on previously low developed coast (compare with Figure 3:2). The worst situation would be the combination of high degree of urbanisation with high rates of land take. This is not observed

Figure 3:5. Land take as percentage of initial urban area on the coastal zone (2000-2006) on the 10 km buffer (left) and 300 m buffer (right). Zoomed areas represent two opposite cases: Trieste (1) with a land take of 1% (depicted in red); Durres (2) with an increase of 100% over the 2000-2006 (new urbanised areas depicted in red).

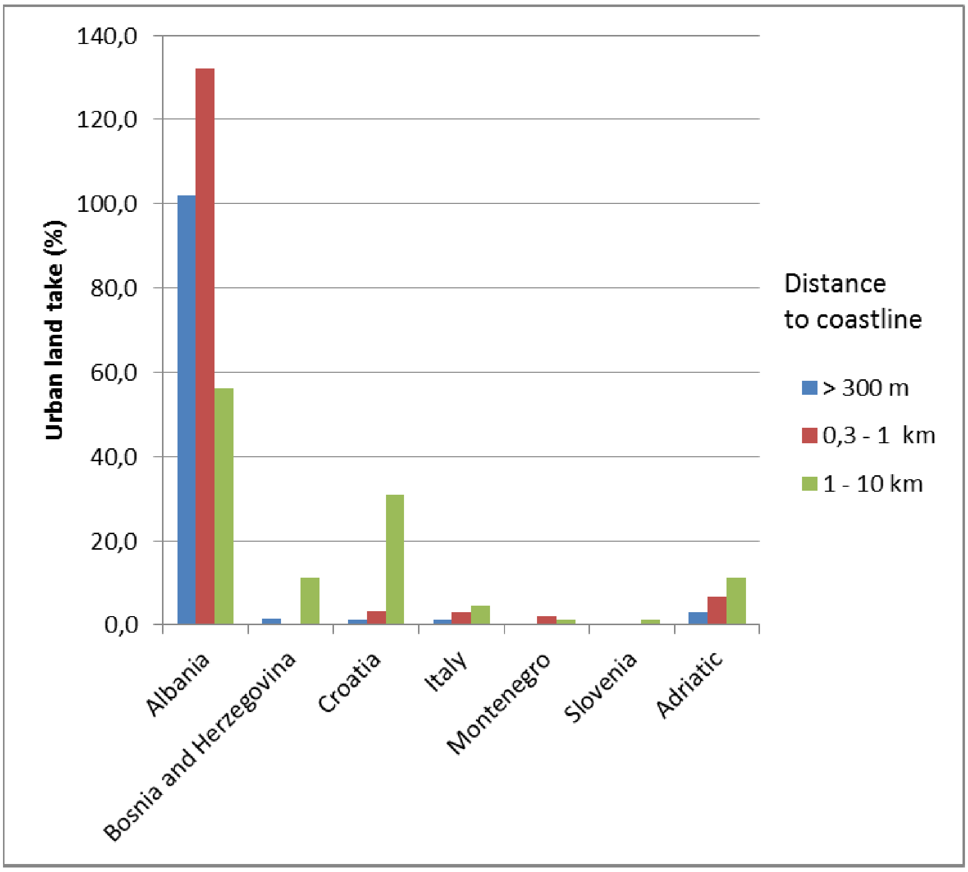


on the Adriatic area. Finally there is the opposite case of very low rates of urbanisation and low rates of land take, which occurs in some parts of Croatia.

Changes of land take in relation to distance to the coast

Figure 3:5 already illustrates that in most part of the Adriatic land take is higher landwards (left part of the figure) compared with the first 300 m of the coast (right part of the figure). This is corroborated in Figure 3:6, with the exception of Albania. There is a general trend to increase land take rates as we move far from the coastline.

Figure 3:6. Land take on the period 2000-2006 as percentage of initial built-up by distance to the coastline. Results are aggregated by country and for the overall Adriatic region.

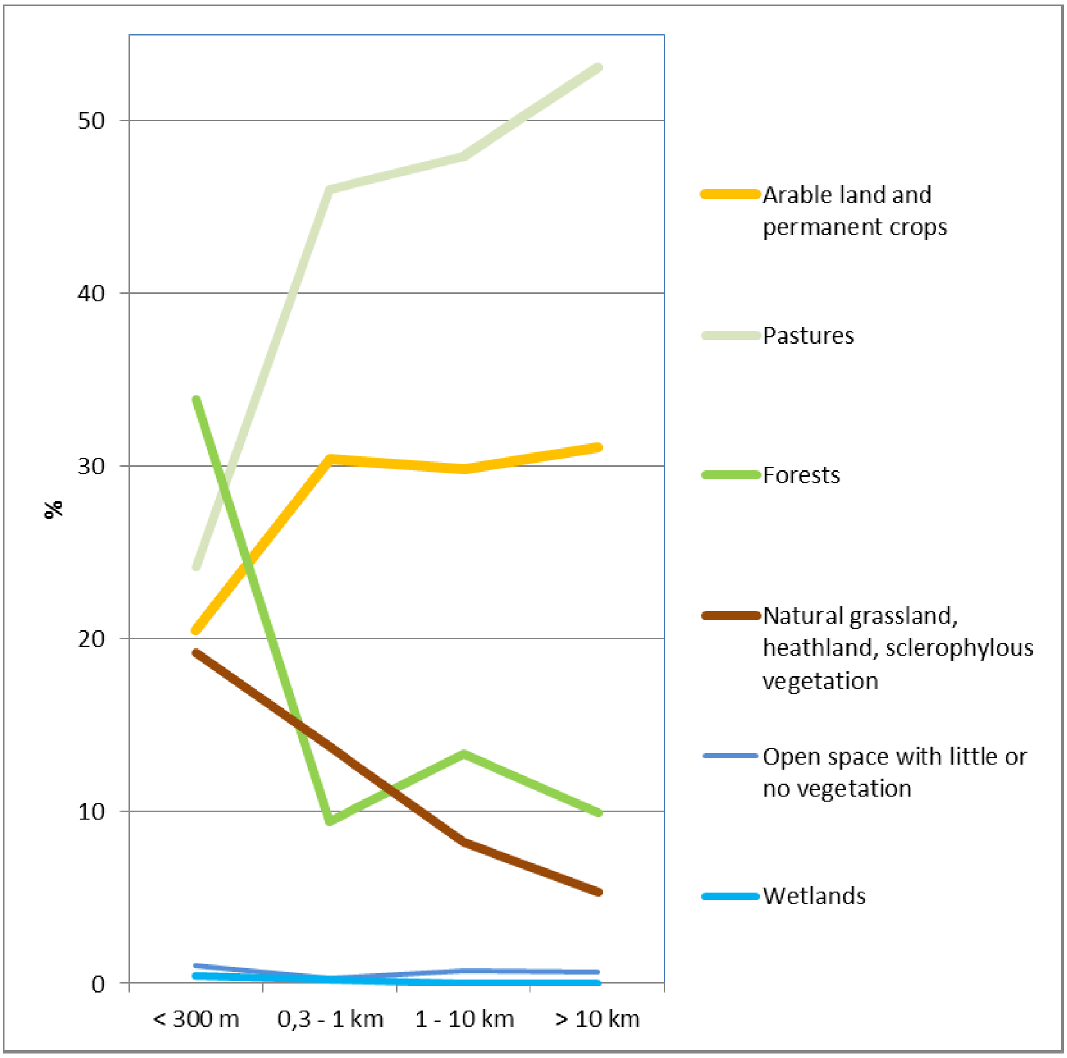


What has been lost by the process of urbanisation?

This is a critical aspect to better understand the potential impacts of the observed urbanisation patterns. Most of the urbanisation process has taken place on agricultural land and pastures. However, on the first 300 m of the coast, 35% of the new built-up areas were at expenses of forest land, which is a significant percentage.

Loss of wetlands, one of the most sensitive ecosystems, has been minimal in the region.

Figure 3:7. Origin of the land taken due to urbanisation as % of total uptake, by distance to the coast. For example 20% of the new built up areas in the period 2000-2006 where developed on previous agricultural land on the first 300 m of the coastal zone. Similarly, about48% of new built-up areas took place on previous pastures on the 1 – 10 km buffer.



3.2.3. Land take (change 2006-2012)

<u>How much land has been urbanised in the period 2006-2012? What are the differences compared with the previous period?</u>

The process of urbanisation on the region for this period (2006-12) has taken place at an average rate of 3084 ha/year on the first 10 km of the coast, significantly lower compared to the land take of 4600 ha/year on the previous period (2000-06).This decrease is largely explained by the stabilization of Albania's hotspot detected in the previous period.

While in 2000-06 most of the increase was concentrated in Albania, in 2006-12 the new land take has relocated to other coastal regions: especially in Croatia and Italy (Figure 3:8), but also in Montenegro and Bosnia Herzegovina. This pattern is valid for both 300 m and 10 km buffers. However, new urbanised areas tend to concentrate on the first 300 m buffer in contrast with the previous period when urbanisation concentrated on the 1-10 km buffer.(see Figure 3:9).

Figure 3:8. Land take as percentage of initial urban area on the coastal zone (2006-2012) on the 10 km buffer (left) and 300 m buffer (right).

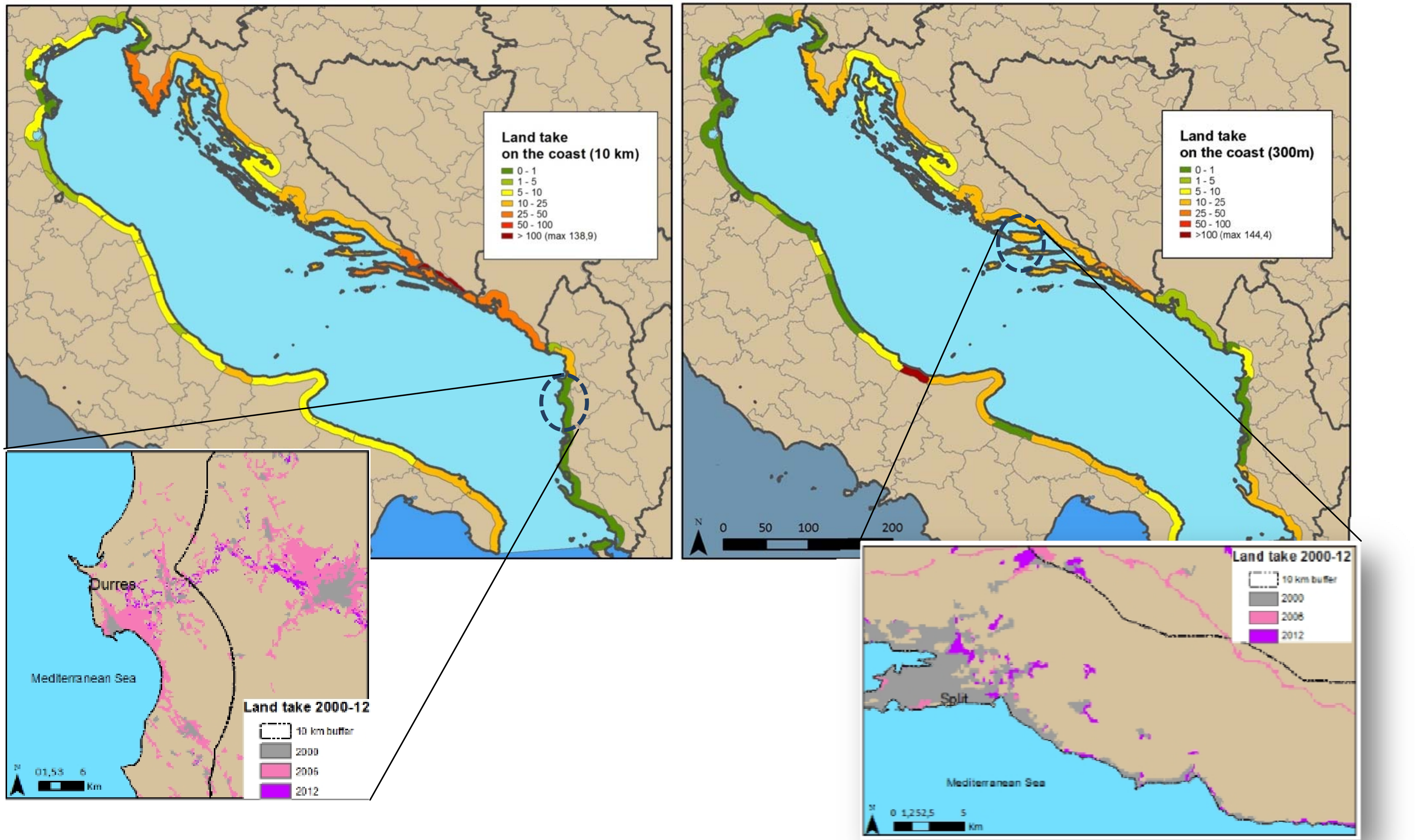


Figure 3:8 illustrates land take% disaggregated by coastal buffers (300m and 10 km from the coastline) and by coastal administrative units. Main highlights of Figure 3:8 in contrast with 2000-06 period (Figure 3:5) are:

(i) The situation in Albania improves considerably both in the 10km and 300 meters buffer. The swift urban growth detected in the first period is settled. The zoomed area in Durres corroborates it(Figure 3:8).

(ii) Croatian coast has gone through a relevant increase of coastal urbanisation in 2006-12. The situation aggravates in first 300 meters, increasing the land take from 1% to more than 10% in most of the Croatian coast. This pattern reflects an homogenous expansion of artificial surfaces on the whole Croatian, without relevant spatial differences. The zoomed area of Croatia (Figure 3.8) confirms the extent of the coastal land take process, especially relevant in the immediate coastline.

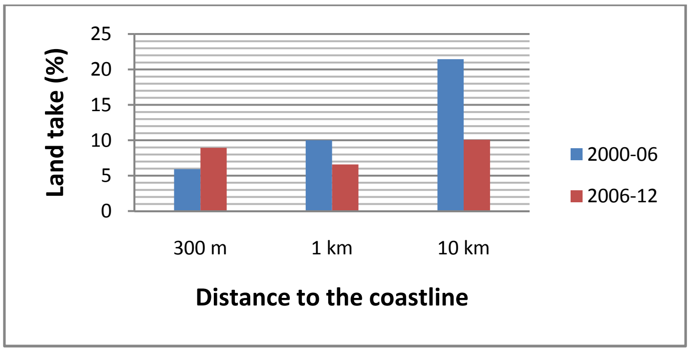
(iii) Bosnia and Herzegovina also experience a significant increase compare with the values of the first period. In fact, the highest percentages of growth for the 10 km (138,9%) belongs to the Bosnian coast.

(iv) Montenegro with a 30% land take considerably increase in the 10 km buffer comparing with the precedent period.

(v) Italian coast has undergone as well an increase of urbanization (300m and 10km), this is especially true in the southern region, with a hotspot in Campobasso.

(vi) In Slovenia a modest increase can be observed in the 10 km buffer, however, is by far the most stable Adriatic country in terms of coastal urban growth.

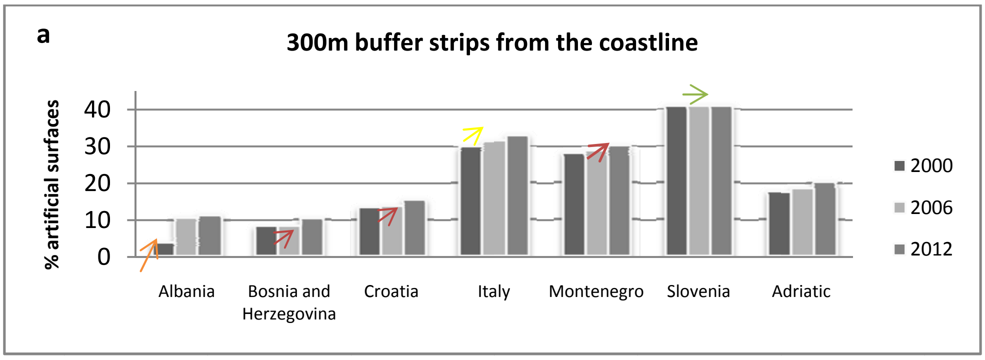
Figure 3:9. Land take as percentage of initial urban area on the coastal zone (10 km buffer) for the period 2000-06 and 2006-12.

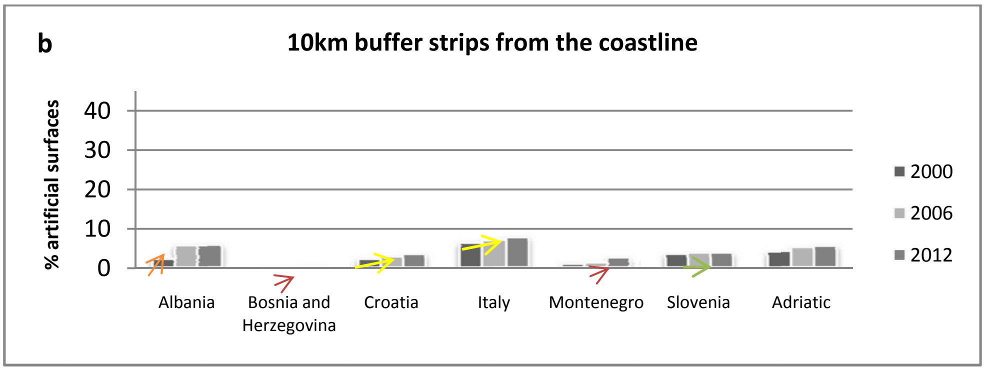


It could be concluded that on the West Balkan coast, urbanisation has moved from Albania, on the previous period, to the rest of the countries in the first 300m buffer. Figure 3:10a confirms for the 300m buffer a higher increase of urbanisation in the second period in: Bosnia and Herzegovina, Croatia and Montenegro (in red). Albania, the country with the lowest rate of built-up in the coastal zone had the highest increase in the first period (in orange). Finally, Italy and Slovenia with a steady behaviour over the two periods: Italy with a moderate increase in both periods (in yellow) and Slovenia with the highest rate of built-up in the 300m buffer but without increase of coastal urbanisation.

For the 10 km buffer (Figure 3:10b), Croatia and Italy (in yellow) show similar patterns over the two periods. Important increases of urban areas (10 to 25%) were already observed on some spots of Croatian and Italy coast during the period 2000-06. This trend has been corroborated, and extended for the period 2006-12. Bosnia and Herzegovina and Montenegro (in red) again with a higher increase in the second period.

Figure 3:10. Built-up by buffer strips from the coastline: 2000, 2006 and 2012.





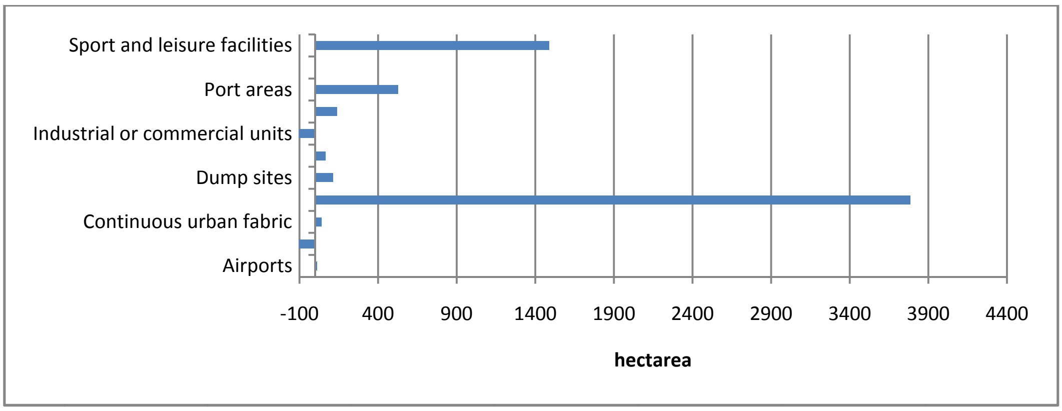
<u>What has been constructed in the first 300 meters coastline buffer (2000-12)?</u>

To disaggregate the category 'Artificial surfaces' into detailed nomenclature provides additional information of the land take nature. Figure 3:11 quantifies the surfaces taken over the 2000-12 period at CLC L3.

Discontinuous urban fabric is the artificial class more expansive. This class includes buildings, roads and artificially surfaced areas associated with vegetated areas and bare soils (between 30 to 80 % of the total surface should be impermeable). This definition includes: residential suburbs, scattered blocks of residential flats, hamlets, holiday cottage houses, etc.

It is also interesting to observe the relative weight of the artificial class 'Sport and leisure facilities' strongly correlated with tourism land uses such as camping, sport ground, leisure parks, golf courses, etc. Marinas are excluded and belong to 'Port areas' class together with quays, dockyards and port infrastructures.

Figure 3:11. Hectares taken by artificial surfaces classes over the 300 meters buffer (2000-12).

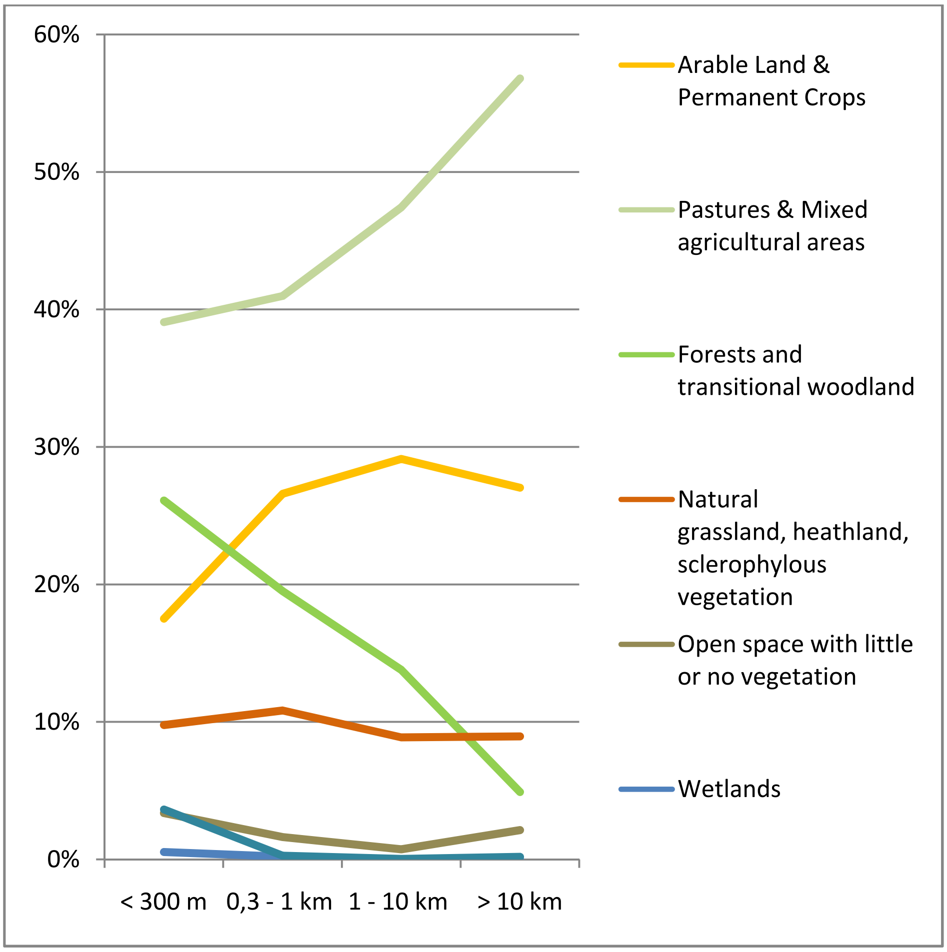


What has been lost by the process of urbanisation?

There are no significant differences on the behaviour of the land taken by the urbanisation process during this second period. Almost 75% of the urbanisation process in the first 10km from the coastline took place on pastures and agricultural areas. We can also observe the same negatively correlated pattern between forest and pastures areas: while forest losses decreases as we move away from the coastline, pastures is by far the land use class more affected by the expansion of urbanization farther away from the coastline.

The only difference between the two periods is the intensity between these two land uses in the first 300 meters. In 2000-06 forest is the land use class more affected by the expansion of artificial surfaces (see fig. 3:7) but in 2006-12 more than 50% of the land take of the first 300 meters occurs in pastures & mixed agricultural areas instead of forest surfaces (see fig. 3:12).

Figure 3:12. Origin of the land taken due to urbanisation as % of total uptake, by distance to the coast (2006-12).



3.2.4. Implications for good environmental status and ecosystem integrity on the Adriatic region

From the analysis of the indicator some lessons could be learned that are relevant for the coastal ecosystems. The most critical issue is how to keep the balance between human activities and the ecosystem values. This indicator definitely does not provide the exact threshold and place where to revert particular land use changes. However, it provides boundary conditions that reflect the most extreme situation where habitat loss is most dramatic –and consequently biodiversity and related services strongly affected:

- Hot spots either with already high degree of urbanisation or by rapid land take
- Areas and amount of natural systems lost (e.g. amount of forest converted to artificial land).

In addition, it could guide to put more attention on places where potential land take could take place in the future based on the observed patterns.

The more concrete outcome could be differentiated by the distance to the coastline:

- Set back zone. The conclusions highlighted below are extracted from the 300 m buffer, which is wider than the 100m fixed for the setback zone. However, this is still a good proxy to identify the most relevant process:
    - There is a clear differentiation between the Western part of the Adriatic coast, characterised by low elevations, and the Eastern part with more abrupt topography. In the second case there is a chance to concentrate the future urban development on the lower part of the coast, i.e. areas of potential pressure on the future (see for example Figure 3:3 comparing the urbanisation on the first 10 km in reference with the wider area).
    - A considerable part of the setback zone is already constructed, reaching high values in certain areas. Moreover, land take is still taking place in that zone, although at lower pace than the rest of the coastal buffers. Therefore this is clearly an area that needs better implementation of planning policies.
    - Land taken on the coast is mainly at expenses of natural areas, which adds additional pressure on that part of the coast.
- General observations related to the 10 km buffer:
    - Some hot spots of rapid urbanisation have been detected.
    - Further development on the coastal zone should be carefully planned specially on those areas with already medium to high percentage of built-up area present (above 5%).
    - The 1-10 km buffer is the most dynamic area in terms of land take and will likely continue in the future according to current trends on the region.
    - Further urban development should explore and promote land reuse or land recycling of previous developed land.
    - Land take on natural areas should be avoided since this is one of the most impacting land use change.

3.3. Complementary indicators

3.3.1. Overview

This part of the report provides complementary analysis that could support findings of the candidate indicator. These results are only illustrative in order to show further analysis that could be developed with the same source data as the indicator *Changes on land us.*

The fragmentation indicator is the more complex one in terms of computing requirements and, therefore, it has not been tested on the Adriatic region.

3.3.2. Indicator 8.2.2 Change of landscape types

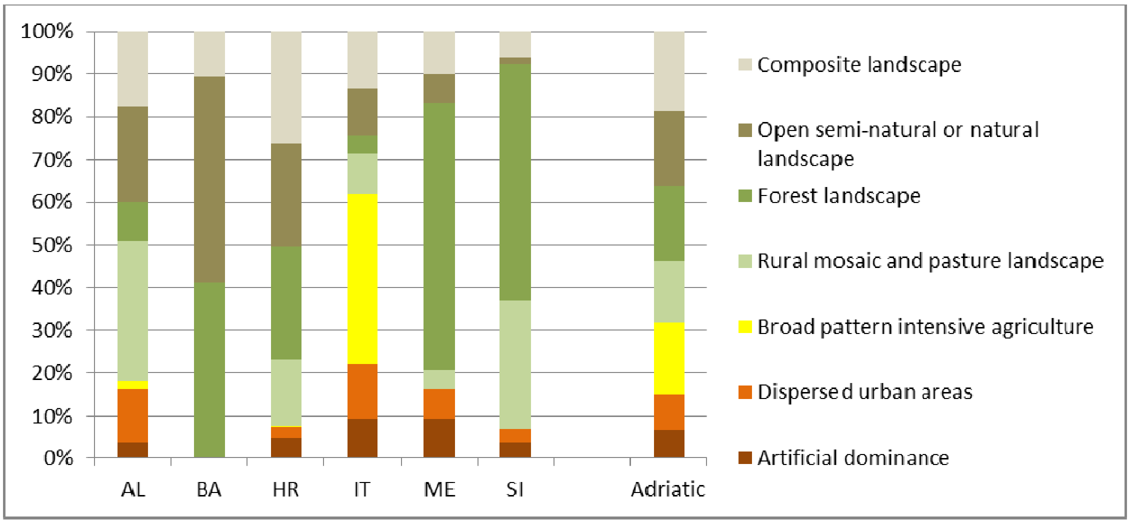
Reference to initial state: distribution of landscape types

In order to better capture the idea of proximity and context, the landscape typologies have been developed as opposite to simple land use classification that only provides information on the use/cover of a particular point (reference unit).

As explained on the methodology, the dominant landscape type is based on the same land use data but aggregated and reclassified according to the predominant land uses in a 5 km radius.

Dominant landscapes are organised in such a way that reflect intensity of use and certain degree of "naturalness":

Figure 3:8. Dominant landscape types on 10 km coastal zone (2000). Data is aggregated by country and by the overall Adriatic region.



- Built-up areas are the most humanised and transformed landscapes.
    - Artificial dominance. It corresponds to cities and metropolitan areas, where the built-up surface is dominant. It is only present on 7 % of the 10 km coastal zone, being Italy and Montenegro above the average.
    - Dispersed urban areas. This landscape type reflects urban areas of lower density.
- Agriculture
    - Broad pattern intensive agriculture
    - Rural mosaic and pasture. This landscape includes higher diversity and lower intensity
- Natural landscapes
    - Forest and open
    - Open landscape. Typical Mediterranean sclerophilous shrubland.
- Composite no dominance

The overall picture is a highly humanised coastal zone: natural landscape accounts for 35% of the area and intensive agriculture (17%) is the most spread human activity (Figure 3:8).

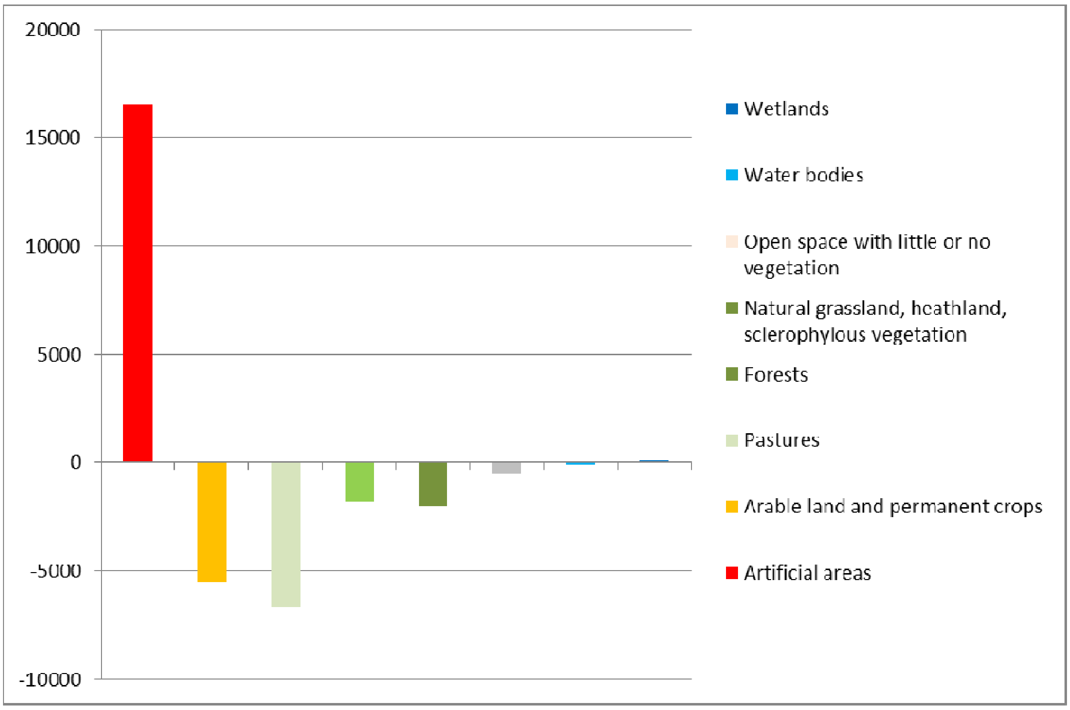
Changes on landscapes (2000-2006): What is the net balance of land use changes?

The period 2000-2006 is characterised by the extension of artificial areas and a significant reduction on agricultural areas (12.166 ha from both arable land and pastures, Figure 3:8). Natural areas are also significantly reduced (11.048 ha have been lost from forests, natural grassland and open spaces). The only positive trend has been observed on wetlands, that slightly increased (300 ha).

This pattern is observed across the different coastal strips (<300 m, 1 km, 10 km). However, the loss of forest and open landscape is relatively higher on the first 300 m.

From a regional perspective, 55% of new artificial areas are developed in Albania. Italy and Croatia are contributing each one to the 20% of the newly urbanised areas.

Figure 3:9. Net change in land use 2000 – 2006 (ha) on the 10 km coastal zone.

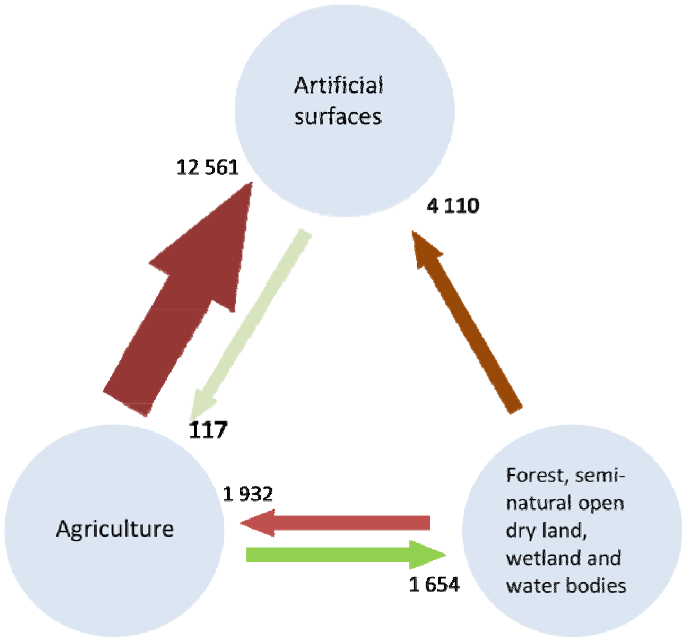


What processes drive the changes?

Net changes only provide a partial picture since they don't reflect all the fluxes and process involved. This is reflected on Figure 3:10, where the dynamics of land use change are presented on the "three-cornered" relationship between artificial surfaces, agriculture and forests and semi-natural land. The process of urbanisation is the one affecting more hectares, primarily from agricultural land, but also from natural areas. It is interesting to observe the changes between agricultural land and natural areas that result in a net gain of agriculture (300 ha for the period 2000-2006).

Figure 3:10 also reflects that from the major fluxes, only a small part result on potential improvement of ecosystems: conversion of agriculture to natural areas.

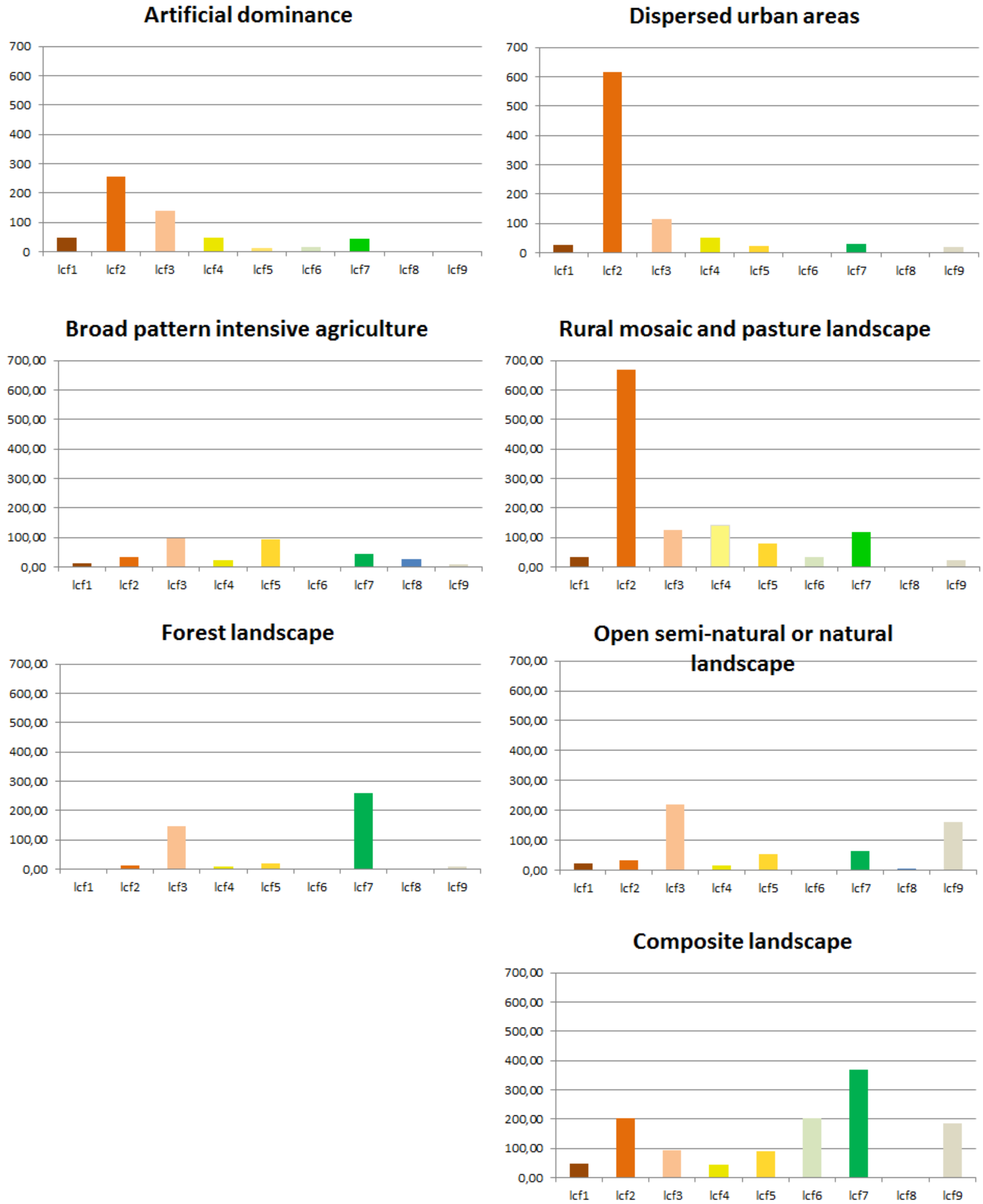
Figure 3:10. The dynamics of major land cover types in the Adriatic zone, 2000- 2006. All figures are in ha. Green arrows indicate changes resulting in positive impact on the ecosystem status. Brown arrows indicated changes resulting on habitat loss.



These patterns can be explored more in depth analysing which land use changes are dominant in each landscape (Figure 3:11). Some patterns emerge:

- Urban sprawl is mainly taking place on dispersed urban areas and rural mosaic. Rural mosaics and pasture landscapes are related to systems with relatively high diversity and very common on the Mediterranean. Those are interesting systems since while keeping certain degree of humanisation; maintain certain level of ecosystem quality and services. Therefore, urbanisation on these landscapes is a clear indication of thread to the biodiversity.
- Intensive agricultural areas are the more stable ones, in the sense of low changes, for the given period.
- Forest landscapes are primarily affected by changes related to forest management and, secondly, by the development of transport infrastructures.

Figure 3:11. Distribution of land use changes (ha) by dominant landscape types on the coastal zone (10km). Each figure represents a different dominant landscape type, then the amount of change of each land cover flow is represented. Legend for land cover flows are depicted at bottom.



lcf1 Urban land management
lcf2 Urban residential sprawl
lcf3 Sprawl of economic sites and infrastructures
lcf4 Agriculture internal conversions
lcf5 Conversion from other land cover to agriculture
lcf6 Withdrawal of farming
lcf7 Forests creation and management
lcf8 Water bodies creation and management
lcf9 Changes of Land Cover due to natural and multiple causes

3.3.3. Implications for good environmental status and ecosystem integrity on the Adriatic region

The objectives could be summarised as follows:

- Keep the mixed landscape structure. It is related to the diversity of landscape types, but also promoting those with higher biodiversity.
- Connect patches of natural areas.

Looking at specific landscape types, some additional targets could be defined:

- Artificial dominance, linked to the core of the urban/metropolitan areas. Promote reusing and recycling of artificial land while keeping the good quality of life in the urban areas.
- Dispersed urban areas, characterised by a high degree of urbanisation. Those are the areas of greater concern since a considerable part of the urbanisation take place here. Promote compact development, i.e. infilling existing areas when feasible (densification while keeping minimum quality of the place).
- Agricultural areas
    - Intensive agriculture. There are no major threads related to land use changes. Major impacts may come from agricultural practices, like eutrophication by fertilisation.
    - Rural mosaic and pasture landscape. More traditional landscape, with potential added cultural values. This landscape should be preserved and limit further urbanisation.
- Natural areas. Urbanisation is the major concern since it has a strong impact on fragmentation and habitat lost.

4. Conclusions

The test of the indicator “Changes on land use” on the Adriatic region has demonstrated that:

- It is possible to monitor land use changes with a relatively simple methodology by deriving land use information from satellite imagery.
- There is a trade-off between the resolution and the capability to capture linear elements and also built-up on the territorial waters.
- The proposed indicator is useful to identify hot spot areas, and therefore it could be used as a support for better planning and assist on the prioritisation of actions. However, the local knowledge is fundamental to complement the information provided by the indicator.
- It is possible to identify patterns of urbanisation and, consequently, identify potential areas at higher risk of land take in the immediate future.
- The indicator provides means to categorise the relevance of potential impacts according to the amount of pressure and type of land use change.
- The indicator provides a basis for the countries to define, according to their local knowledge and policies, the GES and potential measures to preserve and reduce the impact of land use changes on coastal ecosystems.
- The taken approach describes a methodology to identify analytical units within the coastal zone which help to better understand the dynamics of land use changes. These analytical units can also be improved by the availability of additional local data/knowledge on ecosystem zoning on the coast.

5. References

Bajocco, S., De Angelis, A., Perini, L., Ferrara, A. Salvati, L., 2012, 'The Impact of Land Use/Land Cover Changes on Land Degradation Dynamics: A Mediterranean Case Study', *Environmental Management*, 49(5), p.980-989.

Breton, F., Ivanov, E., Morisseau, F., Nowell, M. 2014. *D4.2 Report, accompanying database and supporting materials on LEAC Methodology and how to apply it in CASES*.PEGASO 06/Deliverable.

Cori, B., 1999, 'Spatial dynamics of Mediterranean coastal regions', *Journal of Coastal Conservation*, 5(2), p.105-112.

Dale,V. H. , Brown, S. , Haeuber, R. A. , Hobbs, N. T. , Huntly, N. , Naiman, R. J. , Riebsame, W. E. , Turner, M. G. and Valone, T. J., 2000. Ecological principles and guidelines for managing the use of land. *Ecological Applications* 10:639–670.

EC - DG.ENV, 2013. Mapping and assessment of ecosystems and their services an analytical framework for ecosystem assessments under action 5 of the EU biodiversity strategy to 2020: discussion paper - final, April 2013. Publications Office, Luxembourg.

EEA, 2006. The changing faces of Europe’s coastal areas, EEA report. European Environment Agency; Office for Official Publications of the European Communities, Copenhagen, Denmark: Luxembourg.

EEA, 2015.SOER 2015.The European environment, state and outlook 2015.Publications Office, Luxembourg.

Falcucci, A., Maiorano, L. andBoitani, L., 2007. Changes in land-use/land-cover patterns in Italyandtheirimplications for biodiversityconservation. *LandscapeEcology*. 22(4):617-31.

Feranec, J., Jaffrain, G., Soukup, T. and Hazeu, G., 2010, 'Determining changes and flows in European landscapes 1990–2000 using CORINE land cover data', *Applied Geography*, 30(1), p.19-35.

Freire, S., Santos, T. and Tenedório, J.A., 2009. Recent urbanization and land use/land cover in Portugal. The influence of coastline and coastal urban centers. *Journal of Coastal Research* , Vol. 56, December, pp.1499 – 1503

Gibbs, H. K., Helkowski, J. H., Holloway, T., Howard, E. A., Kucharik, C. J., Monfreda, C., Patz, J. A., Prentice, I. C., Ramankutty, N., Snyder, P. K., Foley, J. A., De Fries, R., Asner, G. P., Barford, C., Bonan, G., Carpenter, S. R., Chapin, F. S., Coe, M. T. i Daily, G. C., 2005. Global Consequences of Land Use. *Science*, 309(5734), p.570-574.

Haines-Young, R. and Weber, J.-L., 2006, *Land accounts for Europe 1990–2000. Towards integrated land and ecosystem accounting*, Copenhagen

Haines-Young, R., 2009, 'Land use and biodiversity relationships', *Land Use Policy*, 26, p.S178-S186.

Haines-Young, R., Potschin, M. Kienast, F., 'Indicators of ecosystem service potential at European scales: Mapping marginal changes and trade-offs', *Ecological Indicators*.

Khalil, F., 2011. Urban Sprawl Vs Urban Renewal: What Role for Town and Country Planning Instruments in Ensuring Sustainable Cities? Case of Algeria. *Procedia Engineering* 21: 760-66.

Kienast, F., Bolliger, J., Potschin, M., Groot, R. S., Verburg, P. H., Heller, I., Wascher, D. i Haines-

Young, R., 2009, 'Assessing Landscape Functions with Broad-Scale Environmental Data: Insights Gained from a Prototype Development for Europe', Environmental Management.

Lo, K. F. A. Gunasiri, C. W. D., 2014, 'Impact of Coastal Land Use Change on Shoreline Dynamics in Yunlin County, Taiwan', *Environments*, 1(2), p.124-136.

Perdigao, W. and Christensen, S.,2000. *The LaCOAST atlas: land cover changes in European coastal zones*. Joint Research Centre, Ispra.

Plan Bleu, 2006. Methodological sheets of the 34 priority indicators.

Santoro, Lescrauwaet, Taylor and Breton, 2014.*Integrated Regional Assessments in support of ICZM in the Mediterranean and Black Sea Basins (No. Intergovernmental Oceanographic Commission Technical Series 111), PEGASO project*. Intergovernmental Oceanographic Commission of UNESCO, Paris.

Serra, P, Pons, X., Saurí D. 2008. Land-cover and land-use change in a Mediterranean landscape: A spatial analysis of driving forces integrating biophysical and human factors. *Applied Geography*, 28(3): 189-209.

Symeonakis, E., Calvo-Cases, A. Arnau-Rosalen, E., 2007, 'Land use change and land degradation in southeastern Mediterranean Spain', *Environmental Management*, 40(1), p.80-94.

Thornes JB, 2005,'Stability and instability in the management of Mediterranean desertification.', en: *Environmental Modelling: Finding Simplicity in Complexity*, John Wiley & Sons, p. 303-315.

V. Perdigaoi S. Christensen, 2000, *The LACOAST atlas: Land cover changes in European coastal zones*, Joint Research Centre, Milan.

Weber, J.-L., 2007, 'Implementation of land and ecosystem accounts at the European Environment Agency', *Ecological Economics*, 61(4), p.695-707.

Annex I. Data sources

The following tables describe the data used on the pilot case.

Name	Description	Spatial Resolution	Coverage	Organisation	Version	Source	Use Constraints/Limitations
EEA coastline for analysis (line)	The criteria for defining the coastline is the line separating water from land. The EEA coastline is a product derived from two sources: EUHYDRO [link not available - yet] and GSHHG [http://www.soest.hawaii.edu/pwessel/gshhg/] A priority defined in the input data, first EUHYDRO geometry and, as auxiliary data, GSHHG dataset. The EUHYDRO do not cover the requirement for EEA coastline. The EUHYDRO gaps are in Iceland, Canarias, Madeira, Azores, small islands (not represented in EUDEM) and the northern of Black Sea. The creation process was focused on generating the coastline as line dataset and, later, as a secondary product, defining the polygon layer sea-land. The fundamental step into the workflow was the selection of sea features using a water mask polygon (value in EUHYDRO datasets = 255). The inland water bodies (freshwaters) are rejected by this criteria, except the water bodies connected, at least by one point, to the sea (it is the cases of some transitional water bodies).	1:100000	European oceans	European Environment Agency (EEA)	v 1.0, Jun. 2013	https://sdi.eea.europa.eu/internal-catalogue/srv/eng/search?uuid=6060e5ce-6958-48a0-9815-8f806c807351	EEA standard re-use policy: unless otherwise indicated, re-use of content on the EEA website for commercial or non-commercial purposes is permitted free of charge, provided that the source is acknowledged (http://www.eea.europa.eu/legal/copyright).
MSFD provisional dataset on sea regions and sub-regions	Draft version of the regions boundaries at sea to be used for the MSFD reporting. This dataset has not been approved by Member States.	1:1000000	European oceans	European Environment Agency (EEA)	Internal version, Sep. 2013	https://sdi.eea.europa.eu/internal-catalogue/srv/eng/search?uuid=81197a77-db68-49c4-8678-	Use limitation. Strictly for internal use.

Name	Description	Spatial Resolution	Coverage	Organisation	Version	Source	Use Constraints/Limitations
						1fdd2acc41dc	
Corine Land Cover	CLC is an inventory of land cover in 44 classes, and presented as a cartographic product, at a scale of 1:100 000.	100m	EEA39	European Environment Agency (EEA)	v 17, Dec. 2013	https://sdi.eea.europa.eu/continental/europe/natural_areas/corine_land_cover/land_cover/eea_r_3035_100_m_clc_2000_rev17/clc00_code_00_100.tif	Unless otherwise indicated, re-use of content on the EEA website for commercial or non-commercial purposes is permitted free of charge, provided that the source is acknowledged.

Name	Description	Spatial Resolution	Coverage	Organisation	Version	Source	Use Constraints/Limitations
GISCO NUTS 2010	The NUTS nomenclature is a hierarchical classification of statistical regions defined by Eurostat. The NUTS classification subdivides the EU economic territory into 3 statistical levels. The Regulation (EC) No 1059/2003 of the European Parliament and of the Council on the establishment of a common classification of territorial units for statistics (NUTS) was enforced the 11 July 2003. This regulation provided the NUTS classification with a legal background. Since then, 12 new countries joined the European Union. The NUTS regulation was officially enforced in these 12 countries the day of their accession to the EU.	1:100000	Europe	EUROSTAT	v 4258	http://ec.europa.eu/eurostat/web/gisco/geodata/reference-data	This dataset has been created for cartographic purposes. Use agreement with EUROSTAT

Name	Description	Spatial Resolution	Coverage	Organisation	Version	Source	Use Constraints/Limitations
S-NUTS -ESPON ITAN project	For the regional neighbourhood, the Similar to NUTS (SNUTS) nomenclature has been created. Total population has been gathered from National Statistical Institutes, then harmonised to United Nations Data for the period 1980-2010. Two levels of map harmonisation are available (one for mapping purpose and one for GIS calculations).	not available	Albania, Kosovo, Montenegro, Bosnia-Herzegovina, Serbia	ESPON	v 1	http://database.espon.eu/db2/resource?idCat=44	The ESPON 2013 Programme, by these terms and conditions of use, allows the visitor a non-exclusive and non-transferable right to access to the ESPON 2013 Database. "Use" means storing, loading, installing, executing, or displaying the ESPON 2013 Database and/or its content. The visitor may use the data included in the ESPON 2013 Database for non-profit purposes only, including the production of derivative works for the purpose of illustration for teaching or for another professional or personal use. The source has to be cited twofold as: © ESPON Database Origin of data: ESPON project (acronym), organization mentioned in the metadata as the 'responsible party'

Name	Description	Spatial Resolution	Coverage	Organisation	Version	Source	Use Constraints/Limitations
EU-DEM	The Digital Elevation Model over Europe from the GMES RDA project (EU-DEM) is a Digital Surface Model (DSM) representing the first surface as illuminated by the sensors. The EU-DEM dataset is a realisation of the Copernicus programme, managed by the European Commission, DG Enterprise and Industry. EU-DEM covers the EEA39 countries and it has been produced by a consortium led by Indra, Intermap edited the EUDEM and AGI provided the water mask. The EU-DEM is a 3D raster dataset with elevations captured at 1 arc second postings (2.78E-4 degrees) or about every 30 meter. It is a hybrid product based on SRTM and ASTER GDEM data fused by a weighted averaging approach. The projection onto an Inspire compliant grid of 25m resolution has been performed by the Joint Research Centre of the European Commission.	25m	EEA39	European Commission, DG Enterprise and Industry	preliminary version, 2012	http://www.eea.europa.eu/data-and-maps/data/eu-dem	Access to the data is governed by the draft delegated regulation on Copernicus data and information policy, as approved by the EC on 12th of July 2013, and in the process of decision making by the Council and European Parliament. This delegated act supplements regulation (EU) No 911/2010 of the European Parliament and of the Council on the European Earth monitoring programme (GMES). It establishes registration and licensing conditions for GMES/Copernicus users and defines criteria for restricting access to GMES/Copernicus dedicated data and GMES/Copernicus service information. The following credit must be displayed when using these data: "Produced using Copernicus data and information funded by the European Union - EU-DEM layers." Access and use of the data is made on the conditions that: 1. When distributing or communicating Copernicus data and information to the public, users shall inform the public of the source of that data and information. 2. Users shall make sure not to convey the impression to the public that the user's activities are officially endorsed by the Union.

Name	Description	Spatial Resolution	Coverage	Organisation	Version	Source	Use Constraints/Limitations
Dominant land cover types	Dominant land cover types are defined by classification of the CORILIS layers into dominant classes. A land cover type is dominant in a point when its density value (Vn) in that point is bigger than a threshold value. Vn is the smoothed value of class n in a given cell of the map. When co-dominances exist a supplementary criterion is needed in order to give priority to one class in front the others (Vn> mean + standard deviation). This hierarchical criterion is based in theoretical assumptions.	1km	EEA39	European Environment Agency (EEA)	version 16, jun 2013		EEA standard re-use policy: unless otherwise indicated, re-use of content on the EEA website for commercial or non-commercial purposes is permitted free of charge, provided that the source is acknowledged (http://www.eea.europa.eu/legal/copyright).

Annex II. Definition of coastal area

Conceptual definition of coast

Given the nature of the coast as a transition and dynamic system, with an often intensive human activity, its delineation has certain complexity since there is not a single factor that could easily delineate its geographic extension.

Some assessments use the term ‘coast’ to refer only to the littoral waters when the focus of the analysis is the shallow, marine system that experience significant land-based influences (EC - DG.ENV, 2013). But, the target of this pilot case is the land part of the coastal zone, which is directly linked through the land-water interface to the marine environment. In fact, Ecological Objective 8 (and related indicators) is based on the requirements originating from the geographic coverage of the revised Barcelona Convention and the ICZM Protocol, as well as the LBS Protocol. In all these documents, the spatial coverage extends to the terrestrial part of the coastal zone.

More in concrete, the Mediterranean ICZM Protocol defines the Coastal zone as “...geomorphologic area either side of the seashore in which the interaction between the marine and land parts occurs in the form of complex ecological and resource systems made up of biotic and abiotic components coexisting and interacting with human communities and relevant socio-economic activities.”(Article 2).

All the elements presented so far provide a certain idea to the concept of coast, although none of them provide a clear indication, threshold or reference to delineate such system. However, the following elements are widely accepted as characteristics of the coastal zones:

- Proximity to the sea (land component) or to the coastline
- Presence of unique ecosystems
- Influence on the climatic conditions
- Related human activities

In practice it is reflected in four different approaches:

- Administrative units next to the sea. This is a very pragmatic approach since it is directly linked to planning and management. However, this approach is far from reflecting the geomorphologic and ecosystem approach.
- A geographical unit: including deltas, estuaries, lagoons, wetlands, islands and other relevant feature of the coast, from the coastline to the interior a model of elevation can be used. Some rules have to be established about the maximum elevation threshold (50 m for ex.) about the features adjacent to the coastline (urban structures, for ex.). So that a high coast and low coast can be defined spatially for the inland part of the coast. It takes also the water part of the coast, following a bathymetric limit depending of ecosystems to be studied. Advantage: it takes into account the ecosystems spatial representation. Limitation: It does not take into account the broad concept of coastal landscapes which encompasses both natural and cultural elements (mosaic of “interacting ecosystems”). For example, this definition excludes coastal plains occupied by traditional agriculture with high ecological function. It should be overlapped with administrative units to include statistics.
- A geometric unit: Grids (1x1km, 100x100 meters, etc.) or buffers (100m from coastline, 10 km, 50 km, etc.). Advantage: useful to zoom in the areas under coastal policies and also to make a comparison between the coast and the rest of the country, etc.). Limitation: it should be overlapped with the other units to get full ecological and statistical information.
- Land elevation criteria: specially used in coastal population and human exposure to

hazards. It can also be interesting for LULC analysis. The underlying physical structure of landscape (e.g. altitude) may constrain LULC patterns. It can explain why in some countries/areas urban development is concentrated on the coast is also due to geomorphological conditions

- Catchment criteria: specially used in land-ocean interaction analysis. Limitation: the coastal zone can be extended too far from the coastline.

Operationalisation by ICZM

The Mediterranean ICZM Protocol operationalises the coastal zone by:

(a) The seaward limit of the coastal zone, which shall be the external limit of the territorial sea of Parties to the Protocol; and

(b) The landward limit of the coastal zone, which shall be the limit of the competent coastal units as defined by the Parties. (Article 3)

For the Adriatic region, the 'official' definitions of the coastal zone differ between countries due to the status of ratification of the ICZM Protocol:

- The Croatian Ministry of Environment has defined competent coastal units as those situated on the coast and those that completely or partially lie within the 3 kilometres wide coastal belt.
- The Montenegro coastal zone has been defined by the CAMP and comprises six coastal municipalities.
- Other countries such as Italy or Albania have not defined their “official” coastal zone and NUTS3 have been used in previous regional reports.

Figure 2.1 depicts the current coastal zone in the Adriatic according to different status of definition of the official area. There is a clear difference between the Easter side and Italy in terms of the extension of the coast landwards. Whereas it is clear that this is the official definition of coastal zone, it is proposed to delineate additional analytical units inside the coastal zone in order to better understand the land use changes and its spatial dependencies.

Figure 0:1. Adriatic coastal Zone. Croatia and Montenegro follow official definition. For the rest of the countries administrative units have been selected.

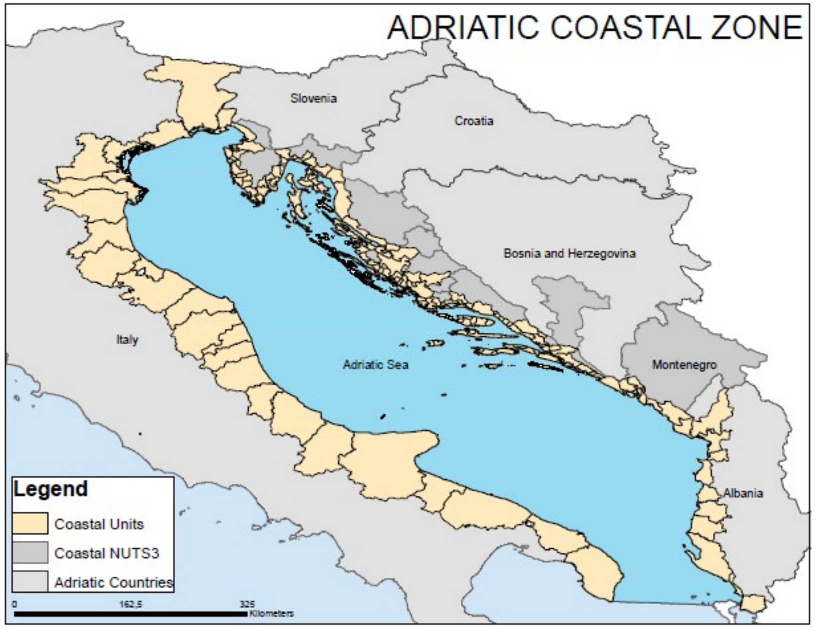
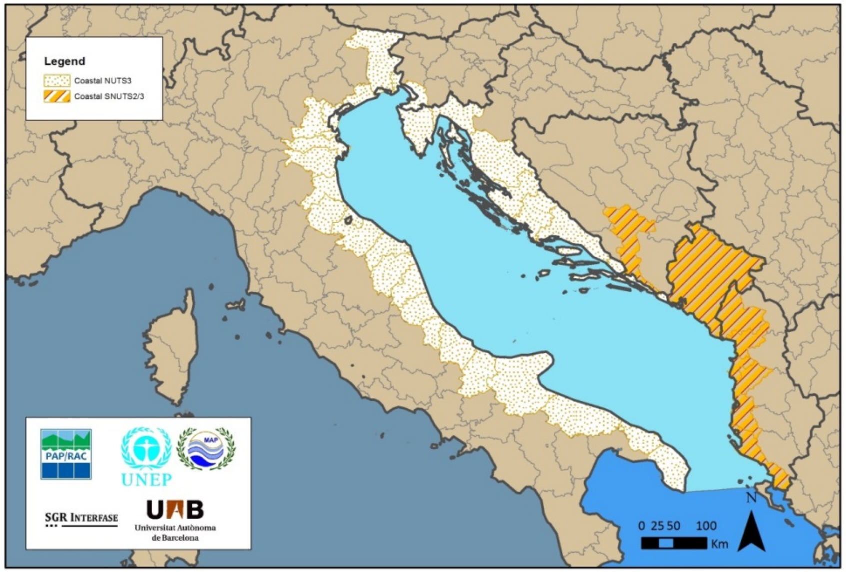


Figure 0:2 Administrative divisions (NUTS3) for the Adriatic area



Source: NUTS3 2010 (GISCO/EUROSTAT, 2010) and Similar to NUTS2/3 from GADM v2 and UMS RIATE (ESPON ITAN, 2014).

A proposal for defining analytical subunits inside the terrestrial part of the coastal zone

Since the administrative units are strongly tied to characteristics of country and can vary largely on size, it is proposed to define analytical subunits:

- Define the coastal zone by a **certain buffer landwards** to the coastline that would integrate the most relevant coastal ecosystems and would provide more similar areas between countries A wide variety buffer widths have been used ranging from 1 km to 100 km (Burke et al. 2001; Nicholls and Small, 2002; Pernetta and Milliman, 1995; Freire, et al. 2009; Bajocco et al., 2012), related to different geographical contexts (from worldwide to local), different issue being addressed and different objectives of management. However, at European scale the buffer of 10 km is the most widely used for analysing coastal land use/land cover changes. This threshold was established in the context of LACOAST Project (Perdigao & Christensen, 2000) by analysing the land cover changes for the whole European coasts as a function of the distance from the coastline. Results demonstrate that over 10 km from the coastline, percentages of surfaces occupied by the different land cover classes become relatively constant. The 10 km criterion is followed in EEA's assessments (European Environment Agency, 2006, p. 11); this unit of analysis has proven to be useful not only at European level but also for the Mediterranean region. For instance, the PEGASO project defined two coastal units: the 1st km from the coastline; and the 10 km coastal zone (Santoro et al., 2014, p. 41). The 10 km band has also been used by Plan Bleu to develop the indicator "Share of artificialized coastline" () .When more precise analyses are required, the 10 km coastal zone can be subdivided into 1 km bands.

- Integrate all the **coastal ecosystems** that may go beyond the buffer defined on the previous point (it may be relevant on river plains or deltas).

- Define certain **elevation limit**, if it is pertinent, to avoid the inclusion of mountain areas not fitting on the coastal context. For example the EEA has developed land typologies which includes low coast (< 50 m within the first 10 km) and high coast (> 50 m in the first 10 km).

In order to assess the suitability of each criterion on the Adriatic a stepwise implementation has been developed.

On the first step the following criteria has been used:

- a 10km buffer landwards from the coastline (obtained from sea regions).
- a 2km buffer around a selection of coastal ecosystems (based on European Ecosystem Types, though it could also be delineated from land cover information):
    - Coastal wetlands (coastal lagoons and estuaries)
    - Coastal terrestrial habitats (coastal dunes and sandy shores, coastal shingles, and rock cliffs, ledges and shores).

The first criterion intends to represent an influence area of the shore, in order to capture: i) the specific ecosystem (especially the interface processes) and ii) the urban areas that might generate pressure over the coast. The aim of the second criteria is to include all inland areas that are under a direct influence of the maritime environments, these being characterized by the transitional character and where there is potential presence of valuable biophysical features (fauna, flora and geomorphologies).

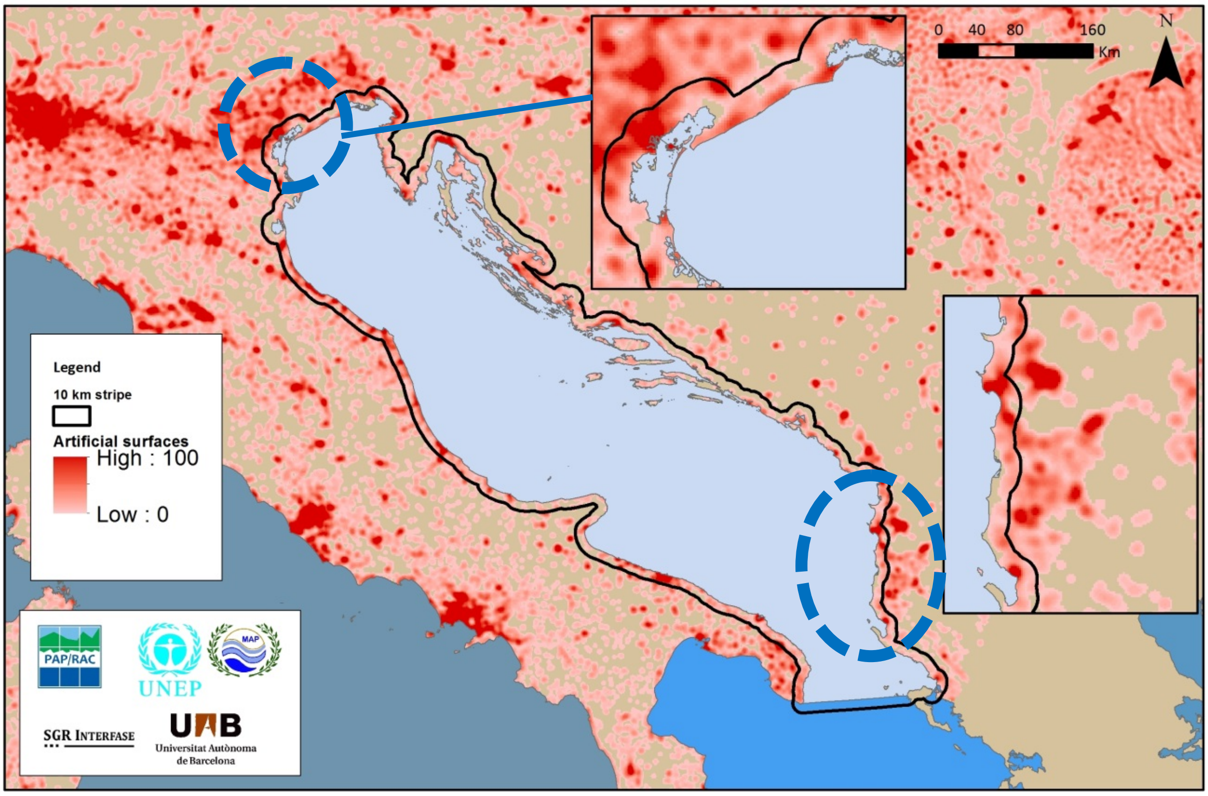
As a result of this first delineation it is identified that almost all the coastal ecosystems (as defined at continental scale) are integrated on the 10 km buffer. There are only 285 ha which correspond to coastal ecosystems, according to land cover classification, and expand beyond the 10 km buffer.

Another important aspect is to ensure the integration of coastal cities. Human activities are very intensive on many parts of the coast, reflected on the settlements established for centuries. Therefore we need to ensure that coastal cities and related urban areas are included on the delineated coastal zone. We defined cities, and its periphery, based on the continuity of the built-up area (the physical basis). However, the city and its built environment have certain influence beyond the strict physical limit. To integrate this aspect of proximity we have developed an urban layer which reflects the probability to be near an urban area in a 5 km radius.

As can be seen in Figure 0**:3**all the coastal cities (red spots) are included in the 10 km buffer. Also its extension and area of influence lies mainly within defined coastal area.

At this point, it is clear that the 10 km buffer includes all the ecosystems that we may consider "coast". However, the question is if we have also integrated other systems that may not be considered coast, for example high elevation mountains, or certain plains that are beyond a coastal range (shadow zone - Figure 0:4). It is also relevant to question to what extent high elevation areas should be considered coast (Figure 0:5).

Figure 0:3. Urban areas on the Adriatic and the 10 km buffer from the coastal line.



Source: Corilis 2006

Figure 0:4. Buffer of 10 km on the Croatian coast. Red line indicates the 10 km inwards from the coastline. Shaded are depicts a small valley in the 10 km buffer and behind a mountain range –not directly facing the coast.

Source: Google Earth

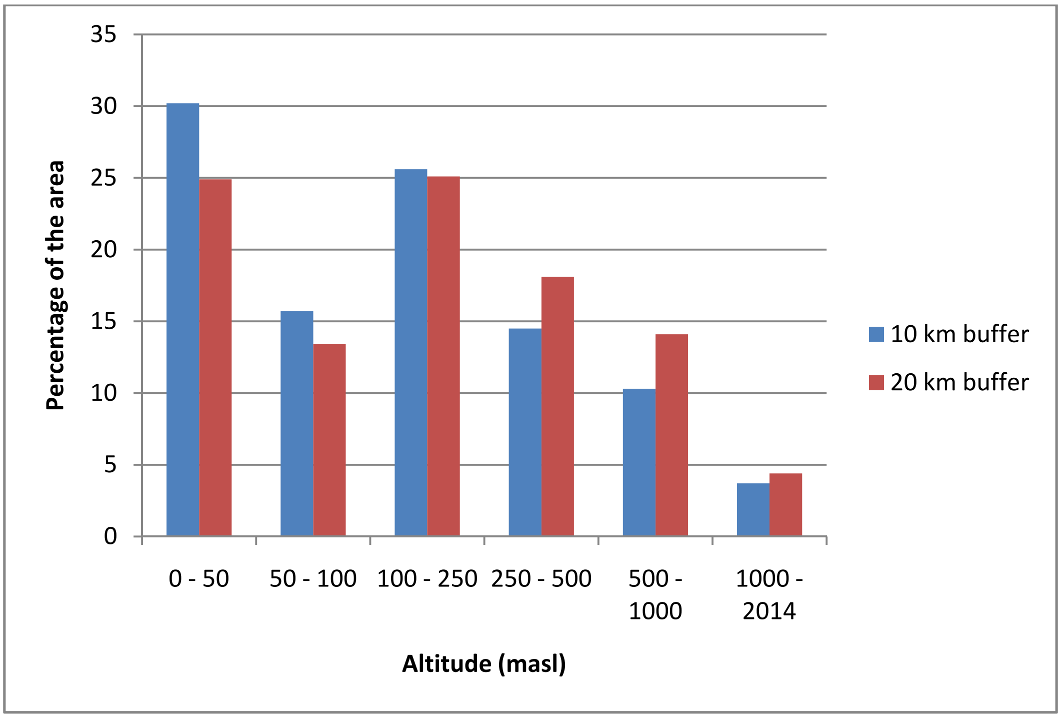
Figure 0:5. Buffer of 10 km on the Croatian coast. Elevation contour for 500 m and 1000 m asl.

Source: Google Earth

In order to explore the effect of the altitude the 10 km buffer has been extended to 20 km from the coastline. The extension to 20 km buffer was considered given the high variability on the coastal topography in the area and to explore to what extent the plains facing the sea extended landwards.

Area below 50 m in the 10 km buffer accounts for the 30% of the strip (Figure 0:6). This percentage, as it is logic, decreases to 25% on the 20 km buffer. No matter the buffer considered the area below 250 m accounts for more than 50% of the total area. Finally, the area above 500 m ranges from 15% in the 10 km buffer to 18% in 20 km buffer.

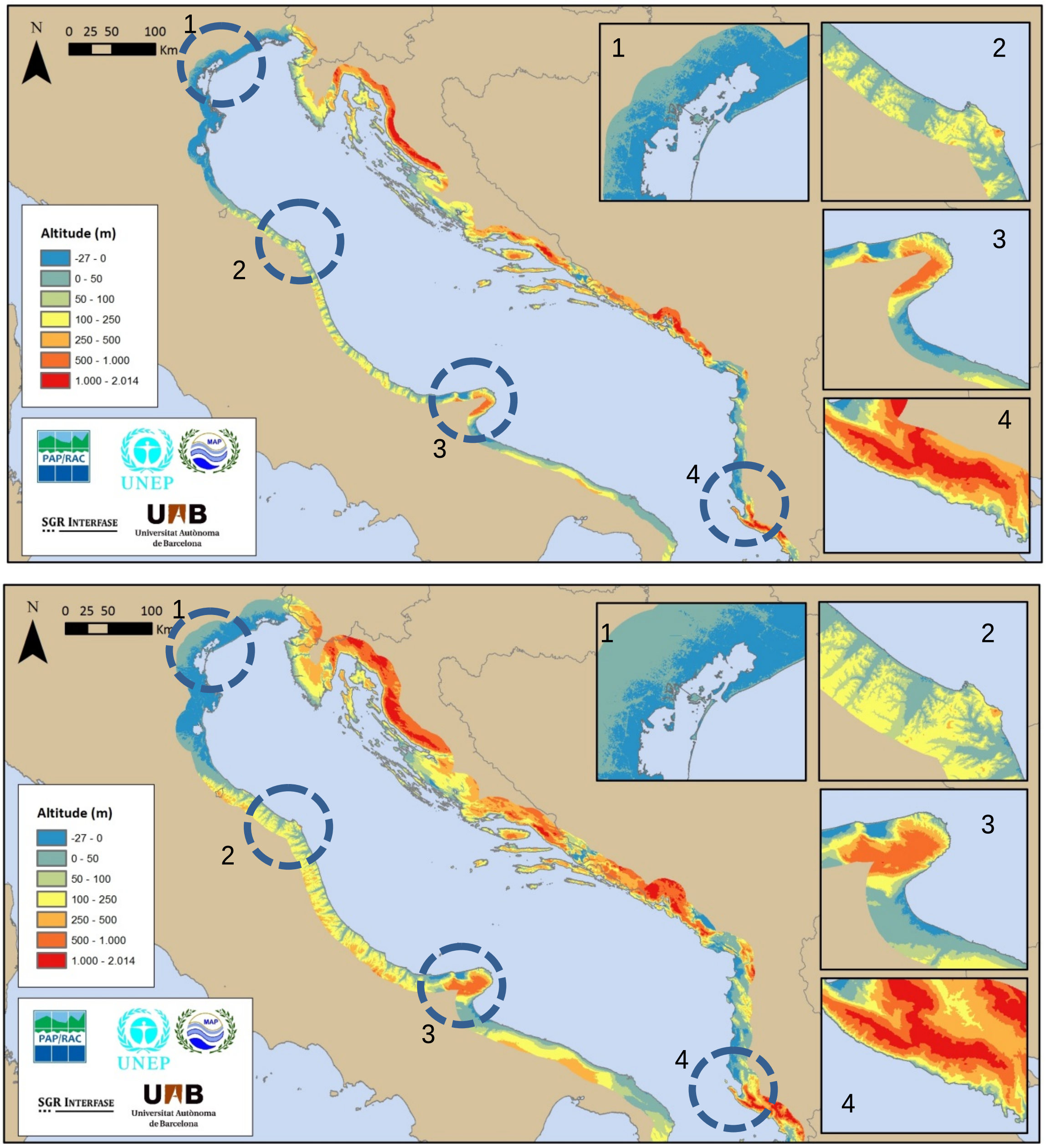
Figure 0:6. Comparison of distribution of hectares across different altitude ranges within the two different coastal buffers (up to 10 km and 20 km from the coastline).



However, these general statistics integrate a quite diverse coastal typology on the Adriatic (Figure 0:7). Namely:

- Low coast (blue-green areas on the map). Coastal areas < 50 m, mainly on the Po Valley and N of Albania.
- Mid coast (yellow-orange areas on the map). Coastal areas dominated by mid-range mountains (100-250 m). This is the case of large part of the Italian coast and parts of Croatia (including Istria peninsula).
- High coast (red areas). Coastal areas above 500 m, very often reaching 1000 m. This type of coast is found almost exclusively on the East coast of the Adriatic (large part of Croatia, Bosnia and Herzegovina, Montenegro and South of Albania).

Figure 0:7. Mean altitude (masl) for the Adriatic coastal region (top: 10 km buffer from the coastline; bottom: 20 km buffer). Source: EUDEM 25m - GSGRDA (JRC, 2012).



The four zoom areas on the map highlights specific cases:

The **zoom area 1** corresponds to Venice. Extending the buffer from 10 km to 20 km it shows that the complete area is still below 50 m.

The **zoom area 2** corresponds to Ancona (Italy).This is an example of mid coast. Extending the buffer from 10 to 20 km completely integrates the part of the valleys facing the coast below 50 m.

The **zoom area 3** corresponds to the Gargano Peninsula (Foggia, Italy) and it includes a mix of low coast, mid coast and high coast (see also Figure 0:8). Extending the buffer from 10 to 20 km makes easier to see that most of the Peninsula is above 500 m. In that case we wonder to what extent the area above 500 m should be considered coast. It is under certain influence of the coastal climatic conditions. However, in terms of topography it seems more a plateau extending landwards beyond the 20 km buffer.

Figure 0:8. Gargano Peninsula (Foggia, Italy). Elevation contour for 500 m.

The **zoom area 4** is located on the SW of Albania. This is a typical area of high coast. It can be seen that the highest elevations area above 1000 m. It seems logical to exclude the area above certain elevation since it is more related to the inland mountain range system. It is relevant to understand the physical barrier to coastal development and, consequently, land take.

Conclusions

This document explores several approaches to assist on the delineation of the coastal zone on the Adriatic, considering that the selected approach should be easy to extend to the whole Mediterranean Basin.

The selection of **administrative units** as it is currently approached by Member States presents some limitations

- Not all countries select the same administrative level (ranging from county to NUTS3 or equivalent).
- As a consequence of selecting different administrative units there is a wide disparity between countries on the area covered by the coastal zone. Even if NUTS3 or NUTS3-equivalent units are selected for all the Member States there is quite a disparity on the area covered.

From the literature review and existing practices it is commonly accepted in Europe to use the **10 km buffer** from the coast line. The results show that

- This area integrates all the characteristic coastal ecosystems (following the European Ecosystems Map).
- This area integrates all the coastal cities and the main area of influence.
- Such approach facilitates comparability in terms of total area.

However, extending the analysis integrating the **elevation** component we have identified:

- Coastal areas below 50 m extend far beyond the 10 km buffer (in most cases goes beyond 20 km landwards).
- Extending the elevation to mid coast (250 m) integrates almost all valleys facing the sea.
- From several cases analysed it seems that areas above 500 m could not properly be considered coastal zone. Those areas are more related to the inland mountains or plateaus.

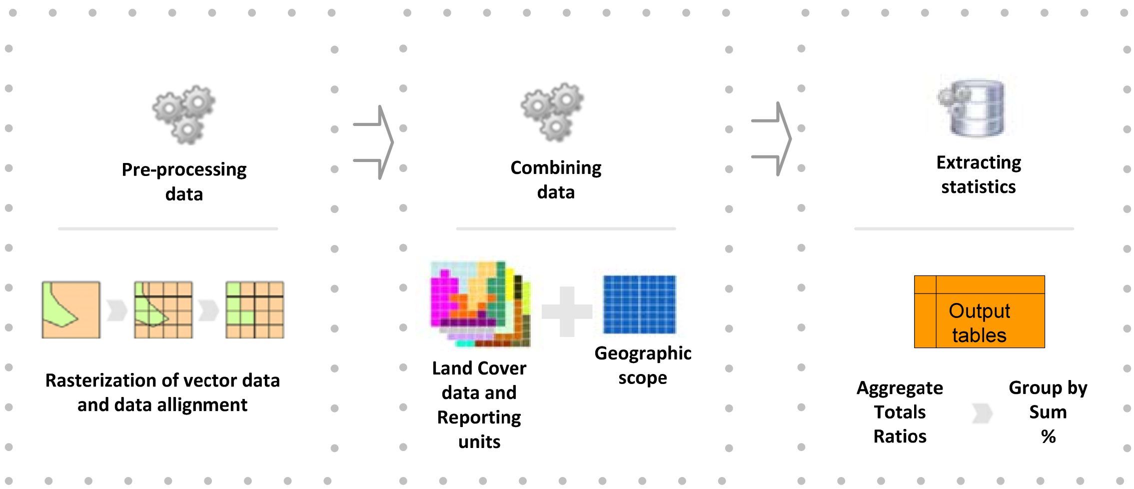
Annex III. Methodology

This section describes the technical procedure that should be carried out to implement the analysis of land use changes in the Adriatic region.

3.1 Data preparation and data processing

The methodological process consists on different steps that can be summarised as:

- Pre-processing data
- Combining data
- Extracting statistics



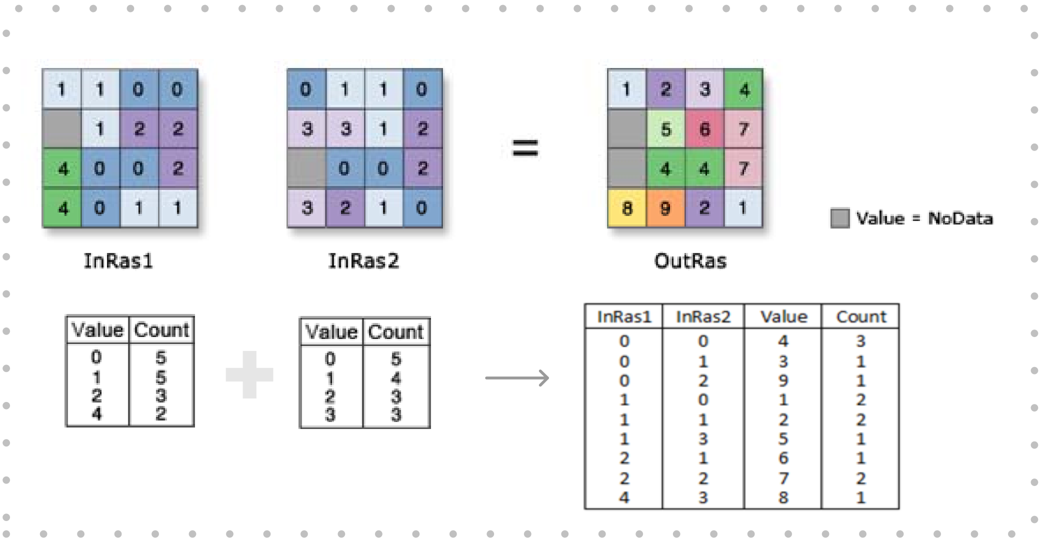
- **Pre-processing data**

The main object of these processes is to prepare the different datasets that will take part in the analysis. It is needed to rasterize those vector data, aligning all the produced rasters to a reference dataset (in this case, Corine Land Cover dataset). The 'Maximum area' criterion is used, as it is one of the most standard methods for rasterization processes.

An adjustment to an extent of analysis should be applied to all the input datasets. This extent of analysis will be determined by the dataset covering the maximum area. Moreover, and considering the following combine step, all 'no-data' values should be reclassified to 0 in order to be computed by the combine tool.

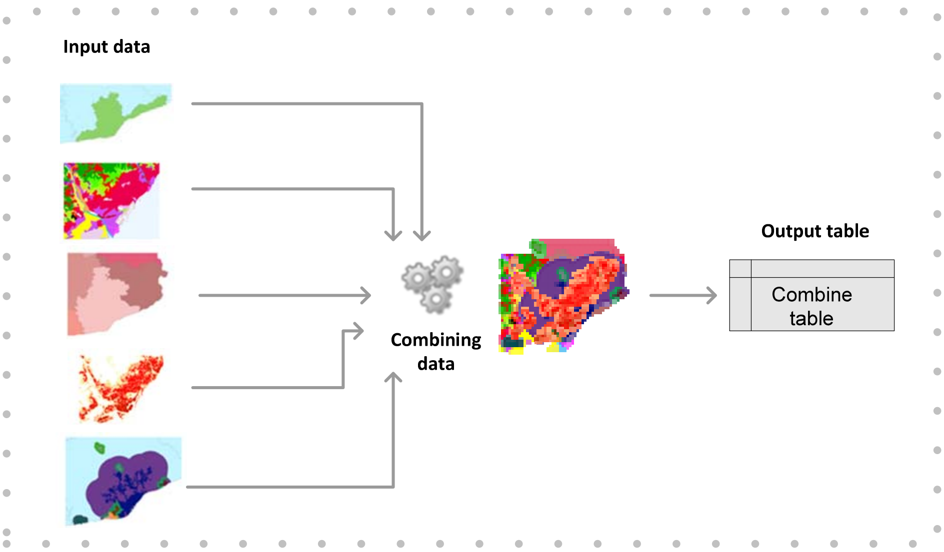
- **Combining data**

The combine technique computes the unique combination of values from multiple input rasters.



In this case, we are combining all the datasets that are participating in the analysis:

- Baseline land cover data (y0, y1, and y2): CORINE Land Cover 2000 and 2006. When available, CORINE Land Cover 2012.
- Dominant landscape data (y0): Dominant Landscape Type 2000
- Land cover change data (y0-y1)
- Land cover flows (y0-y1)
- Administrative units: Coastal NUTS3
- Elevation data categorised by three altitude classes: up to 50 m, up to 300 m and above 300 m.
- Distance to the coast differentiating the setback influence, 1 km and 10 km stripes.



- Extracting statistics

In order to compute the different parameters for the indicator, some statistics must be extracted by means of aggregating data, summing up totals and calculating percentages.

3.2 Indicator land use change

State of land cover classes at different time shots (y0, y1 and y2)

The state of land cover structure is used to describe the important land cover units in the defined coastal region and to identify how these units are spatially distributed.

- Steps

Taking the combine table, an aggregation ('group-by') by the different analytical units has to be done and summing up the total amount of hectares. That is, by land cover classes (at level 2), by distance-to-the-coast classes, by altitude, by dominant landscape type and by NUTS3.

- Output

The expected output is the coverage of land cover classes at the different time shots, total area in hectares (ha) per each of the analytical units (distance-to-the-coast classes, by altitude, by dominant landscape type, and by NUTS3).

NUTS3	Land cover classes (level 1)	Land cover classes (level 2)	y0 - 2000	y1 - 2006	y2 - 2012
NUTS code	Artificial surfaces	Residential (high density)	ha	ha	ha
		Residential (low density)	ha	ha	ha
		Industrial, commercial and transport units	ha	ha	ha
		Mine, dump and construction sites	ha	ha	ha
		Artificial, non-agricultural vegetated areas	ha	ha	ha
	Agricultural areas	Arable land	ha	ha	ha
		Heterogeneous agricultural areas	ha	ha	ha
		Pastures	ha	ha	ha
		Permanent crops	ha	ha	ha
	Forest and semi natural areas	Forests	ha	ha	ha
		Open spaces with little or no vegetation	ha	ha	ha
		Scrub and/or herbaceous vegetation associations	ha	ha	ha
	Water bodies	Water bodies	ha	ha	ha
	Wetlands	Wetlands	ha	ha	ha

Land take intensity (y0-y1)

The intensity of land take represents a proportion (%) of a specific area that has changed between two land cover inventories from a non-artificial to an artificial area.

- Steps

From the previous baseline table, here there are only considered the artificial classes in y1 that were non-artificial in y0. The total amount of land take is divided by different analytical units to compute the percentage.

- Output

The output table represents the percentage of land take per each analytical unit. In the following example by dominant landscape type:

Dominant Landscape type	Land cover classes (level 2)	y1 - 2006	% of dlt
Artificial dominance	Residential (high density)	ha	%
	Residential (low density)	ha	%
	Industrial, commercial and transport units	ha	%
Dispersed urban areas	Residential (high density)	ha	%
	Residential (low density)	ha	%
	Industrial, commercial and transport units	ha	%
	Artificial, non-agricultural vegetated areas	ha	%
Broad pattern intensive agriculture	Residential (high density)	ha	%
	Residential (low density)	ha	%
	Industrial, commercial and transport units	ha	%
	Artificial, non-agricultural vegetated areas	ha	%
Rural mosaic and pasture landscape	Residential (high density)	ha	%
	Residential (low density)	ha	%
	Industrial, commercial and transport units	ha	%
Forest landscape	Artificial, non-agricultural vegetated areas	ha	%
Open semi-natural or natural landscape	Mine, dump and construction sites	ha	%
Composite landscape	Industrial, commercial and transport units	ha	%

<u>Percentage of Land cover types taken by urban development</u>

It is also interesting to analyse the origin of land cover modified by land take.

- Steps

From the first baseline table, and filtering by the artificial classes in y1 that were non-artificial in y0, the focus is the land cover classes at y0. The total amount of land take is divided by different analytical units to compute the percentage.

- Output

The output table represents the percentage of land take per each analytical unit. In the following example by the distance to the coast:

Distance to the coast	Land cover classes (level 2)	y1 - 2006	% of dist
< 50 m	Arable land	ha	%
	Heterogeneous agricultural areas	ha	%
	Pastures	ha	%
	Permanent crops	ha	%
	Forests	ha	%
	Open spaces with little or no vegetation	ha	%
	Scrub and/or herbaceous vegetation associations	ha	%
	Water bodies	ha	%
	Wetlands	ha	%
50 – 300 m	Arable land	ha	%
	Heterogeneous agricultural areas	ha	%
	Pastures	ha	%
	Permanent crops	ha	%
	Forests	ha	%
	Open spaces with little or no vegetation	ha	%
	Scrub and/or herbaceous vegetation associations	ha	%
	Water bodies	ha	%
	Wetlands	ha	%
> 300 m	Arable land	ha	%
	Heterogeneous agricultural areas	ha	%
	Pastures	ha	%
	Permanent crops	ha	%
	Forests	ha	%
	Open spaces with little or no vegetation	ha	%
	Scrub and/or herbaceous vegetation associations	ha	%
	Water bodies	ha	%
	Wetlands	ha	%

Proportion (%) of the area of built-up land in the wider reference region

- Input data

Land Cover data: CORINE Land Cover 2000 and 2006. When available, CORINE Land Cover 2012.

Coastal region: 10 km buffer

Administrative units: NUTS3

- Steps

From the first baseline table data is filtered by artificial classes at y0 by 10 km strip and NUTS3.

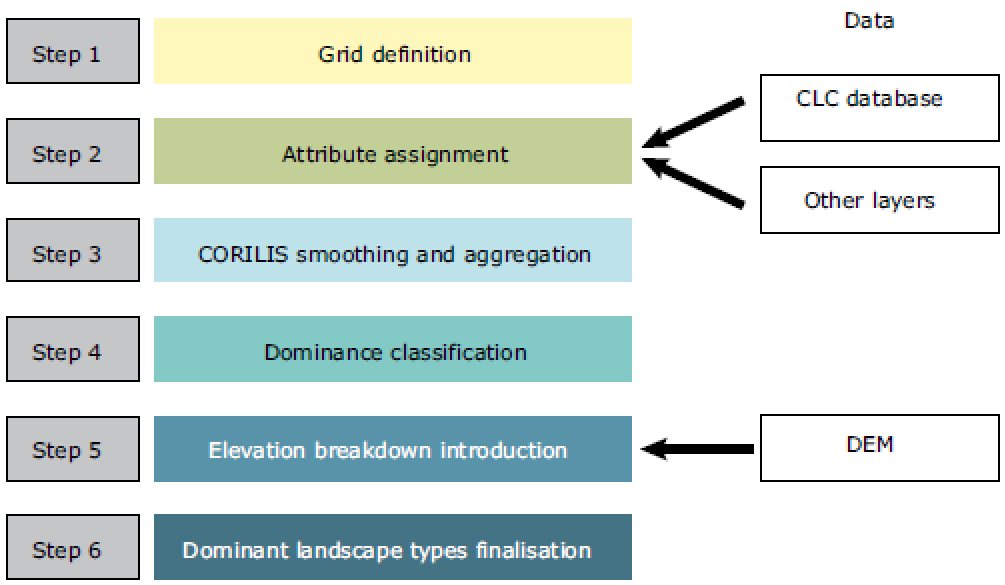
- Output

Percentage of built-up in coastal units as a proportion of the area of built-up land in the wider reference region (NUTS3).

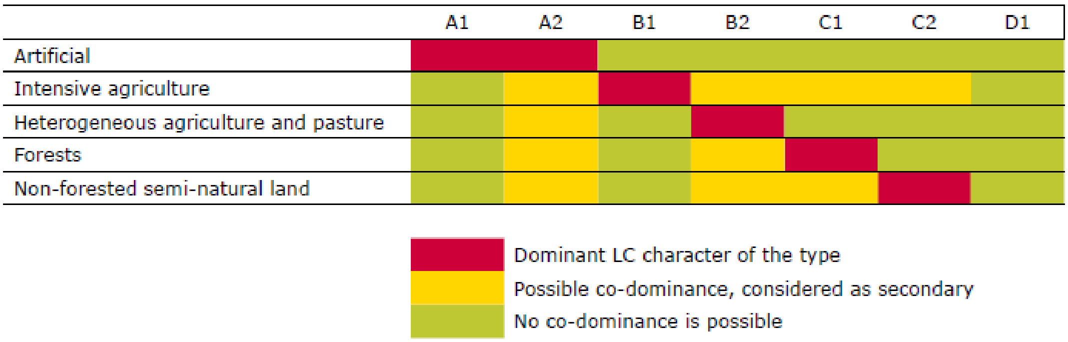
3.3 Indicator 8.2.2 Change of landscape types indicator

Landscape types

The approach, which is summarised in the figure below, is based on a six step process that involves combining the results of applying the CORILIS smoothing algorithms to the underlying CLC cover data for the seven major cover types, and intersecting the results with a set of discrete relief classes derived from a digital elevation model.



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



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

3.4 Indicator 8.2.3 Share of non-fragmented coastal habitats indicator

The indicator shows the change on the average size of patches of natural and semi natural areas, on the basis of land cover maps produced by photo-interpretation of satellite imagery.

Natural and semi-natural areas are represented by selected land cover categories which are forests, pasture, agricultural mosaics, semi-natural land, inland waters and wetlands. For a given region/ country, the change in average patch size of the selected land cover categories is the difference between two dates in their mean value, calculated as their quadratic mean.

The indicator is produced by using a simple mathematical calculation, the quadratic mean between the mean values of the patch size of a given area between two dates. By using the quadratic mean, the size of the individual objects matters as much as their number; in most cases, strong fragmentation of the larger areas matters more than fragmentation of small ones. At the same time, when a small patch in an area disappears completely (in time 2), the mean value for that area will be greater than at the time it was still present (time 1), unless the number of patches (n) in time 2 cannot be less than in time 1. That means that patches with size = 0 have to be taken into account too.

The Quadratic Mean or Root Mean Square (RMS) is the square root of the mean square value of a variable so it is a statistical measure of the magnitude of a varying quantity. It can be calculated for a series of discrete values or for a continuously varying function, using the following formula:

Quadratic Mean or Root Mean Square = SQRT (1/n ((X1)2 + (X2)2 + (X3)2 +........+ (Xn)2)

where X = Individual score and n = Sample size (number of scores or units)

Calculation can be done by NUTS level 2 or 3, or by river basin, as well as by country and biogeographical zone. The analysis can be done separately for different classes of patch size (e.g. large, medium and small), in order to capture specific trends and avoid some bias mentioned previously.

ANNEX IV. Analysis of existing approaches

European level

At the European level the first experience of LC changes analysis focused on coastal areas is the LACOAST project. The objective of the project was:

- Quantify land cover changes of the European coastal zones for a period of 20 years (1970-1990).
- To contribute to demonstration programme of ICZM
- To support reporting on the state of environment by the European Environment Agency, providing information that would allow to deriving environmentally related indicators.

In order to attain these objectives and to identify the analytical units the project conducted an in depth analysis on land cover classes as a function of the distance from the coastline. The analysis demonstrated that over 10-15 km from the coastline, percentages of surfaces occupied by the different land cover classes become relatively constant. Therefore the inland limit of the coastal zone was taken considering the lower boundary of the steady zone: 10 km. For the analysis the following data was used: the CLC90 database and Landsat MSS satellite images from the 1970s (V. Perdigao and S. Christensen, 2000). Changes of LC in the quoted period included five LC change flows: urban development, agricultural development, afforestation (wasteland), swamping and creation of water bodies. The major outcome of the project was and Atlas of land cover changes of European coastal zones.

Since 2001, the European Environment Agency (EEA) has developed a reference work for European land take indicator and land cover flows, with special focus on coastal assessment (EEA, 2006). The previous work developed on the LACOAST project was a starting point for this comprehensive analysis. It is interesting to observe that the data available at that time (Table 1) has not shown a big improvement. Only the update of CLC to CLC2006 (and CLC 2012 to come later on 2015) could be added to the previous list. Although the report had a complete overview on the all land use changes, there were a specific focus on land take including the following indicators:

- Share of built-up in the 0-1 and 1-10 km coastal strips for each NUTS3 region
- Land take as percentage of increases of built-up in the 0-1 and 1-10 km coastal strips for each NUTS3 region.

Table 0:1Data used on the report "The changing faces of Europe's coastal areas" (EEA, 2006).

Databases available for this report

Data source	LaCoast database	Corine land cover 1990	Corine land cover 2000	Corine coastal erosion	Natura2000 database	Eurosion
Data custodian	JRC	EEA	EEA	EC/EEA	DG ENV	DG ENV
Status	Finished	Finished	Finished	Historical	Version 2004	Finished in 2004
Responsible authority	JRC and DG ENV	European Commission — DG Environment, Nuclear Safety and Civil Protection	EEA	EEA	DG ENV is the owner of the database. Management by ETC-BD	DG ENV
Period – Start date	1975–1976, depending on the country	1986	1999	1985	Staring network in 1992	January 2002
Period – End date	1986–1995, depending on the country	1995	2001	1990	On-going	May 2004
Data availability	100 %	100 %	100 %	100 %	100 %	Depending on the layer
Geographic coverage	10 Member States of the EU (Belgium, Denmark, France, Germany, Greece, Ireland, Italy, Netherlands, Portugal, Spain)	EU-25 (with the exception of Finland, Greece, Sweden, United Kingdom, Cyprus, Malta), Bulgaria and Romania	EU-25 Member States of the EU and Liechtenstein	EU-12 Member States except the Greek Islands, former German Democratic Republic, Madeira and Azores	EU countries (EU-15 plus several EU-10 and accession countries)	EU-15, Bulgaria, Cyprus, Estonia, Latvia, Lithuania, Malta, Poland, Romania, Slovenia and European ultra-peripherical regions
Spatial resolution	Minimum mapping unit 25 ha	Minimum mapping unit 25 ha	Minimum mapping unit 25 ha	Minimum mapping unit 25 ha	Depending on Member States	Depending on the layer
Temporal coverage	2 periods: 1975–1976 and 1986–1995	1990 +/- 5	2000 +/- 1 year	1990 +/- 5	Depending on Member States	Depending on the layer
Quality	Accuracy ≥ 85 %	Accuracy ≥ 85 %	Accuracy ≥ 85 %	Accuracy ≥ 85 %	Depending on Member States	Depending on the layer
Access conditions	Agreed dissemination policy from the start	Dissemination policy available	Agreed dissemination policy from the start	Dissemination policy available	Agreed dissemination policy from the start	Depending on the layer

BIOPRESS GEOLAND project focuses on the identification of historical changes (1950 – 1990 – 2000) in LC for the purpose of measuring changes in habitats and their biodiversity. The types of LC changes (as determined by the 44 CLC) were grouped and renamed to represent types of 'pressure' on biodiversity, such as urbanisation, arable intensification, abandonment, afforestation, deforestation, and drainage (Köhler et al., 2006).

R. Haines-Young and J.-L. Weber, 2006present the most extensive and detailed document about land accounting based on the CLC data. It contains nine major types of LC flow (LCF) and also a more detailed flow account. The following nine LC flows were described: LCF1 – urban land management, LCF2 – urban residential sprawl, LCF3 – extension of economic sites and infrastructures, LCF4 – agriculture internal conversion, LCF5 – conversion from forested and natural land to agriculture, LCF6 – withdrawal of farming, LCF7 – forest creation and management, LCF8 – water body creation and management, LCF9 – changes of LC due to natural and multiple causes.

The concept of LC flows was also applied to the Burkina Faso territory (Jaffrain, 2006). Two LC databases of 1992 and 2002, named BDOT (*Base de donnees d'occupation des terres*) are derived from the CLC nomenclature and specification but are adapted to the Soudan-Sahelian region. The objective was to show among other things, the main trend and pressure over the natural and semi-natural areas (forest, savannah, and steppe) that took place between 1992 and 2002. Thus, nine flows (at the first level) have been identified showing the 'stock' available for some LC classes in the different LC data, and providing also the changes (both in terms of quantity and quality) in this decade between different LC works.

At the Mediterranean level

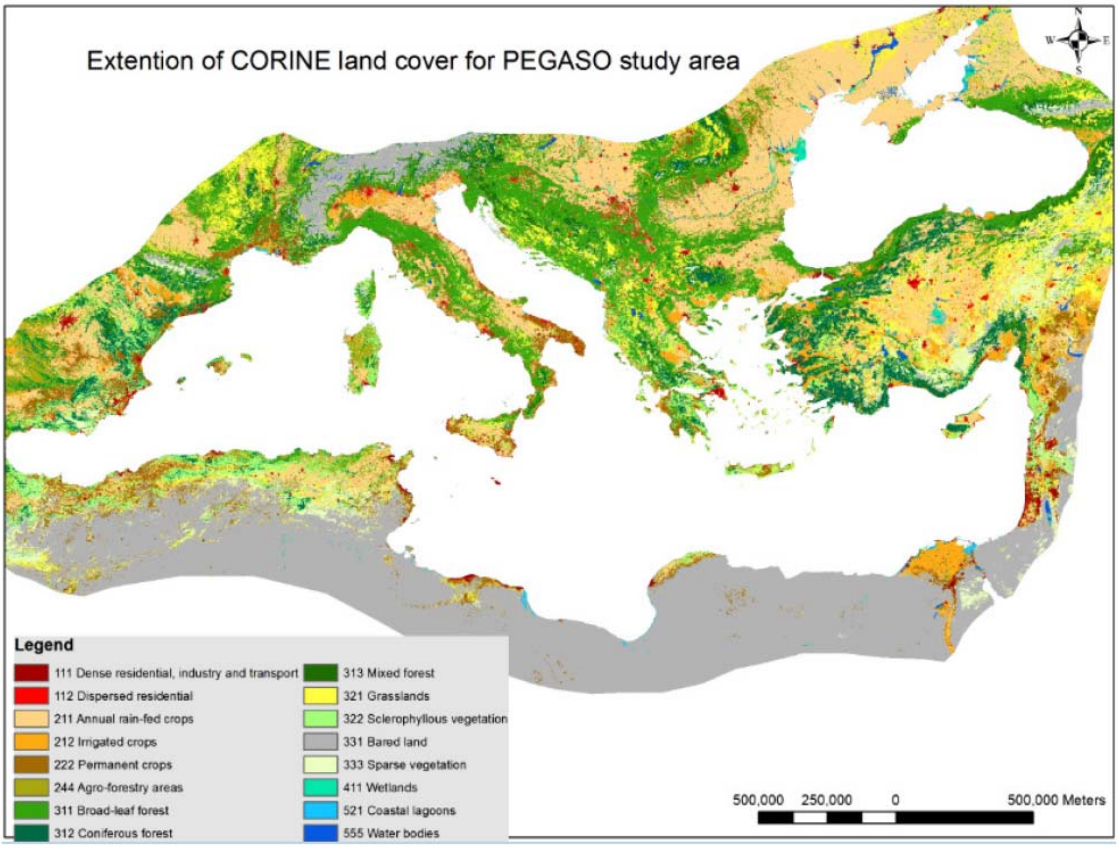
In the EU FP7 project PEGASO, a PEGASO Land Use has been produced for the whole Mediterranean and Black Sea basins. Building on a Corine Land Cover simplified classification, to adapt the land uses to the non- European countries, PEGASO land cover has used all relevant and available satellite images to cover both basins. The land use map has been done at year 2000 and 2011.

The classes developed under PEGASO project are quite similar to the CORINE LC. The nomenclature was modified by merging some classes and excluding others in order to ensure relative differentiation of the retained classes 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'.

Table 0:2 Hierarchical nomenclature for PEGASO land cover derived and adapted from CORINE LC.

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)

Figure 0:9 Map of land cover classes for the Mediterranean region developed under the PEGASO project



For the purpose of analysis of land cover changes the following grouping of land cover classes were considered:

- Urban artificial covers
- Intensive agriculture
- Mixed and extensive agriculture
- Forest
- Grassland
- Scrubland
- Desert and sparse vegetation
- Wetlands
- Water

The focus of the analysis was on urban developments and natural capital status and trends. It was a first prototype for this regional cover, allowing comparisons among countries, regions and, local PEGASO sites. Moreover, the spatial indicators developed on these issues were integrated in the PEGASO Indicator set to assess sustainable development at the coast in the context of the ICZM Protocol for the Mediterranean, and similar policy for the Black Sea.

Figure 10 shows the trend on coastal urbanisation. The project adopted three analytical units:

- 1 km
- 10 km
- 50 km

The 50 km was taken as a reference for the ICZM protocol since it was not possible to extract all the administrative units.

Figure 0:10Degree of coastal urbanization in year 2011 for the Mediterranean and Black Sea countries, expressed as a percentage from the total area for three coastal buffers within each