UNEP/MAP WG.549/Inf.3

27 February 2023
Original: English

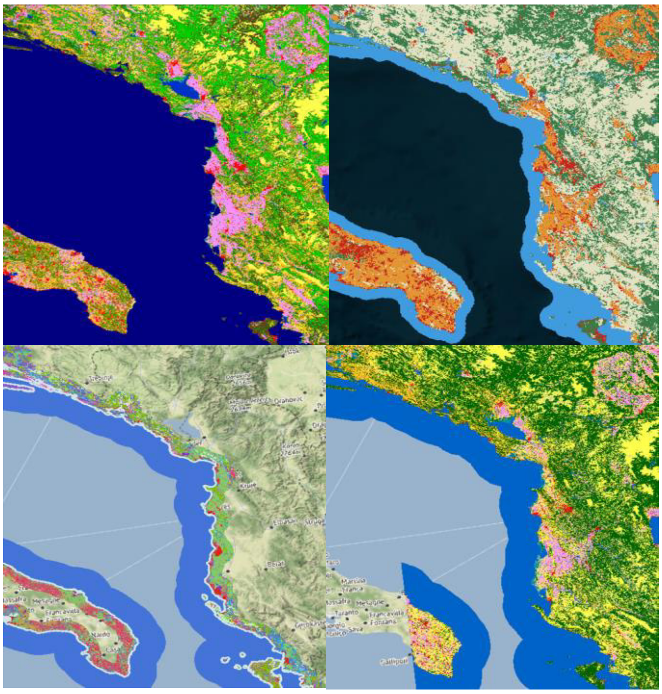
Meeting of the Ecosystem Approach Correspondence Group on Monitoring (CORMON) Coast and Hydrography

Marseilles, 28-29 March 2023

Agenda item 5: The Guiding Factsheet for the Candidate CI 25 "Land cover change"

Upgraded Guidance Factsheet for Candidate Common Indicator 25 "Land cover change" – Rationale and background

UNEP/MAP PAP/RAC
Split, 2023



Upgraded Guidance Factsheet for Candidate Common Indicator 25 “Land cover change” - Rationale and background

August 2022

Authors:

Martina Baučić, Antonio Morić Španić, Frane Gilić

Contents

1. Introduction

This report elaborates on the proposal for the upgrading of the Guidance Factsheet for the Candidate Common Indicator on Land cover change (LCC) 25 [1] of the Integrated Monitoring and Assessment Program (IMAP) of the UNEP/MAP Ecosystem Approach (EcAp) initiative (hereinafter LCC indicator 25) as approved by the EcAp Coordination Group meeting held in September 2019. The meeting recommended to test it and propose improvements if needed. The GEF Medprogramme project provides an opportunity to test this indicator and in the following chapters some improvements are presented and justified.

The Mediterranean Sea Programme: Enhancing Environmental Security (MedProgramme) addresses major present and future threats to environmental sustainability and climate related impacts. The seven child projects funded by the Global Environment Facility (GEF) over the 2021-2025 period aim to kick start the implementation of priority actions to reduce the major transboundary environmental stresses affecting the Mediterranean Sea and its coastal areas, while strengthening climate resilience and water security and improving the health and livelihoods of coastal populations. This task was developed under the MedProgramme child project 2.1 Mediterranean Coastal Zones: Water Security, Climate Resilience and Habitat Protection, Activity 1.1.1. Development of the materials for the consultations in support of Integrated Coastal Zone Management (ICZM) Protocol ratification/implementation.

The LCC indicator 25 aims to support implementation of the ICZM Protocol, particularly related to the balanced allocation of uses, preserving open coastal space, securing setback zones, avoiding urban sprawl by limiting linear extension of urban development including transport infrastructure along the coast and securing ecosystem health. These objectives are among the most important ones of the ICZM Protocol. Being a Candidate Common Indicator, the land cover indicator is still in a testing phase. Thus, the Guiding Factsheet adopted by the EcAp Coordination Group in 2019 (hereinafter CCI 25 Guidance Factsheet) [1] is reviewed and updated including more extensive use of elevation data to adapt this indicator to be used for identification of low-lying coastal zones that are under complex risks caused by coastal flooding, erosion and salinization. The analytical units are upgraded with low elevation coastal zone and new indicator’s parameters are introduced. Also, due to the availability of satellite data as open source of higher resolution proposals of more detailed mapping units and change detection are proposed.

The following sections of the report include description of the methodology used for elaboration of the proposal, rationale for the indicator upgrade with regard to the assessment outputs, i.e. additional analytical unit (Low Elevation Coastal Zone) and description of upgraded indicator's parameters. As more and more free/open data is available today including land cover data and elevation data derived from the satellite imageries, the report provides a list of available data for calculation. Based on the findings, the report elaborates proposals for upgrading the current methodology for indicator calculation and ends with a summary of proposed changes. Annex 1 includes the proposal for upgrade version of the CCI 25 Guidance Factsheet [1]. One more report is elaborated in the iteration with this report: the Manual (step-by-step) for calculation of the proposed upgraded LCC indicator 25.

2. Methodology

The development of proposals for upgrading the current methodology for LCC indicator 25 included various work, from desktop search to iteration and consultation with another activity that was performed simultaneously: Testing and validation of the proposed methodology upgrade on the pilot sites. The elaboration of the upgraded LCC indicator 25 was an iterative process. Firstly, the initial proposal of analytical units and upgraded indicator parameters related to elevation breakdown was developed (referring to the Additional analytical units under step/point 7/b of the Guiding Factsheet [1]). After the testing and validation process were completed, the proposal for upgrading LCC indicator 25 could be revised and finalized. Thus, the upgraded CCI 25 Guidance factsheet together with the Manual for indicator calculation could be finalized as well.

To successfully combine expertise from the both activities: upgrading the indicator and testing and validating, the joint expert team was formed and joint tasks are executed as shown on the Figure 1.

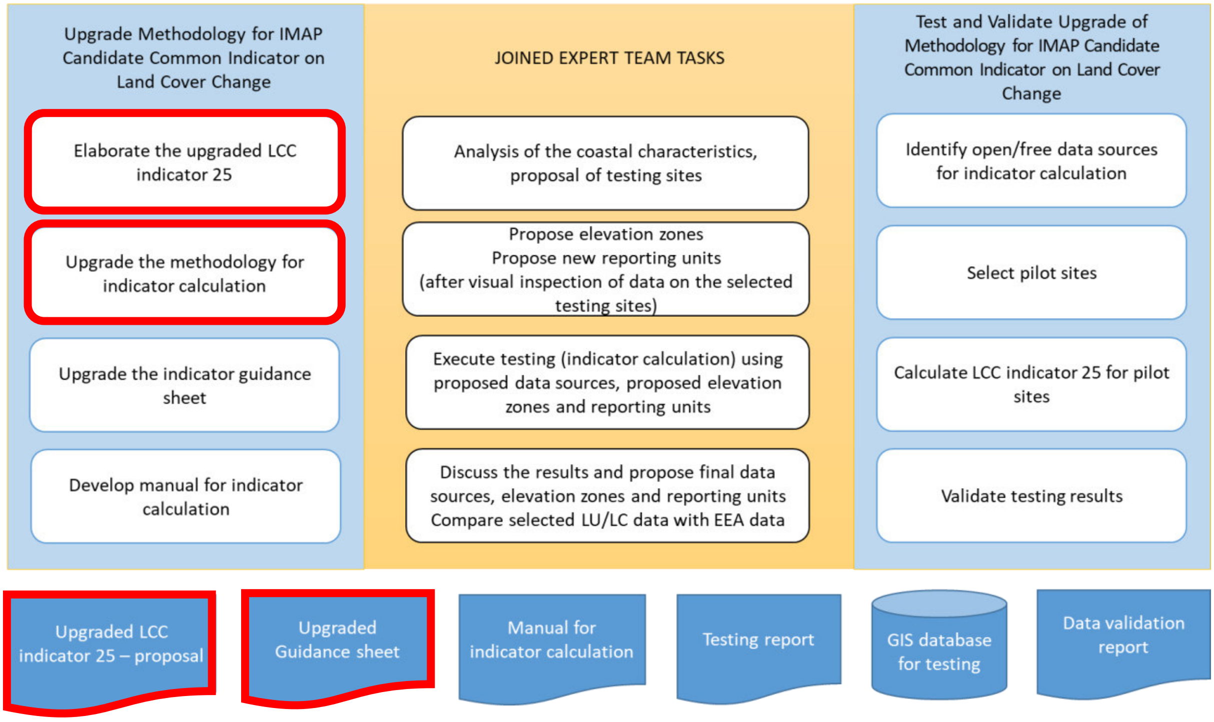


Figure 1: Main steps and deliverables in development of proposals for the upgraded LCC indicator 25 (red coloured elements highlights the tasks elaborated within this report and the report itself)

The following steps are performed and described within this report:

a) elaborate the upgraded LCC indicator 25;

b) upgrade the methodology for indicator calculation.

The first part of the work elaborates the rationale for the indicator upgrade with elevation zones. The extensive study of the significance of elevation zones in the coastal area is performed (in the context of Indicator25 LCC main goal) and conclusions are drawn. Special emphasis is given to the adaptation of coastal zones to climate changes and most appropriate altitudes for elevation zones are proposed. Most relevant scientific references are added as the supplement to the proposal.

The second part proposes the creation of new analytical units and new indicator's parameters for first and every next monitoring. New analytical units could be a combination of coastal zone or/and strips, administrative borders and elevation zones. The rationale for proposed one is explained supported by the relevant scientific references.

Based on the results of testing and validation [2, 3], the third part summarizes findings about adequacy of open data sources for upgraded LCC indicator 25 calculation. However, the objective was to have open data that are available for the whole Mediterranean region. Special considerations are given to adequacy of the classification schemas for the land use/land cover change, temporal and positional resolution. The most appropriate open data sources are proposed in this report. The European Environment Agency (EEA) various products are considered together with Copernicus Land Monitoring Service and Sentinel Data Products. Since 2017, data sources are providing better positional resolution and thus the current LCC indicator 25 minimum mapping units of 25 ha and 100 m for linear elements are revised, as well as minimum change detection area of 5 ha. Thus, the fourth part elaborates the methodology for upgraded indicator calculation and proposes the new minimum mapping units and minimum change detection.

Based on the work described above, the upgraded CCI 25 Guidance Factsheet is drafted and after the testing and validation phase, the final version is elaborated and given in Annex 1 of this report. Finally, based on all the results, the manual (step-by-step) for calculation of the proposed upgraded LCC indicator 25 is developed [4]. The manual preferably include use of open-source software wherever suitable.

Preliminary results were discussed with the PAP/RAC representatives during three meetings. The first meeting was held in January 2022 and the second one beginning in March 2022: the both in the PPA/RAC premises. The third meeting was held in March 2022 as an online meeting with the participants from the PAP/RAC team, European Environmental Agency experts and external experts working on testing.

3. Rationale for indicator upgrade with elevation zones

The upgrade of the LCC indicator 25 should strengthen implementation of the ICZM Protocol and thus ultimately foster sustainable development of coastal zones. Balanced allocation of uses, preserving open coastal space, securing setback zones, avoiding urban sprawl by limiting linear extension of urban development and securing ecosystem health are the most important objectives of the ICZM Protocol. The LCC indicator 25 serves particularly IMAP Ecological Objective 8 “The natural dynamics of coastal areas are maintained and coastal ecosystems and landscapes are preserved”.

Current Candidate Common Indicator 25 LCC includes land use/land cover change of purpose to which land is profited by humans. Therefore, the urbanization pressures on coastal ecosystems are identified. In the context of climate changes and particularly the coastal flooding, the pressures on the coastal ecosystems are becoming more complex. Since low urbanized areas prone to coastal flooding potentially generate more pressures over coastal ecosystems such as pollution of coastal waters, it is important to consider coastal flooding risks together with land take. Moreover, there are many direct impacts of coastal flooding on coastal ecosystems and landscapes such as erosion and salinization particularly effecting beaches, wetlands and river deltas. This is the reason why Low Elevation Coastal Zone is added as analytical unit. In this way the information generated with this indicator will allow multiple analyses and synergies, such as between the evolution of coastal zones, mainly urbanization and climate change.

Keeping in mind that the main objective is to maintain the natural dynamics of coastal areas and to preserve coastal ecosystems and landscapes, and that urbanization or land take is an almost irreversible process, the upgraded indicator should provide an inventory of the urbanization pressures on coastal ecosystems. Intensification of dynamic spatial processes in the coastal area has stimulated the need to expand and supplement LCC Indicator 25. In order to gain a better insight into anthropogenic pressures on terrestrial habitats and opportunities to prevent coastal floods (driven by increasing climate change) they need to be related to elevation zones.

The following chapters elaborates and justify introduction of elevation zones as additional analytical units in the context of habitat distribution and coastal flooding.

3.1. Habitats

The current CCI 25 Guidance Factsheet [1] describes Additional analytical units under step/point 7/b of the statistical analysis as follows: *"Elevation breakdown within the coastal area. Distance to the coast and elevation are elements that configure different habitat distribution and patterns. With available local knowledge 3 to 5 elevations classes could be considered to be analysed independently within the coastal area in order to better link the pressure of land take to specific habitats. An example follows: < 50 m asl, 50 – 300 m, >300 m)."*

The coasts of the Mediterranean Sea vary in terms of climatic conditions, geomorphological characteristics and others. Therefore, the elevation breakdown with the aim of better differentiating habitats (in addition to the distance to the sea, as suggested by the CCI 26 Guidance Factsheet), should be done individually per each geographic region. An initial elevation breakdown is elaborated below, as starting point for further modification according to the local conditions.

By analysing the spatial characteristics of the coastal area, land cover / land use categories, spatial processes caused by anthropogenic impact and biogeographical specifics of the Mediterranean area, the initial elevation breakdown is given in Table 1.

Table 1: Initial elevation breakdown considering habitat types for the Mediterranean coastal area

Elevation zones (meters above sea level)	**Spatial characteristics**
< 5	low-lying terrain, wetlands, water bodies
5 - 10	low-lying terrain, intensive land take processes
10 - 50	mostly urbanized areas, agricultural areas
50 - 100	trend to urbanization, land abandonment
100 - 300	dominance of forests and semi-forests areas
> 300	dominance of forests

Further modification of the above elevation zones according to local conditions asks to decide on a classification scheme of terrestrial habitats. Today, the International Union for Conservation of Nature (IUCN) habitat classification scheme is widely used and has been selected as the relevant global habitat inventory framework [5]. The global map of terrestrial habitats was created using the IUCN habitat classification scheme [6]. The level 1 of IUCN scheme has 8 habitat classes, which are then subdivided into lower subclasses as illustrated in Figure 2 [7]. An insight into spatial distribution of the terrestrial habitats could help in determining more specific elevation zones adequate for a particular region. Figure 3 depicts global habitat map for the year 2015 available through Google Earth Engine online service.

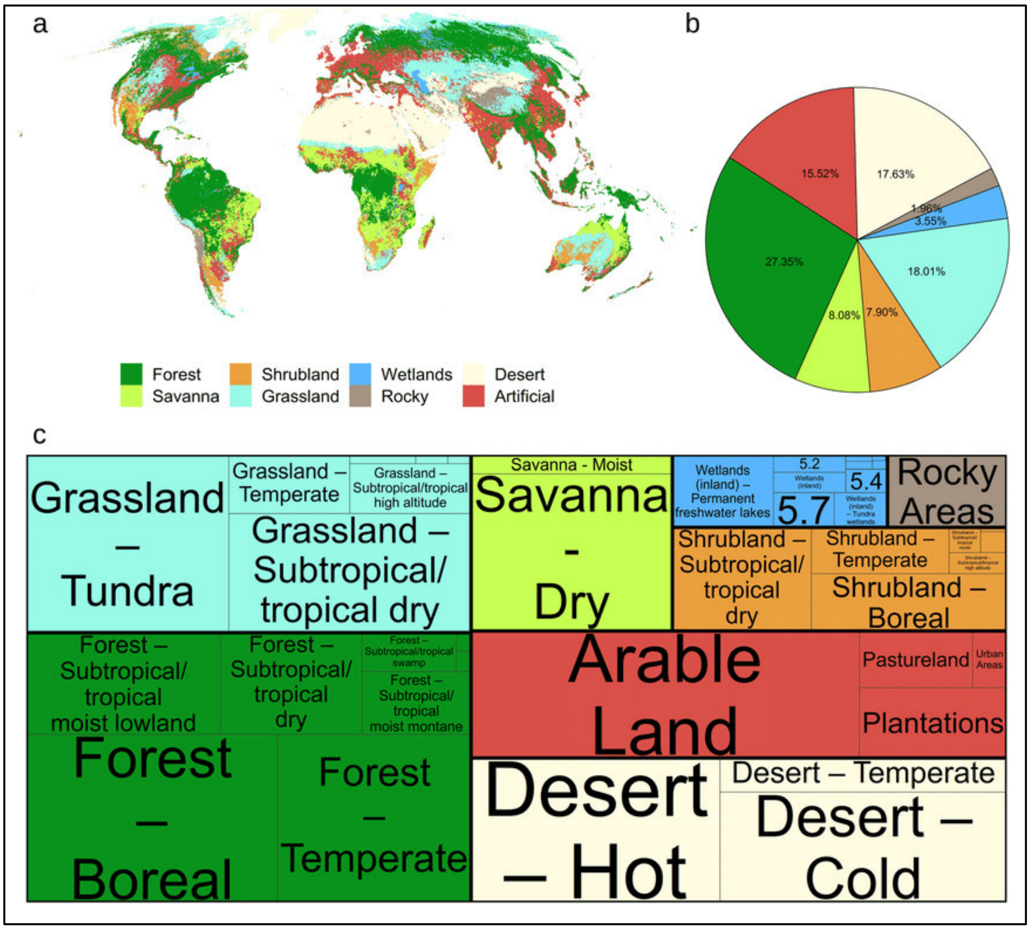


Figure 2: The IUCN habitat classes globally [5]

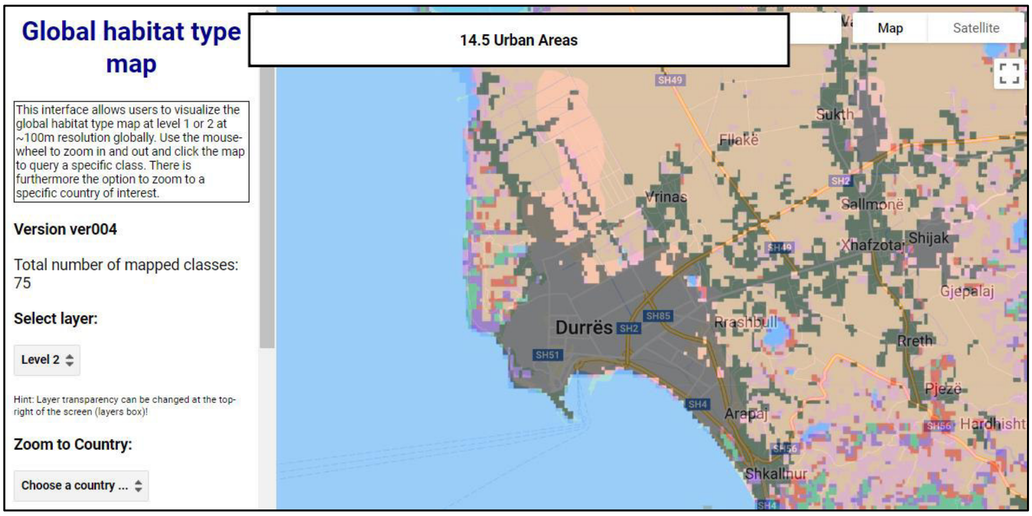


Figure 3: Global habitat type map online service [6].

3.2. Low Elevation Coastal Zone

The urbanization pressure on coastal ecosystems is identified as main threat in the CCI 25 Guidance Factsheet [1]. Land take as irreversible process has negative impacts such as habitat loss and fragmentation. In addition to urbanization, coastal zones are exposed to natural hazards of which coastal flooding, erosion and salinization have the most significant impacts [8]. Due to climate change, an increase of risks in coastal zones is foreseen on natural and built environment. Figure 4 provides the summary of assessment of observed hazards to coastal ecosystems and seas by climate and non-climate drivers. According to [10], the severe disturbances on Mediterranean coasts are due to sea level rise impacts together with reduced precipitation and prolonged droughts; and to intensive urbanization. Relative sea level change is a main driver causing risks in low-lying coastal areas, particularly in river deltas, lagoons, wetlands, along sandy beaches and in many coastal settlements [8, 9]. Particularly, the extreme storm surge events induce impacts on coastal zones: direct (e.g. flooding, erosion and damages to the built assets) and indirect ones (e.g. salt intrusion, water supply contamination and coastal water pollution) [11, 12]. Sandy beaches are projected to be more and more affected by erosion and eventually disappear [8]. The main impacts of sea level rise to natural environment identified in [14] are the following:

- Loss of coastal habitats, including wetlands, mangroves and beaches;
- Loss of currently dry land to advancing seas;
- Stronger, deeper and more destructive storm surges;
- Worsening coastal erosion;
- Disruption and destruction of shorebird and sea turtle nests;
- Population declines in fishes, shellfish and other species that rely on coastal wetlands for at least part of their lives;
- Population declines in migratory birds — including waterfowl — that rely on coastal habitats during seasonal migrations.

During storm events in low-lying coastal zones, the compound flooding may occur by superimposing high sea levels and heavy precipitation resulting in large run-off volumes of storm waters. In areas with undeveloped storm water systems and sealed urban land, the risks may be amplified. Today, the Mediterranean coasts are at the highest risk of compound flooding [13] and projection are that climate change will increase the risk of compound flooding along most European coastlines.

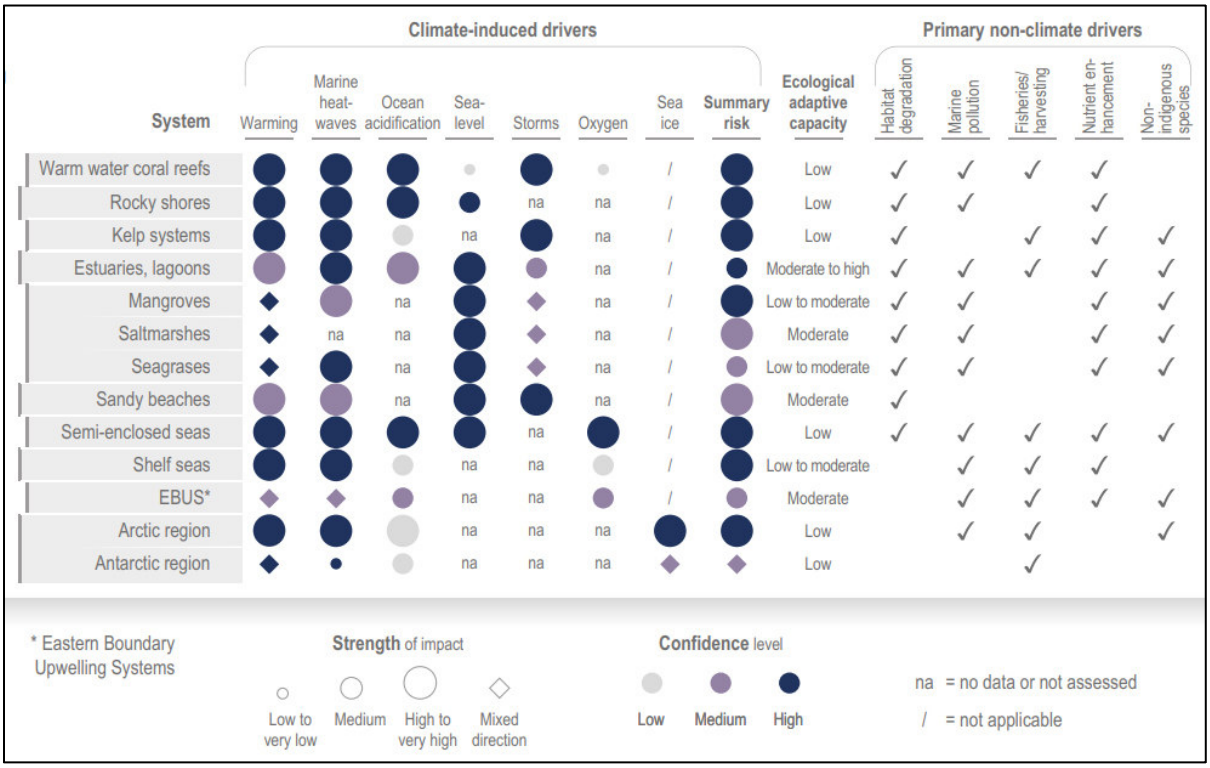


Figure 4: The assessment of observed hazards to coastal ecosystems and seas [8]

Authors in [15] conclude that coastal management in Mediterranean also needs to address long-term problems particularly the coastal flooding, refereeing to the case studies of coastal cities (Venice and Alexandria), deltas (Nile, Po, Rhone and Ebro), and islands (Cyprus).

Sea level change is caused by global seal level rise, astronomical tides, storm surges and waves. There are areas with sinking of land (subsidence) having additional local sea level rise. The projected sea level rise in the Mediterranean potentially reaching 1,1 m at the end of the present century [8]. Figure 5 illustrates projected seal level rise for the Nile delta area under different climate change scenarios.

Mediterranean sea is a micro-tidal having astronomical tides of small amplitude (<0.5m) compared to the extreme positive and negative surface elevation due to storm surges [11]. Exception is North Adriatic where the tidal signal can add up to 30 cm on the 50-year return period sea level height.

In Mediterranean, current storm surges and waves are producing coastal floods that persist for several hours and causes large impacts on coastal natural and built environment [10]. Future projections foresee a decrease in wave heights as well as in number of waves extremes over a Mediterranean [10]. But for most extreme events (storm tide plus storm waves), there are no consensus in projections. For example, the prediction for Venice is an increase of the number and duration of flooding events [8] despite many climatological studies that predict attenuation of storm surges. But then again, the sea level rise will have as a consequence more frequent and severe coastal flooding, as stated by several studies. The report by European Environmental Agency [13] elaborates the following *"..the sea level rise projected for 2100 will increase the frequency of extreme coastal flooding events by a factor of 10 to more than 1.000 along most European coastlines, depending on the location and the emissions scenario.* For Mediterranean region, authors in [12] summarize as follows *"…most of the southern European region does not show significant trends in extreme storm surges; an exception to this are regions as the Alboran Sea, gulfs of Gabes and Sirte, northern Adriatic and the easternmost Mediterranean*". The conclusion in [10] states "*In the future, coastal storms and floods, probably more frequent and intense, will have adverse impacts on ecological balances, as well as human health and well-being, particularly in Mediterranean coastal cities."*

To conclude, even the future climate change impacts are uncertain in terms of occurrences, duration and magnitudes of coastal flooding [13], there is a necessity to consider climate change impacts and incorporate them in coastal planning today [15].

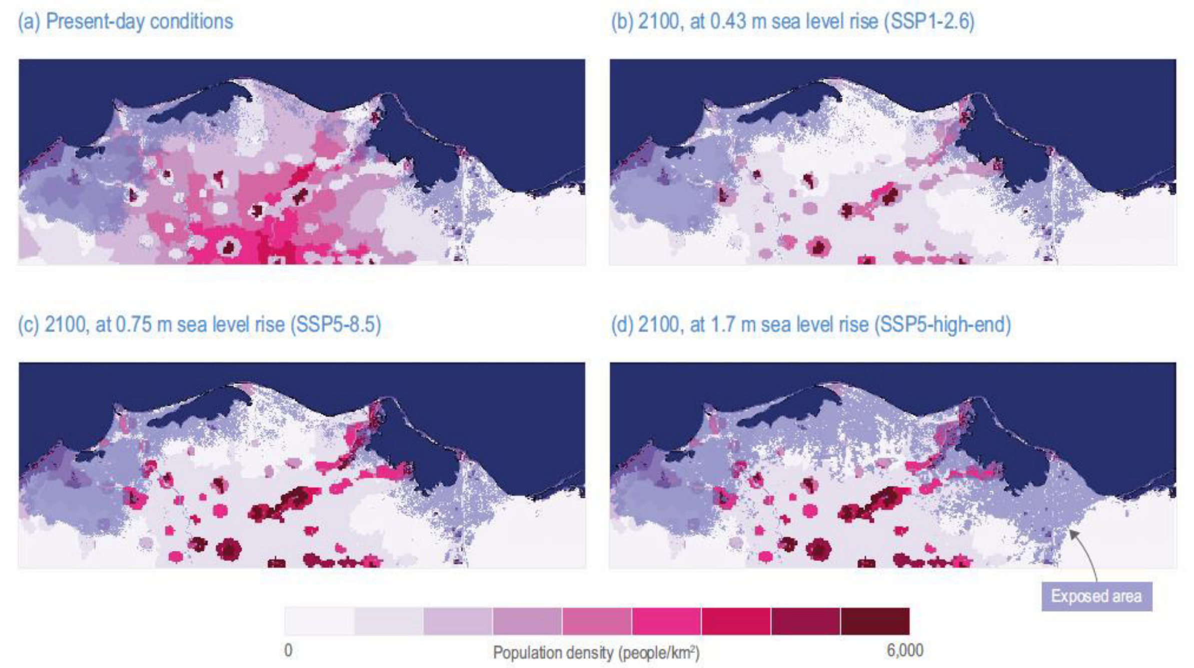


Figure CCP4.6 | Present-day and projected exposure to sea level rise in the Nile Delta, due to sea level change and land subsidence: (a) current exposure, (b) exposure for 2°C of global warming by 2100, (c) exposure for 3°C of global warming by 2100, (d) exposure for a high-end sea level rise scenario involving additional mass losses from the Antarctica ice sheet (Frihy et al., 2010; Ali and El-Magd, 2016; Kulp and Strauss, 2019); sea level scenarios from WG1 AR6 Chapter 9, Fox-Kemper et al., 2021; see Chapter 4 Supplementary Material for additional details.

Figure 5: Land below high-tides in the Nile delta today and projections for year 2100 under three climate change scenarios [8]

The aforementioned rationale about coastal flooding impacts on coastal ecosystems; in terms of ecosystems intensive change by direct impacts but also indirect impacts such as salt intrusion or water pollution; suggest that the new analytical unit should be introduced in the LCC indictor 25. **Thus, the Low Elevation Coastal Zone (LECZ) is proposed as area within the coastal zone prone to coastal flooding, erosion and salinization.** Based on the defined elevation threshold value (e.g. 5 m above sea level), the land area contiguous to the coast below the threshold should be constructed. The indicators on km2 and % of land use/cover should be analysed for the LECZ within each coastal strip/zone.

For the selected time horizon and climate change scenario, the elevation threshold for LECZ should be estimated as the sum of mean sea level rise prediction, astronomical tide, storm surge tide and waves height. As coastal locations have site-specific flooding thresholds due to oceanographic drivers, existing flood defences and coastal morphology [16], the elevation threshold would vary along the Mediterranean coast. As an example for Croatian coastline, the Croatian Waters company elaborates coastal flooding risks with 2,5 m water depth /elevation height [17] adding 0,7 m as sea level rise for SSP5-8.5 climate change scenario for year 2100 equals 3,2 meters above sea level. Figure 6 illustrates elevation zones of 1, 2 and 5 m above sea level for Northern Albania region.

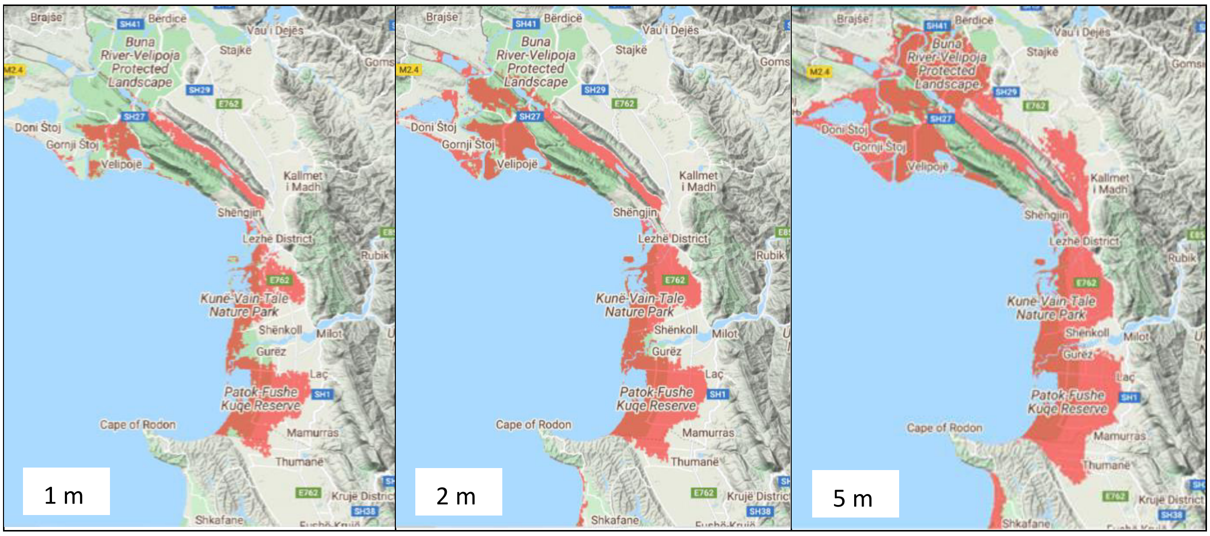


Figure 6: Elevation zones 1, 2 and 5 meters above sea level (Northern Albania)

(source: https://coastal.climatecentral.org/)

To conclude for Mediterranean countries, SLR scenarios together with other effects during extreme sea events, such as combine flooding, result in risk areas extending to 3 m above sea level and higher. Today, open-source global digital elevation models ensure reliable presentation of 5 m elevation above sea level [3] and thus the proposed elevation threshold for LECZ is 5 m above sea level.

4. Additional analytical units and parameters

The Low Elevation Coastal Zone (LECZ) is proposed here as additional analytical unit for calculation of LCC indictor 25. As explained in the previous chapter, the Low Elevation Coastal Zone (LECZ) is an area within the coastal zone, contiguous to the coast and prone to coastal flooding. LECZ should be constructed by use of an elevation threshold encompassing the future risks of coastal flooding caused by climate change. The proposed elevation threshold for LECZ construction is 5 m above sea level. Thus, LECZ indicates the areas under risks of the future extreme sea level events.

Concept of Low Elevation Coastal Zone (LECZ) is introduced in 2011 by McGranahan et al [18] for the purpose of assessing the risks of climate change and human settlements in low elevation coastal zones. LECZ was defined as the contiguous area along the coast that is less than 10 meters above sea level. Overall, this zone covers 2 per cent of the world's land area but contains 10 per cent of the world's population and 13 per cent of the world's urban population. Today, LECZ is widely used term for zones derived from digital elevation models by selecting all land areas contiguous to the coast below respective elevation (eg <10m, <5m).

The current CCI 25 Guidance Factsheet [1] defines the following indicator parameters to be calculated (author's note: term parameters is used in Table 1 in [1], later in [1] named units, hereinafter named parameters). For the first monitoring, the calculated indicator parameters represent the base line from which changes will be calculated. First monitoring indicator parameters are the following:

1. km2 of built-up area in coastal zone;
2. % of built-up area in coastal zone;
3. % of other land cover classes in coastal zone;
4. % of built up area within coastal strips of different width compared to wider coastal units;
5. % of other land cover classes within coastal strips of different width compared to wider coastal units;
6. km2 of protected areas within coastal strips of different width.

Parameters 4 and 5 could be defined more precisely by defining term "wider coastal units" as coastal zone and coastal administrative units. That is in line with the following proposal of additional parameters for LECZ.

By proposing LECZ as additional analytical unit, the additional parameters related to LECZ are introduced as listed above. They should be calculated for the same reporting units, but limiting the calculation for the areas within LECZ.

Additional seven parameters are defined for the first monitoring:

7. **km2 of LECZ;**
8. **km2 of built-up area within LECZ;**
9. **%of built-up area within LECZ;**
10. **%of built-up area within LECZ compared to coastal administrative unit;**
11. **%of other land cover classes within LECZ;**
12. **%of other land cover classes within LECZ compared to coastal administrative unit;**
13. **km2 of protected areas within LECZ in coastal zone;**

For the second monitoring, in addition to the indicator parameters defined for the first monitoring, the following ones are to be calculated:

1. % of increase of built-up area, or land take;
2. % of change of other land cover classes;
3. % of change of protected areas.

By introduction of LECZ, additional three parameters are defined for the second monitoring:

4. **% of increase of built-up area, or land take within LECZ;**
5. **% of change of other land cover classes within LECZ;**
6. **% of change of protected areas within LECZ.**

The current CCI 25 Guidance Factsheet [1] defines the following reporting units for the LCC indicator 25 parameters:

- coastal zone – defined by the country;
- coastal strips - less than 300m, 300m – 1 km, 1 – 10 km from coastline;
- coastal setback – defined by the country or 300 m coastal strip.

(author's note: terms *coastal zone*, *coastal strip* and *setback zone* could have various definitions in another documents and reports).

Moreover, as defined in [1], the LCC indicator 25 parameters should be further refined by the administrative units NUTS3 level or equivalent. To support use of LCC indicator 25 by the local government, responsible for the development of urban plans and managing the coast, new proposal is to use coastal cities/municipalities as administrative units. Additionally, NUTS units are defined for the EU countries serving statistical purposes within EU.

Thus, the CI25 parameters are calculated for spatial units that combine coastal zones, coastal strips and coastal administrative units (cities/municipalities), herein after **reporting units**.

5. Available data for calculation of the upgraded indicator

Based on the results of testing and validation [2, 3], this chapter provides a summary about suitability of open data sources for upgraded LCC indicator 25 calculation. The prerequisite for data to be considered was to be open data and available for the whole Mediterranean region. The most appropriate open data sources available today are proposed here (as new data sources are emerging on almost monthly basis).

The main data sets needed for the LCC indicator 25 calculation are the following:

- Land use/land cover data;
- Coastline;
- Elevation data;
- Administrative units;
- Protected area.

First step was to identify candidate data sources based on the requirements given in CCI 25 Guidance Factsheet and that is elaborated in [1]. The candidate data sources were used for LCC indicator 25 calculation during testing on pilot area as described in [2]. Results are validated against aerial images and in terms of input data and GIS overlay function performed [3]. Following chapters summarize the findings and propose adequate data sets for each data set needed.

5.1. Land-use / land cover data

Identified data sets for land use /land cover data (LU/LC data) are the following:

- **Copernicus Coastal Zones;**
- **Copernicus Global Land Cover and Change;**
- **ESA WorldCover Project Land cover**;
- **ESRI Sentinel-2 Land Use/Land Cover**.

ESRI Sentinel 2 Land Use / Land Cover data set was omitted from further testing because visual inspection reveals that it does not represent enough the heterogeneity of land cover.

According to the accuracy assessments [2,3], the Copernicus Coastal Zones data sets are superior to the other selected data sets. For the monitoring applications, lower accuracy input data such as Copernicus Global Land Cover and Change data asks for visual inspection of detected changes and their verification.

Table 2 summarizes how selected data sets fit to the requirements of LCC indicator 25. Copernicus Coastal Zones data is the superior data source regarding the requirements, but as it does not cover North African and Western Asian countries, the Copernicus Global Land Cover is the best data source for these countries in this moment. ESA WorldCover Project data has potential to became the best source in future as it is planned to be updated annually and thus would enable monitoring.

Table 2: Requirements for LC indicator 25 versus selected land use /land cover data characteristics

Requirements from the indicator guidance factsheet	**Copernicus Coastal Zones**	**ESA WorldCover Project Land cover**	**Copernicus Global Land Cover and Change, CGLS-LC100**
Spatial extent Mediterranean coastlines, coastal strip 10 km width	EEA39 countries 10 km inland buffer zone	World cover	World cover
Spatial resolution 1 ha (grid data), Minimum mapping unit (MMU) 25 ha and 100 m of linear elements	MMU 0,5 ha Min. mapping width: 10 m Min. mapping length (non applicable) Reference scale 1:10.000	10 m resolution	100 m resolution
Change detection Minimum change detection 5 ha	MMU for change: >= 0,5 ha Min.mapping width for change: >= 10 m	unknown	Change is detected based on MODIS data of 300 m MMU (small-scale changes may be missed)
Temporal scale 5 years	6 years, planned to be 3 years Current available data is for year 2012 and 2018.	2020	Annual, between 2015 and 2019
Digital availability	Open data, vector ESRI	Open data, Geotif, 10 m	Open data, Geotif, WGS84

Requirements from the indicator guidance factsheet	**Copernicus Coastal Zones**	**ESA WorldCover Project Land cover**	**Copernicus Global Land Cover and Change, CGLS-LC100**
	shp	resolution WGS84	

Table 3 provides an overview how the LU/LC classification systems of the selected data sets matches the LCC indicator 25 classes.

Table 3: Classification system for LC indicator 25 versus selected land use /land cover data sets' classification systems

Land use /land cover classes by the indicator guidance factsheet	**Copernicus Coastal Zones**	**ESA WorldCover Project Land cover**	**Copernicus Global Land Cover and Change**
	The LC/LU classes represent land use more than land cover.	Based on the UN-LCCS system developed by UN FAO	
Artificial surfaces (also referred as built-up areas) *Surfaces with dominant human influence but without agricultural land use. These areas include all artificial structures and their associated non-sealed and vegetated surfaces.*	1 Urban - including green urban, sports and leisure facilities - including mineral extraction, dump and construction sites, land without current use	50 Built-up - not included are urban parks and recreation areas - not included are waste, dump and exploration (considered under 60 Bare)	50 Built-up
Agricultural *It includes: arable land, permanent crops, pastures and heterogeneous agricultural areas (complex cultivation patterns, land principally occupied by agriculture, with significant areas of natural vegetation).*	2 Cropland - including greenhouses 4.1. Managed grassland	40 Cropland - not included are greenhouses	40 Cultivated and managed vegetation/agriculture (cropland)
Forest and semi-natural land *It includes: forests, scrub and/or herbaceous vegetation associations, open spaces with little or no vegetation*	3 Woodland and forest 4.2 Natural grassland 5 Heathland and scrub 6 Open spaces with little or no vegetation	10 Tree cover (other classes can be present below the conopy – e.g. built-up, schrubs) 20 Shrubland 30 Grassland: natural herbaceous plants irrespective of different human activities such as grazing 60 Bare/sparse vegetation 70 Snow and Ice 100 Moss and lichen	111-116 Closed forest 121-126 Open forest 20 Shrubs 30 Herbaceous vegetation 60 Bare / sparse vegetation... 70 Snow and Ice 100 Moss and lichen

Land use /land cover classes by the indicator guidance factsheet	Copernicus Coastal Zones	ESA WorldCover Project Land cover	Copernicus Global Land Cover and Change
Wetlands *Inland marshes, peatbogs, salt marshes, salinas, intertidal flats*	7 Wetlands*	90 Herbaceous wetland 95 Mangroves	90 Herbaceous wetland
Water bodies *Water courses, water bodies, coastal lagoons, estuaries, sea and ocean.*	8 Water*	80 Permanent water bodies	80 Permanent water bodies 200 Open sea

Classification of the Copernicus Coastal Zones data best matches the required classification system. Another two data sets are using UN-LCCS classification system developed by UN FAO. Use of UN-LCCS classification system could lead to underestimation of built-up areas because certain land cover classes are not recognized as having urban functions. The same with agricultural land, as managed grassland is not recognized as agricultural but natural land.

The next step was validation by visual inspection of data on the selected locations, significant for the monitoring of land cover change. Aerial photos from the reference year are used as higher quality data. Additionally, selected data sets are compared with each other. Detected changes as well as other land use /cover classes of Copernicus Coastal Zones data fits well the aerial image of the same year. Copernicus Global Land Cover data, having pixel of 1 ha, does not recognize small changes but still classifies very well the built-up areas except construction sites that are classified as grassland, bare land or similar. ESA WorldCover Project data reveals very detailed land cover situation and best matches the aerial image. As it is available only for year 2020, its suitability for detecting changes cannot be assessed. On the basis of the superior spatial resolution of 10 m and if it will be updated for coming years, ESA WorldCover Project data is the best candidate to be used for the LCC indicator 25 in future.

Having Copernicus Global Land Cover and Copernicus Coastal Zones data for the same year 2018, it was possible to compare them. Copernicus Coastal Zones data classifies more land as built-up areas in all reporting units. Detailed analysis revealed that it is due to mismatching in classification of urban greenery and construction sites. While Copernicus Global Land Cover classifies greenery in settlements as grassland or shrub or forest, Copernicus Coastal Zones data classifies the same land as built-up. Also, while Copernicus Global Land Cover classifies construction sites as grassland or similar, Copernicus Coastal Zones classifies them as built-up.

To conclude, for the whole Mediterranean region and in this very moment, the best data source for LC/LU data is Copernicus Global Land Cover and Change data. For monitoring purposes, Copernicus

Global Land Cover and Change data does not detect well small area changes and construction sites and thus it is necessary to perform visual inspection of detected changes and to verify them. ESA WorldCover Project data has potential to became the best source in future, if it will be updated for coming years (as recently announced).

In the context of the accelerated development of satellite technologies and the available global land cover maps that mostly use the UN classification, we suggest that the LCC indicator 25 LU/LC classification be adapted to the UN-LCCS classification system. Current LCC indicator 25 LU/LC classes cannot be identified by automatic and semi-automatic map production but by visual inspection. Therefore, it is very uncertain if and when the Mediterranean will be mapped with this classification system and if the data will be updated on a regular basis.

5.2. Coastline

As the coastline is a matter of convention, the first choice should be national official data. For some countries, official coastline data might be not available or not up to date. Thus, the five open coastline data sets have been identified as potentially suitable for calculating LCC indicator 25 (Figure 7):

- **EU-Hydro**
  (northern Mediterranean sea -coverage, data from 2006 – 2012, reference scale 1 : 50 000);
- **EEA coastline for analysis**
  (whole Mediterranean sea -coverage, combination of EU-HYDRO and GSHHG coastline data (see below) and data extracted from EU-DEM);
- **EMODNet coastline**
  (whole Mediterranean sea –coverage, extracted from Sentinel-2 and Landsat-8 images from 2013 – 2020, defined by Lowes Astronomical Tide & Mean Sea Level);
- **A Global Self-consistent, Hierarchical, High-resolution Geography Database (GSHHG)**
  (global coverage, data from 1995, some areas manually edited over the years, reference scale 1 : 250 000, defined by Mean High Water);
- **OpenStreetMap (OSM) coastline** (global coverage, crowdsourced data).

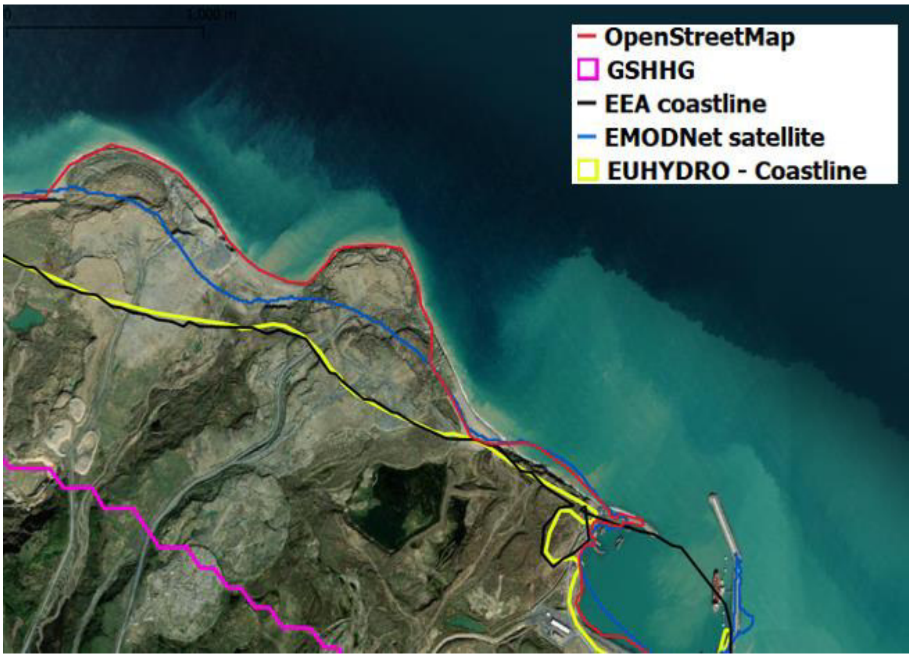


Figure 7 Five coastline datasets identified as potentially suitable for calculating LCC indicator 25

For the pilot site, a visual inspection over aerial images is performed (Figure 7). The OSM coastline was fitting the best and thus it is selected for testing purposes in this project. Further validation of the OSM coastline is performed and reported in [3]. Attention was given on determining whether the coastline includes all linear details of 100 m minimum size such as small bays, rocks, small facilities in ports, docks and similar. Conclusion of the validation is that the OSM coastline satisfies the LCC indicator 25 requirement in the pilot area and can be used as reference coastline for year 2022.

Final recommendation for coastline data source is to use national official data and if not available or up to-date to use the OSM coastline. The OSM data should be checked, e.g. by visual inspection over aerial images. If necessary, OSM coastline should be manually edited and thus updated.

5.3. Elevation data

The elevation datasets identified as potentially suitable for calculating parameters for this indicator are the following:

- **Copernicus DEM 30**

  (digital surface model (DSM), generated from WorldDEM (TanDEM-X – DLR & Airbus), radar data, spatial resolution 30 m, absolute vertical accuracy < 4 m (90 %), data from year 2010 to 2015, open source);
- **FABDEM**

  (digital terrain model (DTM), generated from Copernicus DEM of 30 m spatial resolution with forests and buildings removed, open source only for research purposes);

- **ALOS World 3D – 30 m**
  (DSM, generated by optical stereo mapping, spatial resolution: 30 m, absolute vertical accuracy < 5,6 m (90 %, 30° – 50° N), data from year 2006 to 2011, open source);
- **ASTER GDEM**
  (DSM, generated by stereo mapping, spatial resolution 30 m, data from year 2000-2013, open source);
- **SRTM DEM**
  (DSM, radar data, spatial resolution 30 m, absolute vertical accuracy < 6 m (90 %), data from year2000, date reprocessed with new algorithm: NASDEM, open source).

By vertical accuracy, Copernicus DEM 30 and FABDEM are the most accurate and thus further used for testing and validation. The results are summarized below.

Copernicus DEM 30 has reported absolute vertical accuracy better than 4 m (90 % linear error), relative vertical accuracy for slopes up to 20 % better than 2 m, for slopes greater than 20 % better than 4 m, and absolute horizontal accuracy is better than 6 m (90 %). Regarding spatial resolution, as LCC indicator 25 requires 25 ha as minimum mapping unit and 100 m for linear elements, the both elevation data sources satisfy the requirements. Visual inspection revealed that for the lowest elevation zones Copernicus DEM data are characterized by many small zones, often at the level of individual pixels proving that Copernicus DEM data is loose for the lowest zones. FABDEM data represent the same low-lying terrain with more homogeneous elevation zones what was expected considering that it is a model of bare land (without buildings and trees) and made for modelling of flood.

Hence, it is confirmed that Copernicus DEM includes uncertainties in identifying the lowest elevation zones 0-1 m and 1-2 m and that aggregated elevation zone 0 – 5 m should be used. FABDEM data reveals low-laying terrain well and could be used for delineation of the lowest zones 0-1 m and 1-2 m.

As FABDEM is freely available only for non-commercial purpose, the Copernicus DEM is suggested as the most suitable for conducting parameter calculations, keeping in mind that elevation threshold of 5 m is the lowest one that could be used for construction of LEZ. In this project, FABDEM is used too but only for testing in part of the pilot area: three municipalities in Boka kotorska bay in Montenegro.

5.4. Administrative units

For administrative units data, the first choice should be national official data. For some countries, official administrative units data might be not available or not up to date. Thus, the OpenStreetMap (OSM) data has been identified as suitable for obtaining data on administrative units. The OSM data satisfy spatial accuracy for pilot area, as described in (ref 2). The OSM data should be inspected before use and perhaps manually edited. As administrative units data sets contain exact boundaries defined by various decisions and do not include uncertainties arising from sources such as used sensor data, data interpretation or used algorithms, further data validation is not performed.

The CCI 25 Guidance factsheet requires reporting units to be NUTS3 equivalents. Nomenclature of territorial units for statistics (NUTS) administrative/statistical units is a hierarchical system that divides territory of the EU, the UK, the EFTA countries, and some other countries in three levels where NUTS 3 level represents small regions with population between 150 000 and 800 000. Thus, to identify which country administrative units correspond to NUTS3 level, one should consult Eurostat (https://ec.europa.eu/eurostat/web/nuts/background) or decide based on population value.

Final recommendation for administrative units data source is to use national official data and if not available or up to-date to use the OSM data. The OSM data should be checked and if necessary, OSM administrative units should be manually edited and thus updated.

5.5. Protected areas

For protected areas data, the first choice should be national official data. For some countries, official data on protected areas might be not available or not up to date. Thus, World Database on Protected Areas (WDPA) has been identified as the most exhaustive and suitable for obtaining data on protected areas. WDPA is managed by UNEP World Conservation Monitoring Centre (UNEP-WCMC) and is being updated on a monthly basis. It includes comprehensive attribute data as name, area in km2, management category, status, type of designation, status year, country and location, governance type, managing authorities, management plan etc. Status year attribute is important for monitoring – calculation of protected areas changes over the years. As protective areas data set contains exact boundaries defined by various decisions and do not include uncertainties arising from sources such as used sensor data, data interpretation or used algorithms, further data validation is not performed.

Before calculation of LCC indicator 25, it is suggested to check if WDPA contains all protected areas that are defined on national level, and include those data if they are excluded from WDPA.

6. Methodology for upgraded indicator calculation

The current methodology for LCC indicator 25 includes several steps that needs to be re-examined in the context of new available data sets and additional analytical unit introduced. Following paragraphs briefly elaborates the issues that have arisen and proposes the methodology upgrade.

Data compilation

New data sources are proposed and that has impacts on data compilation. The main issues are the following.

In the context that new data sources are emerging on the monthly basis it should be stressed that the same data source should be used for land cover/land use data for change detection (difference of land cover between two reference years). It is because different data sources have different quality and classification schemas and that could result with misleading data about the change (as shown during validation reported in [3].

Special consideration should be given **to land cover/land use classification schemas** and their mappings to the LCC indicator 25 classes. For example, in case that Land Cover Classification System (LCCS) developed by United Nations (UN) is used by the used data source, urban green areas are considered as vegetation, while dump and construction sites as bare land. The LCC indicator 25 defines aforementioned land cover as built-up. Additionally, LCCS classification does not differentiate between managed and natural grassland, but LCC indicator 25 considers managed grass land as agricultural and natural grassland as forest and semi-natural land. Thus, it is necessary to provide table with the mappings of used classification schema to the LCC indicator 25 classes and stress that while interpreting the results. In this report, a proposal is elaborated to adopt LCC indicator 25 classes to UN-LCCS classification system. As most of the global land cover maps are using UN-LCCS, the above described mappings of classification systems will not be necessary.

For the construction of the reporting units (that are combination of coastal strips/zone and administrative units) and for the Low Elevation Zone, it is recommended that the same coastline is used as baseline. The GIS layers representing reporting units and LECZ could be fixed to certain reference year. That will provide the same analytical units for evaluating the change. Also, not many changes in administrative units and terrain elevation data are to be expected within the temporal scope of monitoring.

Data processing

In the context of today computer power and software efficiency, the GIS analysis could be performed over vector and raster data and there is no need to convert all data to raster. Reporting units and protected areas data could remain as vector data representing correctly discrete nature of that geographic features. Land use / land cover is mostly raster data and could remain in that data model. Various "zonal statists" functions could be performed combining vector and raster data to retrieve LCC indicator parameters, as proved during testing [2] and described in Manual [4].

Regarding GIS operations, certain levels of uncertainty could be introduced for the narrower coastal strip of 300 m, particularly if using data of more coarse spatial resolution such as Copernicus Global Land Cover data of 100 m. In that case, the significant area of the coastal strip is not covered by whole pixels but by their parts. Various calculation strategies are applied by algorithms – how to include values of partially overlaying pixels in the calculation. To avoid the situation where the results depend on the used algorithm, raster data could be firstly resampled to smaller grid e.g. of 10 m. Thus, the vast majority of the pixels are completely inside the polygon of the narrowest coastal strip and used algorithms will have minor influence on the results [3].

Data confidence and uncertainties

The uncertainties in the LCC indicator 25 parameters are introduced by input data and by the calculation steps. To correctly interpret and to understand limitations of the results, the calculated LCC indicator 25 parameters, it is necessary to perform uncertainty assessment, hereinafter validation. Validation should provide information about reliability of LCC indicator 25 parameters that measure land cover changes in coastal areas, and most important the reliability of calculated land take in the monitoring period (increase of built-up areas).

The input data validation could include studying of the reports provided by the data producers and an analysis of data fitting for LCC indicator 25. Furthermore, the comparison with the data of higher quality could be done by visual inspection on the selected locations, significant for the monitoring of land cover change. The visual inspection is proved as an essential part of any validation able to identify uncertainties which could not be detected by the quantitative methods. Aerial photos from the reference year could be used as higher quality data.

The uncertainties introduced by the calculation steps have sources in GIS overlaying of data with various spatial quality and in definitions of geographic features mapped. For LCC indicator 25 parameter, overlaying of land use/land cover data with spatial resolution of 100 m over the narrowest coastal strip of 300 m width could introduce uncertainties. Regarding uncertainties introduced by the definition of geographic features, the coastline is a key geographic feature for LCC indicator 25 calculation. Coastline is a reference line for construction of coastal strips, it represents border between sea and land in land use/land cover data and it should correspond to line of 0 meters above the sea level in elevation data. As sea water level varies, the coastline as geographic feature depends on intended use and its horizontal position and shape varies in data sets. Thus, the comparison between coastline incorporated in main data sets should be performed: reporting units, land use/land cover data and elevation data.

An overview of input data quality and introduced levels of uncertainties should be provided in validation report, an accompanying document to the main document providing calculated LCC indicator 25 parameters. Validation results should be taken into account when interpreting the LCC indicator 25 parameters.

Spatial scope guidance and monitoring station,

The current CCI 25 Guidance factsheet [1] defines minimum mapping unit (MMU) of 25 ha and 100 m linear elements and minimum change detection of 5 ha.

Today, available open-source land use / land cover data satisfies that requirements, and enable more detailed mapping and change detection. Two suggested data sources, Copernicus Global Land Cover and ESA WorldCover Project Land cover, have spatial resolution of 100 m and 10 m (Table 2) and thus the new proposed MMU is the: 100 x 100 m (area of 1 ha).

Regarding minimum unit for change detection, the Indicator Guidance Factsheet requires 5 ha. Copernicus Global Land Cover data detects changes based on MODIS data of cca 300 m spatial resolution and thus minimum units for change detection could be considered as 9 ha. Validation within this project reveals that Copernicus Global Land Cover could not detect changes of several hectares and thus it is recommended that detected changes should be validated by visual inspection and updated. The ESA WorldCover Project data is not yet available for two or more years and minimum unit for change detection is not declared. But, ESA WorldCover Project data has very fine spatial resolution of 10 m (1/100 of 1 ha) and because of that one can suppose that change of 1 ha could be detected. To conclude, in the context of new emerging land use /land cover datasets, the new proposed MMU for change detection is: 100 x 100 m (area of 1 ha), and it corresponds to MMU.

Temporal scope

The current CCI 25 Guidance factsheet [1] defines that temporal scale for monitoring is 5 years. The Quality Status Reports (QSR) for the Mediterranean are developed every 6 years. Consequently, it is recommended that two temporal scales are synchronized and new temporal scale for LCC indicator 25 is proposed to be 3 years. That will ensure two monitorings within one QSR period.

7. Summary

The proposed issues elaborated above are summarized in the Table 4. Under assumption that the proposals will be approved, the CCI 25 Guidance factsheet is updated as given in the Annex 1.

Table 4: Summary of the proposed CCI 25 Guidance factsheet updates

	Current CCI 25 Guidance factsheet	Proposed updates
Reporting/analytical units	• coastal zone – defined by the country; • coastal strips - less than 300m, 300m – 1 km, 1 – 10 km from coastline; • coastal setback – defined by the country or 300 m coastal strip. (author's note: terms coastal zone, coastal strip and setback zone could have various definitions in another documents and reports) Moreover, reporting units should be further refined by the administrative units NUTS3 level or equivalent. Coastal zone – defined by the country, ratified ICZM	• coastal zone – defined by the country; • coastal strips - less than 300m, 300m – 1 km, 1 – 10 km from coastline; • coastal setback – defined by the country or 300 m coastal strip. Moreover, reporting units should be further refined by the coastal administrative units cities/municipalities (the lowest level of authority responsible for development of urban plans and managing coast. Reporting units are combination (overlay) of: • Coastal strips - less than 300m, 300m – 1 km, 1 – 10 km from coastline; • Low Elevation Coastal Zone (LECZ) • Coastal administrative units LECZ is an area within the coastal zone contiguous to the coast and prone to coastal flooding, erosion and salinization (proposed elevation threshold for LECZ is 5 m above sea level) Coastal Administrative units cities/municipalities are the lowest level of authority responsible for development of spatial/urban plans and managing coast.

	Current CCI 25 Guidance factsheet	Proposed updates
Indicator parameters	1. km^2 of built-up area in coastal zone 2. %of built-up area in coastal zone 3. %of other land cover classes in coastal zone 4. % of built up area within coastal strips of different width (see Table 1) compared to wider coastal units 5. % of other land cover classes within coastal strips of different width (see Table 1) compared to wider coastal units 6. km^2 of protected areas within coastal strips of different width	4. % of built up area within coastal zone (see Table 1) compared to coastal zone and administrative unit 5. % of other land cover classes within coastal zone (see Table 1) compared to coastal zone and administrative unit By proposing LECZ as additional analytical unit, the additional parameters related to LECZ are introduced as listed below. They should be calculated for the same reporting units, but limiting the calculation for the areas within LECZ. 6. km2 of LECZ in coastal zone; 7. km2 of built-up area within LECZ in coastal zone; 8. % of built-up area within LECZ in coastal zone; 9. % of built-up area within LECZ in coastal zone compared to coastal administrative unit; 10. % of other land cover classes within LECZ in coastal zone 11. % of other land cover classes within LECZ in coastal zone compared to coastal administrative unit; 12. km2 of protected areas within LECZ in coastal zone;
	For second monitoring the following units will also be relevant: 12. % of increase of built-up area, or land take 13. % of change of other land cover classes 14. % of change of protected areas	For second monitoring the following units will also be relevant: 15. % of increase of built-up area, or land take within LECZ; 16. % of change of other land cover classes within LECZ; 17. % of change of protected areas within LECZ.
Data sources (open and with global coverage)		• ESA WorldCover Project Land cover; • OpenStreetMap (OSM) data for coastline and adm units • Copernicus DEM 30 • World Database on Protected Areas (WDPA)
MMU	• Minimum mapping unit (MMU) 25 ha • MMU for change detection 5 ha	• Minimum mapping unit (MMU) 1 ha • MMU for change detection 1 ha
Temporal scale	5 years	3 years
Manual		Developed.
Validation		Validation performed for proposed open-source data.

	Current CCI 25 Guidance factsheet	Proposed updates
Habitats - elevation breakdown		Initial elevation breakdown proposed. (< 5, 5 – 10, 10 – 50, 50 – 100. 100 – 300, > 300)
LULC classes	CCI indicator 25 own classification	Based on the UN-LCCS system developed by UN FAO
	Artificial surfaces (also referred as built-up areas) - *Surfaces with dominant human influence but without agricultural land use. These areas include all artificial structures and their associated non-sealed and vegetated surfaces.*	50 Built-up
	Agricultural *It includes: arable land, permanent crops, pastures and heterogeneous agricultural areas (complex cultivation patterns, land principally occupied by agriculture, with significant areas of natural vegetation).*	40 Cultivated and managed vegetation/agriculture (cropland)
	Forest and semi-natural land *It includes: forests, scrub and/or herbaceous vegetation associations, open spaces with little or no vegetation*	10- Trees 20 Shrubs 30 Herbaceous vegetation 60 Bare / sparse vegetation... 70 Snow and Ice 100 Moss and lichen
	Wetlands *Inland marshes, peatbogs, salt marshes, salinas, intertidal flats*	90 Herbaceous wetland
	Water bodies *Water courses, water bodies, coastal lagoons, estuaries, sea and ocean.*	80 Permanent water bodies 200 Open sea

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