Global Open Maps for the Integrated Monitoring and Assessment Programme of the Mediterranean Sea and Coast

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doi: 10.5281/zenodo.11584703

Abstract: The Integrated Monitoring and Assessment Programme (IMAP) aims to quantitatively assess the status of the Mediterranean Sea and coast in an integrated way. There are 27 indicators that are linked to one of 11 Ecological Objectives. Candidate Common Indicator 25 "Land cover change" (CCI25) has focused on urbanisation – a process that highly compromises ecosystem integrity and is irreversible. CCI25 calculates shares of five land cover classes for the coastal zone of 10 km width. Additional parameters calculate areas under protection and areas up to 5 m above sea level. After the initial calculation, the calculation is repeated every 6 years and changes are detected. The CCI25 is demanding in terms of data: it requires homogeneous data of the entire Mediterranean; certain spatial and temporal resolution; and fitting the semantics of the indicator. National data cannot meet these needs, so the use of global open maps has been tested. This paper presents results for key data sets: land cover, elevation and coastline. The coastline from OpenStreetMap fully meets the needs as well as the Copernicus DEM 30 global surface model. Regarding land cover data, the ESA WorldCover Project has been revealed as the most promising one.

Keywords: ecological objectives; IMAP; land cover; land take; Mediterranean.

1 Introduction

The environmental resources on the coastal area of the Mediterranean is continuously under pressure of anthropogenic activities and climate change impacts (EEA 1999, Papamichael et al. 2022). The process of urbanisation, or land take, is particularly important because it can be considered an irreversible process. Monitoring land cover changes is a key segment for spatial planning and making future decisions in accordance with sustainable development.

The Integrated Monitoring and Assessment Programme of the Mediterranean Sea and Coast and Related Assessment Criteria (IMAP) (UNEP/MAP 2017) established 11 ecological objectives (EO) and 27 common indicators of which 4 are candidates. In this paper, focus is given to the EO 8 Coastal Ecosystems and Landscapes and Candidate Common Indicator 25 "Land cover change" (CCI25) aiming to support the balanced allocation of uses, preserving open coastal space, securing setback zones, avoiding urban sprawl and securing ecosystem health. CCI25 provides an analytical base for The Integrated Coastal Zone Management (ICZM) Protocol (UNEP/MAP/PAP 2008). The Priority Actions Programme Regional Activity Centre (PAP/RAC) is assisting the countries in the implementation of the Protocol's provisions. Being a Candidate Common Indicator, the CCI25 is still in a testing phase. With the aim of testing and improving the CCI25, the comprehensive study was conducted. As the result, the Guiding Factsheet was reviewed and updated (Baučić et al. 2022a). The analytical units are upgraded with Low Elevation Coastal Zone (LECZ) - an area prone to coastal flooding, erosion and salinization (Ali et al. 2022); data sources are updated with open-source data; the mapping units are scaled down from 25 ha to 1 ha; and the change detection units are scaled down from 5 ha to 1 ha. The CCI25 is demanding in terms of data: it requires homogeneous data of the entire Mediterranean; certain spatial and temporal resolution; and fitting the semantics of the indicator. National data cannot meet these needs, so the use of global open maps has been tested. This paper presents results for key data sets: land cover, elevation and coastline.

CCI25 parameters are defined for the coastal zone - an area on the land that is within 10 km from the coastline. This area is further subdivided into three coastal strips: from 0 to 300 m; 300 to 1000 m; and from 1 to 10 km from the coastline. Final reporting units for CCI25 parameters are defined by further dividing coastal strips with administrative units. Additionally, CCI25 parameters are calculated for protected areas and Low Elevation Coastal Zone (LECZ) - the zone that is contiguous to the coastline; under 5 m above sea level; and within the coastal zone. CCI25 quantifies land use/land cover changes in coastal zones for the time interval of 6 years. For the first monitoring, there are 13 indicator parameters and for the second and every subsequent one, there are additional six parameters to be calculated. First monitoring parameters include the calculation of areas under five land cover classes (built-up areas, agricultural, forest and semi natural land, wetlands and water); areas under protection and inside LECZ. Second monitoring parameters include the calculation of land cover change and change in protected areas. CCI25 parameters provide data for various analyses (such as land take per coastal strips). Data aggregation on a national level enables comparison among countries. The pressures of urbanisation to coastal ecosystems could be identified and geolocated but responsibility is on local institutions to interpret and understand these processes, and the drivers behind them.

2 Materials and methods

The upgrading the methodology for CCI25 included work from desktop search to testing and validation on the pilot sites. This paper has focused on elaboration of adequacy of open data for CCI25 calculation. First step was to identify candidate data sources based on the requirements given in the CCI25 Guidance Factsheet. Second step was to test candidate data on pilot area, and third step involved validation against aerial images and higher quality data (Baučić et al. 2022b). Pilot site covers the coastal zone of Albania, Montenegro, Bosnia and Herzegovina, and the south part of Croatia, in total covering 6.424 km^2.

2.1 Land-use / land cover data (LU/LC data)

Three sources for LU/LC data are selected for testing purposes: Copernicus Coastal Zones (CCZ), data sets for year 2012 and 2018 (Copernicus 2024a); ESA WorldCover Project Land cover (ESA WCP), data set for year 2020 (ESA 2024); and Copernicus Global Land Cover and Change (CGLCC), data sets for year 2015 and 2018 (Copernicus 2024b). All three datasets satisfy the requirements of the CCI25 regarding spatial resolution. Copernicus Coastal Zones do not cover the entire coastal area of the Mediterranean but only the northern coasts located in the European Economic Area countries. Classification of the CCZ data best matches the required classification system. Another two data sets are using the UN-LCCS classification system developed by UN FAO (FAO 2024). In the context of land take detection, the most important disparity between UN-LCCS and the CCI25 classification system is in the definition of urban green areas, dump and construction sites. CCI25 classifies them as urban areas because they serve urban functions, while in UN-LCCS urban green areas are considered as a certain type of natural vegetation, while dump and construction sites as bare land. Use of the 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 CCI25 parameters are calculated for the pilot area by all three data sources and results are compared. CGLCC for 2018 was the only data set available for the same year as CCZ data. Thus, the area-based comparison of these two data sets is elaborated. The areas covered by LU/LC classes in coastal zones (0–10 km) are noticeably different when calculated from these two data sets. The largest absolute and relative difference were expressed in agricultural areas, where 106.2 km^2 (1.66%) more are recorded by the CGLCC. The second largest difference is reflected in built-up areas, where 88.1 km2 (1.37%) more are recorded by the CCZ data. The next step was visual inspection of data on the eleven 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 (Baučić et al. 2022c). Figure 1 illustrates visual inspection for the location of Luštica bay in Montenegro.

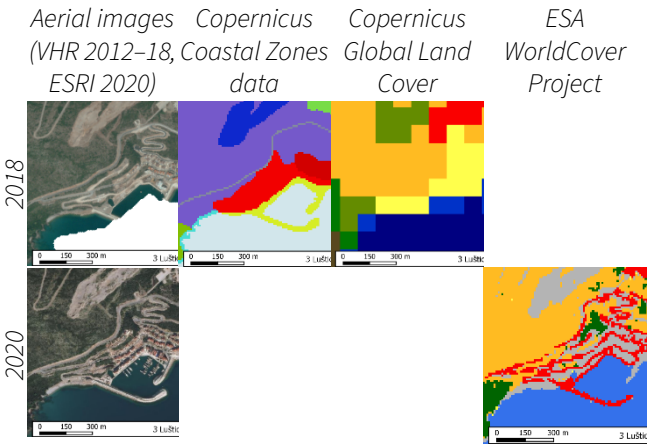

Figure 1. Luštica bay – comparison of various LU/LC data with aerial images.

2.2 Coastline

Five open coastline data sets have been identified as potentially suitable for calculating CCI25: EU-Hydro; EEA coastline for analysis; EMODNet coastline; Global Self-consistent, Hierarchical, High-resolution Geography Database (GSHHG); and OpenStreetMap (OSM) coastline (Figure 2).

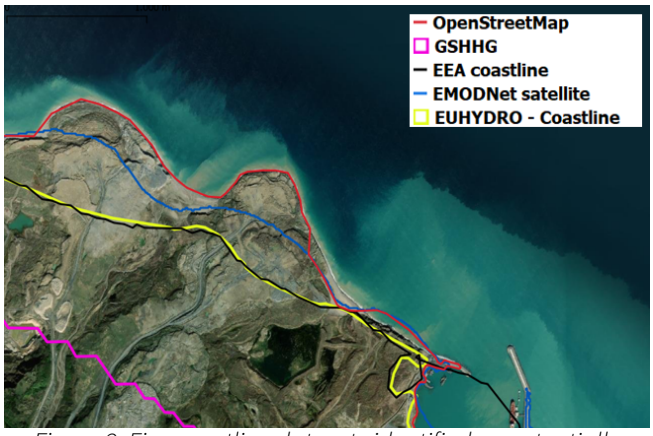

Figure 2. Five coastline datasets identified as potentially suitable for calculating CCI 25.

For the pilot site, a visual inspection over aerial images is performed. The OSM coastline was fitting the best and thus it is selected for testing purposes. OSM coastline data is based on crowdsourced volunteered geographic information and metadata only declared date of last update (OSM 2024). The requirements in the CCI25 factsheet define MMU for linear elements of 100 m. The OSM coastline is validated for the pilot area by visual inspection against the aerial images from the same year. Attention was given on determining whether the coastline includes all details such as small bays, rocks, small facilities in ports, docks and similar. Conclusion of the visual inspection is that the OSM coastline satisfies the CCI25 requirements.

2.3 Elevation data

The elevation datasets identified as potentially suitable for calculating parameters for this indicator are the following: Copernicus DEM 30; FABDEM; ALOS World 3D – 30 m; ASTER GDEM; and SRTM DEM. By vertical accuracy, Copernicus DEM 30 (Copernicus 2024c), and FABDEM (Fathom 2024) are the most accurate and thus further used for testing and validation.

changes and their verification. ESA WCP data is the best source due to its superior spatial resolution of 10 m and it is planned to be updated annually. The main disadvantage of the ESA WCP is the fact that different algorithms, training data, and input variables were used to produce data for 2020 and 2021. This makes land cover change analysis problematic because some changes are a direct result of these differences, and do not represent a real change in land cover.

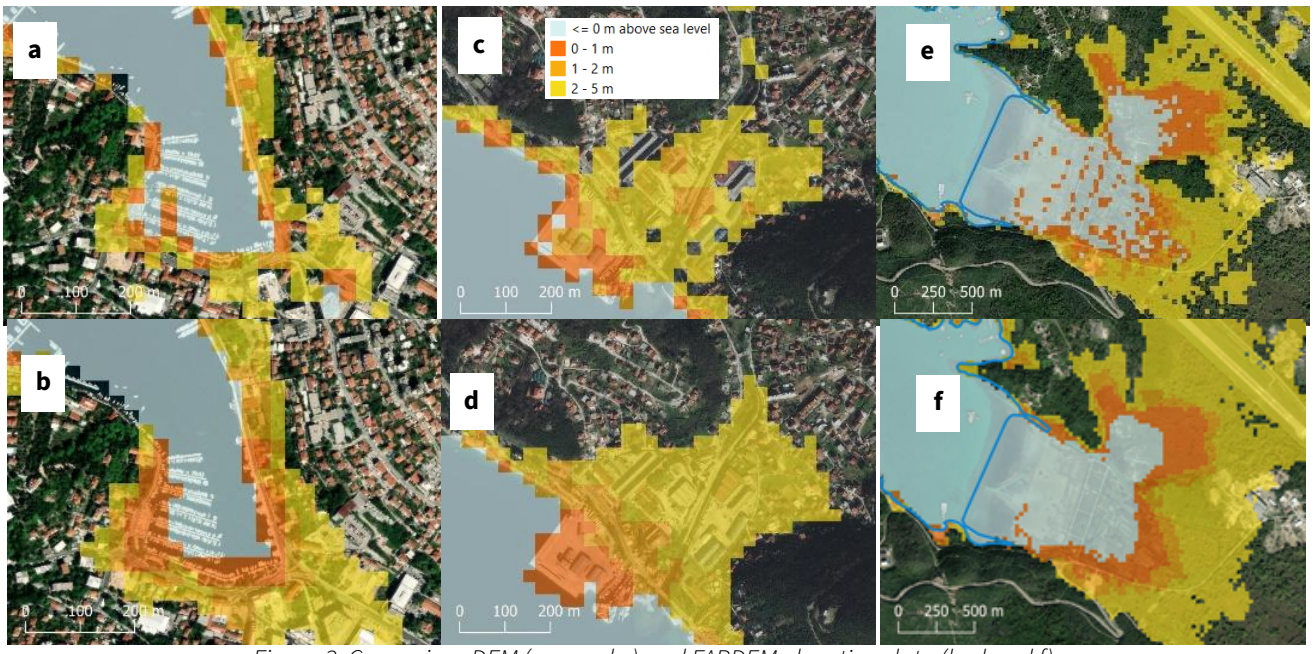

Figure 3. Copernicus DEM (a, c and e) and FABDEM elevation data (b, d and f).

Regarding spatial resolution, as CCI25 requires 1 ha as MMU and 100 m for linear elements, both elevation data sources satisfy the requirements. CCI25 includes Low Coastal Elevation Zone (LECZ) as an additional analytical unit, thus it is necessary to delineate elevation of 5 m above sea level. According to declared vertical accuracies of Copernicus DEM (2 and 4 m), delineation of the lowest zones 0–1 m, 1–2 m, and 2–5 m could be vague (Figure 3, a, c and e). Visual inspection revealed that for the lowest elevation zones Copernicus DEM data are characterised by many small zones (Figure 3, a, c and e), 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.

3 Results and discussion

Based on the testing described above, the most adequate global open maps for the CCI25 calculation are: ESA WCP product for LU/LC data; OpenStreetMap for coastline; and Copernicus DEM 30 global surface model for delineation of LECZ.

Regarding LU/LC data sets, the CCZ data is a superior data source for the CCI25 calculation, but it does not cover the whole Mediterranean region. Common pitfall of CGLCC and ESA WCP data is in the use of the UN-LCCS classification system that could lead to underestimation of built-up areas and agricultural land. CGLCC does not recognize construction sites as land take areas and additional visual inspection of aerial images should be used for detecting

Visual inspection in the pilot area showed that the OSM coastline includes linear details of 100 m minimum size and fits aerial images well. Final recommendation is to check OSM data before use e.g. by visual inspection over aerial images. If necessary, OSM coastline should be manually edited and thus updated.

As FABDEM is freely available only for non-commercial purpose, the Copernicus DEM is suggested as the most suitable for conducting CCI25 calculations, keeping in mind that elevation threshold of 5 m is the lowest one that could be used for construction of Low Elevation Coastal Zone (LECZ).

4 Conclusions

In the context of the development of satellite technologies and the available global open maps, one should reconsider existing spatial planning practice in such a way as to include free satellite data. Such an effort is presented here. The methodology for CCI25 was adapted to satellite data products that brought benefits: spatial and temporal resolution increased; CCI25 can be calculated immediately and without data collection costs. The compromise was in adoption of an UN-LCCS classification system that identifies the land cover class regardless of use, but it will lead to the quantification of urban green areas.

Acknowledgments: The study was funded by the Global Environment Facility MedProgramme Child Project 2.1. “Mediterranean Coastal Zones: Water Security, Climate Resilience and Habitat Protection”, implemented by

PAP/RAC of UNEP/MAP. This research is partially supported through project KK.01.1.1.02.0027, a project co-financed by the Croatian Government and the European Union through the European Regional Development Fund - the Competitiveness and Cohesion Operational Programme.

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