

UNEP/MED WG.522/4

Manual for IMAP

Candidate Common Indicator 25

“Land cover change” calculation

MedProgramme Child Project 2.1

Frane Gilić, Martina Baučić

version 3.0

October 2024



Mediterranean
Action Plan
Barcelona
Convention



Global Water
Partnership
Mediterranean



2.1

Mediterranean
Coastal Zones Climate
Resilience Water Security
and Habitat Protection



PROGRAMME

TABLE OF CONTENTS

1	Introduction	1
2	Required software and basic concepts	2
2.1	GIS application.....	2
2.1.1	Preparing the QGIS interface and defining basic settings	2
2.1.2	Calculating area in (Q)GIS.....	5
2.1.3	Choosing a coordinate reference system (CRS).....	6
2.1.4	Common data formats used in GIS applications	8
2.2	Spreadsheet application	9
3	Acquiring and preparing data.....	10
3.1	Defining the area of interest (AOI).....	10
3.2	Downloading required data.....	13
3.2.1	Land cover/land use (LC/LU) data.....	13
3.2.2	Elevation data.....	14
3.2.3	Coastline data	16
3.2.4	Administrative units data.....	17
3.2.5	Data on protected areas.....	19
3.3	Creating coastal strips and reporting units.....	21
3.4	Preparing other data	34
3.4.1	Preparing LC/LU data	34
3.4.2	Preparing elevation data	40
3.4.3	Preparing data on protected areas	47
4	Calculating indicator parameters.....	52
4.1	Overlaying vector data with the reporting units.....	52
4.1.1	Overlaying data on protected areas with reporting units	52
4.1.2	Overlaying LEZ with reporting units.....	53
4.1.3	Calculating areas of reporting units.....	54
4.2	Overlaying raster LC/LU data with the reporting units.....	54
4.3	Combining all calculated data in one table	57
4.4	Calculating indicator parameters and representing results	60
4.5	Validation steps	69
	References	70

ACRONYMS

AOI – area of interest
ASL – above sea level
CCI25 – IMAP E08 Candidate Common Indicator 25 “Land cover change”
CGLS-LC100 – Copernicus Global Land Services: Land Cover 100 m
CRS – coordinate reference system
DEM – digital elevation model
E08 – IMAP Ecological Objective 8 “Coastal ecosystems and landscapes”
EPSG – European Petroleum Survey Group
ETRS89/LAEA – European Terrestrial Reference System 1989 / Lambert Azimuthal Equal Area
EU – European Union
FABDEM – Forest and Buildings removed Copernicus DEM
FOSS – free and open source
GDAL – Geospatial Data Abstraction Library
GeoJSON – geospatial data interchange format based on JavaScript Object Notation (JSON)
GeoTIFF – Geographic Tagged Image File Format
GIS – geographic information system
GPKG – GeoPackage
IBAT – Integrated Biodiversity Assessment Tool
IMAP – Integrated Monitoring and Assessment Programme of the Mediterranean Sea and Coast and Related Assessment Criteria
IUCN – International Union on Conservation of Nature
LC/LU – land cover/land use
LEZ – low elevation zone
NSA – United States National Security Agency
OSM – OpenStreetMap
TIF/TIFF – Tagged Image File Format
UNEP – UN Environment Programme
WDPA – World Database on Protected Areas
WGS84 – World Geodetic System 1984
WKT – well-known text

1 INTRODUCTION

This manual provides step-by-step instructions on how to carry out IMAP EO8 Candidate Common Indicator 25 “Land cover change” (CCI25) calculation using free and open source (FOSS) software and data.

IMAP stands for the Integrated Monitoring and Assessment Programme of the Mediterranean Sea and Coast and Related Assessment Criteria that was adopted at the 19th Ordinary Meeting (February 2016) of the Contracting Parties (21 Mediterranean country and the European Union) to the Barcelona Convention (short for “Convention for the Protection of the Marine Environment and the Coastal Region of the Mediterranean”) with the aim to quantitatively and integratively assess the status of the Mediterranean sea and coast [1]. IMAP common indicators are the backbone of the Barcelona Convention which defines them as [2]: “indicator that summarizes data into a simple, standardized, and communicable figure and is ideally applicable in the whole Mediterranean basin, or at least on the level of sub-regions, and is monitored by all Contracting Parties”. Currently, there are 24 common indicators and 4 candidate common indicators that are developed. IMAP (candidate) common indicators are linked to one of 11 Ecological Objectives (EO). Candidate common indicators still have some issues that have to be resolved, and one of them is the Candidate Common Indicator 25 “Land cover change” (CCI25), which is linked to the EO8 - Coastal ecosystems and landscapes. The main aim of the EO8, and consequently of the CCI25, is monitoring human activities that are causing “coastal artificialization by sealing the coast with the implementation of coastal structures and therefore impact coastal ecosystems and landscapes” [2].

Main steps in CCI25 calculation which are also chapters of this manual are:

1. preparing software (GIS and spreadsheet application)
2. acquiring all data that are necessary for CCI25 calculation
3. preprocessing acquired data
4. calculating indicator parameters and representing calculation outputs

For each category of input data that are needed for CCI25 calculation, specific data sources were used in manual to illustrate processing workflow. Of course, it is possible to use other data sources and it is possible they will require some variations in workflow. However, manual should provide general instructions for some challenging steps, such as reclassifying initial land cover/land use (LC/LU) classes to those required by CCI25 or instructions on how to determine resolution during raster clipping. The processing steps should not be performed completely rigorously in line with the manual but they can be adapted if needed, as long as they do not have impact on the final calculation results. For example, suggested file names in the manual are based on the input data that are used in manual, but if other input data are used, file names should reflect that.

2 REQUIRED SOFTWARE AND BASIC CONCEPTS

Software applications that are required for the CCI25 calculation include applications that are suitable for managing spatial data, and applications that are designed for working with tabular data – spreadsheet applications.

2.1 GIS application

Dealing with spatial data (i.e., data that have a location) requires a specialized application from the geographic information system (GIS) software domain. One of the most widely used free and open-source (FOSS) GIS applications is QGIS [3]. Its extensive documentation, supportive and large user community, and ability to extend its basic features with many FOSS plugins are the reasons for its popularity and why we have decided to use it for CCI25 calculation. QGIS can be downloaded from <https://www.qgis.org/en/site/forusers/download.html>. It is available for Windows, macOS, and Linux operating systems. In this manual, we have been using QGIS version 3.22 “Białowieża”, which is currently the latest long-term release version. Although CCI25 calculation can be done in other QGIS versions, we suggest using this one to avoid problems with differences in user interface and algorithm names.



Figure 1: QGIS logo [2]

2.1.1 Preparing the QGIS interface and defining basic settings

After opening QGIS, we can immediately save a new blank QGIS project by going to **Project ► Save As...** and defining the name and location where the QGIS project file (file with QGZ extension) will be saved. All algorithms that are available in QGIS cannot be accessed from menus in the top menu bar, but rather through the **Processing Toolbox** panel (highlighted in Figure 2). The **Processing Toolbox** panel can be made visible by clicking on the **Processing ► Toolbox** (Figure 2). If the

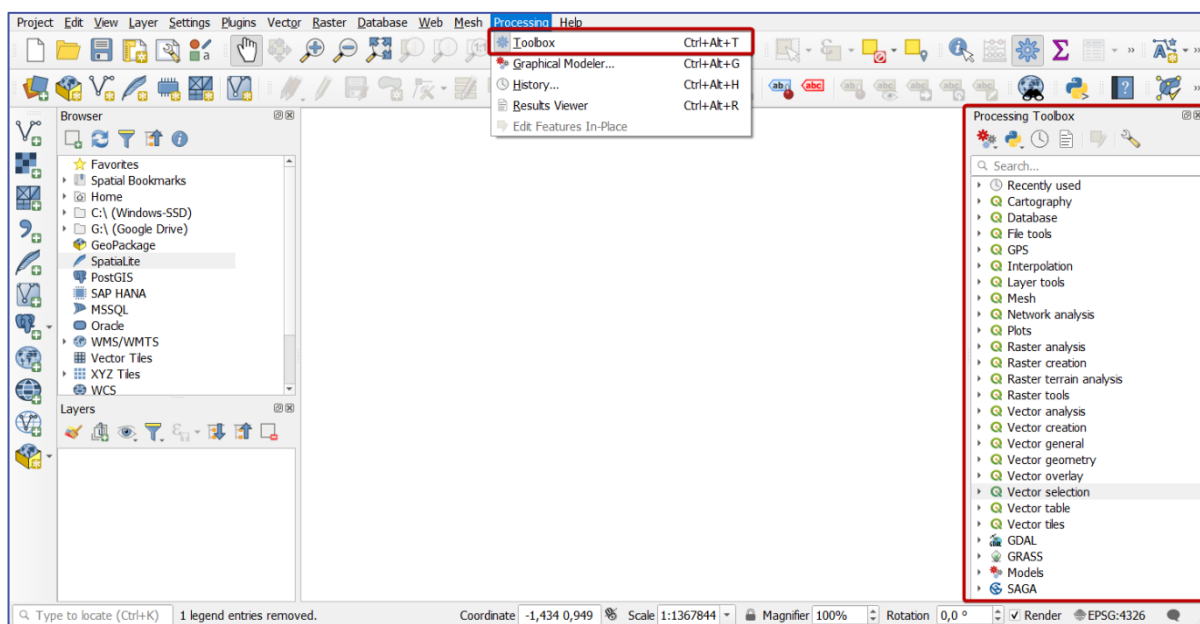


Figure 2: QGIS graphical user interface (Processing Toolbox panel is highlighted)

Processing menu is not available in the QGIS menu bar, the Processing plugin needs to be activated: open the **Plugins** dialog window by going to **Plugins ► Manage and install plugins...**, click on the **Installed** tab on the left side of the window, and check the box next to the **Processing** item (Figure 3). Also check if the box is ticked next to the **GRASS GIS provider** plugin and, if it is not, tick it.

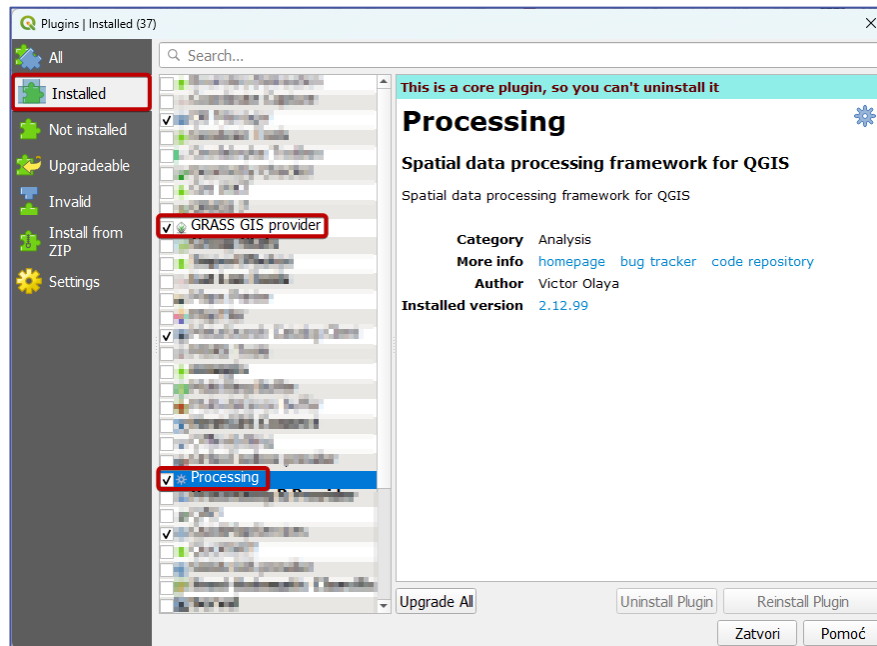


Figure 3: Activating **Processing** plugin

To activate (or deactivate) a QGIS toolbar or a panel, you should go to **View ► Toolbars** or **View ► Panels** and then tick (or untick) ones that are required (or not required). To install, uninstall, activate, or deactivate plugins, go to **Plugins ► Manage and install plugins...** The plugin that should be installed is the “QuickMapServices” plugin. To install it, while in the **All** tab of the **Plugins** dialog window, enter “QuickMapService” in the search bar on top, select the QuickMapServices plugin from the list and click the **Install Plugin** button (Figure 4). Repeat the same procedure for the “Shape Tools” plugin. The Shape Tools plugin enables conducting calculations on the surface of the ellipsoid and is developed by the United States National Security Agency (NSA).

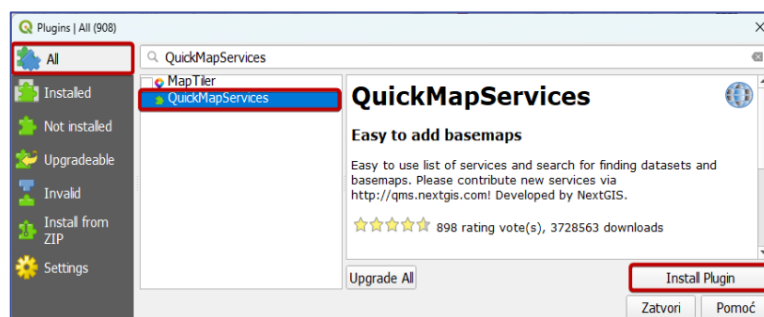


Figure 4: Installing the “QuickMapServices” plugin

QuickMapService plugin enables loading many basemaps in the current QGIS project. After installing it, it is possible to load new basemaps by going to **Web ► QuickMapServices** and choosing one of the basemaps that are grouped by its producers. Figure 5 shows how to add OpenStreetMap (OSM) Standard map to the QGIS project (highlighted with red rectangles). It is possible to load multiple basemaps in the QGIS project. After clicking on one of the basemaps, that basemap is being loaded into the QGIS project and listed in the **Layers** panel (Figure 6). Only some basemaps are listed under **Web ► QuickMapServices**, and to search all available basemaps, click on **Web ► QuickMapServices**

► **Search QMS**, and in the new **Search QMS** panel that opens, search by entering keywords in the search bar (Figure 5, blue rectangles), or by filtering basemaps based on availability in the currently zoomed-in location (click on the **Filter by extent** button). When using basemaps from the QuickMapServices plugin, always carefully check the terms of use, and make sure to appropriately attribute the source of a particular basemap.

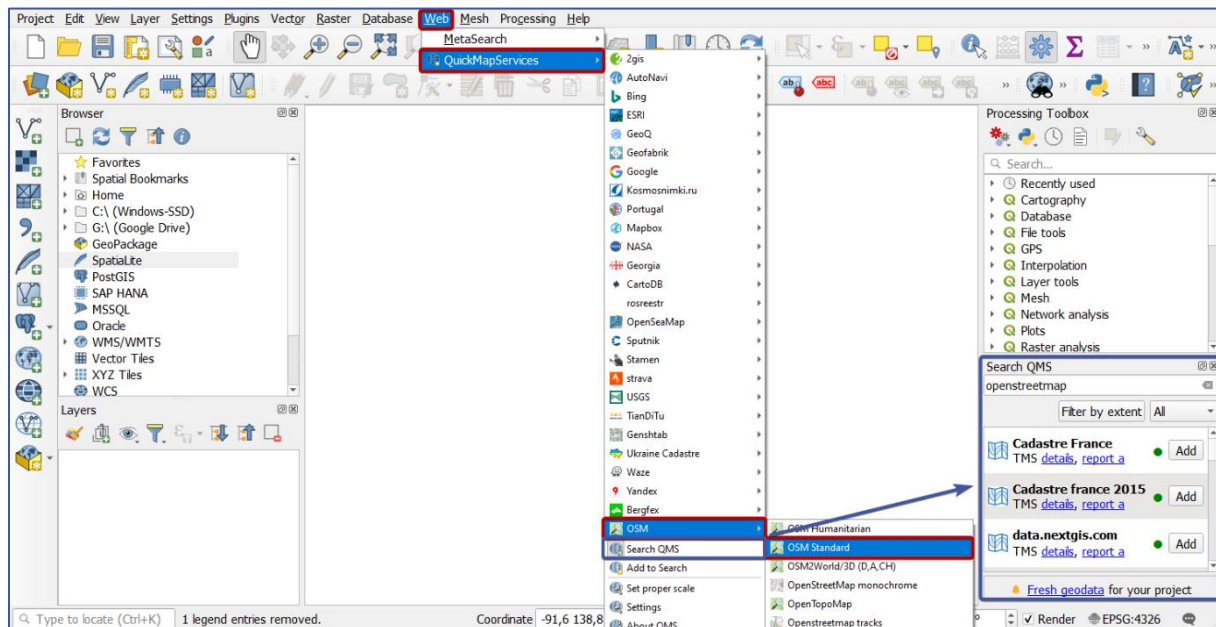


Figure 5: Adding OpenStreetMap (OSM) Standard basemap with the QuickMapServices plugin

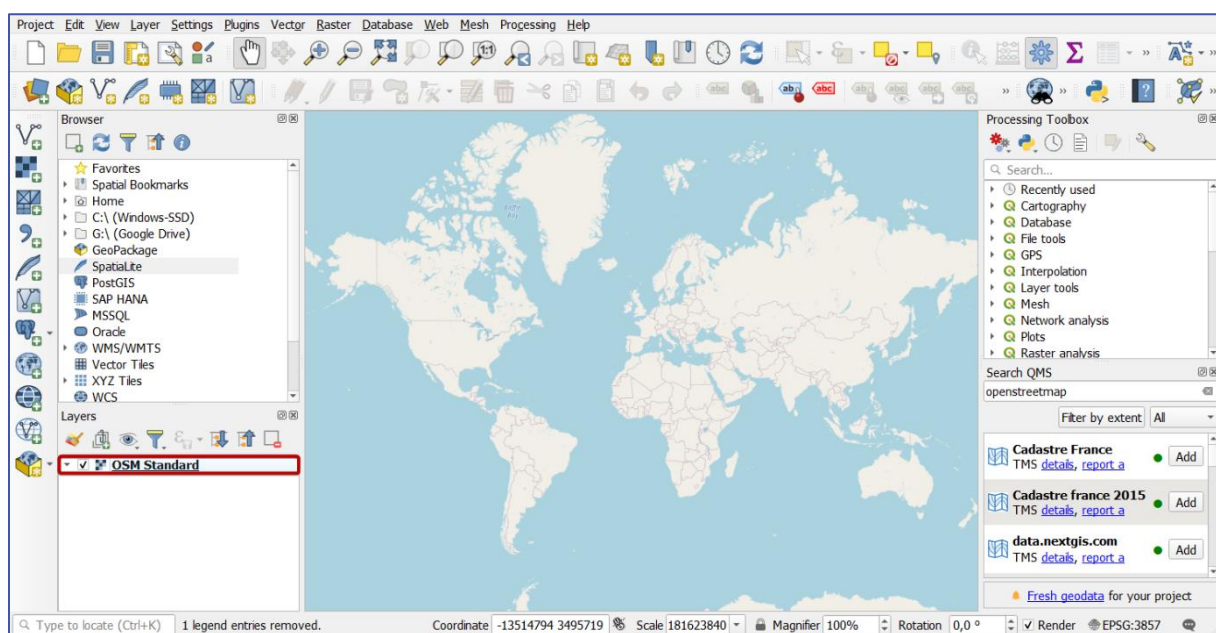


Figure 6: OpenStreetMap standard basemap loaded in QGIS project and listed in the **Layers** panel
(© OpenStreetMap contributors)

Since we will be using only the basic algorithms that are already well established, there should not be any problems with different versions of corresponding libraries. If you want to be completely sure that all versions in your QGIS installation are in line with the versions used for this manual, you can go to **Help ► About** and compare versions: QGIS version: 3.22.10; GDAL/OGR version: 3.5.1; PROJ version: 9.0.1; EPSG Registry database version: v10.064 (2022-05-19); GEOS version: 3.10.3-

CAPI-1.16.1; SQLite version: 3.38.1; SpatiaLite version: 5.0.1; grassprovider version: 2.12.99; and processing version: 2.12.99.

2.1.2 Calculating area in (Q)GIS

The most important results of CCI25 calculations carried out in GIS applications are areas of different land cover/land use (LC/LU) classes. Area calculations in GIS present a special problem posed by the complexity that is caused by the curvature of the Earth's surface. Curved Earth's surface cannot be transformed on a flat surface of a map or a screen on some device without deformation. This has to be kept in mind during area calculations in GIS. Firstly, points from the Earth's surface, which is complex and ever-changing, are being projected on the surface of ellipsoid or spheroid, fairly simple mathematically defined surfaces. At this point, the location of each point is defined in ellipsoidal or spherical coordinates (latitude and longitude). This type of coordinate reference system (CRS) is in QGIS called a "geographic coordinate system". Secondly, the coordinates of these points are being projected from the ellipsoid or sphere to coordinates on the flat surface by a set of formulas that are defined by the so-called cartographic projection. A flat surface in this sense is called a cartographic projection plane, and in QGIS these coordinate systems are referred to as "projected coordinate systems". This second step, which produces the so-called projected coordinates, is not required, and very often positions in GIS datasets are given in ellipsoidal or spherical coordinates. If location is nevertheless given in projected coordinates, and area needs to be calculated based on those coordinates, it should be ensured that cartographic projection preserves the ratio of the area between points on the ellipsoid and corresponding points in the cartographic projection plane. A special group of that kind of projections is called equal-area projections. Finally, in QGIS and some other GIS applications, there are two approaches when calculating area:

1. ensure that all data is being referenced in the projected coordinate system based on equal-area projection, and then make area calculations using projected coordinates
2. make all area calculations on the surface of the ellipsoid or spheroid, using ellipsoidal or spherical coordinates

We suggest the second approach since it simplifies and increases the accuracy of area calculation by avoiding the complexity of choosing the right cartographic projection and problems that arise from raster data reprojection. We acknowledge that both of these approaches have a drawback: areas that are being calculated are not areas on the Earth's surface. Ellipsoid or spheroid cannot perfectly fit Earth's surface, and this misalignment inevitably produces differences between the area on the Earth's surface and the corresponding projected area on the ellipsoid or spheroid. The larger the height difference between the Earth's surface and the ellipsoid or spheroid, the larger the area difference. All data in the same region will be similarly affected by this error, so the final percentages that have to be calculated will not be significantly degraded. Currently, in QGIS (and other GIS applications) there is no better straightforward solution.

To be sure that area calculations will be carried out on the surface of the ellipsoid or spheroid, rather than cartographic projection plane by using projected coordinates, go to [Project ► Properties...](#) and then in the [General](#) tab define suitable ellipsoid in [Ellipsoid \(for distance and area calculations\)](#) dropdown (Figure 7, as explained in [4]). We suggest using WGS84 (EPSG:7030) since the data we will be using are referenced using that ellipsoid. Also, make sure that [Units for distance measurement](#) and [Units for area measurement](#) are set to the desired unit.

However, GIS expert could decide to transform data from geographic to projected CRS before conducting calculations. If so, in calculation report it should be explicitly stated what was the transformation/reprojection procedure, especially for raster data (resampling method, target pixel size, etc.).

2.1.3 Choosing a coordinate reference system (CRS)

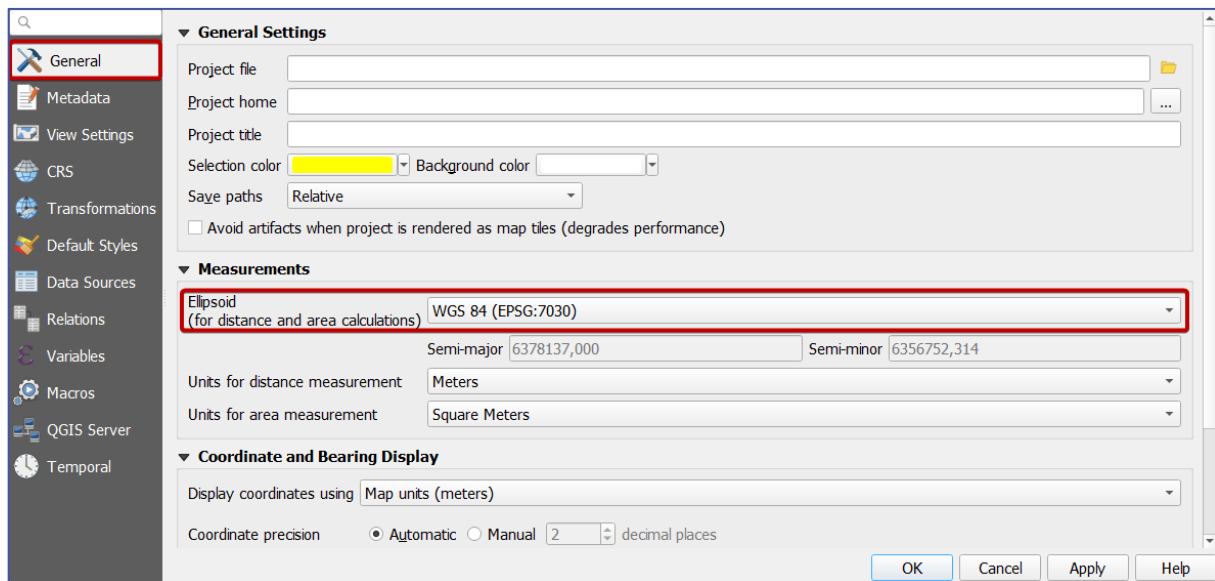


Figure 7: Setting the suitable ellipsoid for distance and area calculations in QGIS

As already discussed in the previous section, choosing the right coordinate reference system (CRS) has to be done carefully. Since settings for area calculations should have already been applied in QGIS project properties (section 2.1.2), here we will focus on choosing CRS that is suitable for data visualization. For visualization purposes, it is common to choose a CRS from a group of projected coordinate systems in QGIS. CRS can be defined on a QGIS project-level by going to [Project ► Properties...](#), and then choosing desired CRS in the [CRS](#) tab. In Figure 8, ETRS89/LAEA Europe CRS is chosen for project-level CRS (EPSG code is 3035 [5], written as “EPSG:3035”), which is a good choice when the whole of Europe has to be visualized. In Figure 8, EPSG:3035 CRS is filtered from the list of all available CRSs by entering “3035” in the [Filter](#) field. Now all data that will be imported in QGIS will be “on-the-fly” reprojected to this CRS, even if they are originally georeferenced/stored in different CRSs. It is important to understand that by changing project-level CRS, data are only temporary, for visualization purposes being “on-the-fly” reprojected to defined CRS, and after closing QGIS, all data remain stored in their original CRSs. For deciding which CRS is the most suitable for a

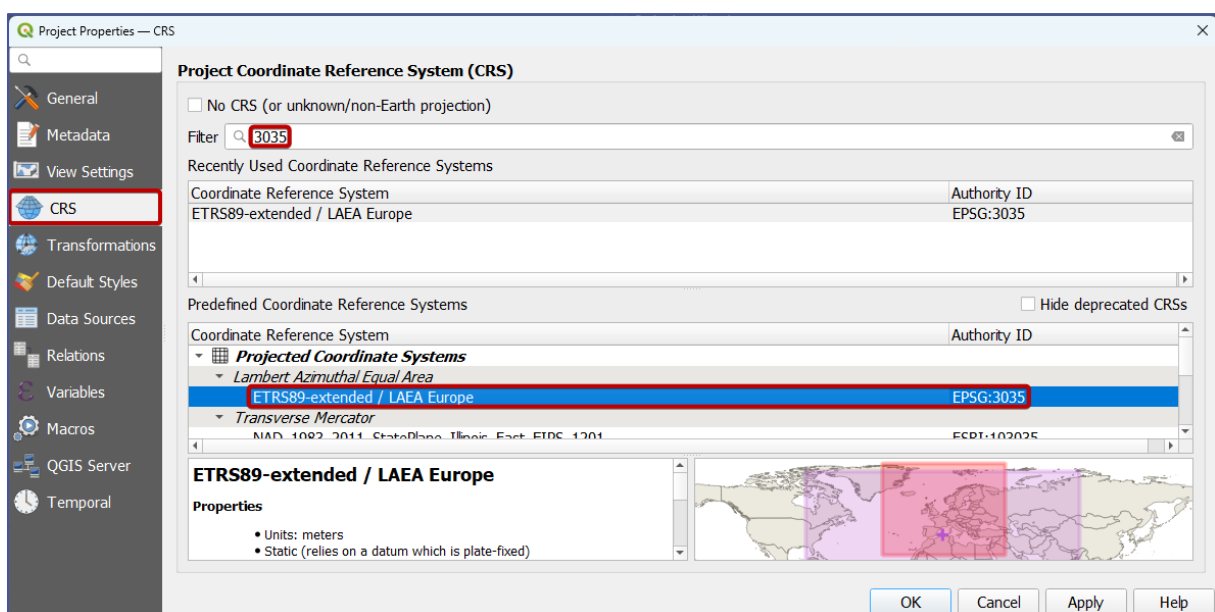


Figure 8: Defining project-level CRS in QGIS project properties

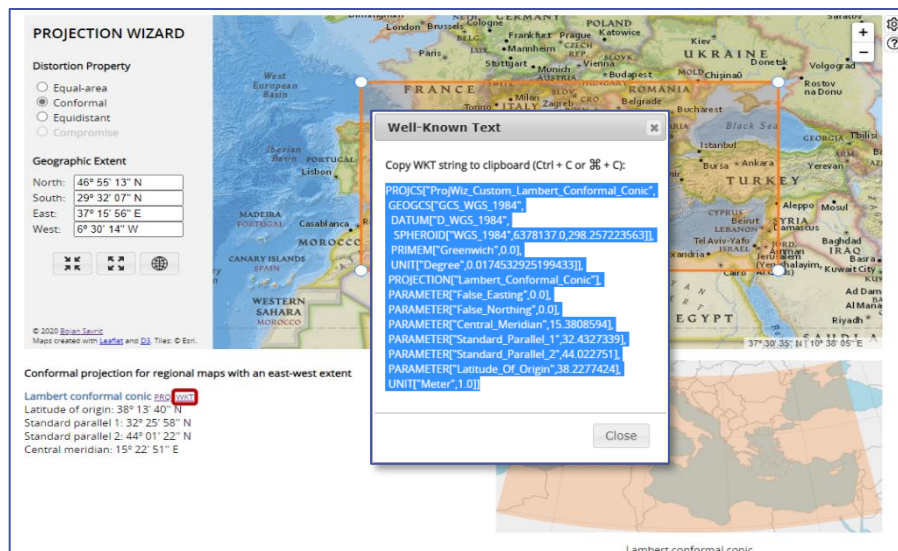


Figure 9: Defining properties of projected coordinate system at <https://projectionwizard.org>

particular area, we suggest consulting Esri's Quick Notes on Map Projections in ArcGIS [6], the United States Geological Survey (USGS) map projections poster [7], or using the web app for interactive choosing the most suitable projection which is available at <https://projectionwizard.org> (Figure 9). After defining project-level CRS, in the bottom right corner, in the status bar in QGIS, the EPSG code of the chosen CRS is shown (visible in Figure 14).

When changing CRSs, sometimes there are multiple ways of transforming coordinates between them. In those cases, QGIS asks a user to choose one of the applicable transformations (Figure 10). Mostly, as in this case, QGIS already chooses the best available transformation, and it is only needed to click on the **OK** button.

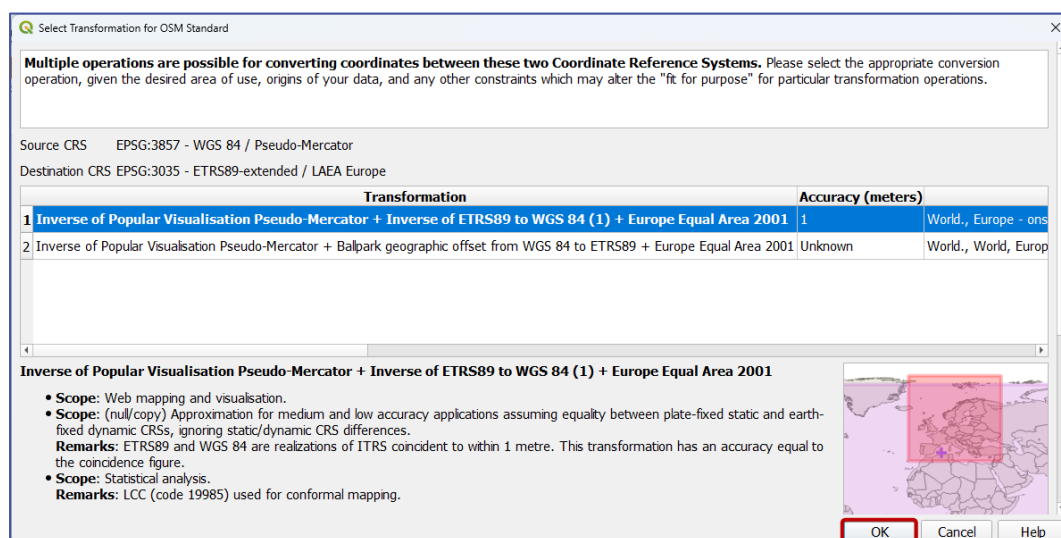


Figure 10: Choosing the most suitable/accurate transformation between CRSs

In case you want to use the projected coordinate system defined at <https://projectionwizard.org> that is not one of the predefined CRSs with EPSG code, click on the WKT (well-known text) link (highlighted in Figure 9) and copy text from the pop-up. In QGIS, go to **Settings** ► **Custom Projection...** and in a new dialog window (Figure 11) click on the button marked with ① in Figure 11, under **Name** define the name for the new CRS (② in Figure 11), in the **Format** dropdown choose "WKT" (③ in Figure 11), paste copied text from the <https://projectionwizard.org> in the **Parameters** field

(4 in Figure 11) and click the **OK** button. This new CRS will now be shown on the list of all available CRS in QGIS. It will be listed under the *User Defined Coordinate Systems* group, and it can be found by entering its name in the **Filter** field (Figure 8).

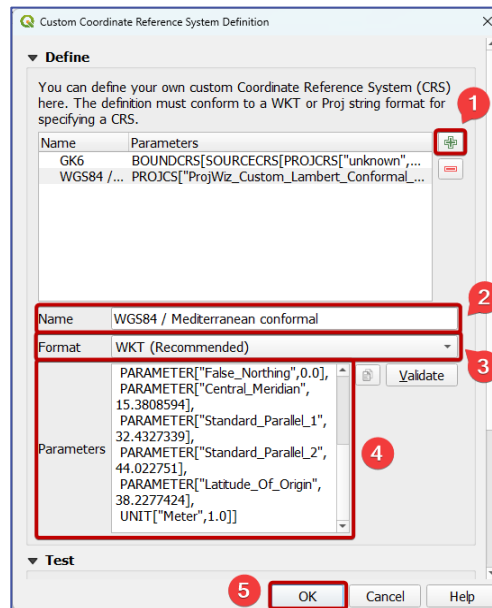


Figure 11: Defining custom CRS

2.1.4 Common data formats used in GIS applications

The most commonly used data formats in GIS applications can be divided into raster and vector formats. Data that are stored in raster and vector data formats are regularly referred to as raster and vector data, or, when imported in GIS application, raster and vector layers. Some raster and vector data formats store data from a single layer in only one file, and some in multiple files.

Simply said, raster data are in form of matrix or a raster, each matrix element has a value and is called a pixel. Each pixel, which is regularly a rectangle, has an indirectly assigned location (i.e., coordinates in some CRS) through coordinates that are assigned to pixels in the corners of the matrix and dimensions of each pixel, which are constant in the whole raster. Raster data are in GIS applications commonly used to represent some spatial property that has a value in every point in space, for example, height above sea level, temperature, etc., but they can also be used to represent some discrete objects in space, such as roads, buildings and so on. Raster data format that will be mostly used throughout this manual is TIF (or TIFF), or more precisely, its extension, GeoTIFF (TIF/TIFF file with embedded information that assign location to the raster and then indirectly to every pixel).

Plainly speaking, in vector data formats, spatial features/objects are stored as points that are defined by their coordinates in some CRS, lines that are defined by points, and polygons that are defined by lines. Ultimately, vector data are based on coordinates of points and accompanying data that define which points are just points, and which are forming lines or polygons. Some data formats allow storing only one type (point, line, or polygon) at a time. Different types of information can be stored along with each feature (each point, line, or polygon) and are called attribute values. Attribute values are stored in the so-called attribute table in which each row corresponds to one feature (point, line or polygon), and each column/filed to one attribute. Vector formats are commonly used to represent discrete features, but are also sometimes used to represent spatially continuous features (for example, land cover). Vector data formats that will be used in this manual are Esri shapefile format, GeoPackage (GPKG), and GeoJSON. Esri shapefile format for a single

vector layer consists of at least three files with extensions SHP, SHX, and DBF, while GeoPackage and GeoJSON formats store all information from one layer in a single file. Visual difference between vector layer with polygonal features and raster layer that both represent land cover over same area are visible in Figure 12.

One important fact that should always be kept in mind while working with QGIS is that in QGZ project file no raster or vector data are stored. QGZ project file stores only, among some other things, locations of raster and vector data storage location. By default settings, always be sure to keep relative location between the QGZ project file and corresponding files of imported raster and vector layers unchanged.

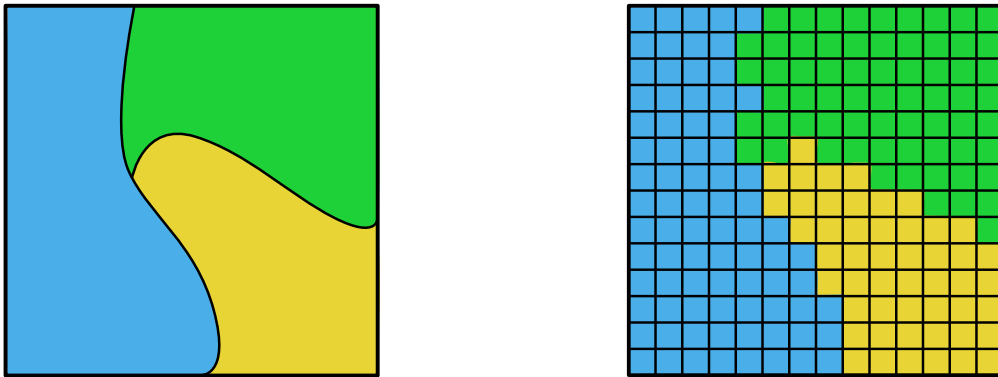


Figure 12: Visual difference between polygonal vector (left) and raster (right) data representing land cover over same area

2.2 Spreadsheet application

Results of spatial analysis conducted in QGIS need to be exported in tabular form and then further analyzed in a spreadsheet application. Any spreadsheet application is suitable for making basic calculations, like proprietary Microsoft Excel [8], free and open-source LibreOffice Calc [9], or even web-based applications like Google Sheets [10]. It is possible that some of these applications will not support some of the more advanced analyses or graphical representations of calculated data.

3 ACQUIRING AND PREPARING DATA

This chapter focuses on acquiring and importing all relevant data in QGIS and then preparing them for conducting spatial analysis. In the following sections, file names that are being used in QGIS will be typed in *italic* style if they can be treated as temporary files, and in ***italic bold*** style if it is advisable to store them permanently. Of course, mentioned file names are just suggestions, and you can use any file names you like.

Main preparation steps include:

1. defining the area of interest (AOI)
2. downloading required data
3. creating coastal strips and reporting units
4. preparing LC/LU and elevation data and data on protected areas for CCI25 calculation

3.1 Defining the area of interest (AOI)

Area of interest (AOI) should be defined as a polygon vector layer with one polygon. To create a new GeoPackage [11] vector layer:

1. go to **Layer ► Create Layer ► New GeoPackage Layer...** (Figure 13)
2. by clicking on the three-dots-button (1 in Figure 13), define the name (you can use ***aoi.gpkg***) and path on the disc where the new GeoPackage (GPKG) file will be stored
3. in the **Geometry type** dropdown select **Polygon** (2 in Figure 13)
4. select the desired CRS (we suggest selecting WGS84 (EPSG:4326) – 3 in Figure 13; if desired CRS is not listed, then by clicking on the button marked with 4 in Figure 13, select desired CRS from the list of all available CRSs in QGIS)
5. finally, click on the **OK** button (5 in Figure 13)

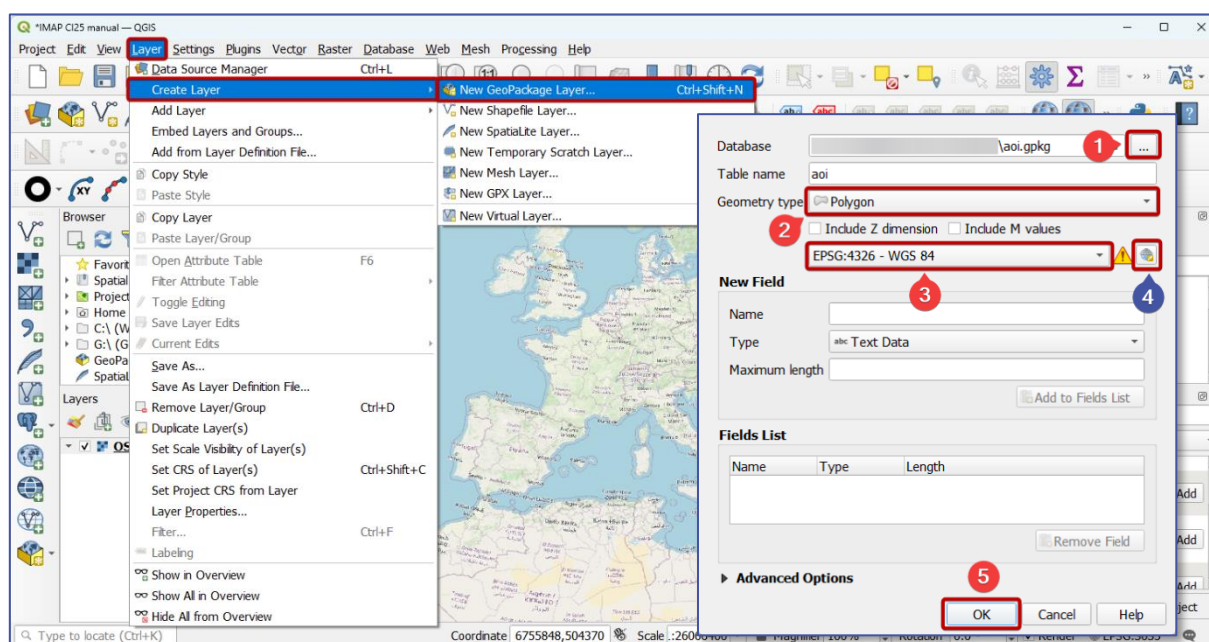


Figure 13: Creating a new GeoPackage vector layer (basemap: ©OpenStreetMap contributors)

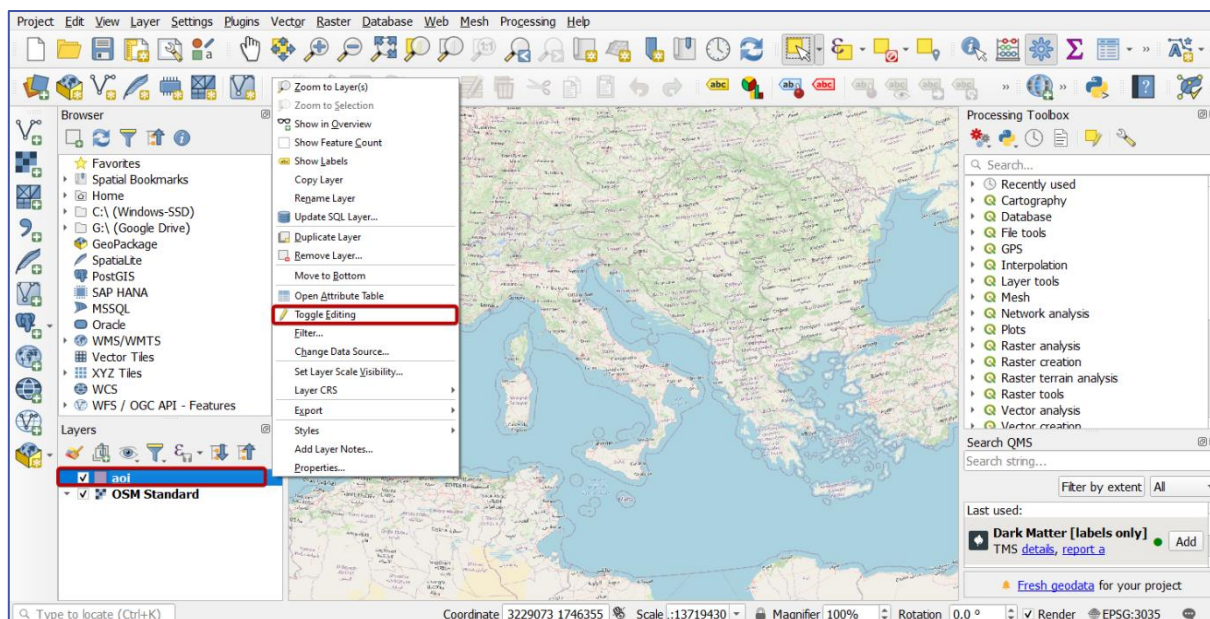


Figure 14: After clicking on the *Toggle Editing*, new features can be added, or existing features can be modified or deleted from a vector layer (basemap: ©OpenStreetMap contributors)

The newly created GeoPackage layer will automatically be loaded into the QGIS and listed in the **Layers** panel (Figure 14). To add a new polygon in a GPKG vector layer, follow these steps:

1. toggle (i.e., enable) editing of GPKG layer (**aoi.gpkg**) by right-clicking on the layer name in the **Layers** panel, and then clicking on **Toggle Editing** (Figure 14)
2. if you did not already, add one of the basemaps using the QuickMapServices plugin (it can be OpenStreetMap: **Web** ► **QuickMapServices** ► **OSM** ► **Standard**, as shown in Figure 5), and zoom (by scrolling the mouse wheel) and pan (by moving the mouse while mouse wheel is pressed) map to the AOI
3. while the AOI layer is selected in the **Layers** panel, go to **Edit** ► **Add Polygon Feature** or click on the  icon marked with 1 in Figure 15 (it is a part of the **Digitizing** toolbar)

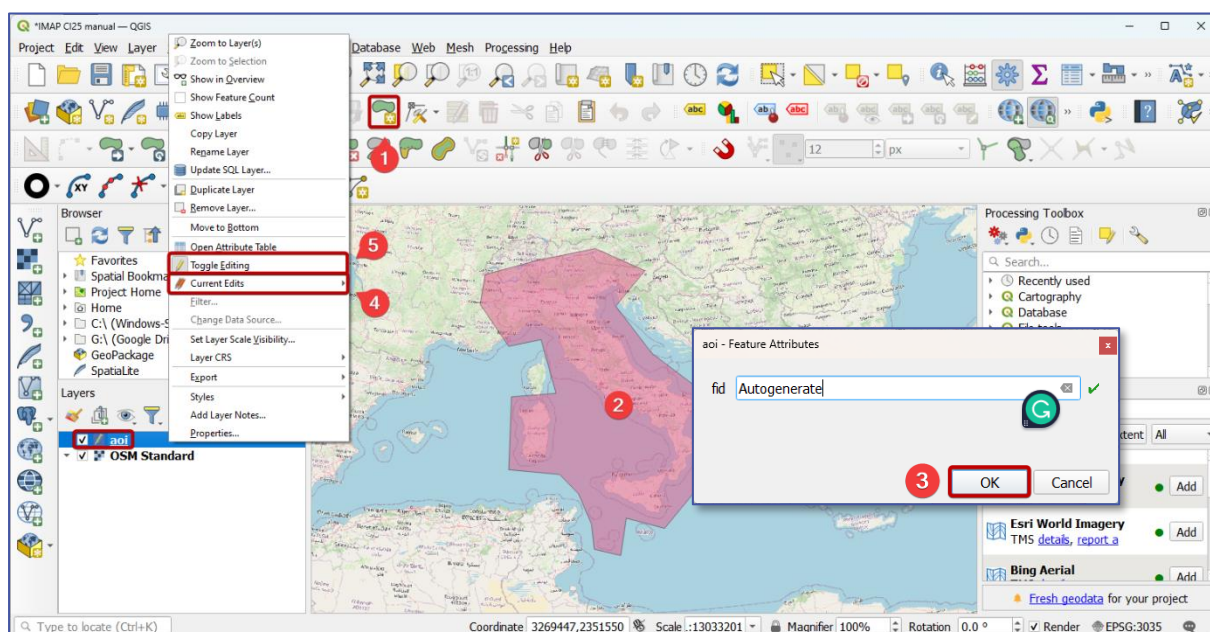


Figure 15: Creating a new polygon in a vector layer (basemap: ©OpenStreetMap contributors)

4. on the map, with left mouse clicks, encircle a polygonal AOI that contains an area for which CCI25 has to be calculated (points that define polygonal AOI do not need to be densely spaced and it is a good practice to encircle a little bit wider area to be sure that you have included the whole AOI, example for Italy is shown on Figure 15, marked with ②)
5. finish polygonal AOI definition by right mouse click (right mouse click will not add a new point)
6. click the **OK** button in a new dialog window (③ in Figure 15)
7. save changes in the AOI vector layer by right-clicking on its name in the **Layers** panel, then clicking on the **Save Layer Edits** (③ in Figure 15), and then again on **Toggle Editing** (④ in Figure 15) to lock the layer from further edits

This AOI polygon in **aoi.gpkg** file will be used to clip input layers with the main purpose to speed up the processing by limiting calculations to its extent.

Metadata and settings for each layer in QGIS can be accessed by right clicking on the layer name in the **Layers** panel, and then clicking on **Properties...** (visible in Figure 14), or, by default settings, by double-click on the layer name in the **Layers** panel. If you double-click on the **aoi.gpkg** layer in the **Layers** panel, the **Layer Properties** window that is shown on Figure 16 will open. **Layer Properties** window that is shown in Figure 16 list options for vector layer. On the left side of the window, there are different tabs. In the **Information** tab, you can read data format that is used for storing data, path on the computer storage where data is stored, CRS that is used to georeference data and some other metadata. In the **Source** tab, you can again see CRS information, you can build spatial index (it is always advisable to build spatial index if it is not already, by clicking on the **Create Spatial Index** button), and define query that will be used to filter features in vector layer based on their attributes values. In the **Symbology** tab, you can define different options for visualization of data stored in each layer. In the **Labels** tab, you can define setting for showing attribute values in the QGIS map view, and in the **Fields** tab you can edit, add, or delete fields/attributes from the attribute table.

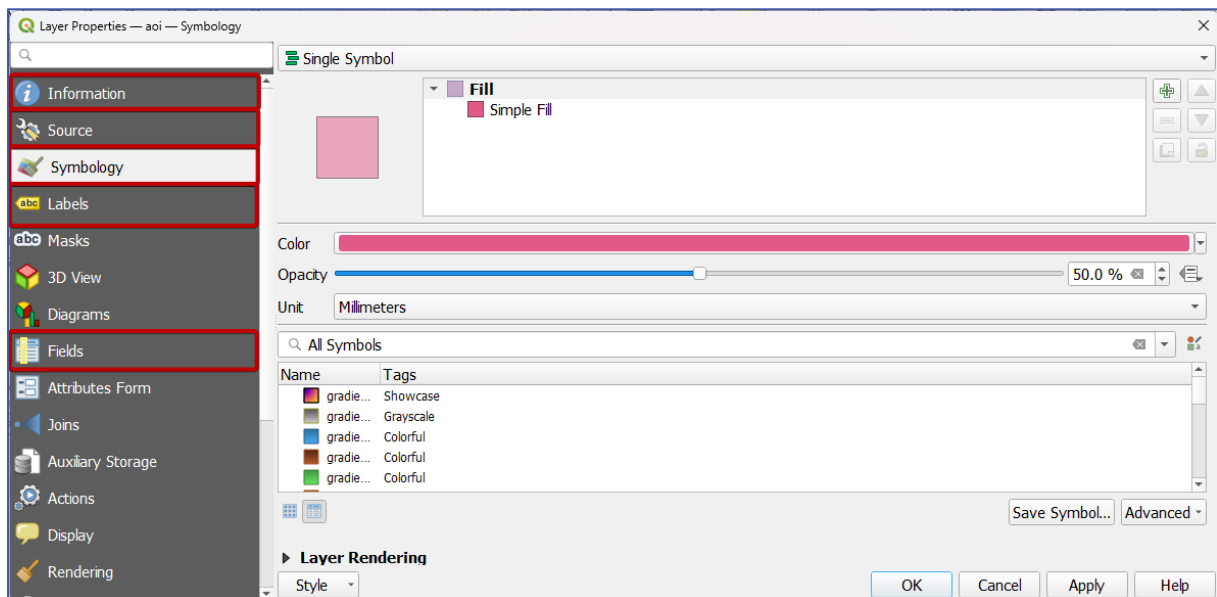


Figure 16: The **Layer Properties** window with the **Symbology** tab opened

To open an attribute table for a vector layer, right click on the layer name in the **Layers** panel and click on the **Open Attribute Table** (visible in Figure 14). If you open attribute table for the **aoi.gpkg** layer, a new window, which is visible in Figure 17, will open. Since **aoi.gpkg** layer has only one polygon feature, attribute table has only one row.

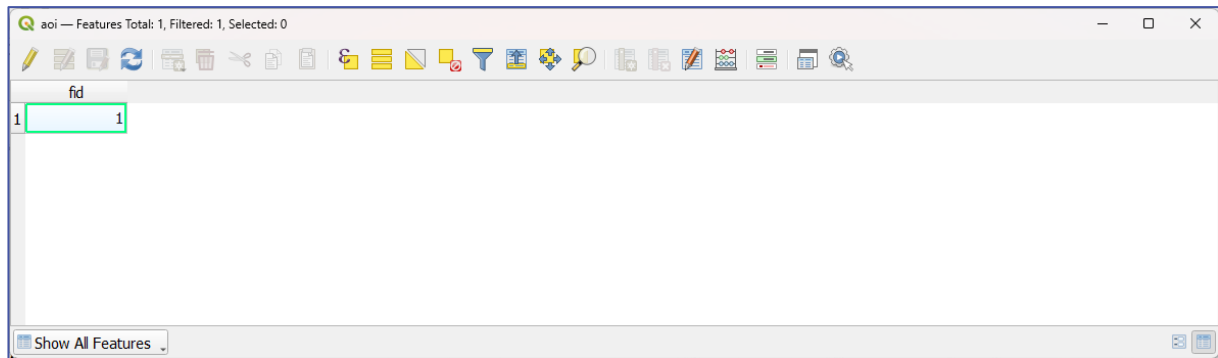


Figure 17: Attribute table for a vector layer

3.2 Downloading required data

Data that have to be downloaded for CCI25 calculation are:

1. Land cover/land use (LC/LU) data
2. Elevation data
3. Coastline data
4. Administrative units data
5. Data on protected areas

3.2.1 Land cover/land use (LC/LU) data

As stated in [18], ESA WorldCover Project Land cover (ESA WCP) is proposed as a source for LC/LU data and specifically land cover data for the year 2021 is proposed to be used for the calculation of the baseline data for CCI25. ESA WCP rasters can be downloaded from <https://viewer.esa-worldcover.org/worldcover/> by following these steps:

1. register and login
2. zoom to the area of interest
3. click on the “Layers” in the vertical menu and select WorldCover V2 2021 layer (Figure 18)
4. click on the “Download” in the vertical menu bar (Figure 18)
5. in a new window that pops up (Figure 19), on which is a list of $3^{\circ} \times 3^{\circ}$ ESA WCP tiles that fully or partly overlaps with the zoomed area, select tiles for download and then click Next
6. in a new window that pops up (Figure 20), click Download



Figure 18: Download link in vertical menu bar of the ESA WCP viewer

☐	Title	Date	Size
☒	ESA_WorldCover_10m_2021_v200_N45E021	2021-12-31T23:59:59Z	73.53 MB
☒	ESA_WorldCover_10m_2021_v200_N45E018	2021-12-31T23:59:59Z	71.94 MB
☒	ESA_WorldCover_10m_2021_v200_N45E015	2021-12-31T23:59:59Z	84.74 MB
☐	ESA_WorldCover_10m_2021_v200_N45E012	2021-12-31T23:59:59Z	81.10 MB
☐	ESA_WorldCover_10m_2021_v200_N45E009	2021-12-31T23:59:59Z	101.95 MB
☐	ESA_WorldCover_10m_2021_v200_N45E006	2021-12-31T23:59:59Z	101.56 MB
☐	ESA_WorldCover_10m_2021_v200_N45E003	2021-12-31T23:59:59Z	97.29 MB
☐	ESA_WorldCover_10m_2021_v200_N42E021	2021-12-31T23:59:59Z	80.71 MB

Figure 19: ESA WCP tiles (3°×3°)

Product downloads		Download overview	
☒	ESA_WORLDCOVER_10M_INPUTQUALITY	Number of products	3
☒	ESA_WORLDCOVER_10M_MAP	Number of files	6
		Download size	297.72 MB

Figure 20: ESA WCP download window

Along with land cover data, the service offers a download of data with a quality description. ESA WCP tiles are 3°×3° GeoTIFF raster tiles with a spatial resolution (i.e. pixel dimension on ellipsoid that is used to approximate the Earth's surface) of 1°/12008 [13]. This resolution corresponds to approximately 10 m at equator for the Map product. ESA WCP raster tiles are georeferenced in the geographic coordinate system WGS84 (EPSG:4326). ESA WCP terms of use are defined in the Product User Manual [13].

3.2.2 Elevation data

FABDEM (Forest and Buildings removed Copernicus DEM) elevation data for non-commercial usage (CC BY-NC-SA 4.0 license) can be downloaded from <https://data.bris.ac.uk/data/dataset/25wfy0f9ukoge2gs7a5mqpq2j7> (Figure 21) by clicking on one of the ZIP archives containing raster elevation data.

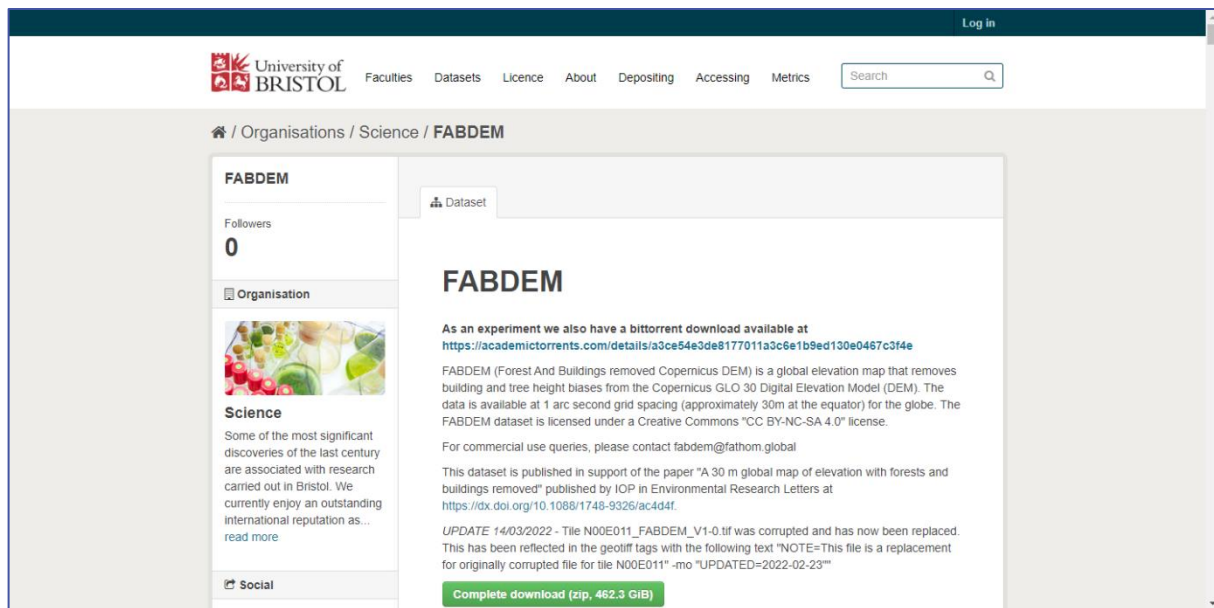


Figure 21: Screenshot of the website from which it is possible to download FABDEM raster data

Selecting the correct ZIP file for downloading might be problematic since there is no map where the coverage of each ZIP file is visible. The coverage of each ZIP file has to be read from the ZIP archive name. For example, if the ZIP archive name starts with “N40E060-N50E070”, it corresponds to the tile that covers an area from 40° to 50° north latitude and from 60° to 70° east longitude. Using a map with a 10-degree graticule grid available at <https://maps.princeton.edu/catalog/stanford-fr122tq8910> might help determine which tile(s) overlaps with the AOI. Each ZIP archive contains multiple (up to 100) raster tiles that cover 10°×10° of the Earth’s surface. Each raster tile covers 1°×1° and can be visualized by going to <https://panda.copernicus.eu/web/cds-catalogue/panda> and following steps 1-2-3 from Figure 22. Make sure to download all ZIP files that contain elevation data that intersect the AOI.

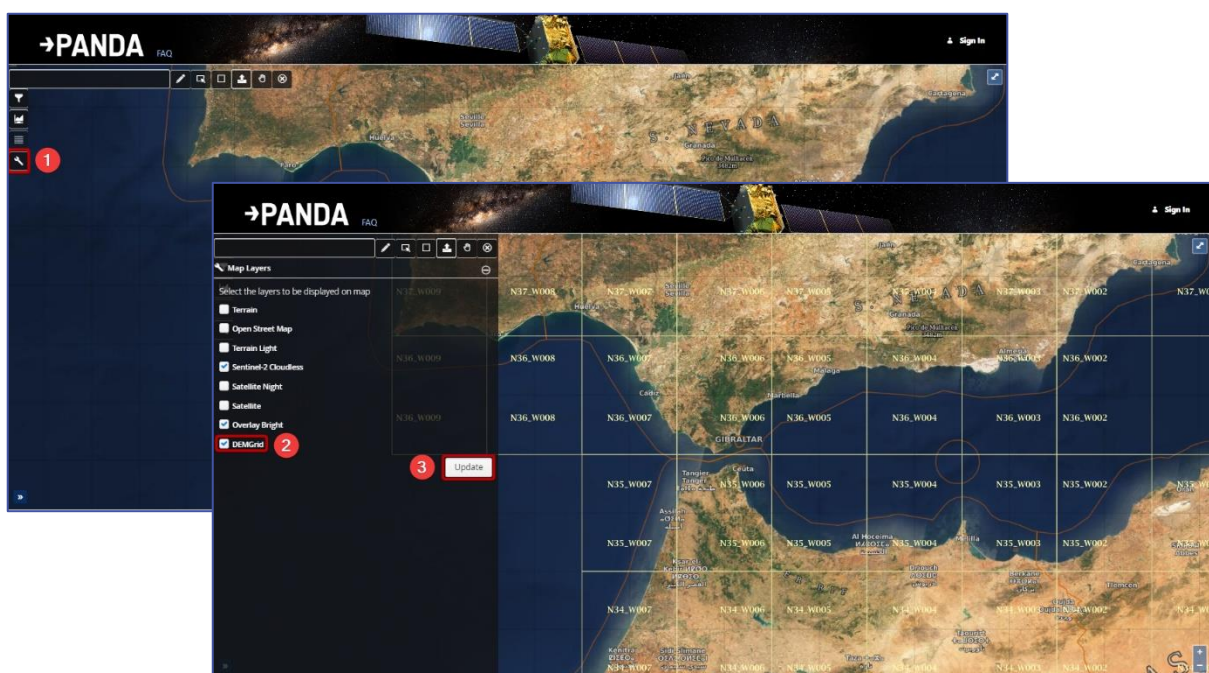


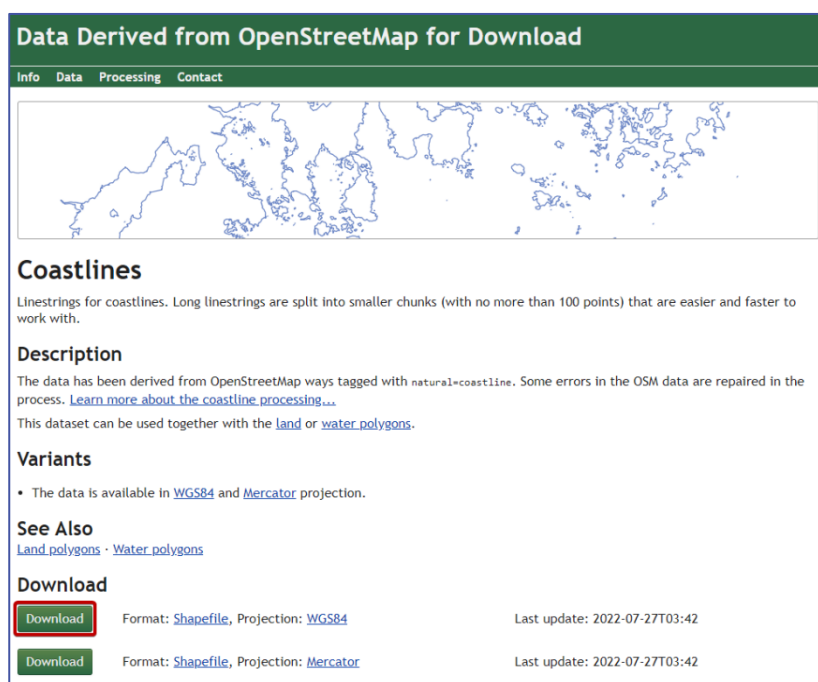
Figure 22: Steps for visualizing 1°×1° Copernicus DEM tiles

This elevation data is a digital elevation model (DEM) called FABDEM (Forest and Buildings removed Copernicus DEM) which is produced from Copernicus DEM [14] by removing heights of buildings and forests and making some other adjustments. As reported by its authors, FABDEM has significantly better accuracy in comparison to other global “freely available” DEMs [15]. Each FABDEM raster tile is georeferenced in the geographic coordinate system WGS84 (EPSG:4326) with a spatial resolution (pixel dimension) in the north-south direction of $1/3600^\circ$ [16], which is around 30 m. Heights are referenced in Earth Gravitational Model 2008 (EGM08, EPSG:3855 [16]).

If elevation data will be commercially used, then Copernicus DEM GLO-30 should be chosen instead of FABDEM. It can be downloaded by following steps described on <https://spacedata.copernicus.eu/web/cscda/data-access>.

3.2.3 Coastline data

According to [12], official coastline data is proposed to be used for CCI25 calculation. If official data are not available, or if they are not dense enough or are outdated, then coastline data can be extracted from the OpenStreetMap (OSM) data [17]. Although OSM data are not official and are crowdsourced, our experience shows that OSM coastline data are highly reliable and up-to-date. OSM coastline data can be downloaded from <https://osmdata.openstreetmap.de/data/coastlines.html>. There are two download options that differ in CRS that is used to georeference the data. We suggest downloading data from the first option that uses WGS84 (EPSG:4326) as a CRS (highlighted in Figure 23). This coastline data is stored in Esri shapefile linestring vector format. Terms of use are available at <https://www.openstreetmap.org/copyright>.



Data Derived from OpenStreetMap for Download

Info Data Processing Contact

Coastlines

Linestrings for coastlines. Long linestrings are split into smaller chunks (with no more than 100 points) that are easier and faster to work with.

Description

The data has been derived from OpenStreetMap ways tagged with `natural=coastline`. Some errors in the OSM data are repaired in the process. [Learn more about the coastline processing...](#)

This dataset can be used together with the [land](#) or [water polygons](#).

Variants

- The data is available in [WGS84](#) and [Mercator](#) projection.

See Also

[Land polygons](#) · [Water polygons](#)

Download

Download	Format: Shapefile , Projection: WGS84	Last update: 2022-07-27T03:42
Download	Format: Shapefile , Projection: Mercator	Last update: 2022-07-27T03:42

Figure 23: Downloading OSM coastline data from <https://osmdata.openstreetmap.de/data/coastlines.html>

Coastline is a baseline for defining a 10-km coastal zone that is needed for constructing CCI25 reporting units. In some areas, especially those where the coast is flat and the intertidal zone is wide, coastlines extracted from different datasets can vary significantly. This is especially problematic when there is a discrepancy between the coastline that is used for generating coastal strips (vector) and the coastline that can be extracted from the LCLU dataset (raster). These discrepancies can lead to omission or commission errors in specific land cover class area for

specific reporting units. Thus, GIS expert should perform visual inspection of areas along the coastline and highlight the reporting units in the calculation report for which this issue has an impact.

3.2.4 Administrative units data

The CCI25 indicator guidance factsheet [18] suggests using coastal administrative units (cities/municipalities) as the lowest level of authority responsible for development of spatial/urban plans and managing coast. According to [12], it is suggested to use national official data on administrative units if they are available. If not, OSM administrative units data can be downloaded from <https://osm-boundaries.com/Map> by following these steps:

1. if you do not already have one, create a new OpenStreetMap account by going to <https://www.openstreetmap.org> and filling out the form that is available after clicking on the “Sign Up” button in the upper right corner (Figure 24)
2. go to <https://osm-boundaries.com/Map> and after clicking on the “Authenticate” button in the top right corner (marked with ① on Figure 25), and again the “Authenticate” button in a new modal window (② in Figure 25), you will be redirected to the <https://www.openstreetmap.org/> where you need to enter your OpenStreetMap account data (previously created username and password or the ones you already had) and after logging in authorize OSM-boundaries to access your OSM account by clicking on the “Grant Access” button (③ on Figure 25)
3. find out which “OSM admin level” (the encircled number before the administrative unit name in the list on the left side – marked with ④ in Figure 25) is equivalent to the units in the project area responsible for development of spatial/urban plans and managing coast.
4. click on the “Download” button (marked with ⑤ in Figure 25)
5. in a new modal window (Figure 26) in a dropdown marked with ⑥ in Figure 26 select the country for which you want to download administrative units data, in both dropdowns marked with ⑦ select the same “OSM admin level” that was determined in step 3, switch from “Include water” to “Land only” (marked with ⑧), and finally click on the “Download” button that is marked with ⑨ on Figure 26 (all other options may remain unchanged)

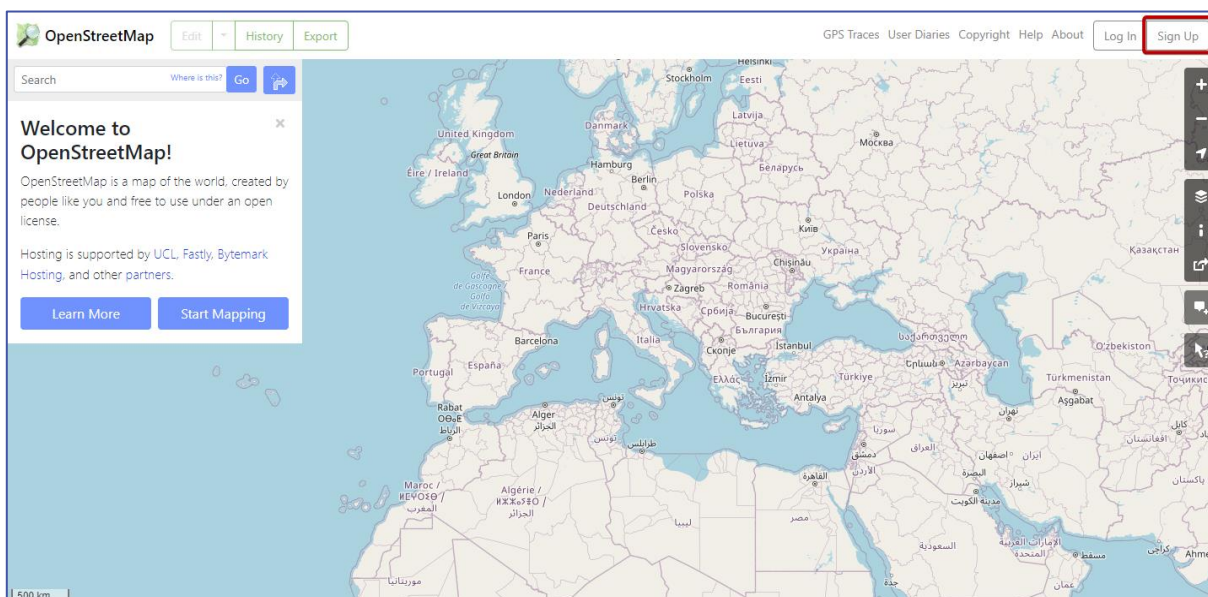


Figure 24: Initiate the creation of a new OpenStreetMap account by clicking on the “Sign Up” button

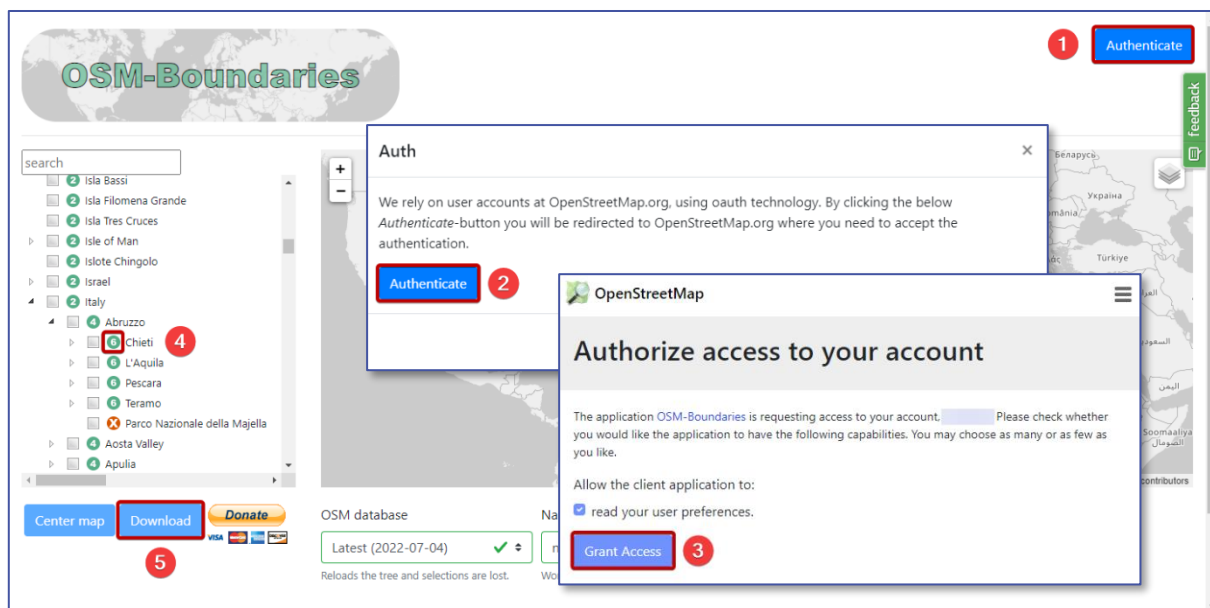


Figure 25: Downloading OSM administrative units data from the <https://osm-boundaries.com/Map>

If only options from step 5 have been changed in the modal window shown in Figure 26, and all others remained unchanged, clicking on the “Download” button will initiate the download of OSM administrative data stored in GeoJSON vector polygon format (actually a compressed `.geojson.gz` file) that is georeferenced in WGS84 CRS (EPSG:4326). Terms of use are available at <https://www.openstreetmap.org/copyright>.

Figure 26: Setting options for downloading OSM administrative units data

When OSM data are used as a source for administrative units, data should be validated by comparison with national official data and visual inspection by expert that is conducting calculations. Even if national official data are outdated, they can still be used as an assistance in validation. Additionally, expert should check if coastline used for generating coastal strips is matching the coastline from the administrative units data. If not, coastline part of administrative boundaries should be replaced with the coastlines of coastal strips.

3.2.5 Data on protected areas

Locations and boundaries of terrestrial and marine protected areas can be obtained from the World Database on Protected Areas (WDPA) available for non-commercial use on Protected Planet websites (<https://www.protectedplanet.net>). WDPA is a UN Environment Programme (UNEP) and International Union on Conservation of Nature (IUCN) project, it is being created in collaboration with governments, non-governmental organizations, academic institutions, and industry representatives [21]. WDPA is being updated every month.

The most current WDPA dataset can be downloaded from <https://www.protectedplanet.net> by following these steps:

1. in the “Thematic Areas” dropdown (marked with ① in Figure 27) in the top menu bar, click on the “Protected Areas (WDPA)” (② in Figure 27)
2. on the new web page, to download the whole WDPA dataset, click on the “Download” button (marked with ③ in Figure 28), and to download only a portion of data, which we suggest, click on the “Explore Protected Areas” button (③ in Figure 28)

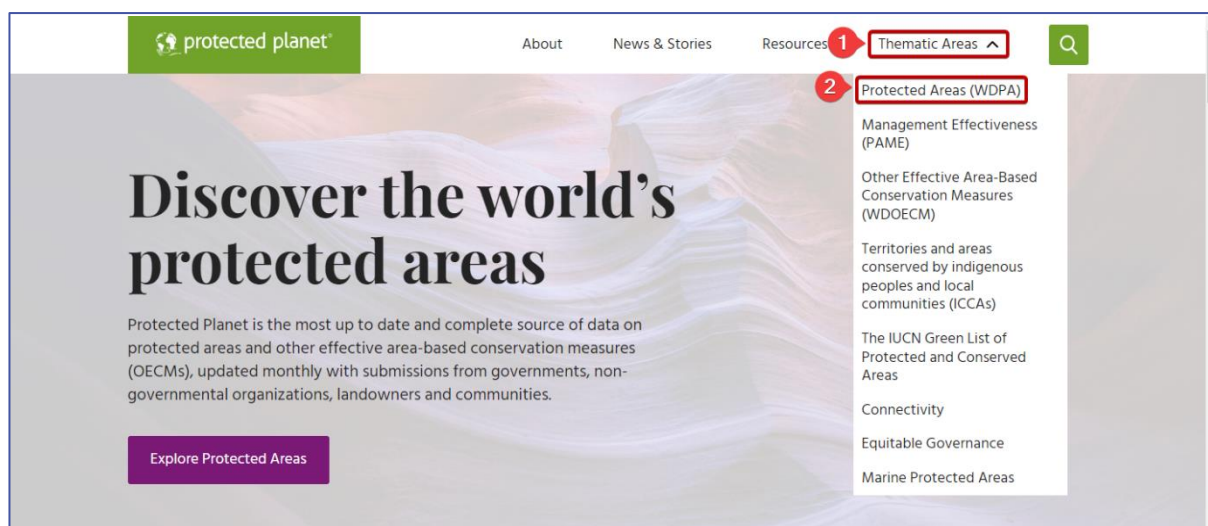


Figure 27: Accessing the WDPA web page on the Protected Planet website

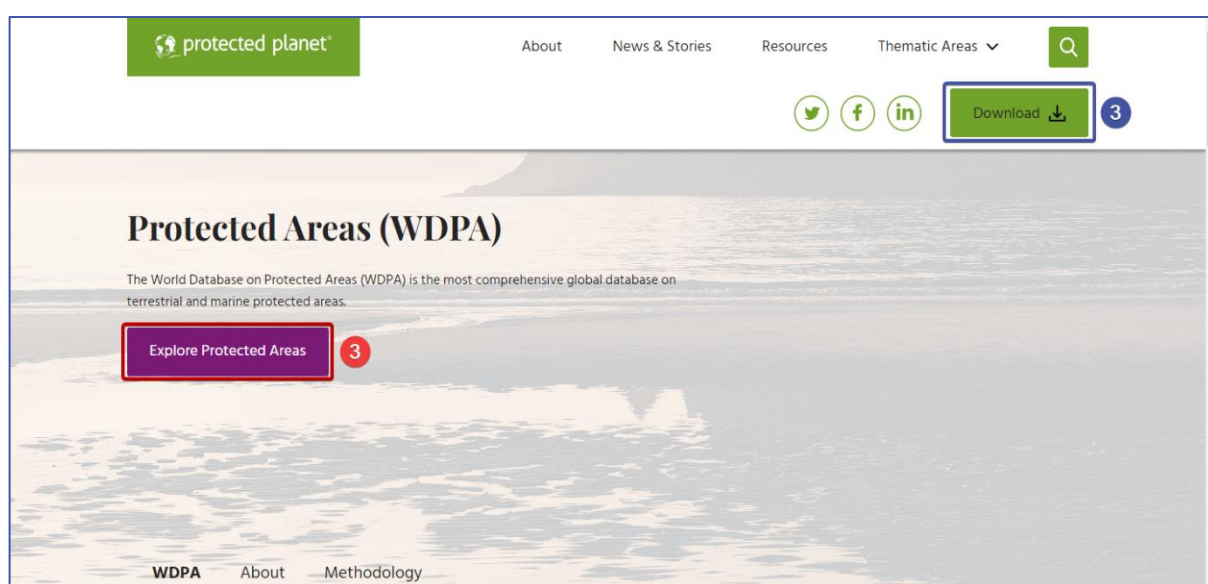


Figure 28: To filter the WDPA protected areas by country, click on the “Explore Protected Areas” button

- after clicking on the “Explore Protected Areas” button (3 in Figure 28), on a new webpage (Figure 29), it is possible to filter the WDPA protected areas based on region (continental scale), country, or to search for a specific protected area; to filter WDPA protected areas within a single country, click on “Countries” (4 in Figure 29), enter a name of the country in the field marked with 5, press *Enter*, and click on the country card (6 in Figure 29)
- after clicking on the country card (6 in Figure 29), a new webpage with map and statistics for the selected country opens, and on it, click on the “Download” button (7 in Figure 30)
- after clicking on the “Download” button, a couple of options are shown, we suggest choosing the “SHP” one (8 in Figure 30), which will after clicking on the “Continue” button in the new modal window (9 in Figure 30), prepare data for download in Esri shapefile vector format
- finally, to download prepared WDPA, click on the “Download” button in the bottom right corner (10 in Figure 30)

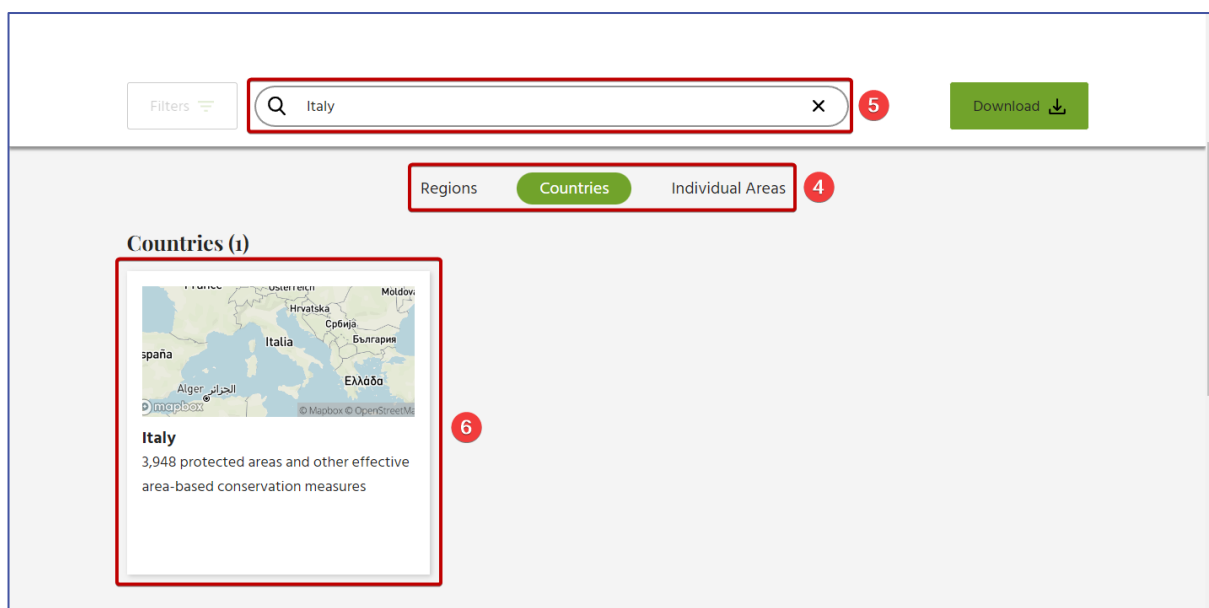


Figure 29: Filtering the WDPA protected areas by country

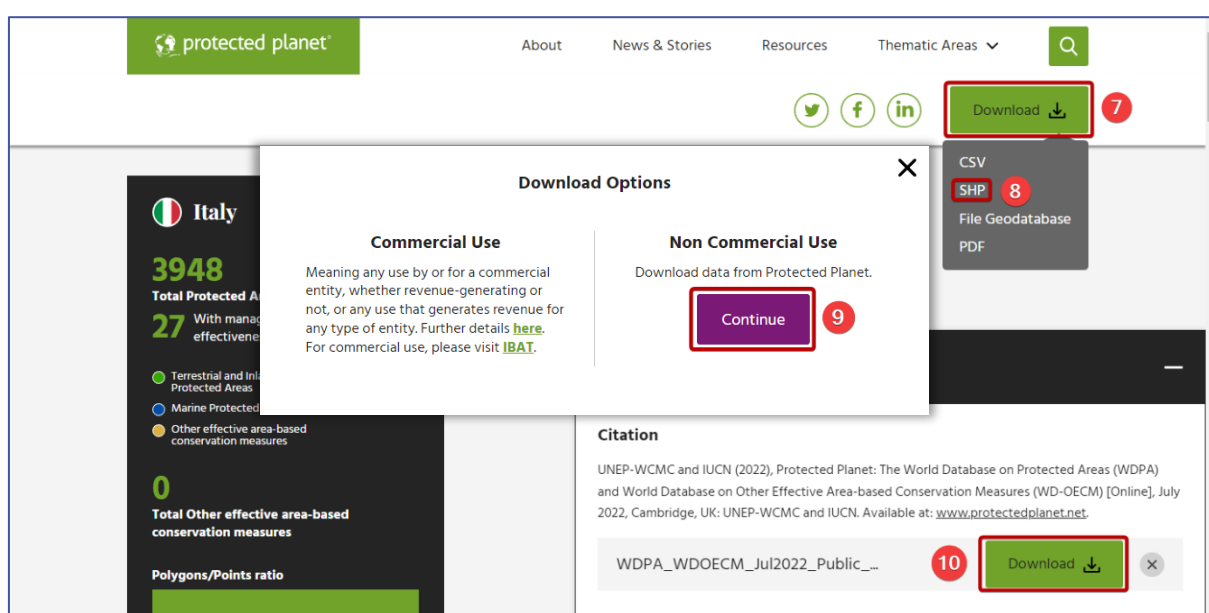


Figure 30: Downloading country-filtered WDPA data on protected areas

Clicking on this “Download” button will initiate downloading of a ZIP archive that contains WDPA data on protected areas stored in Esri shapefile polygon and point vector format. Data are georeferenced in WGS84 (EPSG:4326) CRS. Terms of use are available at <https://www.protectedplanet.net/en/legal>, and attribution is also specified above the “Download” button marked with 10 in Figure 30.

If WDPA data will be commercially used, then data should be obtained from the Integrated Biodiversity Assessment Tool (IBAT) website: <https://www.ibat-alliance.org/>.

3.3 Creating coastal strips and reporting units

So far, in QGIS we have OSM basemap and GPKG vector layer with the polygonal area of interest (*aoi.gpkg*). For constructing coastal strips and reporting units, the following datasets are required: coastline data and administrative units data. All directions and suggestions in the following sections and chapters of this manual that require defining options in dialog windows within QGIS are limited only to those parts that are required to be changed. All other options that are not mentioned should be left in their default state.

Three coastal strips have to be constructed as inland zones that are 0 – 100 m, 300 – 1000 m, and 1 – 10 km away from the coastline. Since QGIS does not natively support creating the so-called geodesic buffer zones (what is a straight line between two points in a plane, is a geodesic between two points on a surface of the ellipsoid – path with the shortest distance) and all downloaded data are in the geographic coordinate system EPSG:4326, we will need the Shape Tools plugin (installation procedure is explained in section 2.1). To construct coastal strips and reporting units, we suggest the following workflow (some of these steps (especially step 6) are computationally expensive, so be prepared for a longer processing time):

7. although not necessary, unzip the downloaded ZIP file with the coastline data (originally named *coastlines-split-4326.zip*), import the Esri shapefile in QGIS by going to **Layer ► Add Layer ► Add Vector Layer...**, and then after clicking on the three-dots-button in a new dialog window (1 in Figure 31) locate *lines.shp* file in the folder created after unzipping (as

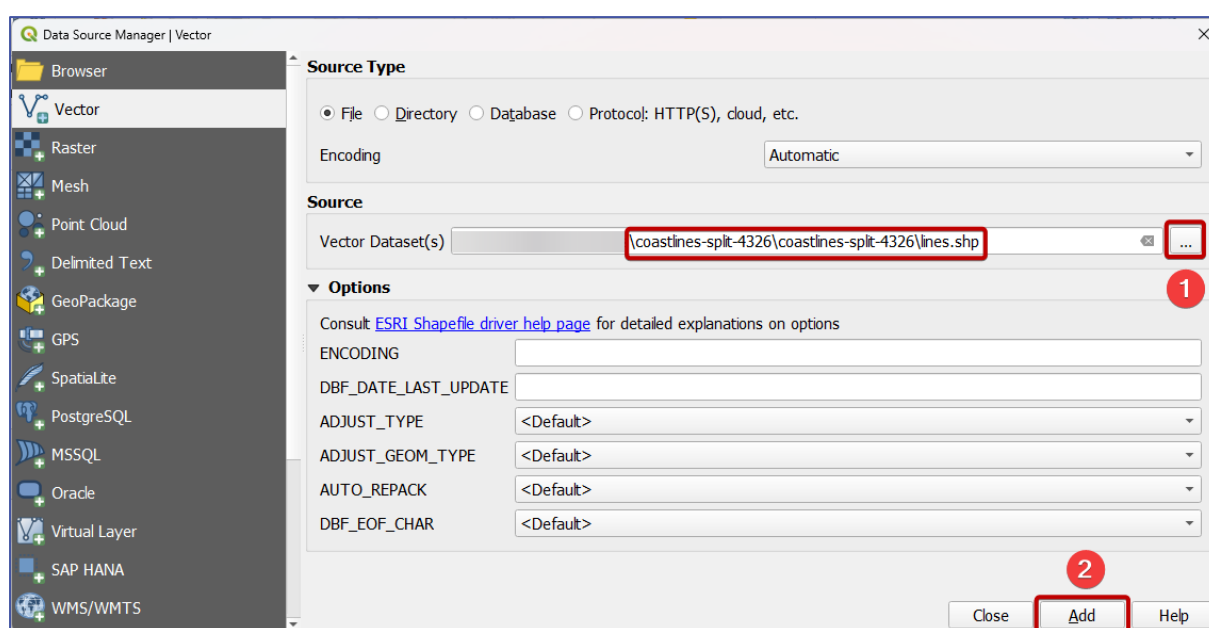


Figure 31: Importing coastline data in QGIS

already mentioned, one Esri shapefile consists of at least three files that have SHP, SHX, and DBF extension), and import it by clicking on the **Add** button (2 in Figure 31)

8. create a spatial index for the imported layer with coastline data (*lines.shp*), which will, under some circumstances, speed up processing done with this layer:
 - a. go to **Vector ► Data Management Tools ► Create Spatial Index...**
 - b. in a new dialog window (Figure 32), under the **Input layer** dropdown (1 in Figure 32) choose the imported coastline data layer (*lines.shp*)
 - c. click the **Run** button (2 in Figure 32; this operation does not create a new layer, but only adds a spatial index to the existing one – for Esri shapefile format it creates a new file with QIX extension in the same location on the disc as other files that compose corresponding Esri shapefile layer)

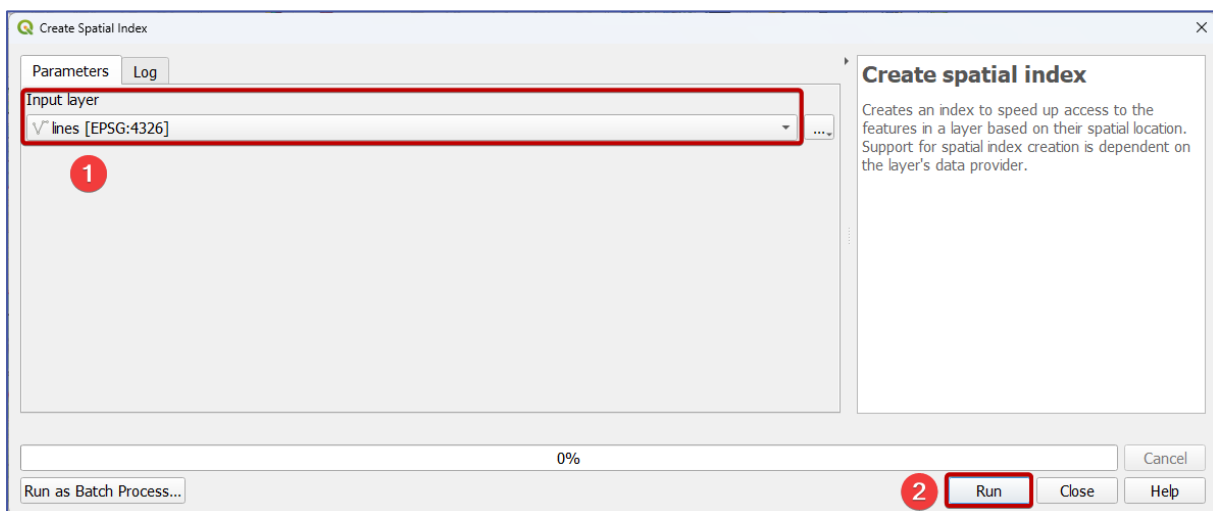


Figure 32: Creating spatial index for vector layer

9. clip the imported coastline data layer (*lines.shp*) with the AOI layer (*aoi.gpkg*):
 - a. go to **Vector ► Geoprocessing Tools ► Clip...**
 - b. in a new dialog window (Figure 33), under the **Input layer** dropdown (marked with 1 in Figure 33), choose the imported layer with coastline data (*lines.shp*)
 - c. in the **Overlay layer** dropdown choose the vector layer in which the area of interest is defined (*aoi.gpkg*) – marked with 2 in Figure 33
 - d. after clicking on the three-dots-button (3 in Figure 33) and choosing **Save as File...**, define storage location, name the output clipped coastline file with **coastline-aoi**,

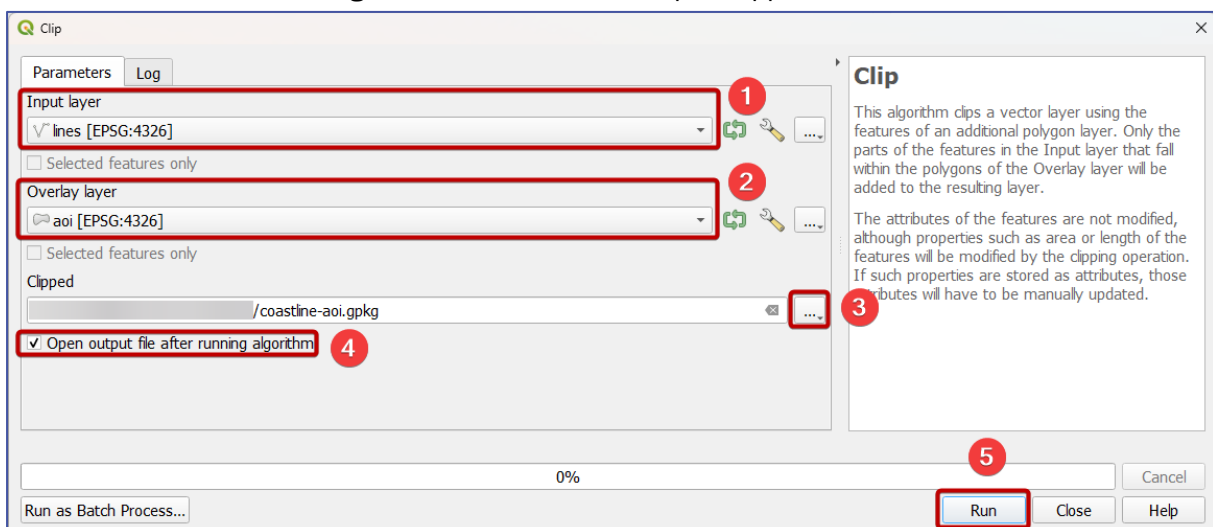


Figure 33: Clipping coastline data to the extent of the AOI

and choose GPKG as filetype (output file will be named **coastline-aoi.gpkg**), as shown on Figure 34

- e. although it should already be ticked, if it is not, always tick the **Open output file after running algorithm** option to load the output layer into QGIS after algorithm finishes with processing (4 in Figure 33)
- f. click the **Run** button to start the clipping algorithm (5 in Figure 33)

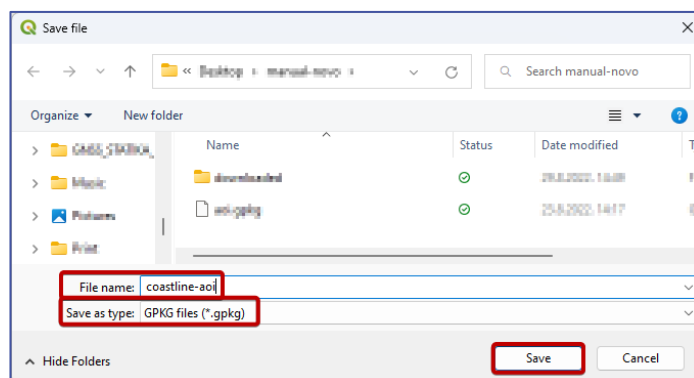


Figure 34: Defining file name and file type when saving a new file (under Windows operating system)

10. densify line vertices in the previously created layer (**coastline-aoi.gpkg**):

- a. go to **Vector ► Shape Tools ► Geodesic shape densifier**
- b. in a new dialog window (Figure 35), under the **Input layer** dropdown (marked with 1 in Figure 35) choose the previously created layer with coastline data clipped to the area of interest (**coastline-aoi.gpkg**)
- c. for **Maximum line segment length (in kilometers)** enter **0.02** (2 in Figure 35), and be sure you are using the right decimal separator (point or comma) which can be checked by going to **Settings ► Options**, in the **General** tab on the left side, under "Sample data: (...) float:"
- d. after clicking on the three-dots-button (3 in Figure 35) and choosing **Save as File...**, define the name and storage location for densified coastline (use **coastline-aoi-densified.gpkg**, choose GPKG as filetype)
- e. click the **Run** button to start the densifying algorithm (5 in Figure 35)

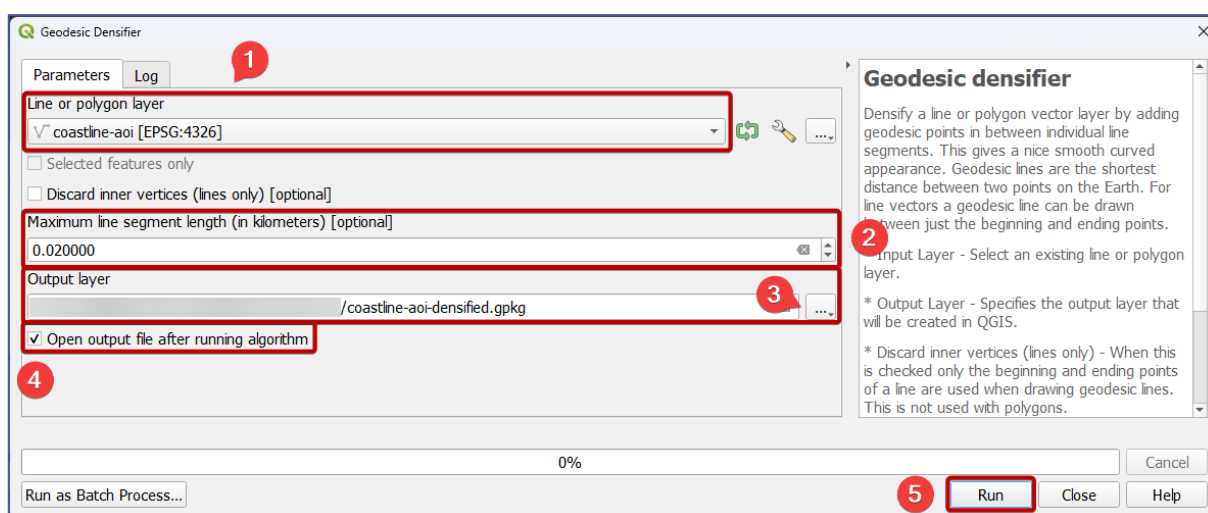


Figure 35: Densifying vertices in coastline data

11. extract vertices from the densified coastline GPKG layer (result for Italy is visible on Figure 37, point coloring will most certainly be different):

- go to **Vector ► Geometry Tools ► Extract vertices...**
- in a new dialog window (Figure 36), under the **Input layer** dropdown (marked with ① in Figure 36) choose the previously created layer with densified coastline vertices (*coastline-aoi-densified.gpkg*)
- after clicking on the three-dots-button (② in Figure 36) and choosing **Save as File...**, define the name and storage location for the output point layer (for name, use *coastline-vertices.gpkg*, choose GPKG as filetype)
- click the **Run** button to start the algorithm (④ in Figure 36)

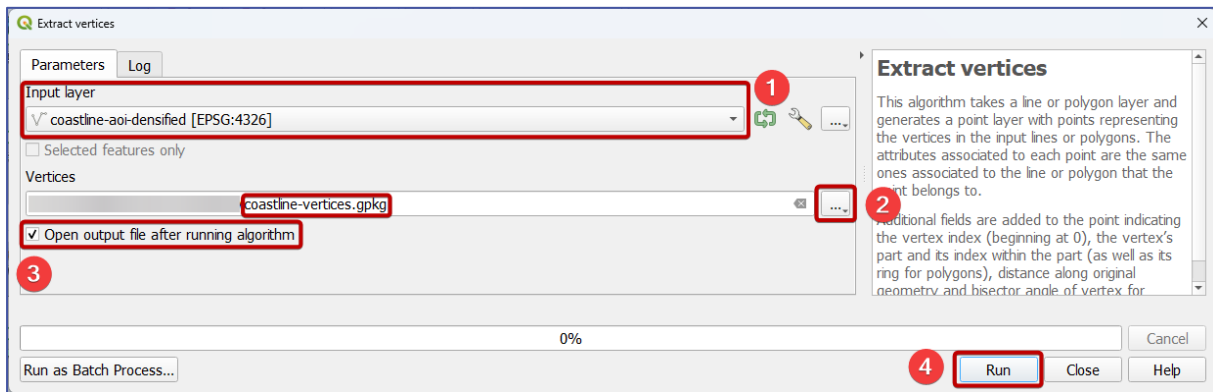


Figure 36: Extracting vertices from the densified coastline data

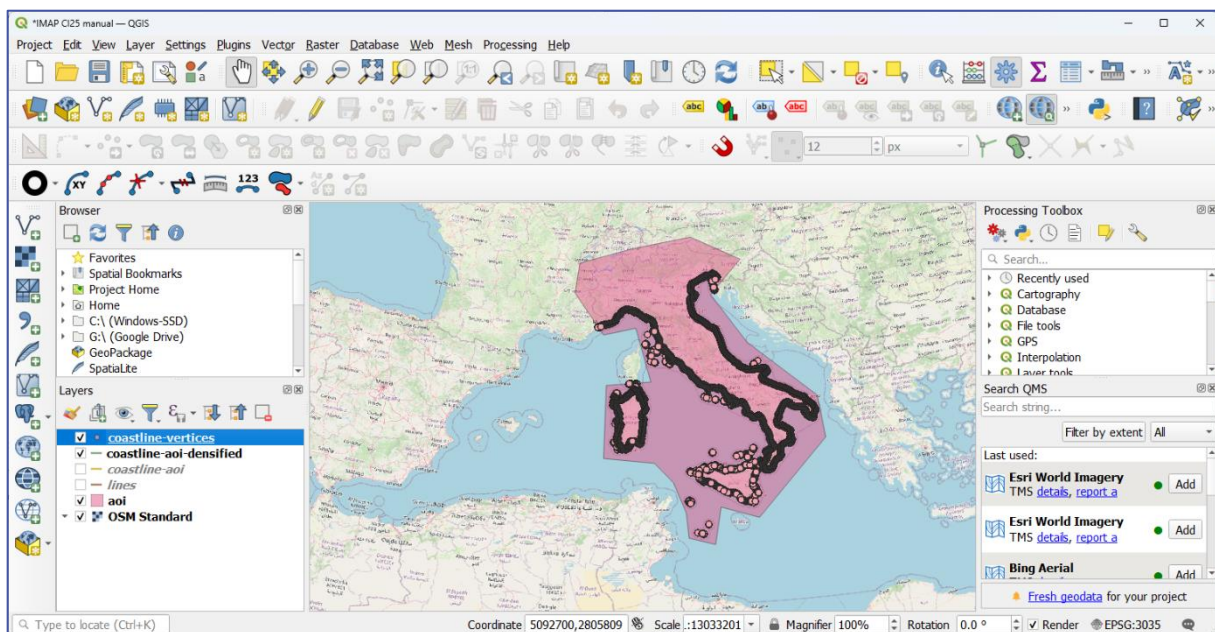


Figure 37: Extracted vertices from the densified coastline data (example for Italy)

- create three buffers (300 m, 1 km, and 10 km) around each extracted vertex in the *coastline-vertices.gpkg* layer:
 - go to **Vector ► Shape Tools ► Create shape ► Create ellipse**, and click on the **Run as Batch Process** button in the new dialog window (highlighted in Figure 38)
 - click twice on the  button that is marked with ① in Figure 39
 - in all three dropdowns highlighted with ② in Figure 39 select the *coastline-vertices.gpkg* as an **Input layer**
 - for **Shape type** select "Polygon" (③ in Figure 39)
 - for the **Semi-major axis** and **Semi-minor axis** enter values as shown in Figure 39 (the first is 300, the second is 1000, and the third is 10000 – marked with ④)
 - for **Radius units** select "Meters" (⑤ in Figure 39)

- g. for the **Number of drawing segments (approximate)** enter 64 (6 in Figure 39)
- h. in the **Output layer** column (marked with 7 in Figure 40), define names and storage locations for output buffer layers (for names, use *buffer-300m.gpkg*, *buffer-1km.gpkg*, and *buffer-10km.gpkg*, choose GPKG as filetype) by clicking on the corresponding three-dots-buttons while taking care that layer names correspond to **Semi-major axis** and **Semi-minor axis** values (marked with 4 in Figure 39)
- i. tick the **Load layers on completion** option (8 in Figure 40)
- j. finally, click the **Run** button to start buffer creation (9 in Figure 40)

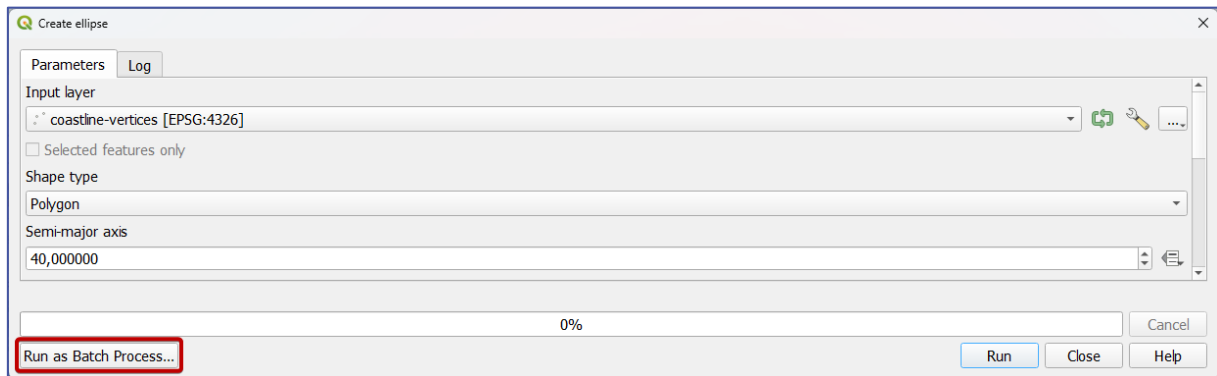


Figure 38: Switching from single-processing to batch-processing point buffer creation

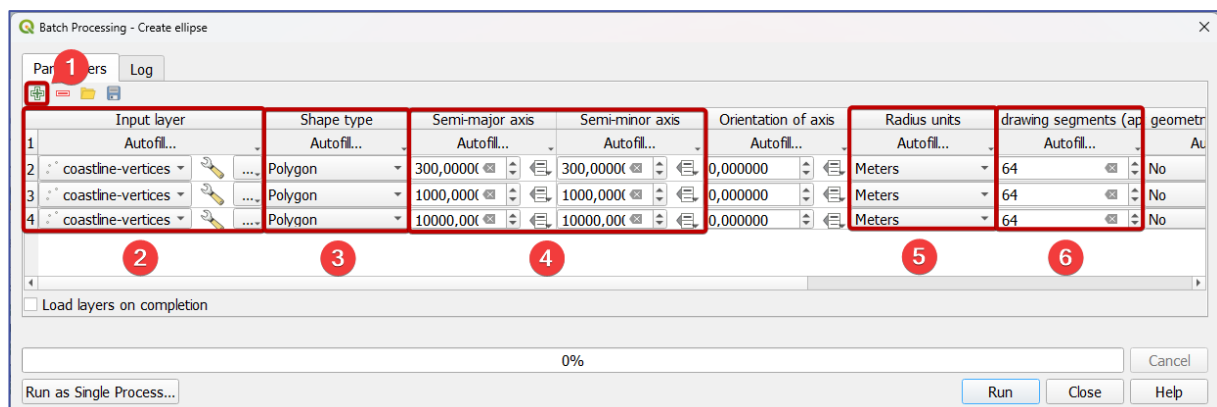


Figure 39: Creating 300 m, 1 km, and 10 km buffers around every extracted vertex from the densified coastline data (1)

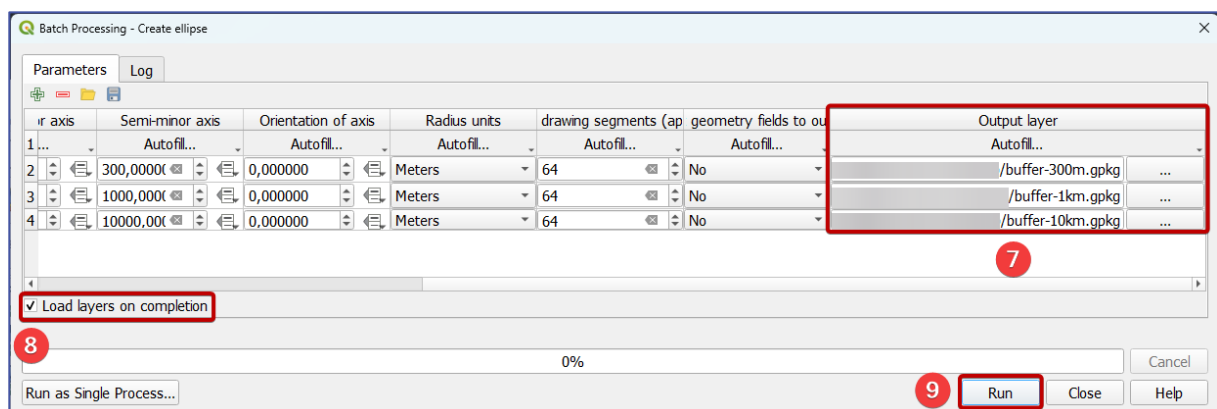


Figure 40: Creating 300 m, 1 km, and 10 km buffers around every extracted vertex from the densified coastline data (2)

13. dissolve 300 m, 1 km, and 10 km buffers:

- go to **Vector ► Geoprocessing Tools ► Dissolve...**, and click on the **Run as Batch Process** button in the new dialog window (highlighted in Figure 41)
- click twice on the  button that is marked with ① in Figure 42
- in the **Input layer** column (marked with ② in Figure 42), select three previously created buffer layers (*buffer-300m.gpkg*, *buffer-1km.gpkg*, and *buffer-10km.gpkg*)
- in the **Dissolved** column, for each layer click on the three-dots-button and define the name and storage location for each layer (for name, use *buffer-300m-dissolved.gpkg*, *buffer-1km-dissolved.gpkg*, and *buffer-10km-dissolved.gpkg*, choose GPKG as filetype) while taking care that layer names in the **Input layer** column correspond to names in the **Dissolved** column (marked with ③ in Figure 42)
- tick the “Load layers on completion” option (④ in Figure 42)
- finally, click the **Run** button to start the dissolving algorithm (⑤ in Figure 42)

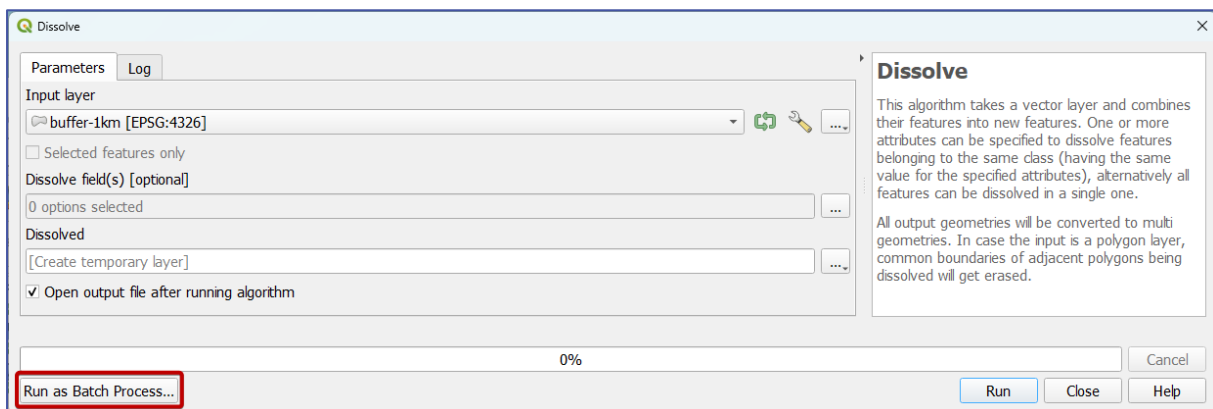


Figure 41: Switching from single-processing to batch-processing dissolving

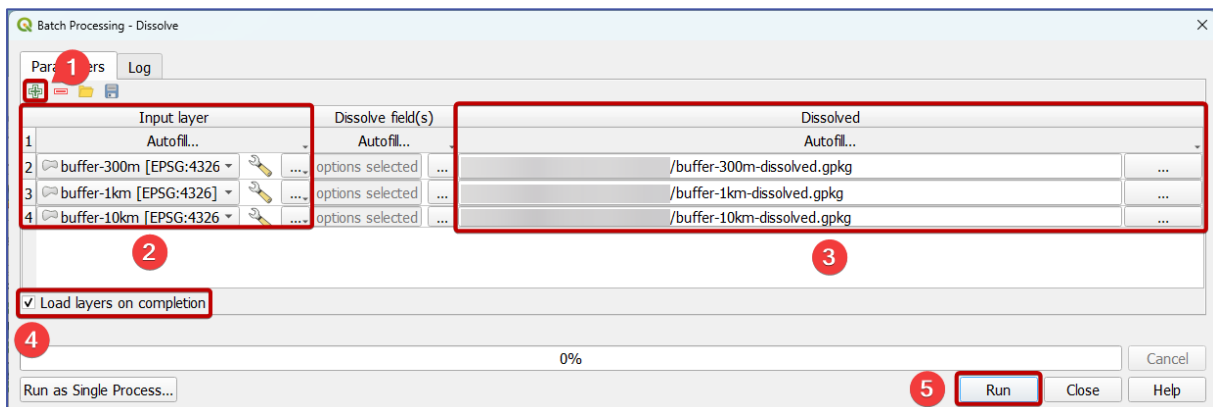


Figure 42: Dissolving 300 m, 1 km, and 10 km buffers

14. create spatial differences from previously created dissolved buffers to generate 300 – 1000 m and 1 – 10 km strips:

- go to **Vector ► Geoprocessing Tools ► Difference...** and click on the **Run as Batch Process** button in the new dialog window (highlighted in Figure 43)
- click once on the  button that is marked with ① in Figure 44
- if in dropdowns in the **Input layer** and **Overlay layer** columns you choose the same layers as in Figure 44 (marked with ②), the upper command will produce a 300 – 1000 m coastal strip, and lower a 1 – 10 km one
- in the **Difference** column (③ in Figure 44), define names and storage location for each output layer by clicking on three-dot-buttons (name upper layer with *strip_300-1000m.gpkg* and lower with *strip_1-10km.gpkg*, choose GPKG as filetype)

- e. tick the “Load layers on completion” option (4 in Figure 44)
- f. finally, click the **Run** button to start the creation of the spatial difference layer (5 in Figure 44)

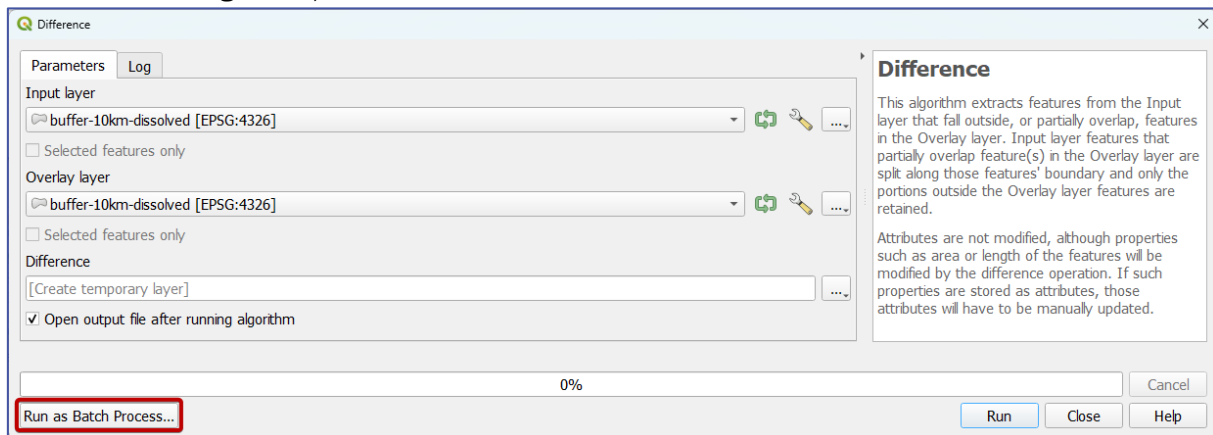


Figure 43: Switching from single-processing to batch-processing spatial difference creation

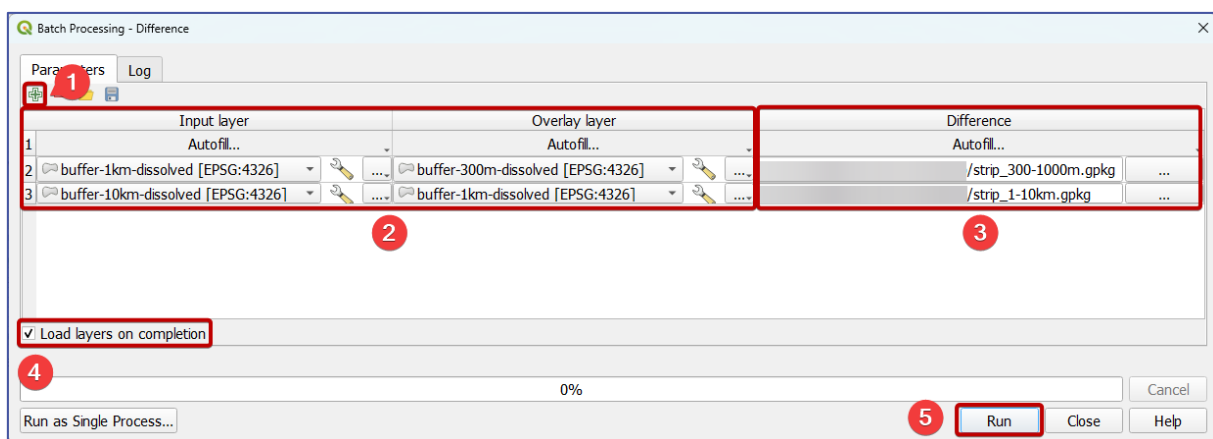


Figure 44: Creating 300 – 1000 m and 1 – 10 km strips

15. merge two layers created in the previous step (*strip_300-1000m.gpkg* and *strip_1-10km.gpkg*) and dissolved 300 m buffer from step 7 (layer *buffer-300m-dissolved.gpkg*):
 - a. go to **Vector ► Data Management Tools ► Merge vector layers...**
 - b. in a new dialog window (Figure 45) click on the three-dots-button (marked with 1)
 - c. in a new window (Figure 46) tick three layers that have to be merged (*strip_300-1000m.gpkg*, *strip_1-10km.gpkg*, and *buffer-300m-dissolved.gpkg*, as is marked with 2 in Figure 46) and click the **OK** button (marked with 3 in Figure 46)
 - d. define a storage location and name for the output layer by clicking on the three-dots-button marked with 4 on Figure 45 and choosing **Save as File...** (name it with *coastal-strips.gpkg*)
 - e. finally, click the **Run** button to start merging layers (marked with 5 in Figure 45)
16. import administrative units data downloaded from OSM-boundary (.geojson.gz file, the filename is starting with “OSMB”) in QGIS by going to **Layer ► Add Layer ► Add Vector Layer...** and then follow the same steps as when importing coastline data (Figure 31), or just drag&drop downloaded file into QGIS (after importing administrative units, map view in QGIS should look like the one on Figure 47; if needed, draw order of different layers could be changed by changing layer’s position (drag&drop) in the **Layers** panel – the first layer in the **Layers** panel will be on top of other layers in the QGIS map view)

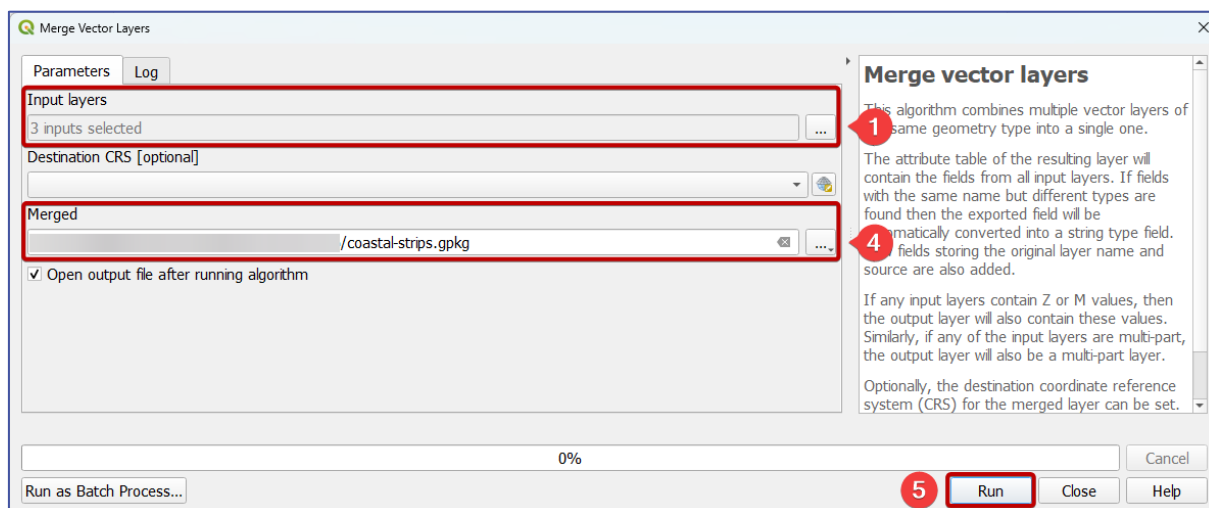


Figure 45: Merging 0 – 300 m, 300 – 1000 m, and 1 – 10 km strips into a single layer

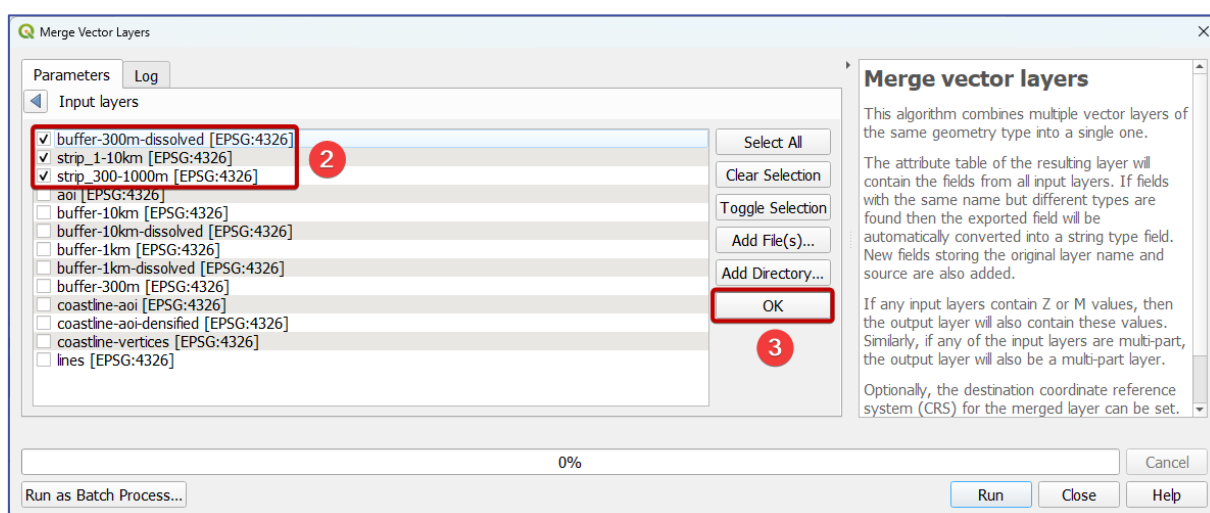


Figure 46: Choosing layers that are going to be merged

17. extract only administrative units that are intersecting previously created coastal strips (layer *coastal-strips.gpkg*):

- go to **Vector ► Research Tools ► Select by location...**
- in a new dialog window (Figure 48) in the **Select features from** dropdown choose the previously imported *.geojson.gz* file with administrative units data (1 on Figure 48)
- tick only **intersect** geometric predicate (2 on Figure 48)
- in the **By comparing to the features from** dropdown choose the coastal strips layer (*coastal-strips.gpkg*, 3 on Figure 48)
- clicking on the Run button (4 on Figure 48), select only those administrative units that intersect (i.e. have any point/part in common) – this operation does not produce any new data (selected polygons are by default settings colored with yellow, as can be seen on Figure 49)

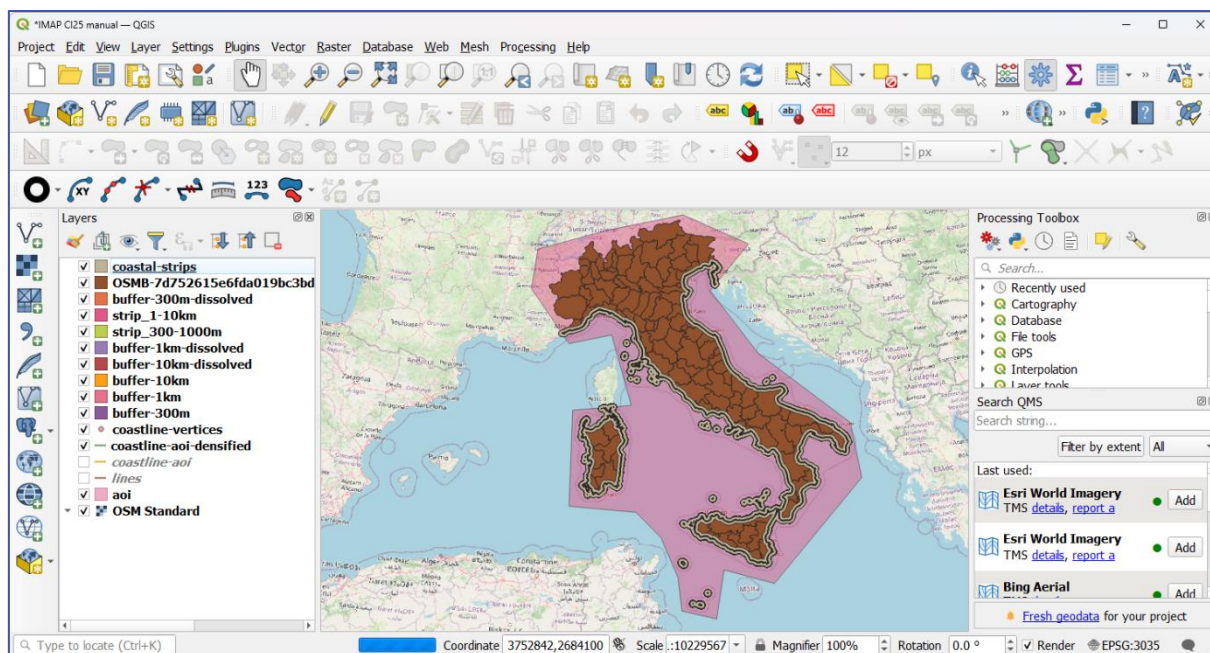


Figure 47: QGIS map view after importing OSM-boundary administrative units data (example for Italy, basemap: © OpenStreetMap contributors)

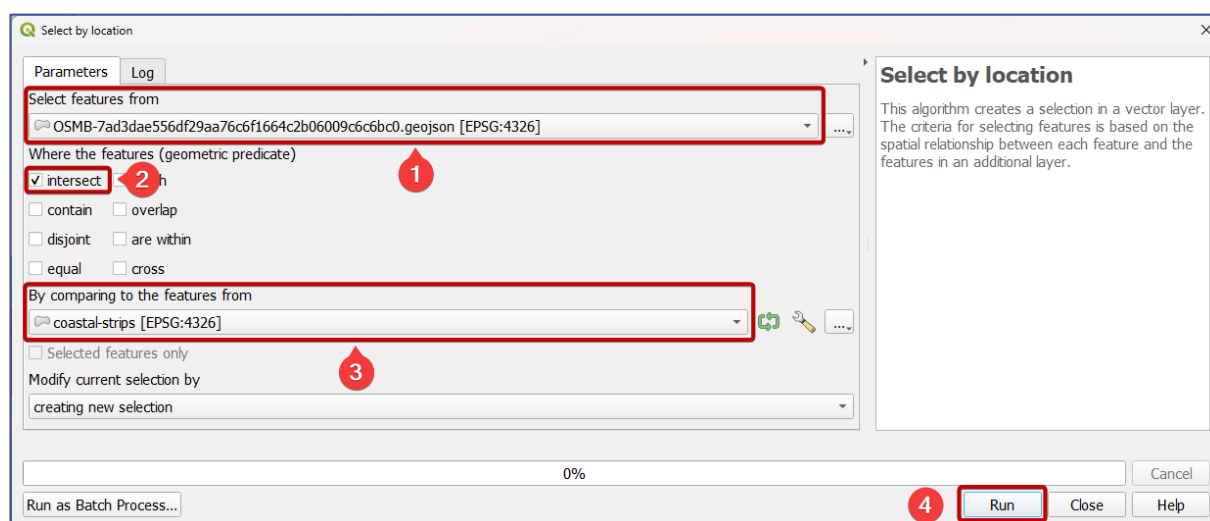


Figure 48: Performing a spatial query (select only administrative units that intersect coastal strips)

- f. in the **Layers** panel, right-click on the imported **.geojson.gz** layer with administrative units in which administrative units that intersect coastal strips are selected and click on the **Export ► Save Selected Features As...** (Figure 49)
- g. in a new dialog window, under the **Format** dropdown choose “GeoPackage” (1 in Figure 50)
- h. click on the three-dots-button (2 in Figure 50) and define a storage location and name for a new GeoPackage file (name file with **administrative-units.gpkg**)
- i. under **Select fields to export and their export options** untick all fields except “name”, “local_name”, and “name_en” (3 in Figure 50), and click on the **OK** button (4 in Figure 50)

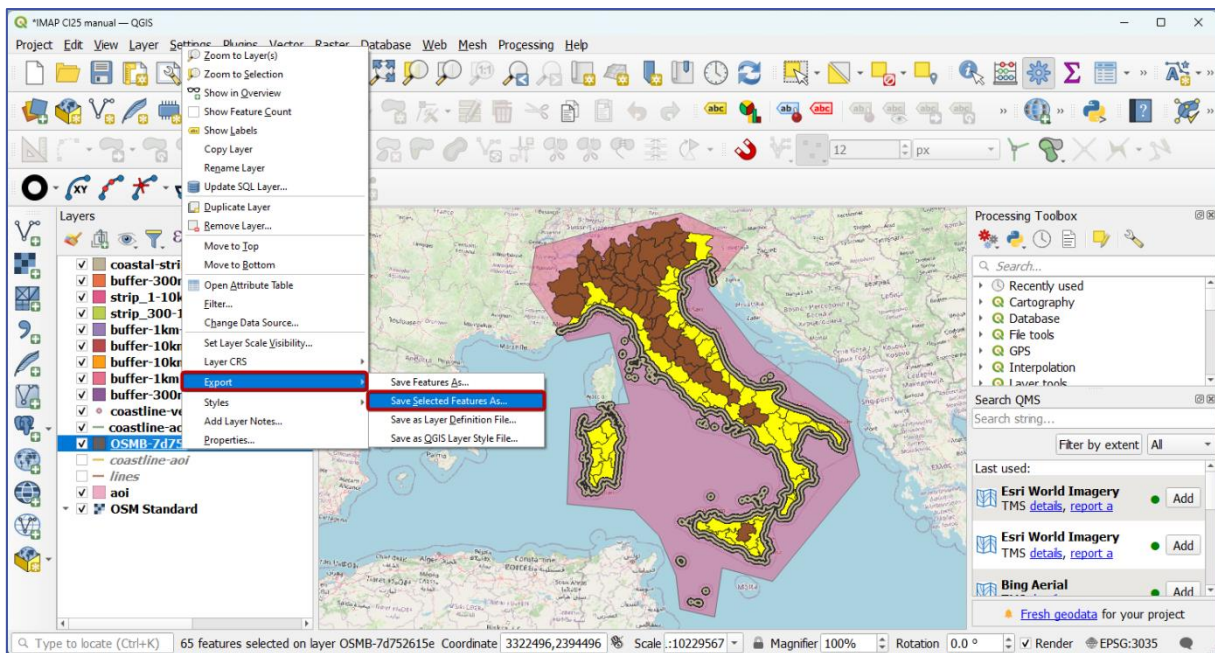


Figure 49: Extracting selected polygons (colored with yellow) from OSM-boundary administrative units data (basemap: © OpenStreetMap contributors)

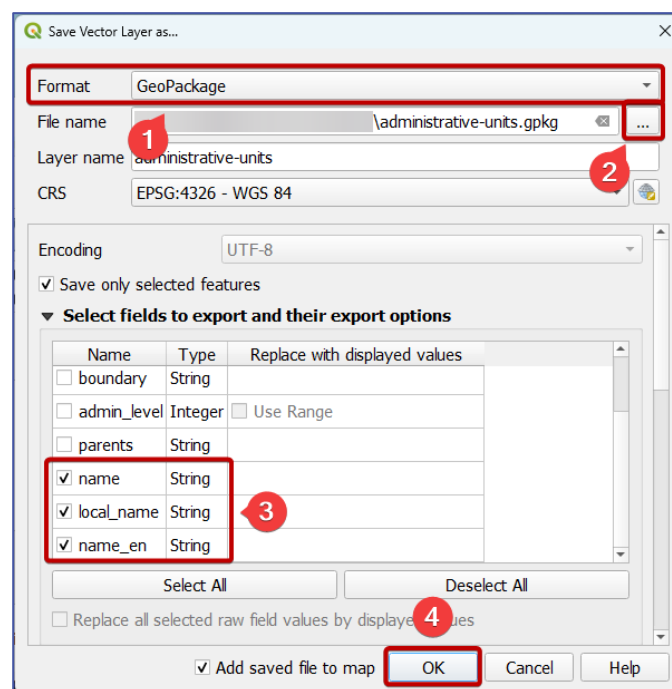


Figure 50: Exporting selected administrative units in the new GeoPackage file

18. create an intersection between coastal strips and administrative units produced in the previous step, which will produce reporting units:
 - a. go to **Vector ► Geoprocessing Tools ► Intersection...**
 - b. in the new dialog window (Figure 51) under the **Input layer** choose the layer with administrative units (**administrative-units.gpkg**, ① on Figure 51)
 - c. under the **Overlay layer** choose the layer with coastal strips (**coastal-strips.gpkg**, ② on Figure 51)

- d. click on the three-dots-button under **Intersection** (3 on Figure 51), choose **Save as File...**, and define a storage location and name for a new GeoPackage file (name file with **reporting-units.gpkg**)
- e. click the **OK** button (4 on Figure 51) to initiate the creation of reporting units

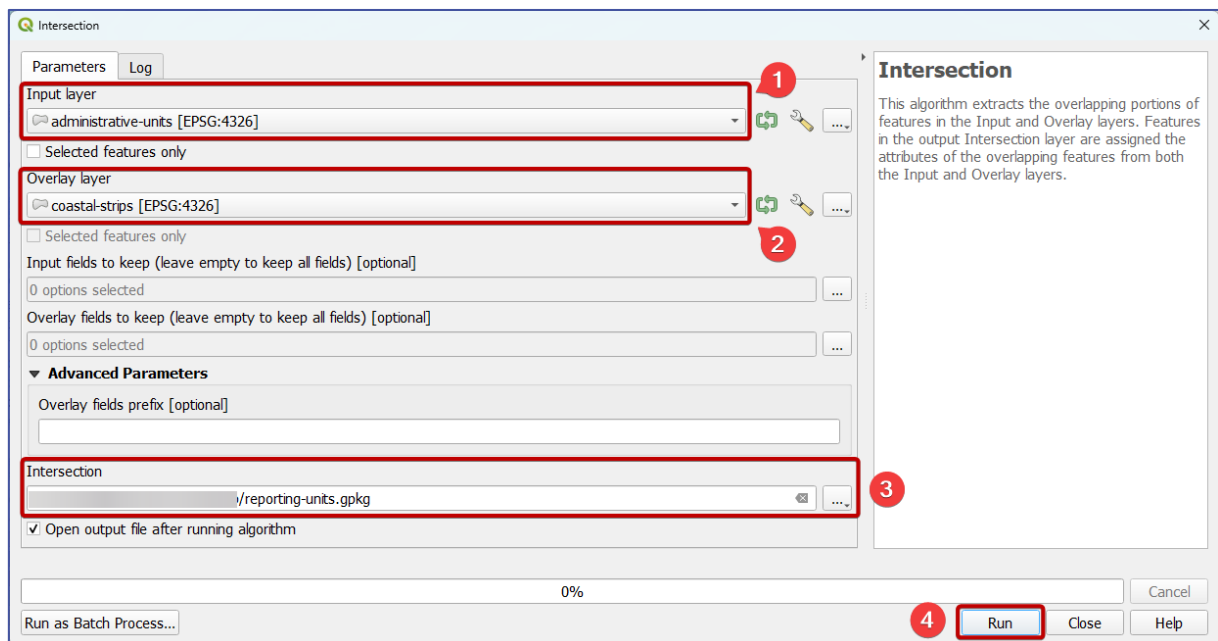


Figure 51: Intersecting administrative units with coastal strips and thus producing reporting units

19. the final step is to clean attribute data in reporting units layer (**reporting-units.gpkg**):
 - a. open attribute table for the **reporting-units.gpkg** layer (right click on the **reporting-units.gpkg** layer name in the **Layers** panel and click on the **Open Attribute Table**)
 - b. enable layer editing by clicking on the icon marked with 1 in Figure 52

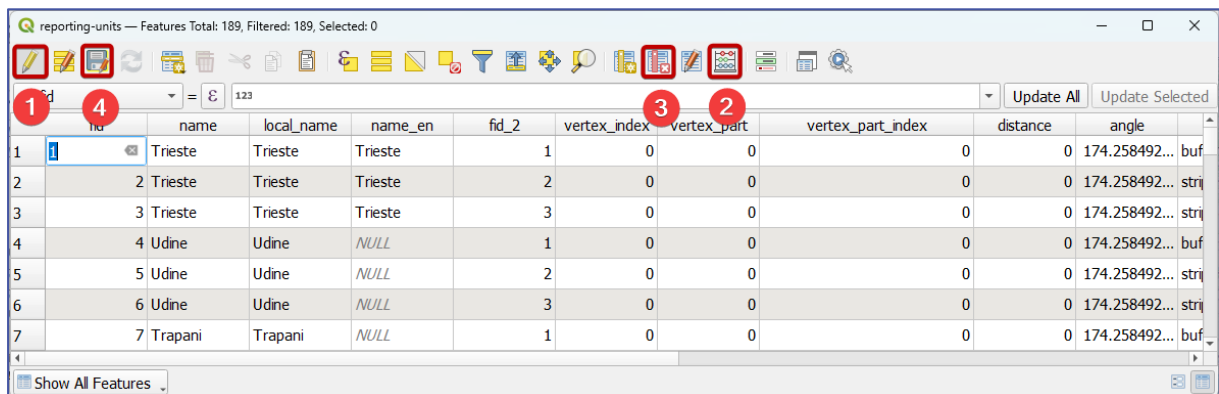


Figure 52: Editing attribute data for a vector layer

- c. create a new attribute with coastal strip names (“0 – 300 m”, “300 – 1000 m”, and “1 – 10 km”) by clicking on the icon marked with 2 in Figure 52, which will open the **Field Calculator** window (Figure 53):
 - i. make sure that the **Create a new field** option is ticked, and that the **Only update # selected features** option, if it is available, is unticked (marked with 1 in Figure 53)
 - ii. in the **Output field name** field enter “strip”, which will be the name for a new attribute (2 in Figure 53)
 - iii. in the **Output field type** dropdown select “Text” (3 in Figure 53)

- iv. for the Output field length enter “30” (4 in Figure 53)
- v. in the Expression window (marked with 5 in Figure 53), paste the following expression:

```
CASE
WHEN "layer" = 'buffer-300m-dissolved' THEN '0 - 300 m'
WHEN "layer" = 'strip_300-1000m' THEN '300 - 1000 m'
WHEN "layer" = 'strip_1-10km' THEN '1 - 10 km'
ELSE 'ERROR'
END
```

- vi. in the area marked with 6 in Figure 53, look for “layer” item in the “Fields and Values” group, click on it, click on the All Unique button (marked with 7), and, if needed, replace underlined parts in the above expression with corresponding items from the list that was generated under the All Unique button (marked with 8)
- vii. click on the OK button (marked with 9 in Figure 53), which will close the Field Calculator window and after which a new attribute named “strip” will be created, and its values will be populated based on the above specified expression

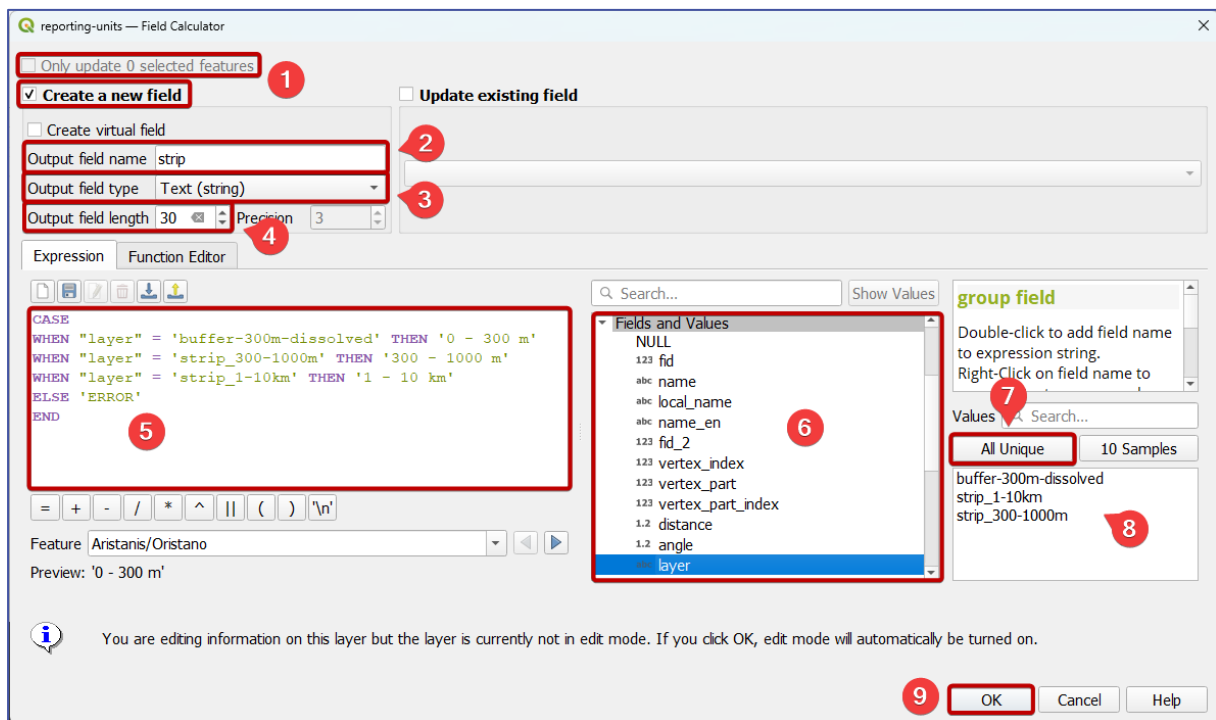


Figure 53: Creating a new “strip” attribute by defining expression in the Field Calculator window

- d. some attribute values in the “name_en” attribute/field are not specified, so they should be copied from the “name” or the “local_name” attribute/field:
 - i. again, open the Field Calculator window by clicking on the icon marked with 2 in Figure 52
 - ii. tick the Update existing field option (marked with 1 in Figure 54), and make sure that the Only update # selected features option (marked with 2 in Figure 54), if it is available, is unticked
 - iii. in a dropdown that is marked with 3 in Figure 54, choose “name_en”
 - iv. in the expression window (marked with 4), enter the following expression:

```

if(
    "name_en" IS NOT NULL,
    "name_en",
    if(
        "name" IS NOT NULL,
        "name",
        "local_name"
    )
)

```

- v. click on the **OK** button (marked with 5), which will close the **Field Calculator** window and populate empty attribute values for the “name_en” attribute with the attribute values from the “name”, and “local_name” attribute, as specified in above expression

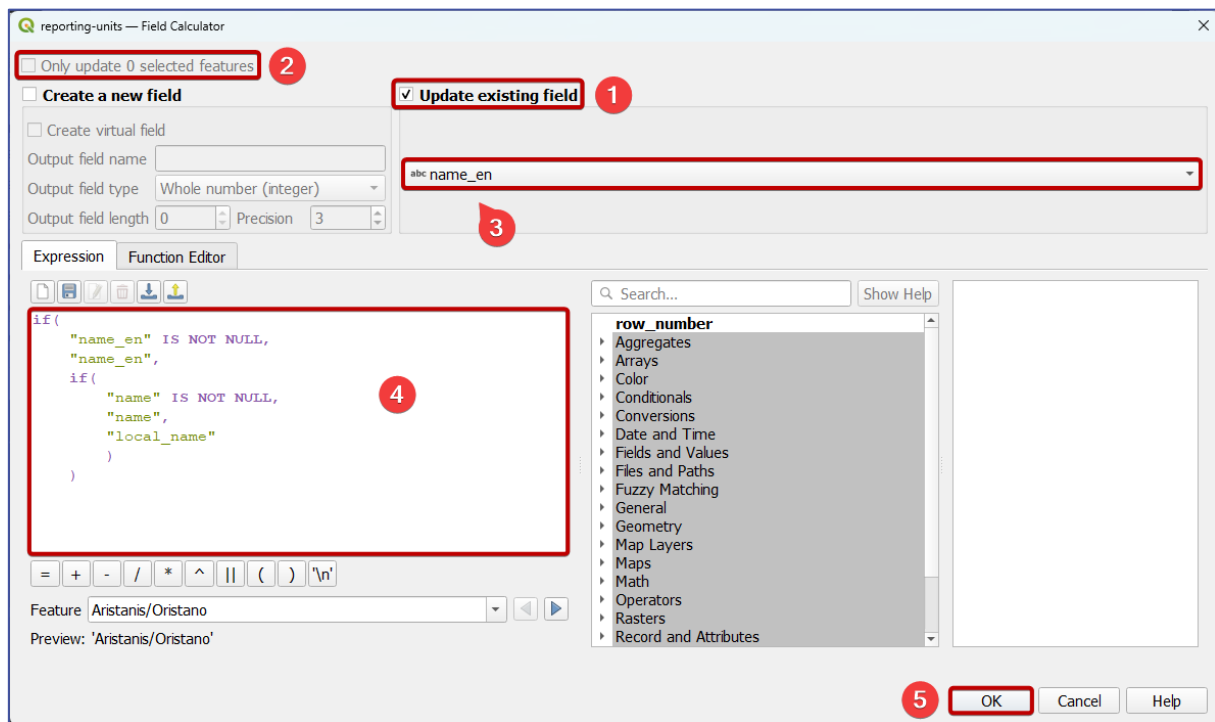


Figure 54: Updating the “local_name” attribute by defining expression in the **Field Calculator** window

- e. remove unnecessary attributes:
 - i. click on the icon marked with 3 in Figure 52
 - ii. in a new window (Figure 55) select attributes “fid_2”, “vertex_index”, “vertex_part”, “vertex_part_index”, “distance”, “angle”, “layer”, and “path” (as marked with 1)
 - iii. click on the **OK** button (marked with 2 in Figure 55) which will delete selected attributes and their values from the attribute table
- f. finally, click on the  icon (marked with 4 in Figure 52) to save all changes that have been done in the **reporting-units.gpkg** layer, and click on the  icon (marked with 1 in Figure 52) to disable layer editing

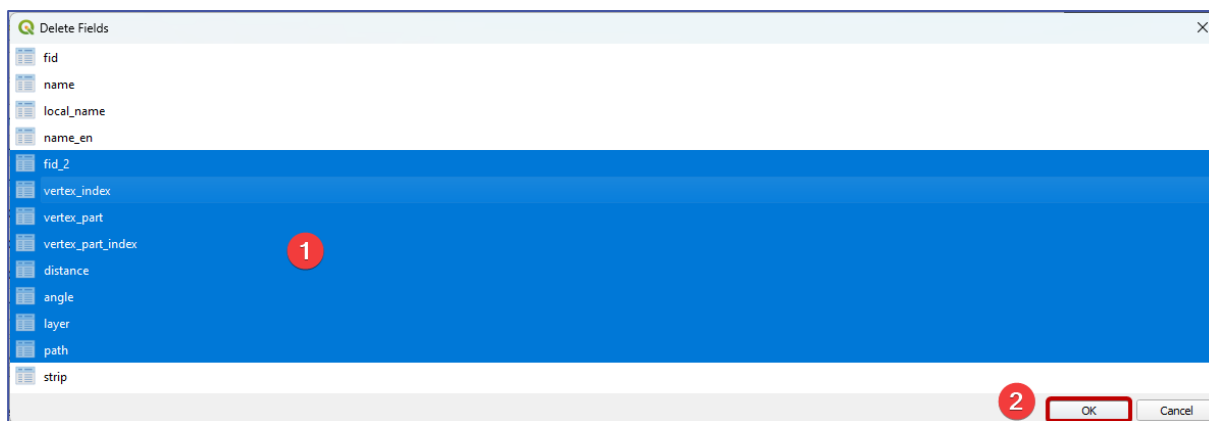


Figure 55: Selecting attributes that are about to be deleted

After this processing, the only layers that can be left in QGIS are: **aoi.gpkg**, **coastline-aoi.gpkg**, **administrative-units.gpkg**, **reporting-units.gpkg**, and basemap imported with the QuickMapServices plugin. All other layers may be removed from the QGIS project by right-clicking on each of them in the **Layers** panel and then clicking on the **Remove Layer...** It is also recommended to save the QGIS project file (it has a QGZ extension) from time to time by going to **File ► Save...** As already discussed, note that in the QGIS project file no raster or vector data is stored, it only stores locations of corresponding files that are stored in the computer storage. Always be sure to retain relative location on the computer storage between the QGIS project file and files that are imported into the QGIS project. All data that are not necessary for further processing can be deleted from the computer storage.

3.4 Preparing other data

Reporting units that are created in the previous chapter will be used for aggregating LC/LU and elevation data, and data on protected areas. In this chapter, these data will be prepared for their further processing and aggregation.

3.4.1 Preparing LC/LU data

All steps in this chapter, as opposed to steps in the previous chapter with the creation of reporting units, need to be done twice, for both years that are chosen for the indicator calculation. In the chapters below, the processing of the ESA WCP data for the year 2021 is described as these data is proposed for the calculation of the CCI25 baseline data.

Downloaded ESA WCP GeoTIFF tiles can be imported in QGIS by going to **Layer ► Add Layer ► Add Raster Layer...** In the new dialog window (Figure 56) click on the three-dots-button (1 in Figure 56), locate and select the ESA WCP GeoTIFF tile(s) that has to be imported, and finally import it by clicking the **OK** button (2 in Figure 56). Make sure you have imported (and previously downloaded) all ESA WCP raster tiles that overlap with the AOI, that is, more specifically, with created reporting units.

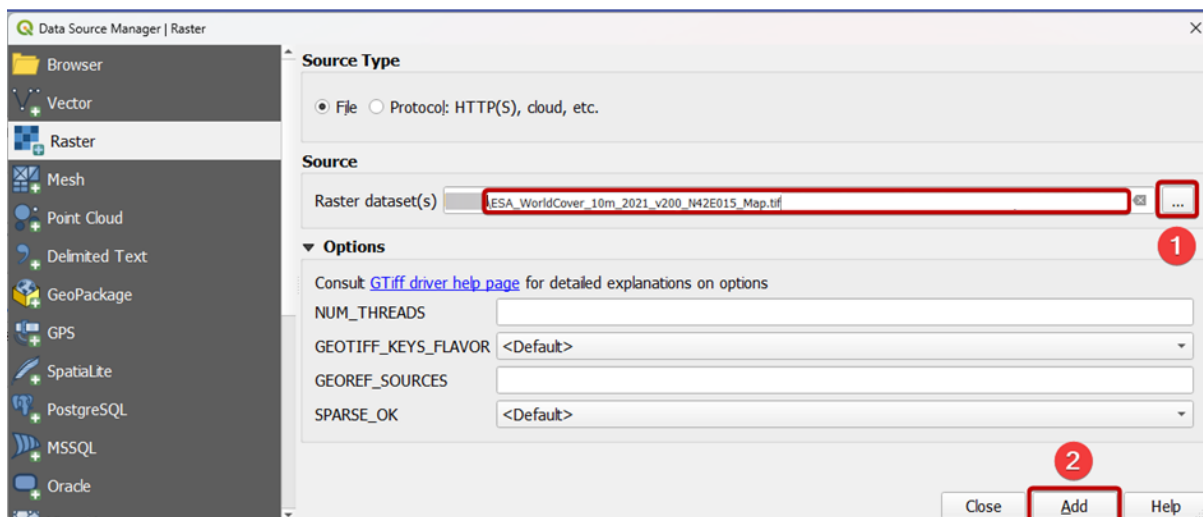


Figure 56: Importing ESA WCP GeoTIFF tile in QGIS

If only one raster tile is imported into QGIS, the following steps can be skipped. Otherwise, all imported rasters from each year should be merged (i.e. mosaicked) into one so that they can be processed jointly. Regular mosaicking (**Raster ► Miscellaneous ► Merge...**) creates a completely new raster which will, in this case, duplicate original data and unnecessarily take additional storage space. Another mosaicking approach is to create a so-called virtual raster. A virtual raster only points to the original raster data, it takes almost none of the storage space and is in QGIS treated as a regular raster. To create a virtual raster that consists of more ESA WCP raster tiles, follow these steps:

1. go to **Raster ► Miscellaneous ► Build virtual raster...**
2. in a new dialog window (Figure 57), click on the three-dots-button under **Input layers** (marked with 1)
3. in a new window (Figure 58) tick all ESA WCP raster tiles from one year (example for the year 2021 marked with 2)
4. click on the **OK** button (marked with 3 in Figure 58)
5. after clicking on the three-dots-button marked with 4 in Figure 57 and choosing **Save as File...**, define the storage location and name for the virtual raster that is about to be created (for name, use *ESA WCP-<year>.vrt*, replace <year> with the corresponding year)
6. click the **Run** button to initiate the creation of a virtual raster (5 in Figure 57)

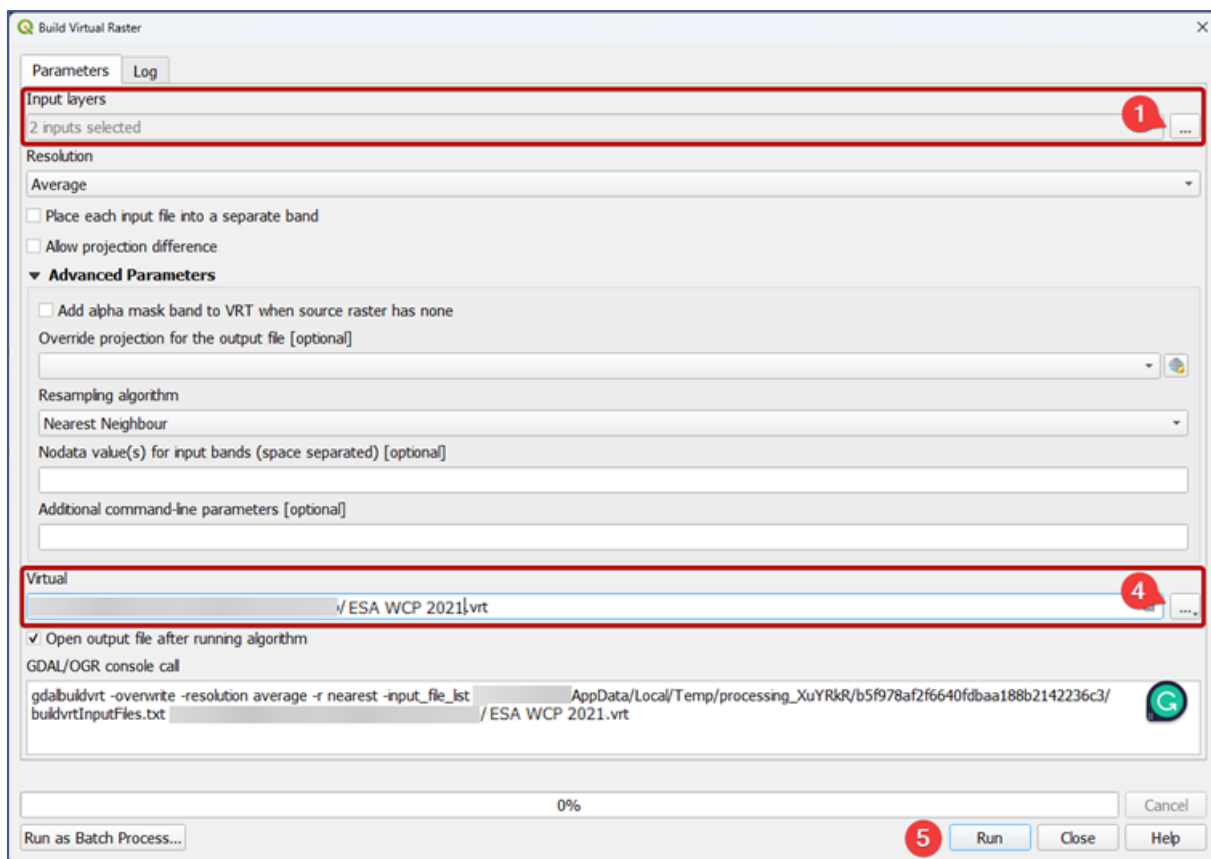


Figure 57: Merging all ESA WCP tiles into one virtual raster

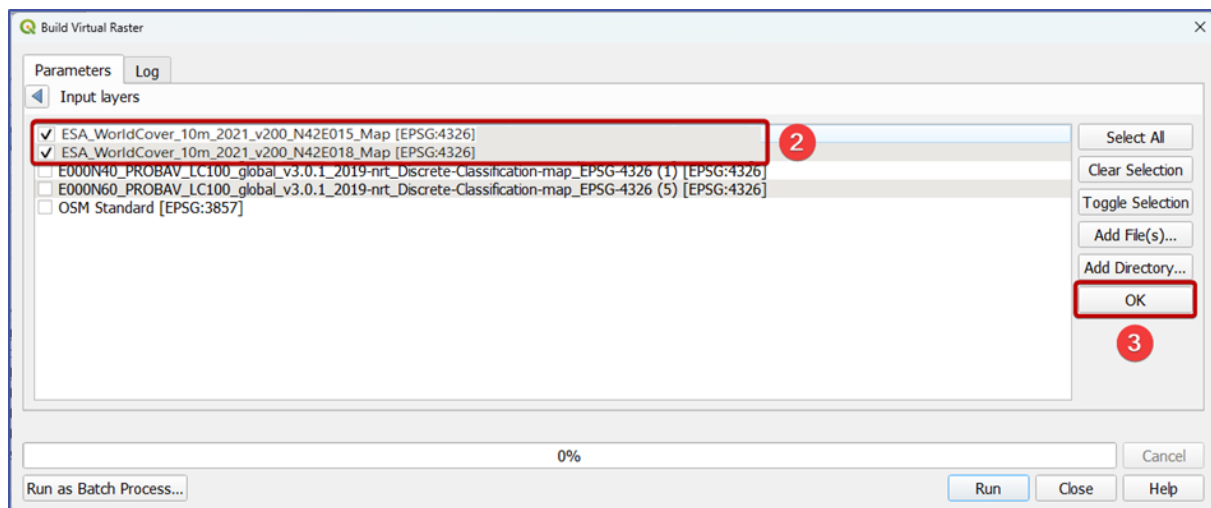


Figure 58: Selecting raster layers that will be merged into one virtual raster

To speed up processing in the next steps, we can create a new raster from previously imported ESA WCP rasters or created virtual rasters in which all pixel values that are outside of reporting units will be removed, that is, set to appropriate “no data value”. This procedure is in QGIS called clipping. We will also increase spatial resolution by 2 times to reduce errors in later calculations. We propose the following workflow (separately for each year):

1. to determine the resolution or pixel size of a ESA WCP raster layer:
 - a. right click on one of the previously created virtual rasters in the [Layers](#) panel
 - b. click on [Properties...](#) in the dropdown menu

-
- QGIS Layer Properties - ESA WCP 2021 | Information
- Information
- X : 9000
 - Y : 2250
 - X : 4500
 - Y : 1125
 - X : 2248
 - Y : 562
- Dimensions** X: 144000 Y: 36000 Bands: 4
- Origin** 9.45
- Pixel Size** 8.3333333333333055e-05, -8.3333333333333055e-05
- Identification**
- Identifier**
- Parent Identifier**
- Title**
- Style ▼ OK Cancel Apply Help

[illegible]

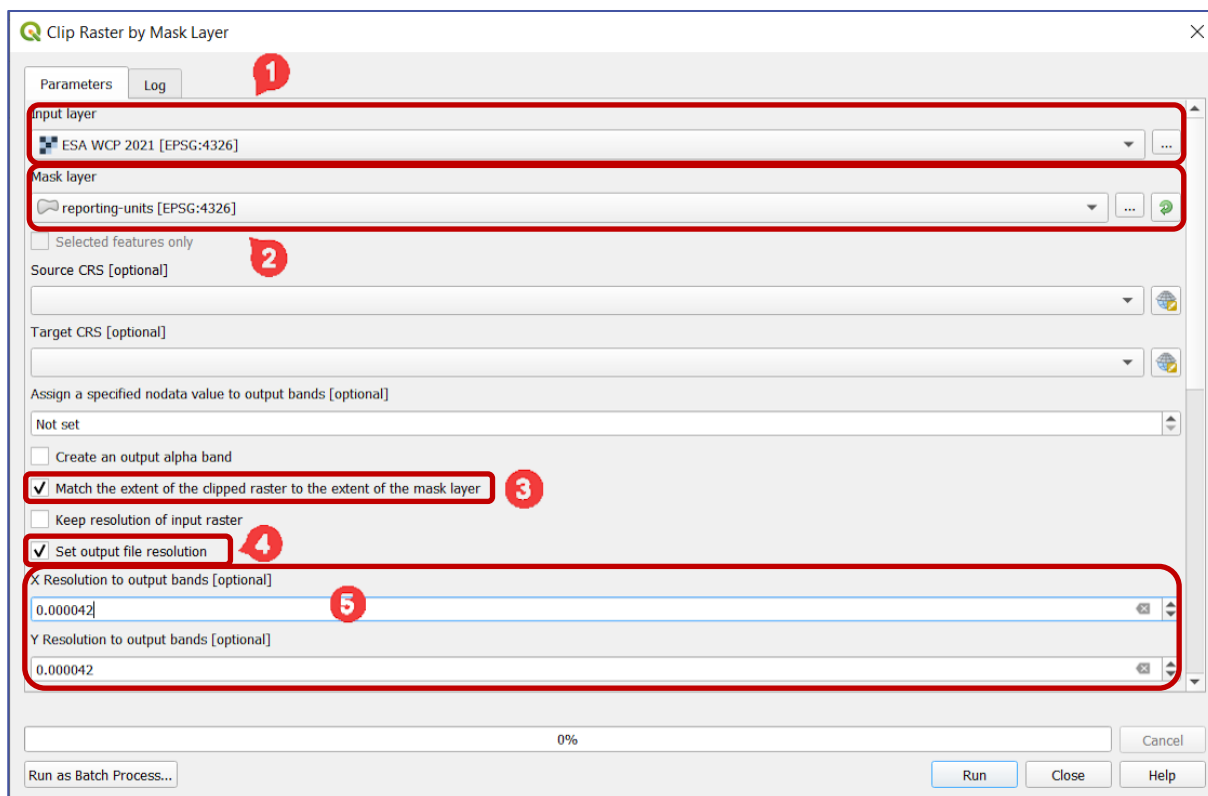


Figure 60: Clipping virtual raster with ESA WCP land cover data to reporting units (1)

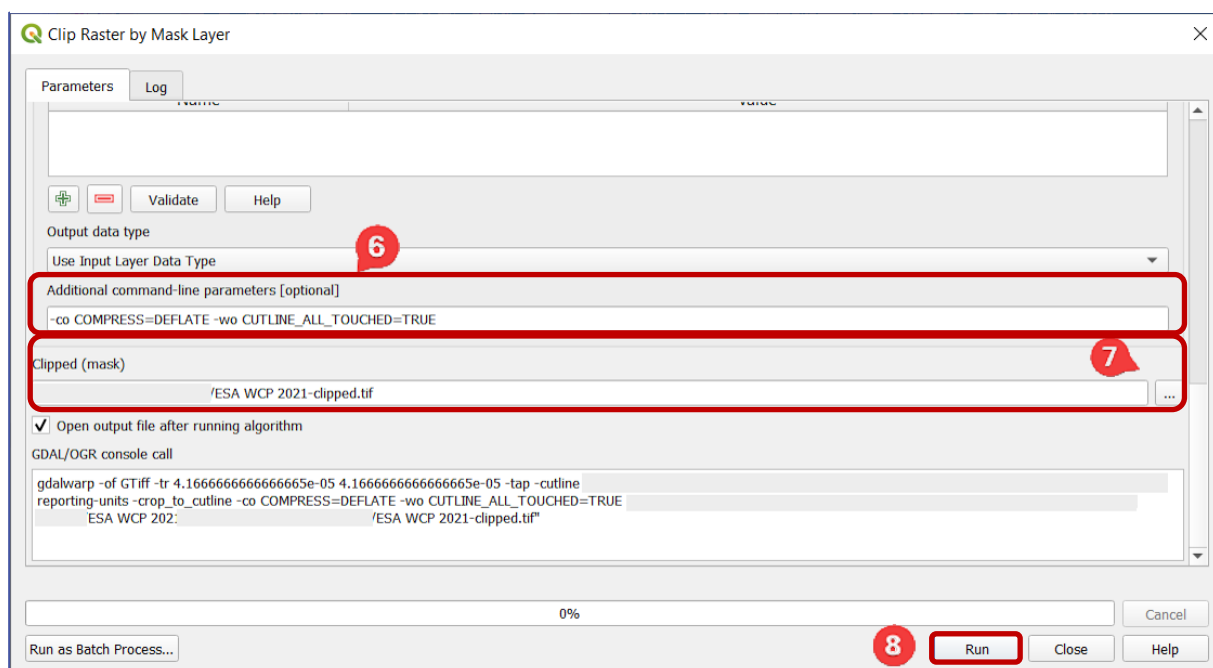


Figure 61: Clipping virtual raster with ESA WCP land cover data to reporting units (2)

After clipping rasters to reporting units for both years, imported original ESA WCP rasters can be removed from the QGIS project (right-click on the layer name in the [Layers](#) panel and click on the [Remove Layer...](#) in the dropdown menu), as well as virtual rasters, if they have been created. An example of a ESA WCP raster after clipping to the reporting units is shown in Figure 62. Again, to change the draw order of different layers in the QGIS map view, drag&drop layers and change their order in the [Layers](#) panel.

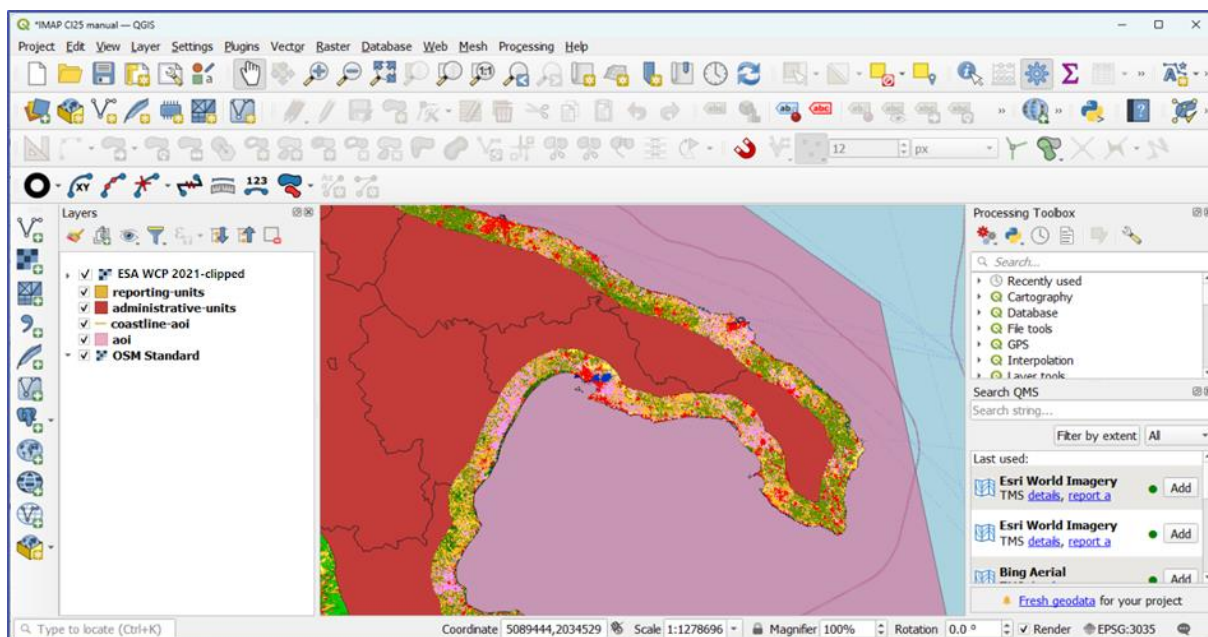


Figure 62: ESA WCP layer after clipping to the reporting units (example for south Italy, basemap: © OpenStreetMap contributors)

Since the classification scheme of ESA WCP data is not the same as the classification needed for CCI25, ESA WCP raster data need to be reclassified to the CCI25 classification. To reclassify ESA WCP raster tiles, follow these steps (separately for each year):

1. in the **Processing Toolbox** panel enter “r.reclass” in the search bar and then double click on the **r.reclass** item (Figure 63)

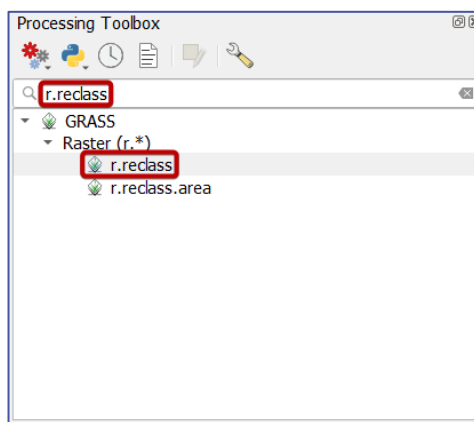


Figure 63: Accessing the **r.reclass** algorithm from the **Processing Toolbox** panel

2. in a new dialog window (Figure 64), under the **Input raster layer** dropdown select the clipped ESA WCP raster tile (**ESA WCP-<year>-clipped.tif**, ① in Figure 64)
3. under the **Reclass rule text**, paste the following text (② in Figure 64):

50	= 1 Built-up
40	= 2 Agricultural
10 20 30 60 70 100	= 3 Forest and semi-natural land
90 95	= 4 Wetlands
80 200	= 5 Waterbodies

4. in the **Output raster format options** paste the following text: **COMPRESS=DEFLATE** (③ in Figure 64)
5. after clicking on the three-dots-button marked with ④ in Figure 64 and choosing **Save as File...**, define the storage location and name for the raster that is about to be created (for

name, use **ESA WCP-<year>-reclassified.tif** (replace <year> with the corresponding year), choose TIF or TIFF storage format)

6. click the **Run** button to initiate the creation of a reclassified raster (5 in Figure 64)

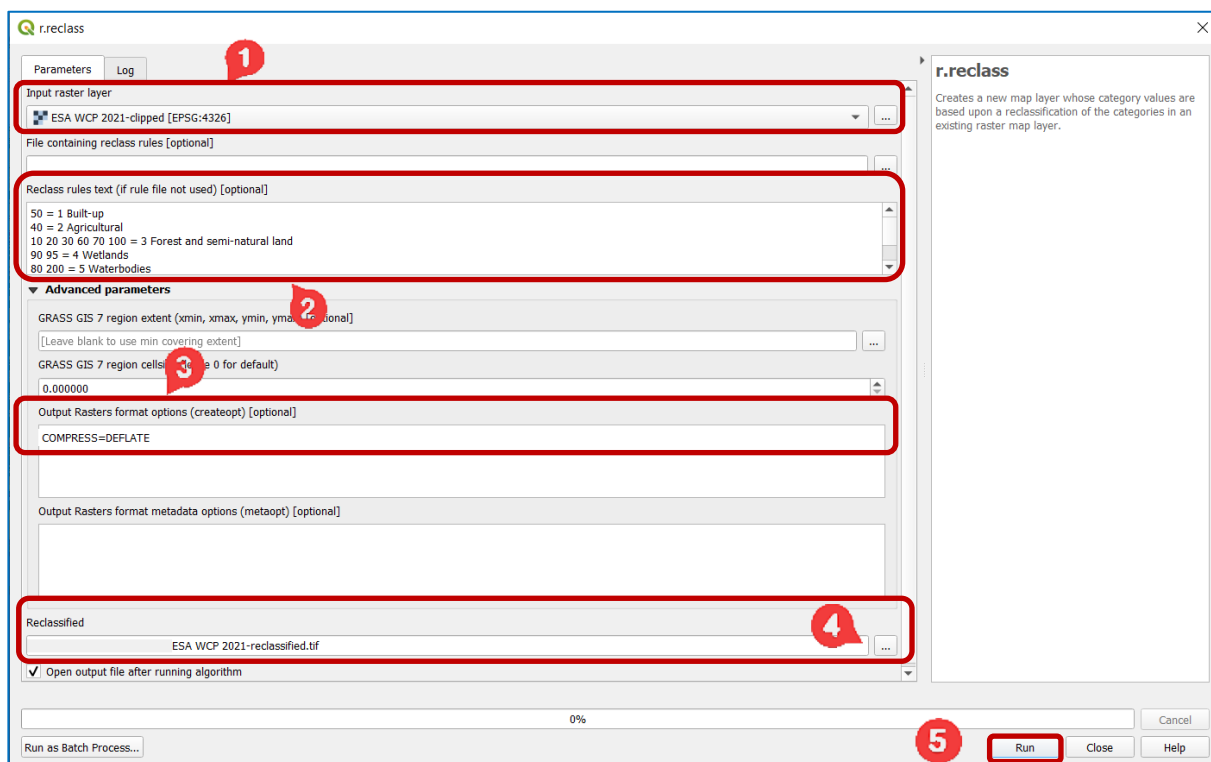


Figure 64: Reclassifying ESA WCP raster tiles to the CCI25 classification scheme

After this processing, only layers that can be left in QGIS are: **aoi.gpkg**, **coastline-aoi.gpkg**, **administrative-units.gpkg**, **reporting-units.gpkg**, **ESA WCP-<year1>-clipped.tif**, **ESA WCP-<year2>-clipped.tif**, **ESA WCP-<year1>-reclassified.tif**, **ESA WCP-<year2>-reclassified.tif**, and basemap imported with the QuickMapServices plugin.

3.4.2 Preparing elevation data

As already mentioned, each downloaded FABDEM ZIP archive contains up to 100 1°×1° GeoTIFF tiles. From these tiles, the flooding zone needs to be extracted. We suggest the following workflow:

1. extract all tiles from the downloaded FABDEM ZIP archive (if multiple ZIP archives have been downloaded, move all tiles to the same folder) and remove metadata files that have an XML extension (do not import tiles into QGIS yet)
2. like with land cover ESA WCP data, instead of making a “real” mosaic that unnecessarily takes storage space and duplicates original data, we can create a virtual raster:
 - a. go to **Raster ► Miscellaneous ► Build virtual raster...**
 - b. in a new dialog window (Figure 65), after clicking on the three-dots-button that is marked with 1, a new dialog which is shown in Figure 66 opens
 - c. by clicking on the **Add Directory...** button (2 on Figure 66) and defining the location (i.e. path on the disc) of a directory where all FABDEM tiles have been extracted from downloaded ZIP files, we have an option to select raster data for creating virtual raster that has not been previously imported into QGIS
 - d. after defining a path to the folder with all FABDEM raster tiles, click the **OK** button (3 on Figure 66) to return to the previous window

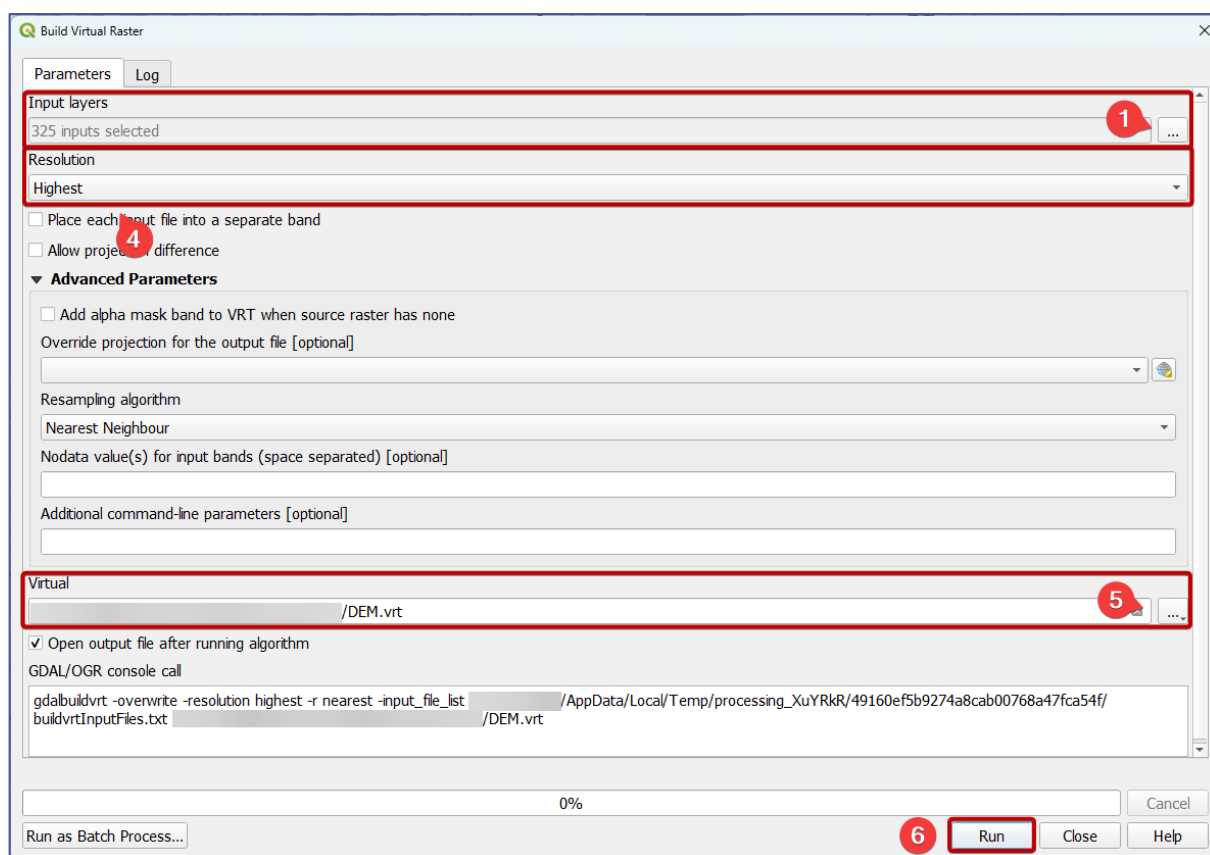


Figure 65: Merging all FABDEM tiles into one virtual raster (1)

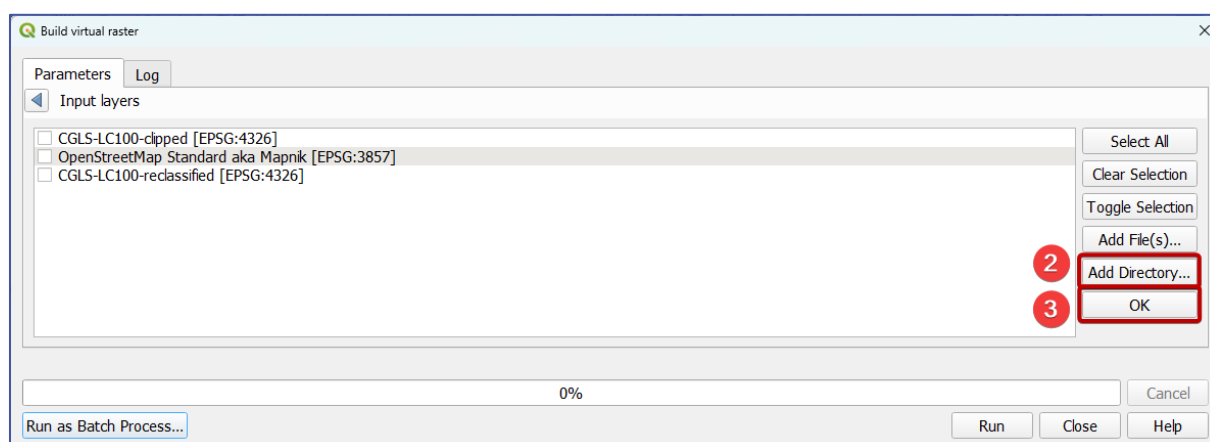


Figure 66: Merging all FABDEM tiles into one virtual raster (2)

- e. in the **Resolution** dropdown choose “Highest” (4 in Figure 65)
- f. after clicking on the three-dots-button marked with 5 in Figure 65 and choosing **Save as File...**, define the storage location and name for the virtual raster that is about to be created (for name, you can use *DEM.vrt*)
- g. click the **Run** button to initiate the creation of a virtual raster (6 in Figure 65)
3. again, like with land cover ESA WCP data, we should remove pixel values for all pixels in a previously created virtual raster that are outside of reporting units, and also ensure that the raster with elevation data is aligned (i.e. pixels in rasters perfectly overlap) with the raster with land cover ESA WCP data (expect longer processing time for this step):
 - a. go to **Raster ► Extraction ► Clip raster by mask layer...**

- b. in a new dialog window (Figure 67) under the **Input layer** dropdown (marked with ①) select the previously created virtual raster with FABDEM elevation data (*DEM.vrt*)
- c. in the **Mask layer** dropdown select reporting units vector layer (**reporting-units.gpkg**, marked with ② in Figure 67)
- d. in the **Assign a specified nodata value to output bands** field enter 9999 (③ in Figure 67)
- e. ensure that the **Match the extent of the clipped raster to the extent of the mask layer** is ticked (④ in Figure 67)
- f. tick the **Set output file resolution** option and paste 0.0000416666666666666665275 in **X Resolution to output bands** and **Y Resolution to output bands** fields (marked with ⑤ in Figure 67) which will, with the tick in the previous step, ensure that the raster with FABDEM elevation data and raster with ESA WCP land cover data are aligned and have the same resolution (be sure to paste the whole number in **X Resolution to output bands** and **Y Resolution to output bands** fields)
- g. in the **Additional command-line parameters** (⑥ in Figure 68) paste the following text (as suggested in [22]): `-co COMPRESS=DEFLATE -wo CUTLINE_ALL_TOUCHED=TRUE`
- h. after clicking on the three-dots-button marked with ⑦ in Figure 68 and choosing **Save as File...**, define the storage location and name for the raster that is about to be created (for name, you can use **DEM-clipped.tif**, choose TIF or TIFF storage format)
- i. click the **Run** button to start the clipping algorithm (⑧ in Figure 68)

Figure 67: Clipping virtual raster with FABDEM elevation data to reporting units (1)

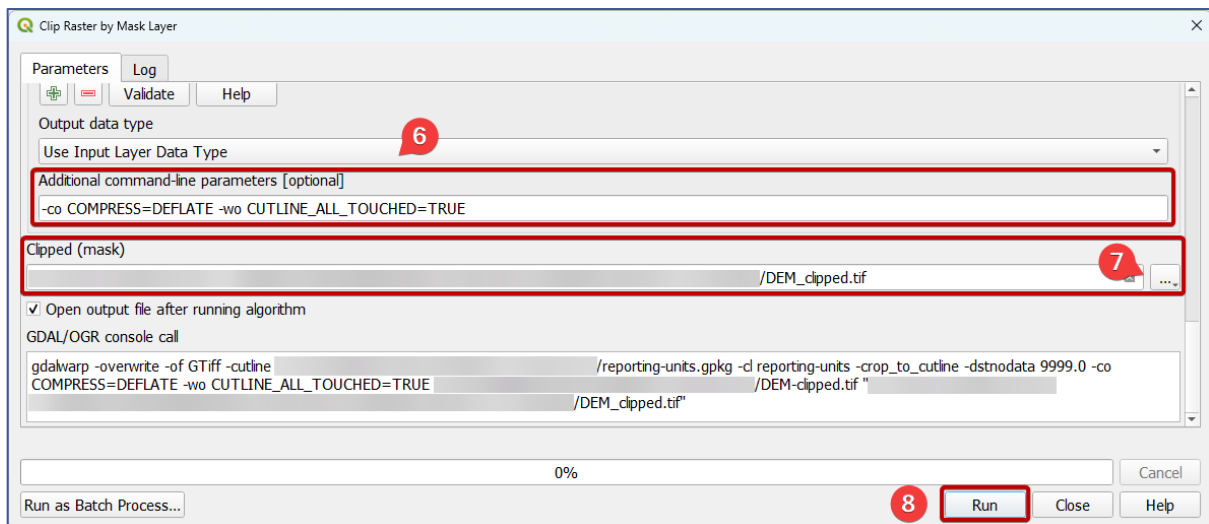


Figure 68: Clipping virtual raster with FABDEM elevation data to reporting units (2)

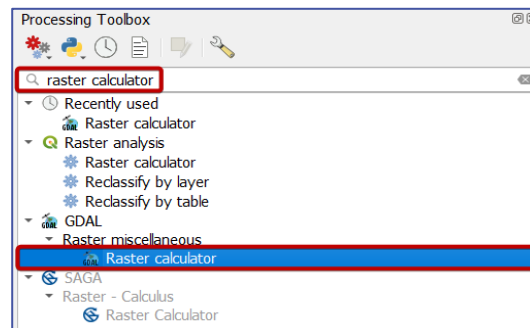


Figure 69: Accessing the GDAL's Raster calculator from the Processing Toolbox panel

- c. in the **Calculation in gdnumeric syntax** field (2 in Figure 71) enter this logical formula: $A \leq 5$ (in this case, 5 is entered because zone that is less than 5 m above sea level is defined as LEZ; make sure to include one space around $\leq$)
- d. in the **Set output nodata value** field enter 0 (3 in Figure 71)
- e. in the **Output raster type** dropdown choose "Byte" (4 in Figure 71)
- f. in the **Additional command-line parameters** field enter: `--co COMPRESS=DEFLATE` (make sure to put two minuses at the beginning, as marked with 5 in Figure 71)
- g. after clicking on the three-dots-button marked with 6 in Figure 71 and choosing **Save as File...**, define the storage location and name for the raster that is about to be created (for name, you can use *LEZ.tif*, choose TIF or TIFF storage format)
- h. click the **Run** button to start raster creation based on the entered formula (7 in Figure 71)

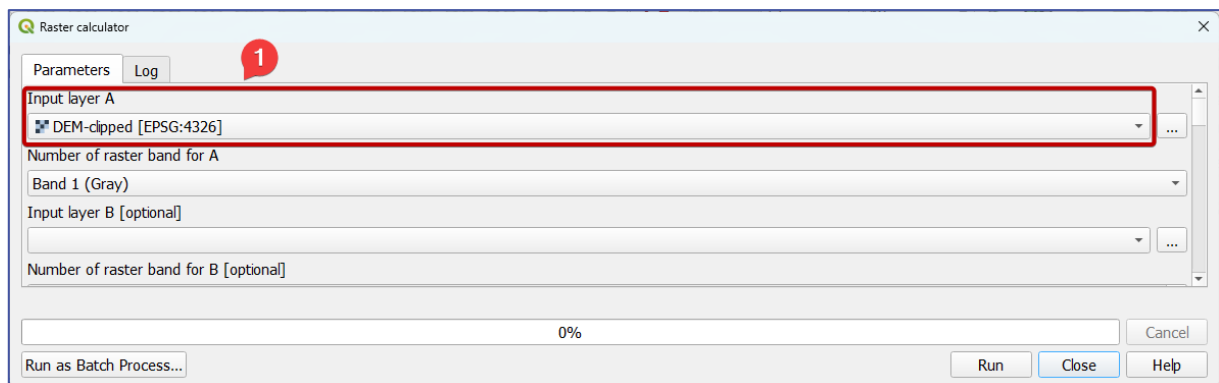


Figure 70: Extracting LEZ from FABDEM with GDAL's Raster Calculator (1)

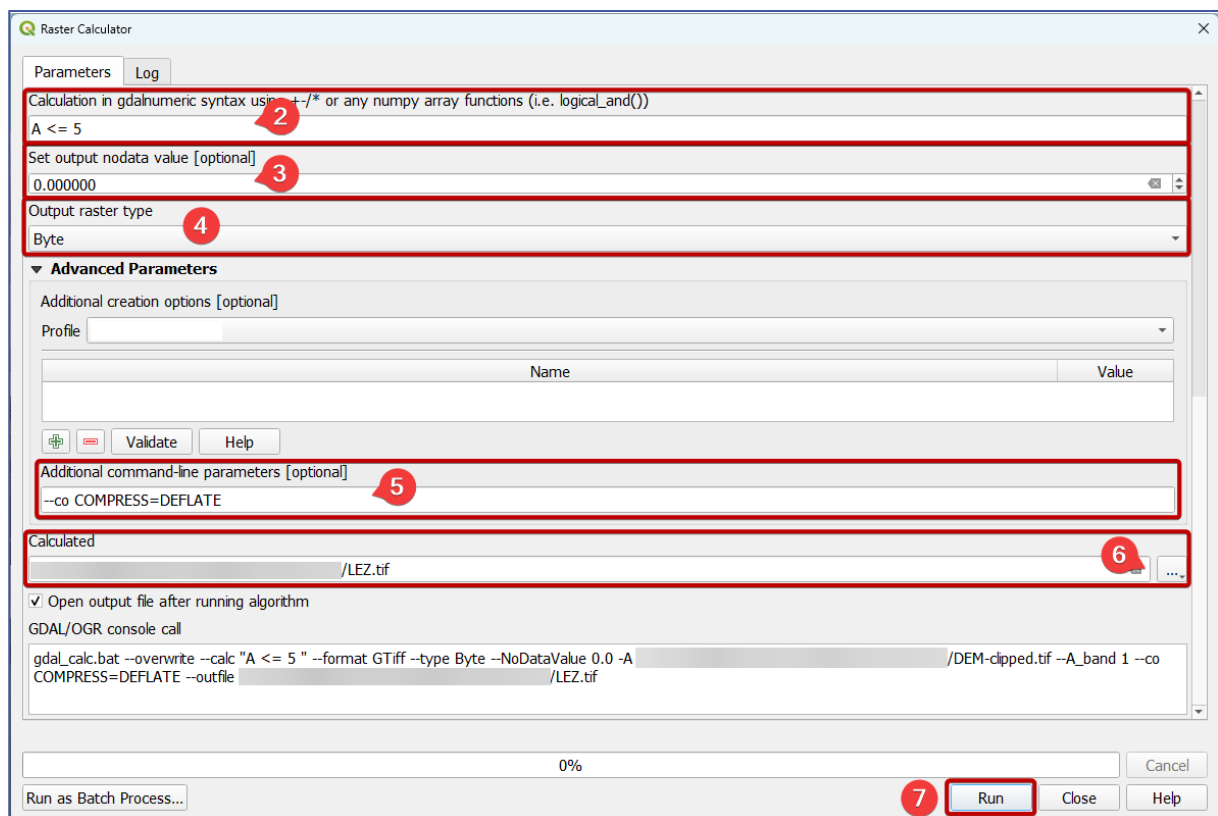


Figure 71: Extracting LEZ from FABDEM with GDAL's Raster Calculator (2)

5. to polygonize (convert raster layer to a vector one) raster created in the previous step with pixel values being 1, if logical formula $A \leq 5$ is evaluated as true, or 0 if it is evaluated as false (in produced raster, pixels with value 1 are pixels from **DEM-clipped.tif** that have elevation less or equal to 5), follow this workflow:
 - a. go to **Raster ► Conversion ► Polygonize (Raster to Vector)**...

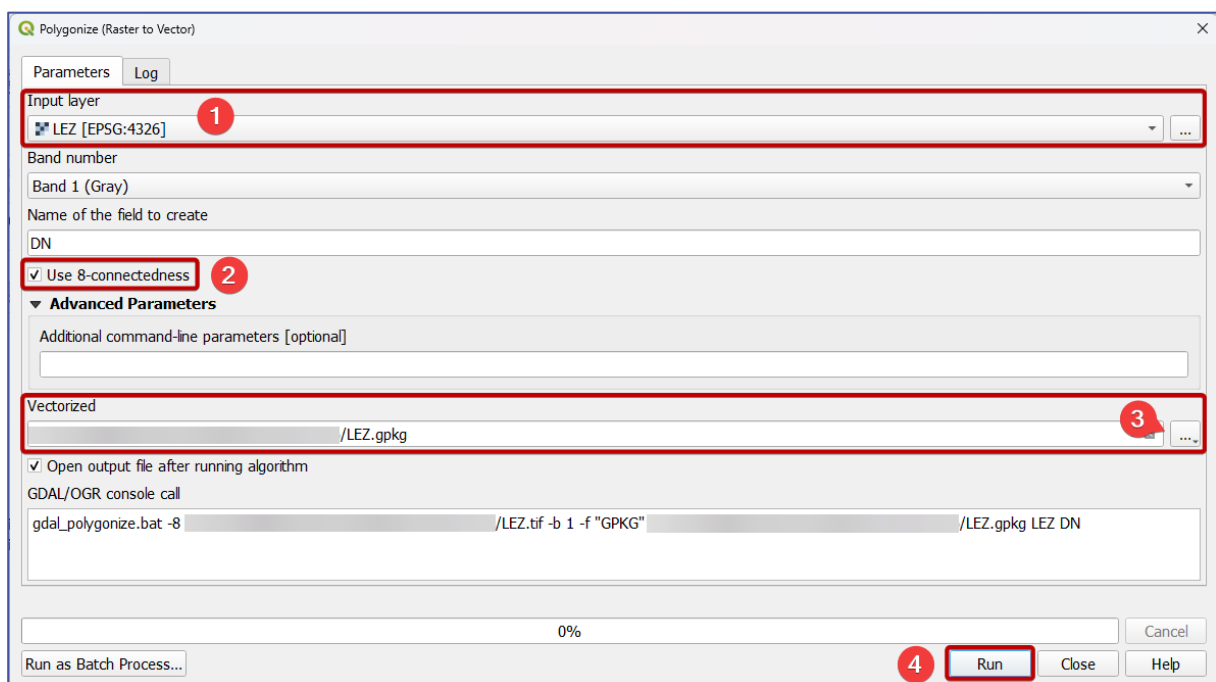


Figure 72: Polygonizing raster layer with low elevation zone (LEZ)

- b. in the new dialog window (Figure 72), in the **Input layer** dropdown (marked with ①), choose the raster that is previously created with the **Raster Calculator** algorithm (*LEZ.tif*)
 - c. tick the **Use 8-connectedness** option (marked with ② in Figure 72)
 - d. after clicking on the three-dots-button that is marked with ③ in Figure 72 and choosing **Save as File...**, define the storage location and name for the vector layer that is about to be created (for name, you can use *LEZ.gpkg*, and choose the GPKG storage format)
 - e. click the **Run** button to start the polygonization algorithm (④ in Figure 72)
6. it is likely that the previously created vector layer (*LEZ.gpkg*) contains polygons that correspond to areas that have an elevation below 5 m ASL but are not contiguous to the coastline, and they should be removed:
 - a. go to **Vector ► Research Tools ► Select by Location...**
 - b. in a new dialog window (Figure 73), in the **Select features from** the dropdown (marked with ①) select a layer that was previously created by the polygonization algorithm (*LEZ.gpkg*)
 - c. make sure **intersect** option is the only one that is ticked under the **Where the features (geometric predicate)** (② in Figure 73)
 - d. in the **By comparing to the features from** select vector layer with coastline data (*coastline-aoi.gpkg*, as marked with ③ in Figure 73)
 - e. make sure that in **Modify current selection by** “creating new selection” is the chosen option (④ in Figure 73)
 - f. click the **Run** button to start the algorithm that will select all polygons in the *LEZ.gpkg* vector layer that spatially have anything, even a single point in common with the coastline – selected polygons are highlighted with yellow color in the QGIS map view, as is visible in Figure 75 (notice that this algorithm, as opposed to the most of the previous ones, does not produce any new data)

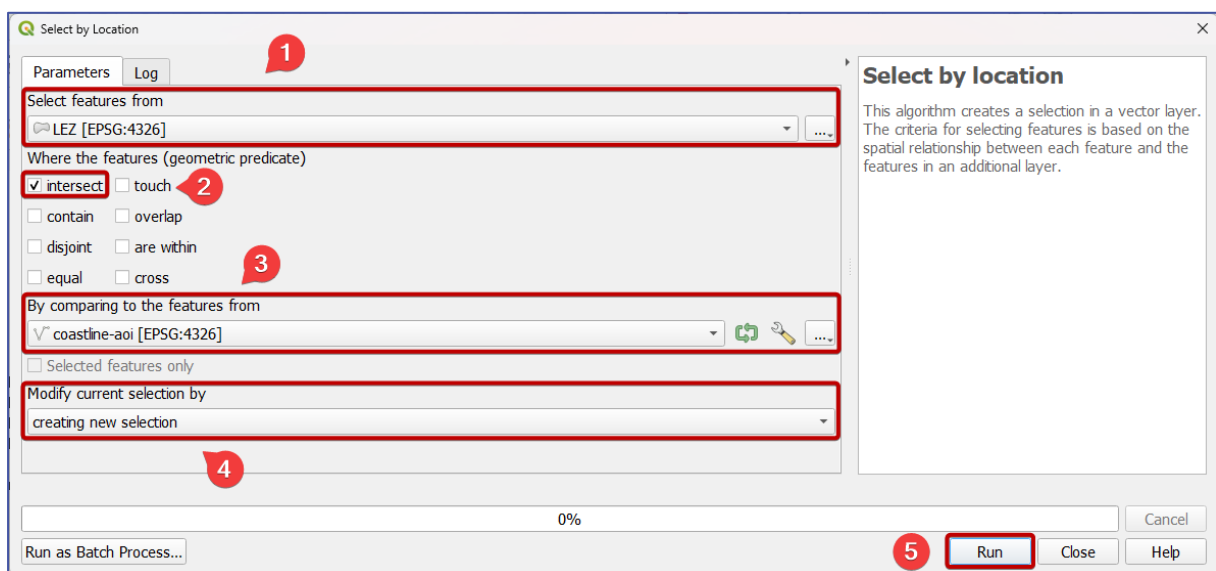


Figure 73: Selecting polygons in the *LEZ.gpkg* layer that intersect with coastline

- g. open the attribute table for the *LEZ.gpkg* layer by right-clicking on the layer name (“LEZ”) in the **Layers** panel and selecting **Open Attribute Table** (as highlighted in Figure 75)
 - h. in the attribute table (Figure 74), click on the  icon (①) to invert the selection (rows that correspond to the selected polygons/features are highlighted with blue color), enable layer editing by clicking on the icon  (②), delete all selected

polygons/features by clicking on the  icon (3), save edits by clicking on the  icon (4), and finally click again on  the icon (5) to disable layer editing

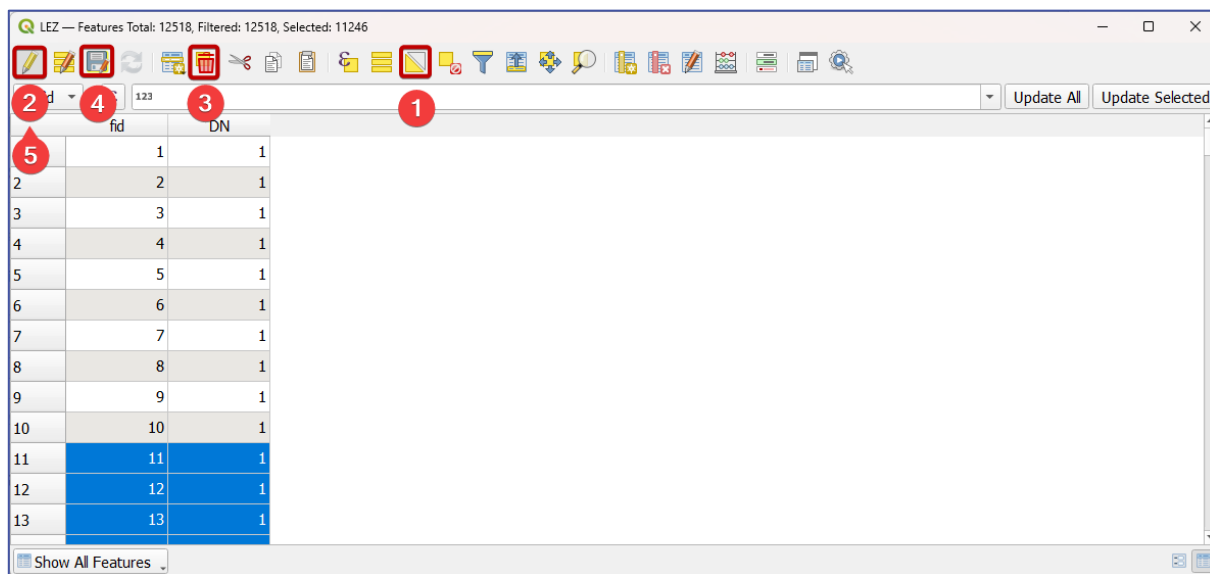


Figure 74: Removing features from the vector layer

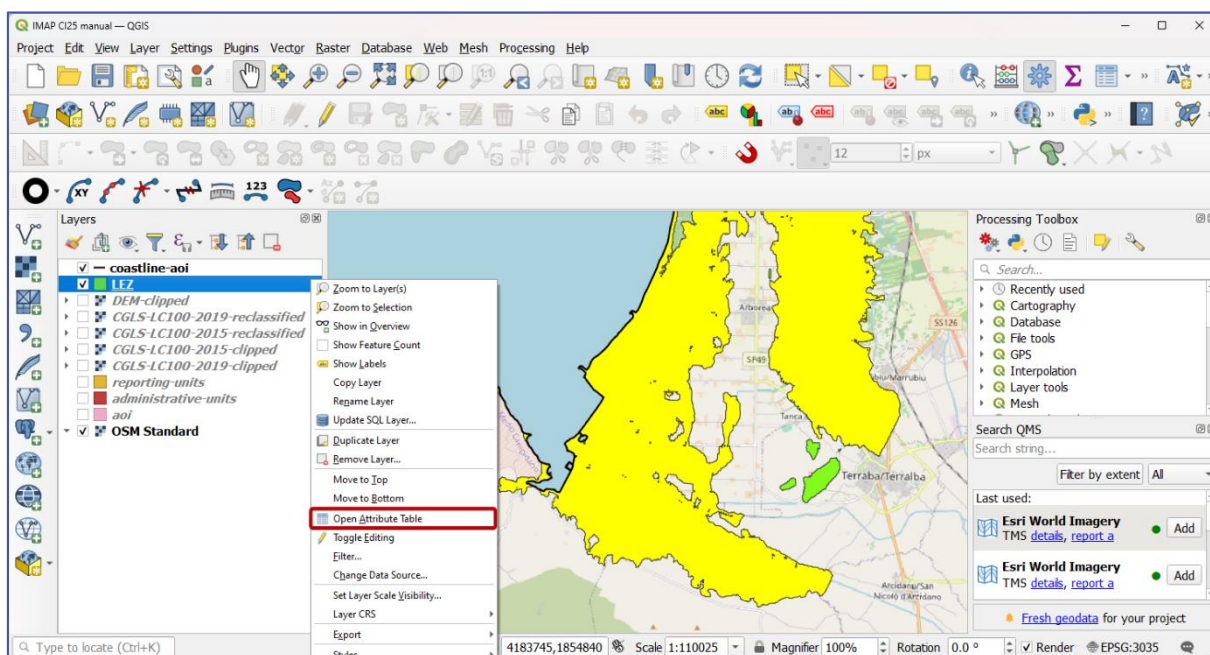


Figure 75: Selected polygons are highlighted with yellow color (by default settings) and all other remain in color assigned in corresponding layer settings – in this case, green (basemap: © OpenStreetMap contributors)

Some features/polygons in the generated *LEZ.gpkg* vector layer have topological errors, that will prevent some algorithms from making processing with them (this can be checked by going to **Vector ► Geometry Tools ► Check Validity...**). To fix those topological errors, you can use the **Fix geometries** algorithm. The **Fix geometries** algorithm can be accessed through the **Processing Toolbox** by entering “fix geometries” in the search bar, and double clicking on the “Fix geometries” item (Figure 76). After double-clicking, in a new dialog window (Figure 77):

1. under the **Input layer** dropdown choose the *LEZ.gpkg* layer (marked with 1 in Figure 77)

2. after clicking on the three-dots-button that is marked with ② in Figure 77 and choosing **Save as File...**, define the storage location and name for the vector layer that is about to be created (for name, you can use *LEZ-fixed.gpkg*, and choose the GPKG storage format)
3. click the **Run** button (③ in Figure 77) to start the algorithm that will create a new *LEZ-fixed.gpkg* layer with fixed topological errors from the *LEZ.gpkg* layer

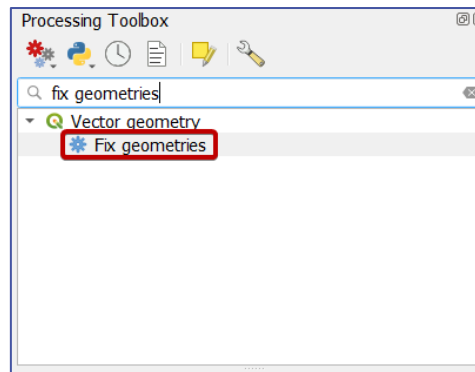


Figure 76: Accessing the *Fix geometries* algorithm from the *Processing Toolbox* panel

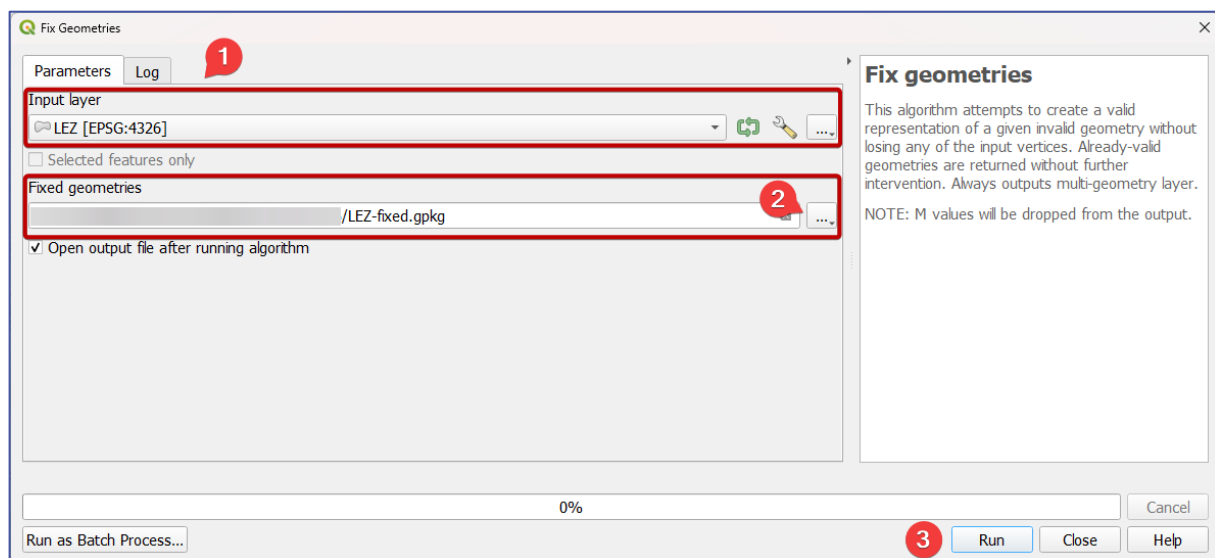


Figure 77: Running the *Fix geometries* algorithm

To make some further calculations easier, remove *LEZ.gpkg* layer from the QGIS project, dissolve *LEZ-fixed.gpkg* layer by going to **Vector ► Geoprocessing Tools ► Dissolve...**, and name the output layer **LEZ.gpkg** (choose GPKG storage format and confirm the prompt that asks if you want to replace existing *LEZ.gpkg* layer).

3.4.3 Preparing data on protected areas

The downloaded ZIP archive with the WDPA data on protected areas firstly needs to be unzipped. In the unzipped folder, there is one or more (mostly three) ZIP archives with the Esri shapefiles. Combined data from all these ZIP archives contain all WDPA data for the area of interest. Each ZIP archive again needs to be unzipped. Only Esri shapefiles that have a name ending with “polygon” need to be further processed in QGIS since they contain polygonal vector layers. All polygonal vector layers need to be merged into one layer, and then two layers have to be generated out of the merged layer: one with polygons that correspond to protected areas that were established before the first year that is chosen for CCI25 calculation, and another one for areas that were established before the second chosen year. To merge multiple Esri shapefile polygon layers without firstly importing them in QGIS, follow these steps:

1. go to **Vector ► Data Management Tools ► Merge Vector Layers...**
2. in the new dialog window (Figure 78), click on the three-dots-button that is marked with ①
3. in a new window (Figure 79), click on the **Add File(s)...** button (marked with ②), navigate to one of the folders created after unzipping ZIP archives, and select the file that ends with “...polygons.shp”

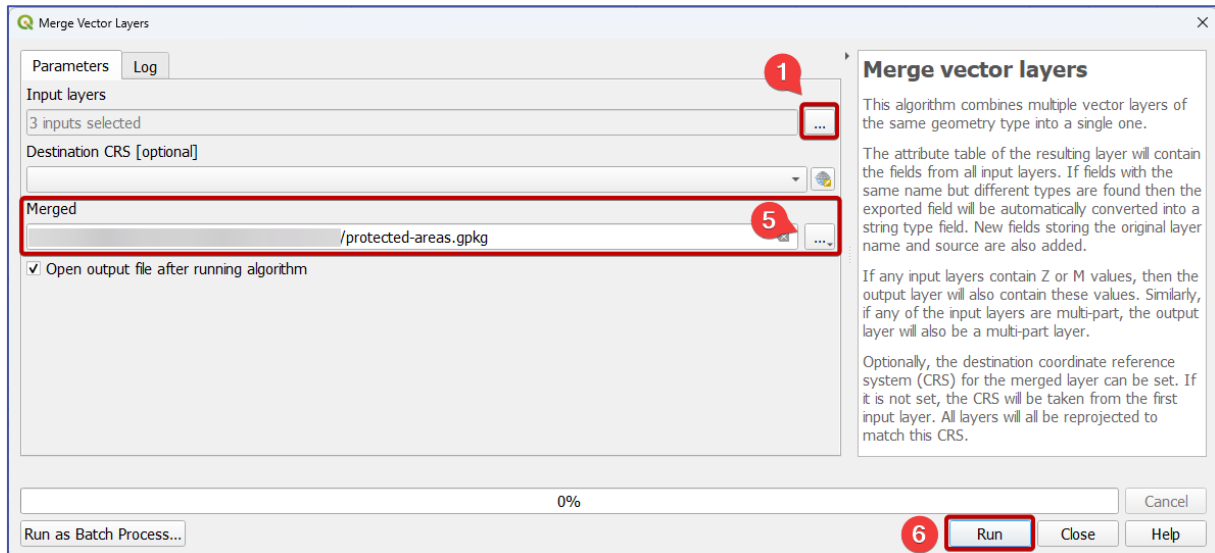


Figure 78: Merging multiple vector layers (1)

4. repeat the previous step for each unzipped ZIP archive
5. make sure only previously selected files that end with “...polygons.shp” are ticked (in the example shown in Figure 79, three files ending with “...polygons.shp” are ticked, as marked with ③)
6. click the **OK** button (④ in Figure 79), which will again open the previous window
7. after clicking on the three-dots-button that is marked with ⑤ in Figure 78 and choosing **Save as File...**, define the storage location and name for the vector layer that is about to be created (for name, you can use *protected-areas.gpkg* and choose the GPKG storage format)
8. click the **Run** button to start merging vector layers algorithm (⑥ in Figure 78)

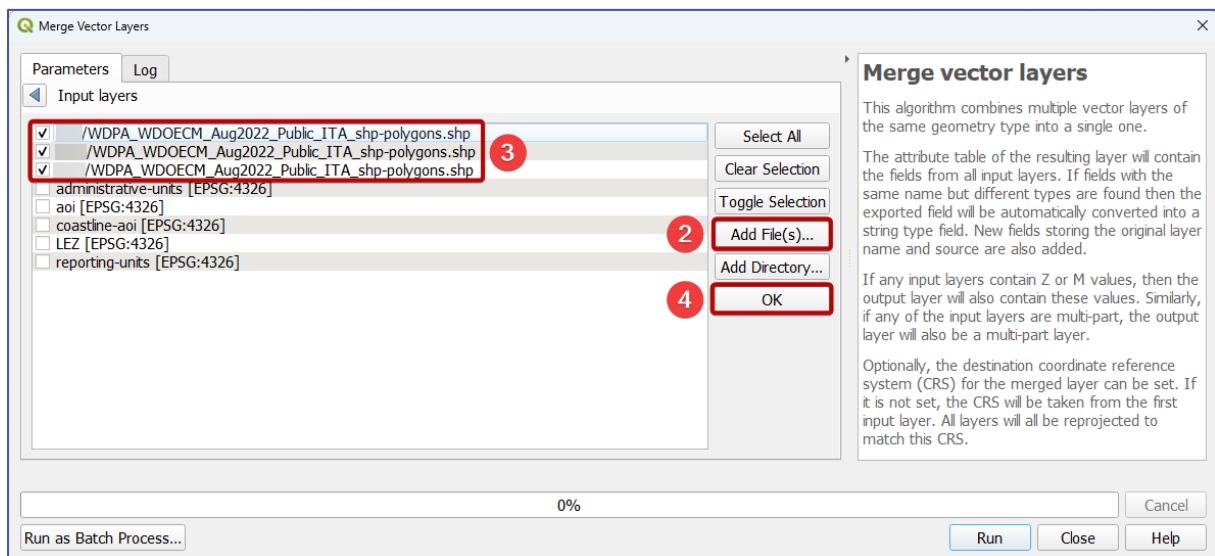


Figure 79: Merging multiple vector layers (2)

The next task would be extracting protected areas based on the year they have been established. Since some protected areas are spatially overlapping (e.g., the same zone can be protected on

different levels or different bases), we will also dissolve all protected areas. By dissolving the polygonal vector layer, all polygons that are overlapping will be flattened in a single polygon in the output layer. It is also important to know that each polygon/feature in the protected areas layer has an attribute “STATUS” that can have values: “Proposed”, “Inscribed”, “Adopted”, “Designated”, “Established”, and “Not Reported”. All polygons that have a value for the “STATUS” attribute either “Proposed” or “Not Reported” should not be used in further calculations. Follow these steps to take all this into account and make sure to go through them twice, for both years that are chosen for CCI25 calculation:

1. right click on the name of the previously created vector layer with merged protected areas (*protected-areas.gpkg*) in the **Layers** panel and click on **Filter...**
2. in an opened **Query Builder** window (Figure 80) find “STATUS” within the **Fields** list (marked with ①), select it, and click the **All** button (marked with ②)
3. in the **Values** list check if there are values “Proposed” or “Not Reported”, or some other unsuitable value (in Figure 80, only values “Adopted”, “Designated” and “Inscribed” are present)
4. now define an expression under **Provider Specific Filter Expression** based on which data will be filtered (marked with ③ in Figure 80):
 - a. double click on the “STATUS_YR” in the **Fields** list, which will insert the “STATUS_YR” attribute name in the correct form in the **Provider Specific Filter Expression** filed
 - b. click on the **<=** button, which will again insert “<=” in the **Provider Specific Filter Expression** filed
 - c. manually enter a year in the **Provider Specific Filter Expression** filed (in Figure 80 it is “2015”)
 - d. if there are no unsuitable values within the **Values** list for the “STATUS” attribute, the final expression would be “STATUS_YR” <= <year> (<year> should be replaced with the correct year), and if there are unsuitable values, then expression should be further expanded to take them into account, for example:
 - i. if there is a value “Proposed” within the **Values** list for the “STATUS” attribute, final expression should be: “STATUS_YR” <= <year> AND “STATUS” != ‘Proposed’
 - ii. if there are values “Proposed” and “Not Reported”, final expression should be: “STATUS_YR” <= <year> AND “STATUS” NOT IN (‘Proposed’, ‘Not Reported’)

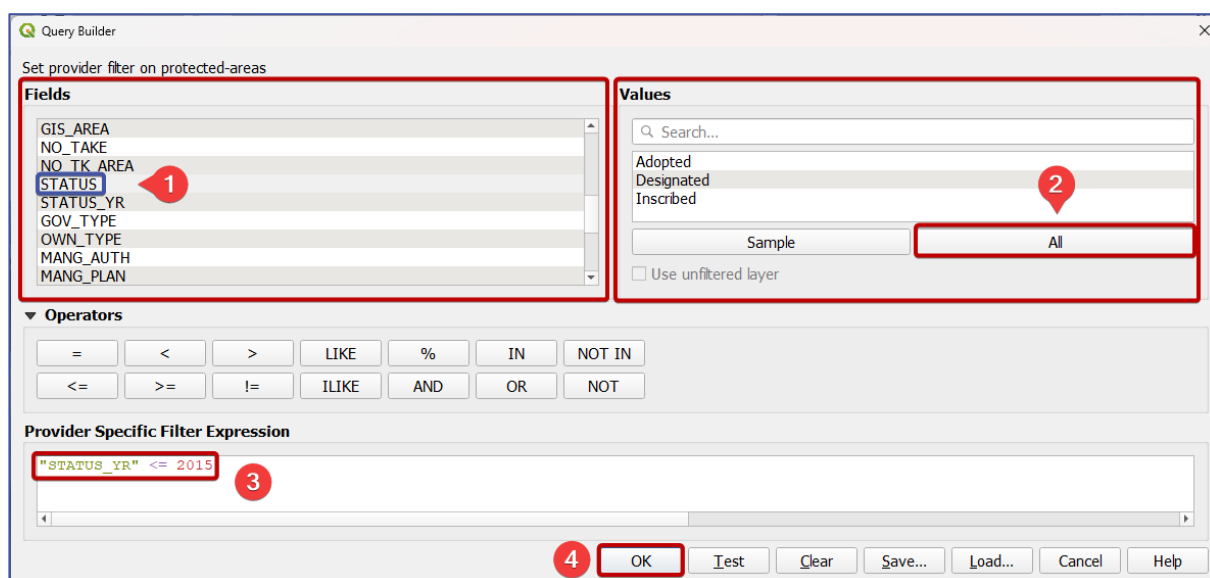


Figure 80: Filtering features in vector based on values of their attributes

5. after clicking on the **OK** button (marked with ④ in Figure 80) polygons/features will be filtered based on the  defined expression, i.e., all features that do not fulfil conditions from the expression will remain stored within the layer, but will not be shown in the map view and will not be used in any processing with this layer, also, next to the layer name in the **Layers** panel, there will be shown a icon
6. to dissolve polygons in this layer, go to **Vector ► Geoprocessing Tools ► Dissolve...**
7. in a new dialog window (Figure 81), under the **Input layer** dropdown (marked with ①) choose the layer with protected areas that was previously filtered (*protected-areas.gpkg*)
8. after clicking on the three-dots-button that is marked with ② in Figure 81 and choosing **Save to File...**, define the storage location and name for the vector layer that is about to be created (for name, you can use *protected-areas-<year>.gpkg*, replace *<year>* with the correct year (same that was used for filtering), and choose the GPKG storage format)
9. click the **Run** button to start the dissolving algorithm (marked with ③ in Figure 81)
10. open attribute table of the created vector layer (*protected-areas-<year>.gpkg*) and delete all attributes except “fid”

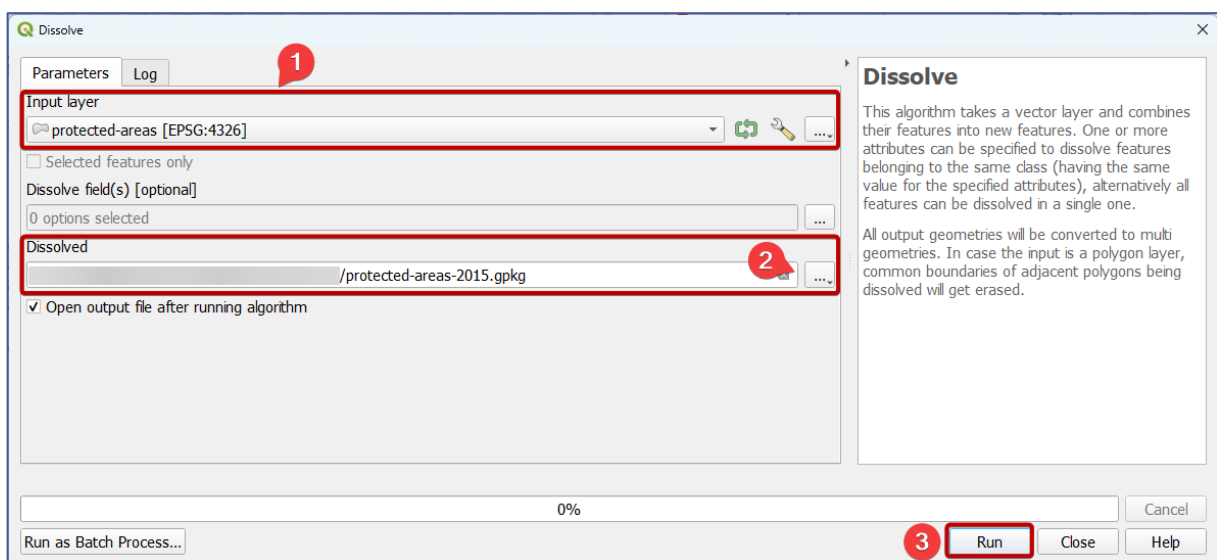


Figure 81: Dissolving features in a vector layer

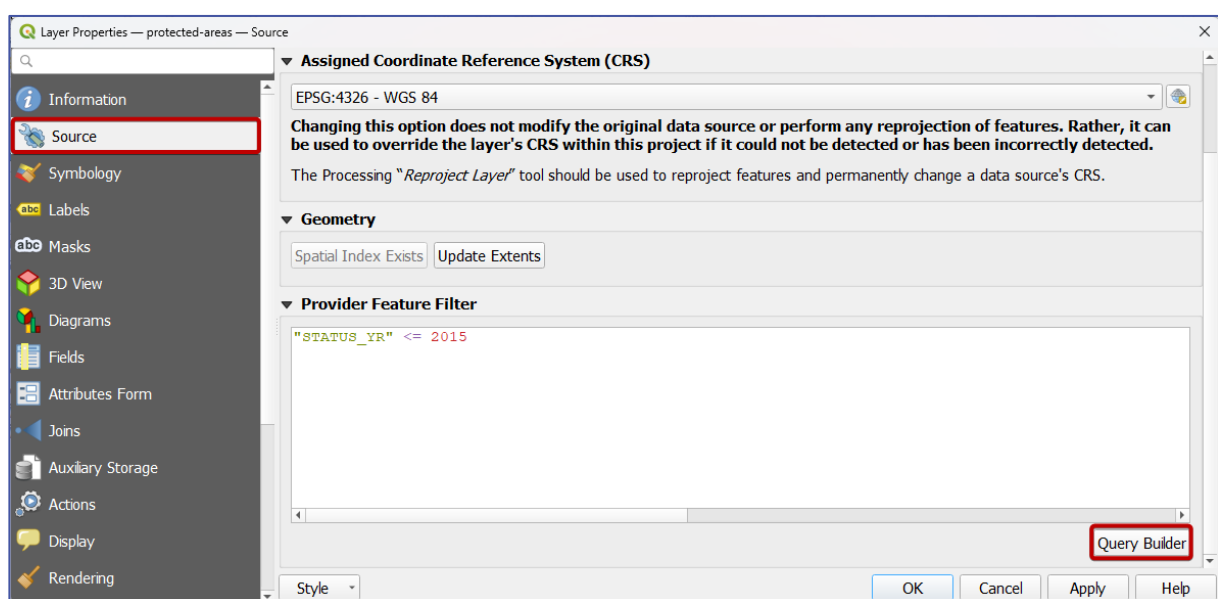


Figure 82: Accessing Query Builder through layer properties

Again, make sure to follow the previous steps twice, for both years that are chosen for CCI25 calculation. After finishing with dissolving protected areas for both years, the filter can be removed by deleting the filter expression in the [Query Builder](#) window. As already mentioned, the [Query Builder](#) window can be accessed by right-clicking on the layer name in the [Layers](#) panel and then clicking on the [Filter...](#), but it can also be accessed through layer properties:

1. right click on the layer name in the [Layers](#) panel and then click on the [Properties...](#)
2. go to the [Source](#) tab on the left side
3. click on the [Query Builder](#) button (as highlighted in Figure 82)

4 CALCULATING INDICATOR PARAMETERS

After processing that is done in previous chapters, all layers that are needed for further processing should be prepared. In the QGIS project, layers that should be present are:

- *aoi.gpkg*
- *coastline-aoi.gpkg*
- *administrative-units.gpkg*
- *reporting-units.gpkg*
- *ESA WCP-<year1>-clipped.tif*
- *ESA WCP -<year2>-clipped.tif*
- *ESA WCP -<year1>-reclassified.tif*
- *ESA WCP -<year2>-reclassified.tif*
- *DEM-clipped.tif*
- *LEZ.gpkg*
- *protected-areas.gpkg*
- *protected-areas-<year1>.gpkg*
- *protected-areas-<year2>.gpkg*
- (and basemap imported with the QuickMapServices plugin)

All other layers that are not in the above list can be removed from the QGIS project and can also be deleted from the computer storage. Some of the layers mentioned above are not directly needed in further steps, but it is advised to keep them stored since they contain useful information that might be needed at some point, especially if some steps would have to be reprocessed. In the following sections, we will first overlay vector layers, and then raster layers with reporting units. After overlaying and area calculations, we will export data to spreadsheets and calculate indicator parameters.

4.1 Overlaying vector data with the reporting units

4.1.1 Overlaying data on protected areas with reporting units

To overlay two layers with data on protected areas with reporting units, go to **Vector ► Geoprocessing Tools ► Intersection...**, click on the **Run as Batch Process...** button, click once on the  button, and define options by following the example shown in Figure 83 (for names of the output layers, you can use *RU-protected-areas-<year1>.gpkg* and *RU-protected-areas-*

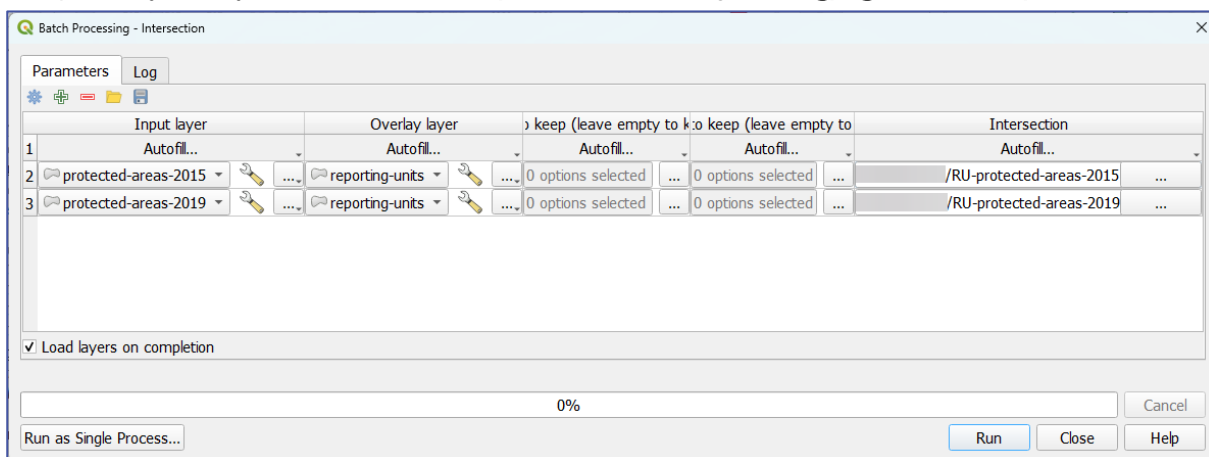


Figure 83: Intersecting layers with protected areas with reporting units

<year2>.gpkg, and choose GPKG storage format). Open the attribute table for both layers, open the [Field Calculator](#) window, and for both layers create a new attribute by following the options shown in Figure 84 and save edits done in an attribute table. Function `$area` will calculate the area of each polygon in the vector layer on the surface of the ellipsoid that was defined in the project settings and will present those areas in the unit that was also defined in the project settings.

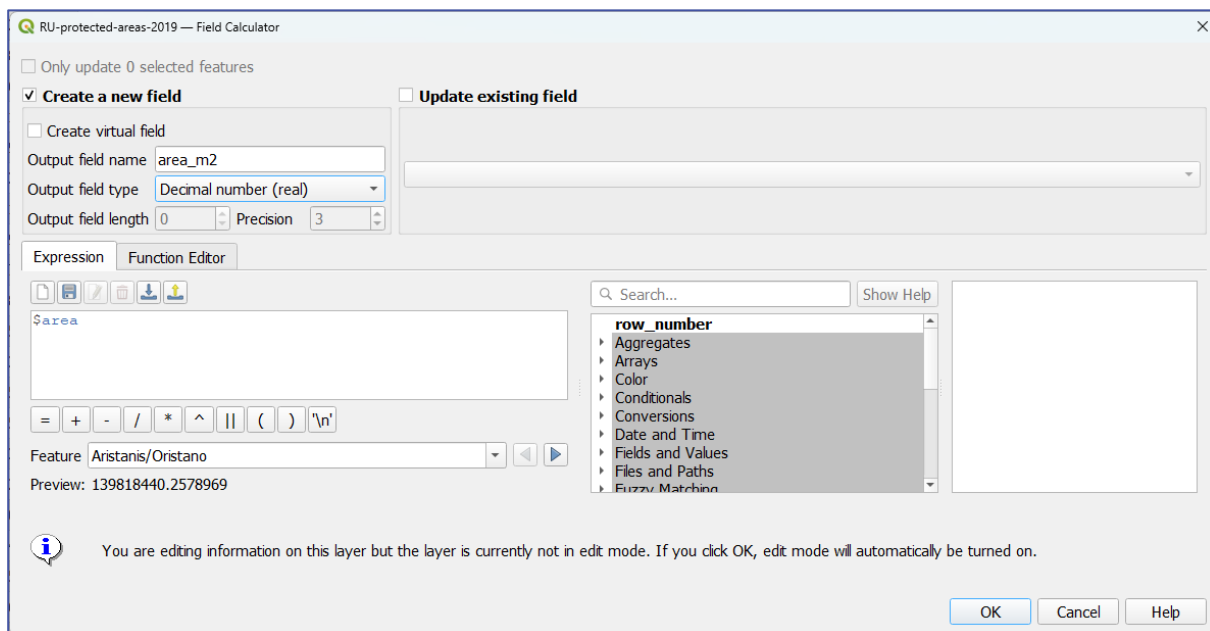


Figure 84: Defining a new attribute in the *Field Calculator* window

4.1.2 Overlaying LEZ with reporting units

Again, go to [Vector](#) ► [Geoprocessing Tools](#) ► [Intersection...](#) to overlay LEZ layer with reporting units layer. Define all options in the same way as in Figure 85, name the output layer with **RU-LEZ.gpkg** and choose the GPKG storage format. Open the attribute table and then in the [Field](#)

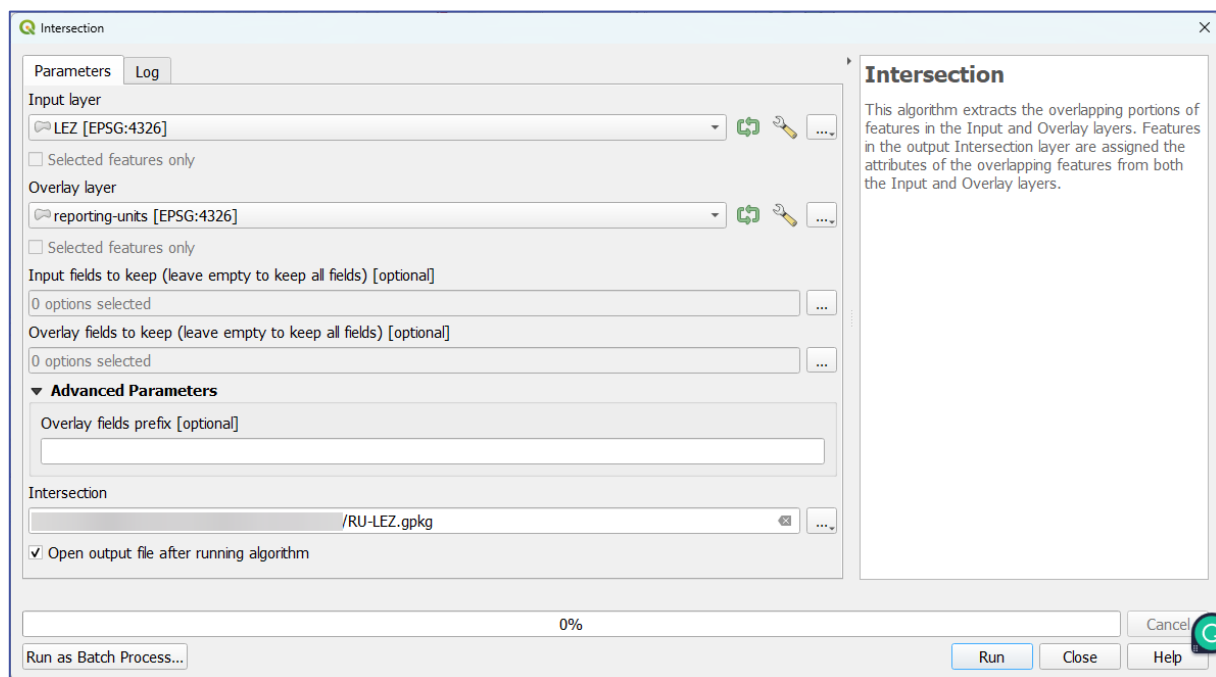


Figure 85: Intersecting LEZ layer with reporting units layer

Calculator window and create a new attribute with values that correspond to the area of each polygon (the same as in Figure 84). When finished, save edits done in the attribute table.

4.1.3 Calculating areas of reporting units

In reporting units layer, create a new attribute with values that correspond to the area of each polygon by opening the attribute table for the reporting units layer, and following settings in the **Field Calculator** window from Figure 86. When finished, save edits that are done in the attribute table.

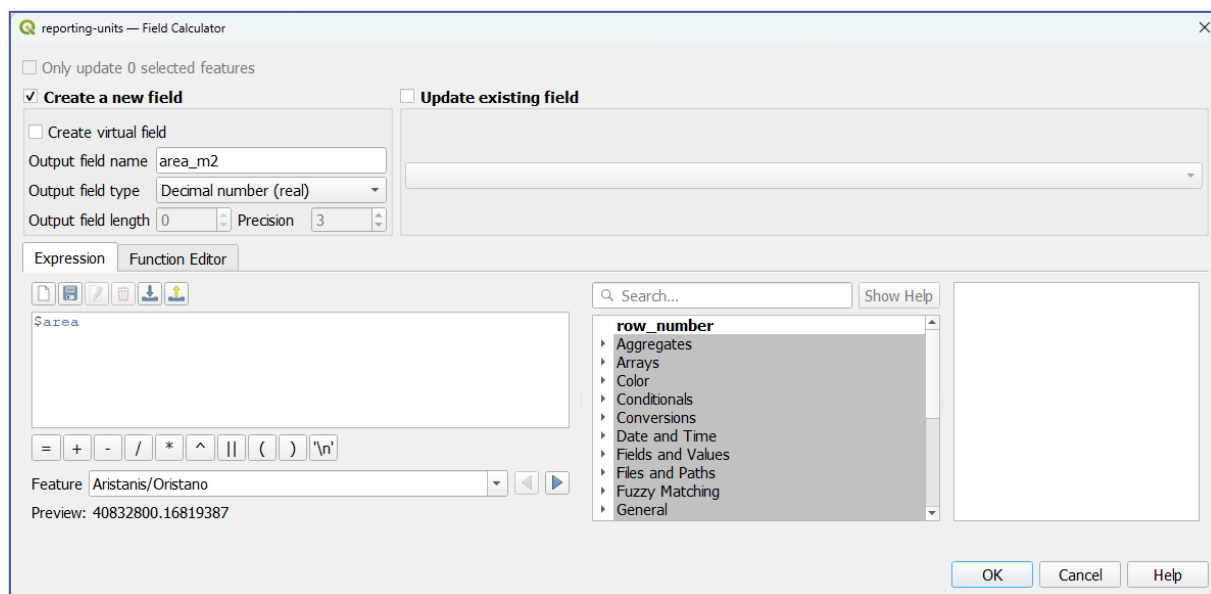


Figure 86: Defining a new attribute in the **Field Calculator** window

4.2 Overlaying raster LC/LU data with the reporting units

We first need to calculate the area of each pixel in the LC/LU raster on the surface of the ellipsoid, then extract pixels that correspond to each LC/LU class, and sum their areas for each reporting unit. To calculate the area for each pixel, enter “`r.mapcalc.simple`” in the search bar of the **Processing Toolbox** panel and double-click on the `r.mapcalc.simple` item. In a new window (Figure 87), in the **Raster layer A** dropdown choose any of the clipped or reclassified ESA WCP layers. In the **Formula** field enter `area()`, and in the **Output Raster format options** field enter `COMPRESS=DEFLATE`. For the name choose `area.tif` and click on the **Run** button to start the algorithm.

Now we will use the raster calculator to extract pixels from the `area.tif` raster that correspond to each LC/LU class and separately for each year that is chosen for CCI25 calculation. In the **Processing Toolbox** panel enter “**Raster calculator**” in the search bar and then double click on the **Raster calculator** item from the “**GDAL**” group (Figure 69). In the **Input layer A** choose reclassified ESA WCP layer for one of the years that were chosen for CCI25 calculation (in the example in Figure 88 `ESA WCP-<year1>-reclassified.tif` was chosen). Under the **Input layer B** choose the previously created `area.tif` raster layer. In the **Calculation in gdalnumeric syntax** field enter `(A==1)*B`, in the **Set output nodata value** enter “`0`”, in the **Output raster type** dropdown choose “**Float32**”, in the **Additional command-line parameters** enter `--co COMPRESS=DEFLATE`, define the name of the output layer as `built-up-<year1>.tif`, and click on the **Run** button. The layer was named `built-up-<year1>.tif` because in reclassified CGLS-LC100 raster, pixels with value 1 match to built-up class, which corresponds to the defined expression `(A==1)*B`. This processing has to be done for additional nine

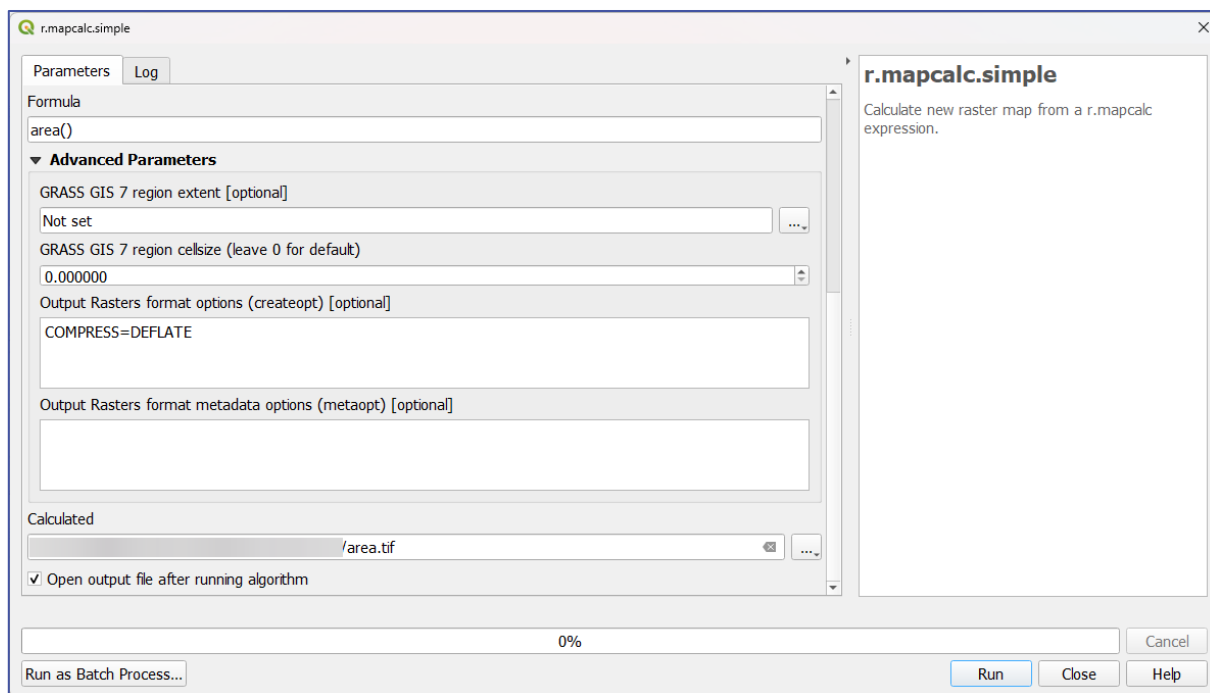


Figure 87: Calculating area for each pixel in the ESA WCP raster layers

times: the first four times with the **ESA WCP-<year1>-reclassified.tif** layer chosen under the **Input layer A** dropdown, and five times with the **ESA WCP -<year1>-reclassified.tif** layer. Every time you need to change the expression in the **Calculation in gdalnumeric syntax** field and output layer name. When the expression is **(A==2)*B**, the output layer name should be **agricultural-<year#>.tif**, when the expression is **(A==3)*B**, it should be **forest-seminatural-<year#>.tif**, when the expression is **(A==4)*B**, it should be **wetlands-<year#>.tif**, and when the expression is **(A==5)*B**, it should be **waterbodies-<year#>.tif**. After this processing, 10 new raster layers should be produced:

- | | |
|----------------------------------|----------------------------------|
| – built-up-<year1>.tif | – built-up-<year2>.tif |
| – agricultural-<year1>.tif | – agricultural-<year2>.tif |
| – forest-seminatural-<year1>.tif | – forest-seminatural-<year2>.tif |
| – wetlands-<year1>.tif | – wetlands-<year2>.tif |
| – waterbodies-<year1>.tif | – waterbodies-<year2>.tif |

Pixel values in these rasters are areas of each pixel in square meters, but only pixels that correspond to the particular LC/LU class, and all other pixels have a value “0”. We could not speed up this processing with the batch processing option, since batch processing does not allow defining all the necessary settings.

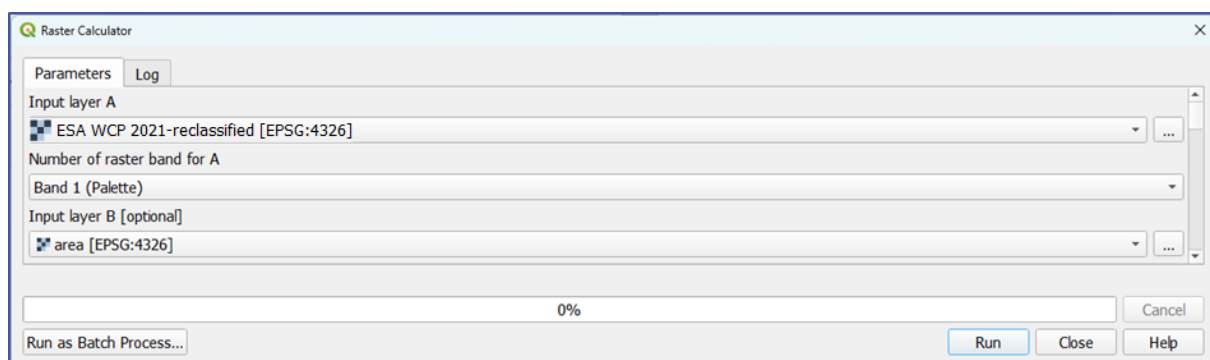


Figure 88: Using GDAL's Raster Calculator to extract pixels from the area.tif raster that correspond to a particular LC/LU class (1)

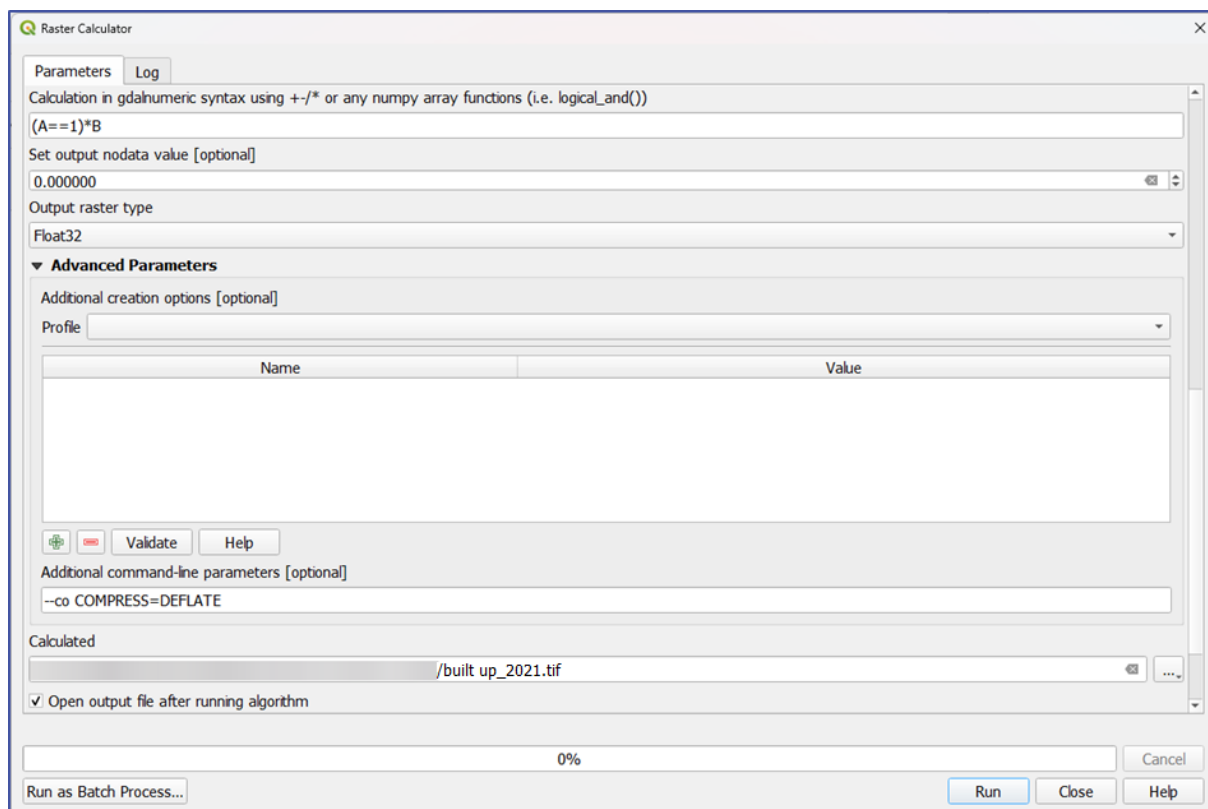


Figure 89: Using GDAL's *Raster Calculator* to extract pixels from the *area.tif* raster that correspond to a particular LC/LU class (2)

We will now use the zonal statistics algorithm to sum all the pixel values from the previously created raster layers that fall within each reporting units polygon. Enter "Zonal statistics" in the [Processing Toolbox](#) panel and double-click on the [Zonal statistics](#) item. In a new dialog window click on the [Run as Batch Process...](#) button, and then press the  button nine times. Under the [Input layer](#) and [Raster layer](#) select the same layer as in the example in Figure 90. In the [Statistics to calculate](#) column, for each row click on the three-dots-button and tick only the "Sum" item. Name the output vector layers in the same way as in the example in Figure 91, make sure the [Load layers on completion](#) option is ticked, and click on the [Run](#) button.

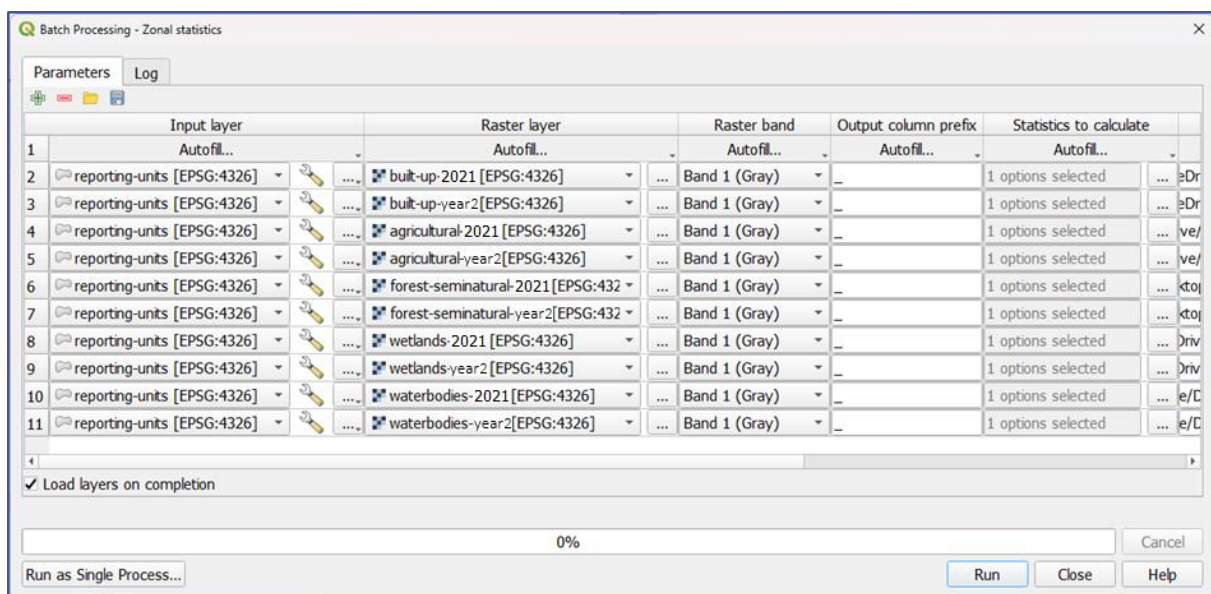


Figure 90: Using the *Zonal statistics* algorithm to sum areas of each LC/LU class within each reporting unit (1)

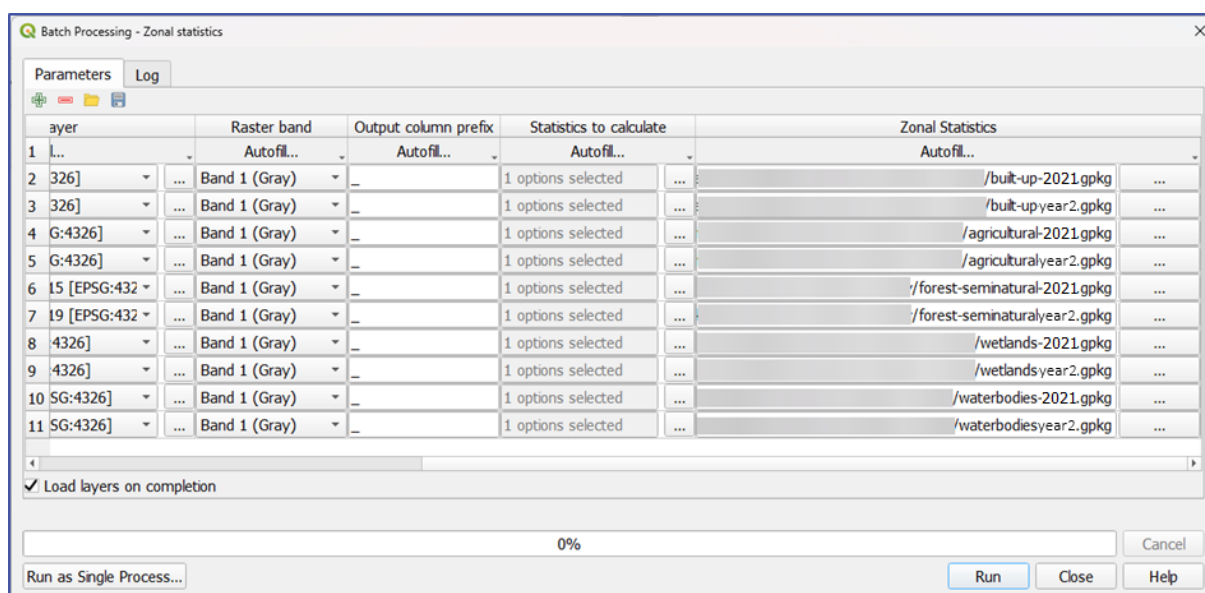


Figure 91: Using the *Zonal statistics* algorithm to sum areas of each LC/LU class within each reporting unit (2)

The same processing that was done with the *Zonal statistics* algorithm needs to be done again, but this time within LEZ across reporting units. All settings should be the same as on Figure 90 and Figure 91, except that *Input layer* should be changed to *RU-LEZ.gpkg* in all rows and names of the output vector layers need to be changed. Names can be changed by just adding prefix “LEZ-” to already defined output layer names that are visible in Figure 91 (for example, name of the layer in the first row in Figure 91 should be changed to *LEZ-built-up-2021.gpkg*). This will produce another 10 new layers, so with *Zonal statistics* algorithm 20 new layers will overall be created.

4.3 Combining all calculated data in one table

After all processing that was done in the previous sections, all data that are required for final CCI25 calculation are prepared and stored in corresponding attribute tables, and they just need to be merged into one table. In the *Layers* panel, right click on the layer with original reporting units (*reporting-units.gpkg*), and click on the *Properties...* In the *Layer Properties* window, in the *Joins* tab (on the left side of the window) click on the  button. In a new window (visible in Figure 92) define settings for joining attribute data of two vector layers and repeat this step for every layer that was produced with the *Intersection* and the *Zonal statistics* algorithm. For joining data from the *RU-LEZ.gpkg* layer follow setting from the left screenshot in Figure 92, and for each of two layers produced with intersecting reporting units with protected areas (*RU-protected-areas-<year1>.gpkg* and *RU-protected-areas-<year2>.gpkg*) follow settings from right screenshot. For each of the first 10 layers that were produced with the *Zonal statistics* algorithm (those layers that do not have a “LEZ-” prefix in their name), follow settings from the left screenshot in Figure 93, and for the second 10 created layers (those that have a “LEZ-” prefix in their name) use settings from right screenshot. After defining all these joins, the *Joins* tab of the *reporting-units.gpkg* layer should look like the one on Figure 94. When joining attribute data, it is necessary to pay attention to the columns representing join field and target field as highlighted on Figure 93 and Figure 94. While target field is always “fid” join field could be “fid” or “fid_2”.

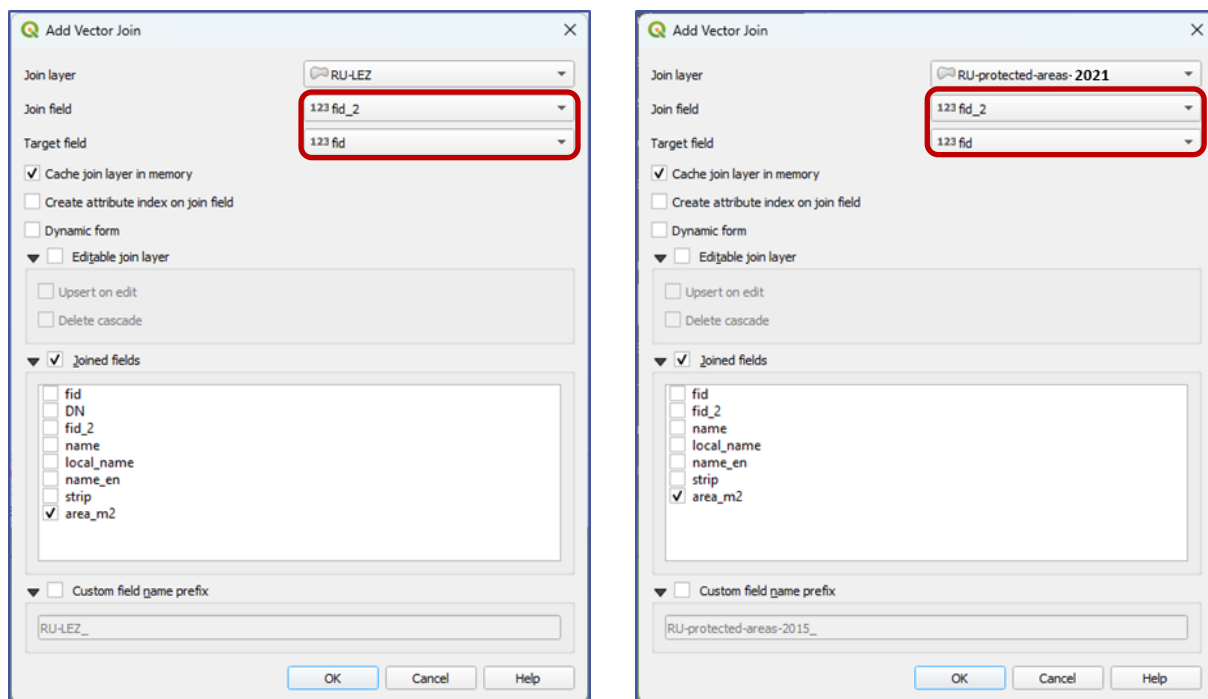


Figure 92: Joining data from attribute table of RU-LEZ.gpkg, and RU-protected-areas-2021.gpkg layers with data from attribute table of reporting-units.gpkg layer

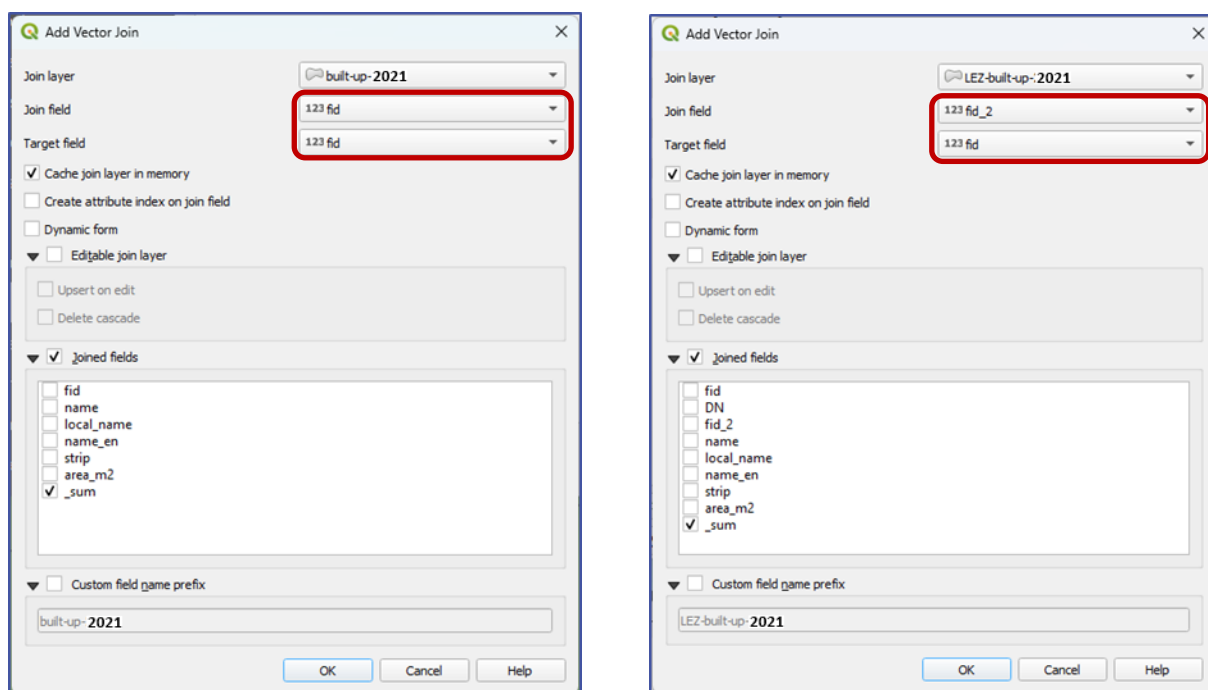


Figure 93: Joining data from attribute table of built-up-2021.gpkg and LEZ-built-up-2021.gpkg layers with data from attribute table of reporting-units.gpkg layer

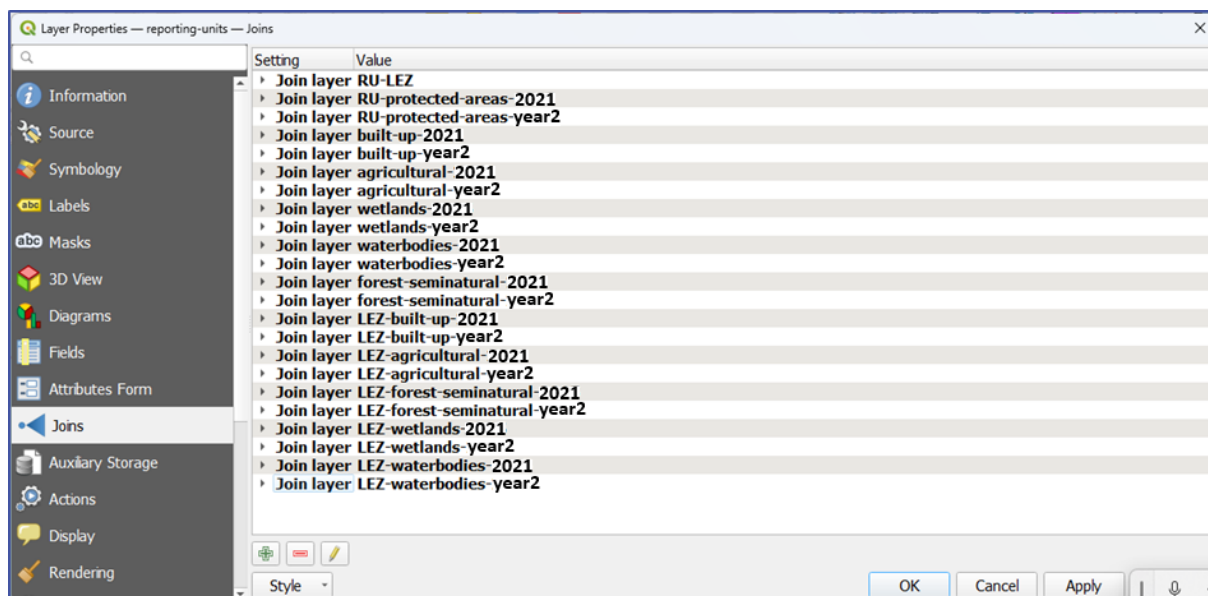


Figure 94: Joins tab of the *reporting-units.gpkg* layer after defining all joins

After clicking on the **OK** button in the **Layer Properties** window (Figure 94), attribute table of the **reporting-units.gpkg** layer should be populated with all data that are needed for calculating CCI25 parameters. In the **Layers** panel, right click on the reporting units layer (**reporting-units.gpkg**), choose **Export**, and then **Save Features As...** In a new **Save Vector Layer As...** dialog window (Figure 95), in the **Format** dropdown choose **XLSX**, in the **File name** field define name and storage location of the output file (you can use **CCI25-calculation.xlsx** for name) and click on the **OK** button.

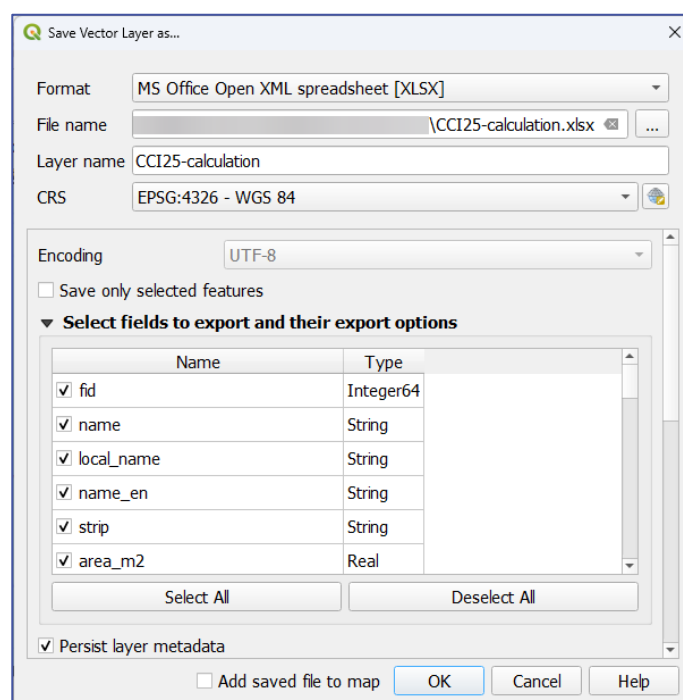


Figure 95: Exporting data from attribute table in XLSX file

4.4 Calculating indicator parameters and representing results

XLSX file that was exported from QGIS contains all data that is necessary to calculate CCI25 parameters. We suggest that before conducting any other calculations, you divide all values in all cells in a spreadsheet that represent area with 1000000 so that results are expressed in km², instead of m². These are the parameters that have to be calculated for first monitoring:

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

For the second monitoring, these parameters have 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
4. % of increase of built-up area, or land take within LEZ
5. % of change of other land cover classes within LEZ
6. % of change of protected areas within LEZ

All these parameters can be calculated by applying suitable filters and summing values in XLSX file or by creating pivot tables. We also suggest that you convert range with values (not empty cells) to table. In Microsoft Excel, to convert range to table, select one cell that is within the range, and then choose one of the predefined table styles after clicking on the **Format as table** in **Styles** group in the **Home** ribbon. After converting to table, spreadsheet should look similar to the one in Figure 96.

	A	B	C	D	E	F	G	H	I
1	fid	name	local_name	name_en	strip	area_m2	RU-LEZ_area_m2	RU-protected-areas-2015_area_n	RU-protected-areas-2019_area_n
2	1	Trieste	Trieste	Trieste	0 - 300 m	14,44094685	5,8103938	2,232523506	2,232523506
3	2	Trieste	Trieste	Trieste	1 - 10 km	168,5141639	1,609116633	88,06970819	88,06970819
4	3	Trieste	Trieste	Trieste	300 - 1000 m	29,13517235	1,922336253	6,93684203	6,93684203
5	4	Udine	Udine	Udine	0 - 300 m	5,389045508	4,675066961	2,876090623	2,876090623
6	5	Udine	Udine	Udine	1 - 10 km	261,446023	248,3850526	82,04528306	82,04528306
7	6	Udine	Udine	Udine	300 - 1000 m	11,51394894	9,321704533	6,812589291	6,812589291
8	7	Trapani	Trapani	Trapani	0 - 300 m	87,0941698	36,67230928	49,18298478	49,18298478
9	8	Trapani	Trapani	Trapani	1 - 10 km	1114,034148	21,65200315	205,628094	205,628094
10	9	Trapani	Trapani	Trapani	300 - 1000 m	155,1766104	29,26653241	67,01235032	67,01235032
11	10	Nord-Est Sardegna	Nord-Est Sardegna	Nord-Est Sardegna	0 - 300 m	134,5117082	37,54668822	46,79671348	46,79671348
12	11	Nord-Est Sardegna	Nord-Est Sardegna	Nord-Est Sardegna	1 - 10 km	1142,798075	13,53574137	4,663905612	4,663905612
13	12	Nord-Est Sardegna	Nord-Est Sardegna	Nord-Est Sardegna	300 - 1000 m	181,5217638	17,00958596	32,01943506	32,01943506
14	13	Padova	Padova	Padova	1 - 10 km	14,84487667	14,84457324	14,39332751	14,39332751
15	14	Ragusa	Ragusa	Ragusa	0 - 300 m	25,28219956	13,66956124	2,397879188	2,397879188
16	15	Ragusa	Ragusa	Ragusa	1 - 10 km	619,2365414	11,83588323	32,08512504	32,08512504
17	16	Ragusa	Ragusa	Ragusa	300 - 1000 m	55,63983446	9,55907744	3,605773639	3,605773639
18	17	Foggia	Foggia	Foggia	0 - 300 m	54,63424066	29,03934671	41,13484714	41,13484714
19	18	Foggia	Foggia	Foggia	1 - 10 km	1394,714722	301,5581317	721,565292	721,565292
20	19	Foggia	Foggia	Foggia	300 - 1000 m	110,7891231	52,00006324	79,05238413	79,05238413
21	20	Frosinone	Frosinone	Frosinone	1 - 10 km	29,24503409	0	16,73924044	16,73924044
22	21	Messina	Messina	Messina	0 - 300 m	106,0084806	33,61608656	41,12672151	41,12672151

Figure 96: Spreadsheet after converting range to table

In columns B, C, and D are the names of the administrative units, and in column E are the names of the coastal strips ("0 - 300 m", "300 - 1000 m", and "1 - 10 km"). In all other columns to the right of the column E are areas that are in example in Figure 96 already divided by 1000000, so they

are expressed in km². To create a pivot table in Microsoft Excel, go to the **Insert** tab and click on the **Pivot Table** button and then by dragging&dropping column/field names in **Filters**, **Columns**, **Rows**, and **Values** areas generate different pivot tables and calculate CCI25 parameters.

In tables and figures below, there are some examples and suggestions how can results of indicator calculation be visualizes in form of tables or graphs.

Table 1: Areas by CCI25 LC/LU classes in the coastal zone (0 – 10 km) and their percentage for Albania, year 2015

2015		Built-up areas	Agricultural land	Forest and semi-natural land	Wetlands	Water bodies	Total coastal zone
Albania	Area in km ²	166.52	1,289.57	1,712.20	36.11	197.56	3,401.96
	% in coastal zone	4.89	37.91	50.33	1.06	5.81	100.00
Durrës County	Area in km ²	55.73	215.13	152.08	2.29	7.64	432.86
	% in coastal zone	12.87	49.70	35.13	0.53	1.77	100.00
Fier County	Area in km ²	12.05	271.41	97.67	11.18	86.52	478.82
	% in coastal zone	2.52	56.68	20.40	2.33	18.07	100.00
Gjirokaštër County	Area in km ²	0.00	0.22	8.68	0.00	0.00	8.89
	% in coastal zone	0.00	2.47	97.53	0.00	0.00	100.00
Lezhë County	Area in km ²	27.90	240.65	156.42	13.11	17.06	455.13
	% in coastal zone	6.13	52.87	34.37	2.88	3.75	100.00
Shkodër	Area in km ²	3.11	77.61	46.79	2.20	6.72	136.44
	% in coastal zone	2.28	56.89	34.30	1.61	4.93	100.00
Tirana County	Area in km ²	22.22	137.95	109.70	0.59	4.75	275.22
	% in coastal zone	8.08	50.13	39.86	0.21	1.73	100.00
Vlorë County	Area in km ²	45.50	346.60	1,140.88	6.74	74.88	1,614.60
	% in coastal zone	2.82	21.47	70.66	0.42	4.64	100.00

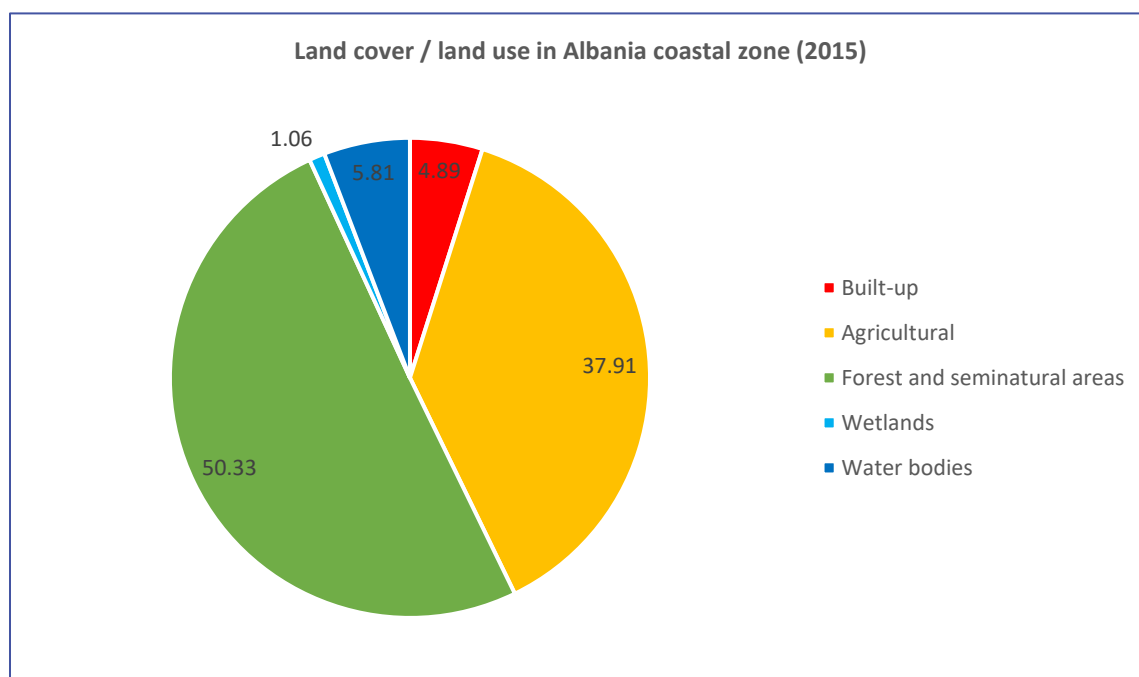


Figure 97: CCI25 LC/LU classes in Albanian coastal zone (0 – 10 km), year 2015

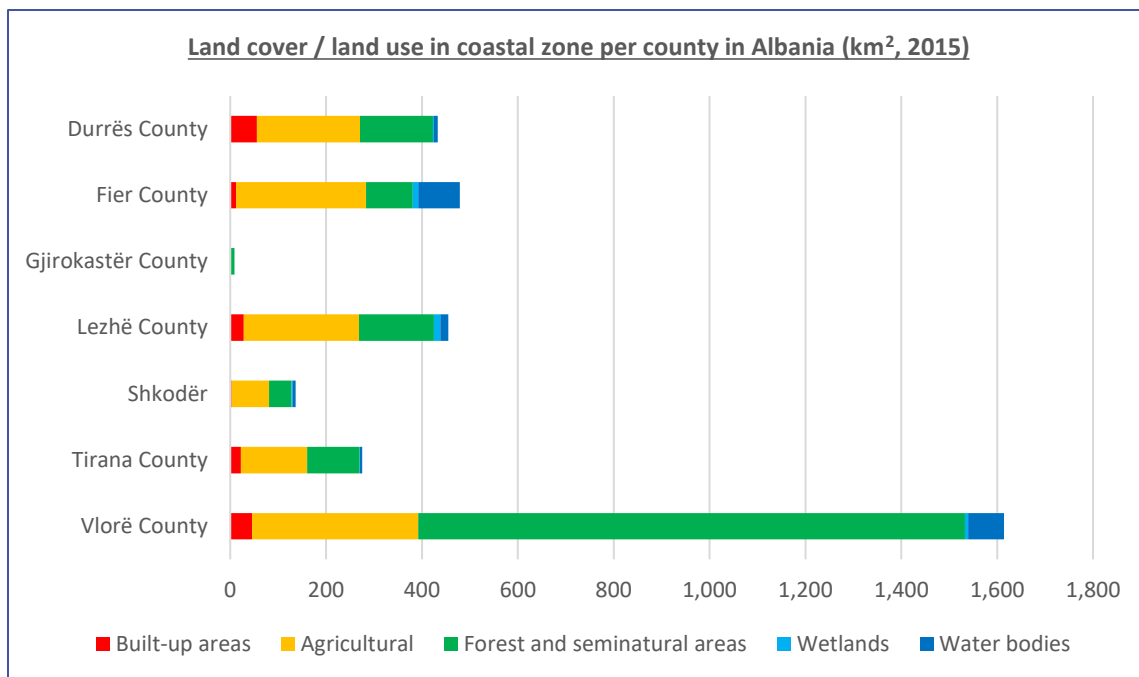


Figure 98: Areas of CCI25 LC/LU classes in Albanian coastal zone (0 – 10 km) per county, year 2015

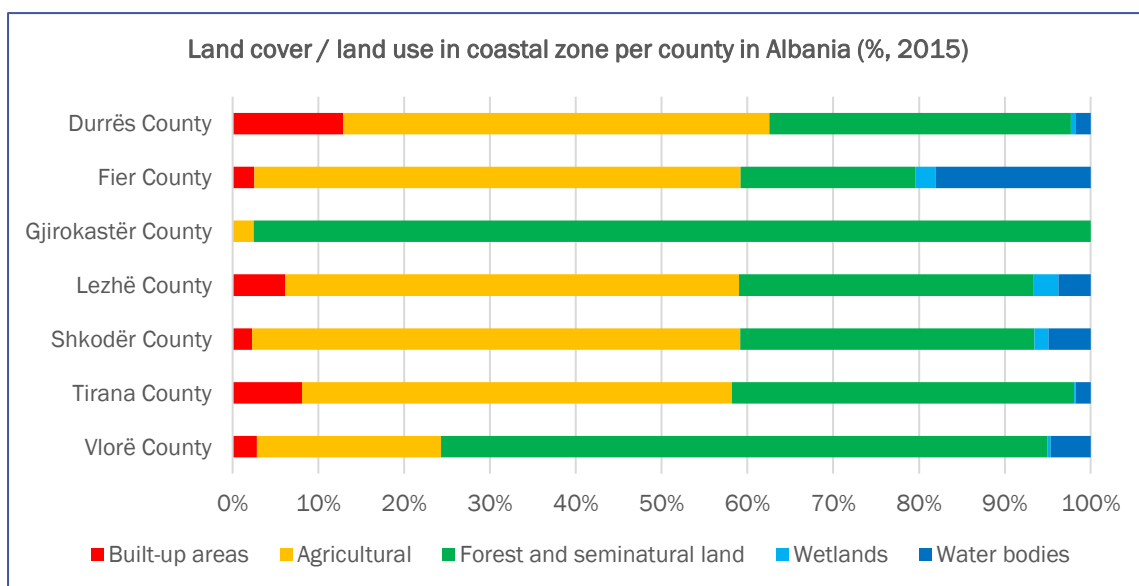


Figure 99: Percentages of CCI25 LC/LU classes in Albanian coastal zone (0 – 10 km) per county, year 2015

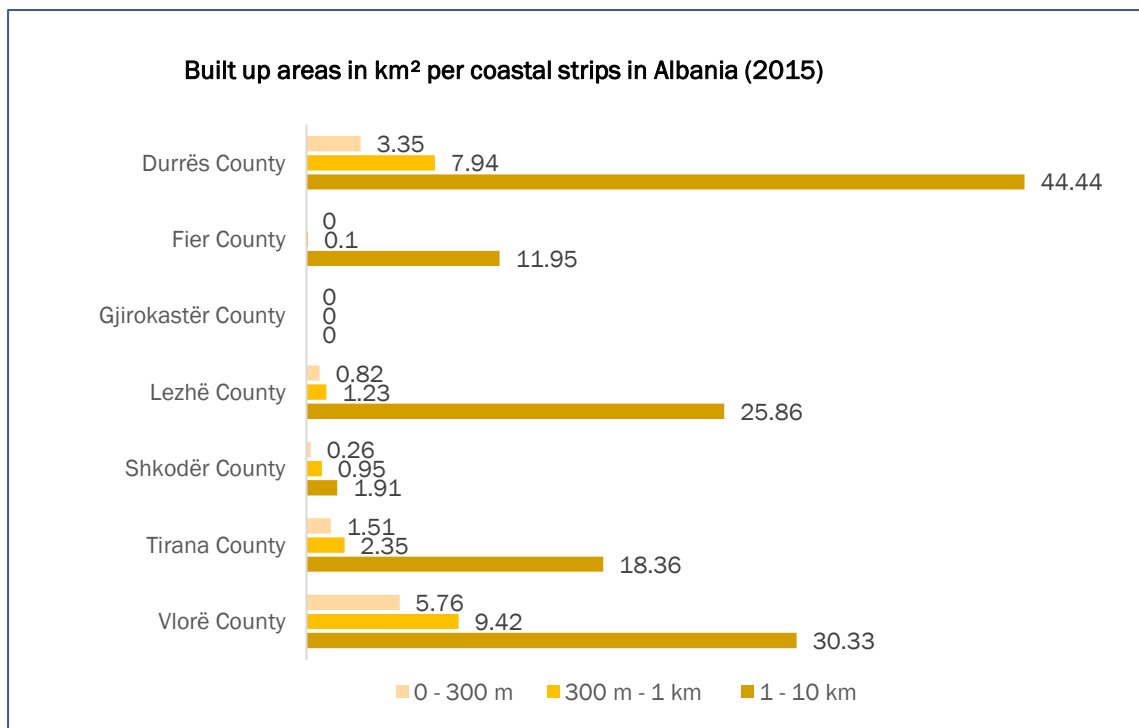


Figure 100: Built-up areas in Albanian coastal zone (0 – 10 km) per counties per coastal strips, year 2015

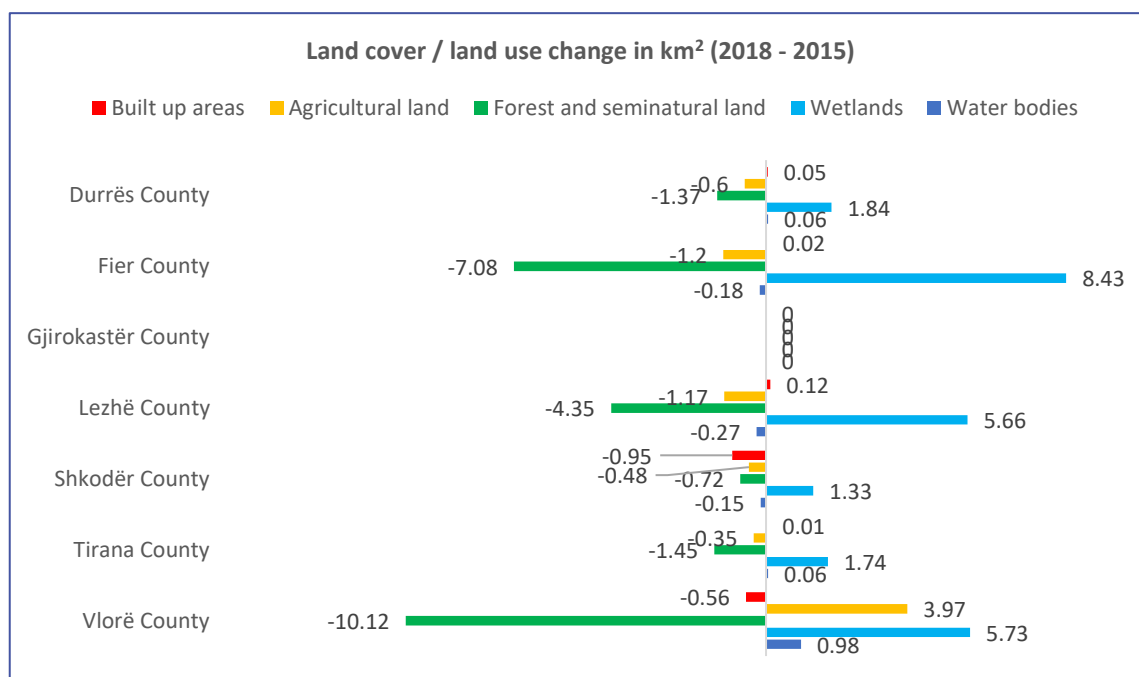


Figure 101: Change (in km²) in CCI25 LC/LU classes in Albanian coastal zone (0 – 10 km) per county, from 2015 to 2018

Table 2: LC/LU change from 2015 to 2018 in km² and percentages per Albanian counties, per coastal strips

	Coastal strips			Coastal zone	Coastal strips			Coastal zone
2018 – 2015	0 - 300 m	300 m - 1 km	1 - 10 km	0 - 10 km	0 - 300 m	300 m - 1 km	1 - 10 km	0 - 10 km
Built-up areas	Areas in km ²				Change in percentage (2018-2015)/2015			
Durrës County	0.02	0.00	0.03	0.05	0.60	0.00	0.07	0.09
Fier County	0.00	0.00	0.02	0.02	0.00	0.00	0.17	0.17
Gjirokastër County	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lezhë County	0.05	0.00	0.07	0.12	6.10	0.00	0.27	0.43
Shkodër County	0.00	-0.25	-0.70	-0.95	0.00	-26.32	-36.65	-30.45
Tirana County	0.00	0.00	0.01	0.01	0.00	0.00	0.05	0.05
Vlorë County	0.00	-0.40	-0.17	-0.57	0.00	-4.25	-0.56	-1.25
Total	0.07	-0.65	-0.74	-1.32	0.60	-2.96	-0.56	-0.79
Agricultural land	Areas in km ²				Change in percentage (2018-2015)/2015			
Durrës County	-0.17	-0.45	0.03	-0.59	-10.63	-4.51	0.01	-0.27
Fier County	-0.04	-0.24	-0.93	-1.21	-26.67	-11.82	-0.35	-0.45
Gjirokastër County	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lezhë County	-0.17	-0.31	-0.69	-1.17	-16.83	-5.36	-0.30	-0.49
Shkodër County	-0.09	-0.09	-0.30	-0.48	-39.13	-4.19	-0.40	-0.62
Tirana County	-0.11	-0.11	-0.14	-0.36	-11.83	-1.25	-0.11	-0.26
Vlorë County	-0.10	0.85	3.22	3.97	-4.85	10.81	0.96	1.15
Total	-0.68	-0.35	1.19	0.16	-11.37	-0.96	0.10	0.01
Forest and semi-natural land	Areas in km ²				Change in percentage (2018-2015)/2015			
Durrës County	-0.56	-0.14	-0.67	-1.37	-5.49	-0.70	-0.55	-0.90
Fier County	-0.51	-1.38	-5.19	-7.08	-30.00	-14.10	-6.02	-7.25
Gjirokastër County	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lezhë County	-1.14	-1.38	-1.83	-4.35	-27.08	-10.92	-1.31	-2.78
Shkodër County	-0.30	-0.16	-0.26	-0.72	-27.03	-3.11	-0.64	-1.54
Tirana County	-0.38	-0.42	-0.65	-1.45	-7.85	-3.85	-0.69	-1.32
Vlorë County	-1.16	-2.44	-6.52	-10.12	-2.08	-2.16	-0.67	-0.89
Total	-4.05	-5.92	-15.12	-25.09	-5.20	-3.45	-1.03	-1.47
Water bodies	Areas in km ²				Change in percentage (2018-2015)/2015			
Durrës County	0.00	-0.01	0.08	0.07	0.00	-1.64	3.10	0.92
Fier County	0.18	-0.11	-0.24	-0.17	1.69	0.00	0.00	-0.20
Gjirokastër County	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lezhë County	-0.12	-0.17	0.01	-0.28	-1.73	-3.05	0.22	-1.64
Shkodër County	-0.02	-0.03	-0.10	-0.15	-1.12	-3.70	-2.43	-2.23
Tirana County	-0.01	0.00	0.07	0.06	-0.36	0.00	6.73	1.26
Vlorë County	0.10	0.09	0.80	0.99	1.25	1.43	1.32	1.32
Total	0.13	-0.23	0.62	0.52	0.38	-0.75	0.47	0.26
Wetlands	Areas in km ²				Change in percentage (2018-2015)/2015			
Durrës County	0.71	0.60	0.53	1.84	94.67	68.97	79.10	80.35
Fier County	0.37	1.72	6.34	8.43	25.52	46.74	104.79	75.40
Gjirokastër County	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Lezhë County	1.38	1.85	2.44	5.67	40.12	42.73	45.78	43.28
Shkodër County	0.41	0.26	0.67	1.34	53.25	49.06	74.44	60.91
Tirana County	0.49	0.53	0.72	1.74	326.67	441.67	225.00	294.92
Vlorë County	1.16	1.90	2.67	5.73	123.40	82.97	76.29	85.14
Total	4.52	6.86	13.37	24.75	60.27	58.04	79.73	68.58

Table 3: Areas in LEZ across LC/LU classes in Albanian coastal zone (0 -10 km) per counties

Administrative unit	Total flooding [km ²]	Total Built-up flooding [km ²]	Built-up in different coastal strips [km ²]			Total Agriculture flooding [km ²]	Total Forest and semi-natural flooding [km ²]	Total Wetlands flooding [km ²]	Total Waterbodies flooding [km ²]
			0 - 300 m	300 - 1000 m	1 - 10 km				
Albania	1052,63	43,30	6,84	8,81	27,65	256,57	466,20	181,52	105,04
Durrës County	129,13	16,37	2,41	4,28	9,67	32,89	65,47	13,96	0,46
Fier County	374,56	5,14	0,02	0,03	5,09	110,15	134,15	74,81	50,30
Gjirokastrë County	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00	0,00
Lezhë County	232,01	7,34	0,86	0,62	5,86	53,17	129,09	35,81	6,61
Shkodër County	76,72	2,27	0,48	1,08	0,71	14,93	45,61	13,30	0,61
Tirana County	40,81	1,64	0,58	0,68	0,38	13,42	16,14	8,14	1,47
Vlorë County	199,39	10,54	2,48	2,11	5,95	32,01	75,75	35,50	45,59

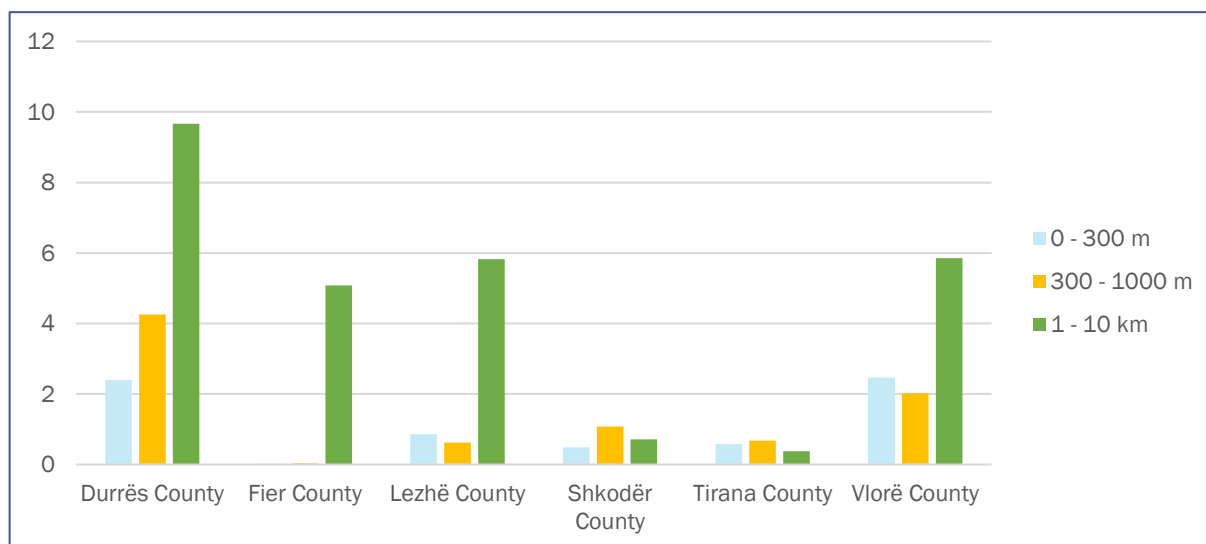


Figure 102: Area in km² of built-up LC/LU class in LEZ in different coastal strips, per counties in Albanian coastal zone (0 – 10 km)

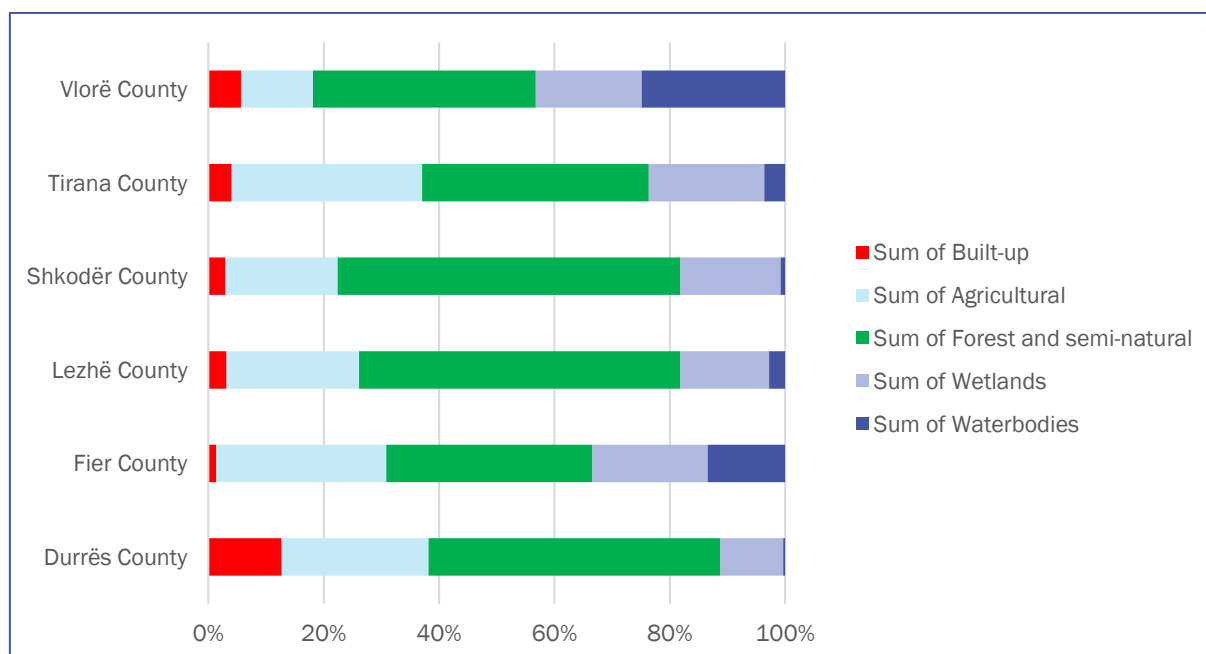


Figure 103: Percentages of areas in LEZ across LC/LU classes in Albanian coastal zone (0 -10 km) per counties

Maps are an important part of the report because they show the spatial distribution of CCI25 parameters. Since one of the results of the calculation is a GIS database, the report can contain basic maps and those showing details specific to a given geographical area and CCI25 parameters. Below are some examples of maps including choropleth and diagram maps. Although not necessary for overview maps, maps should include a scale and a legend. When coastal areas cover large areas, it is necessary to create map tiles, e.g. by QGIS Atlas function, in order to ensure a sufficiently readable map having an adequate map scale.

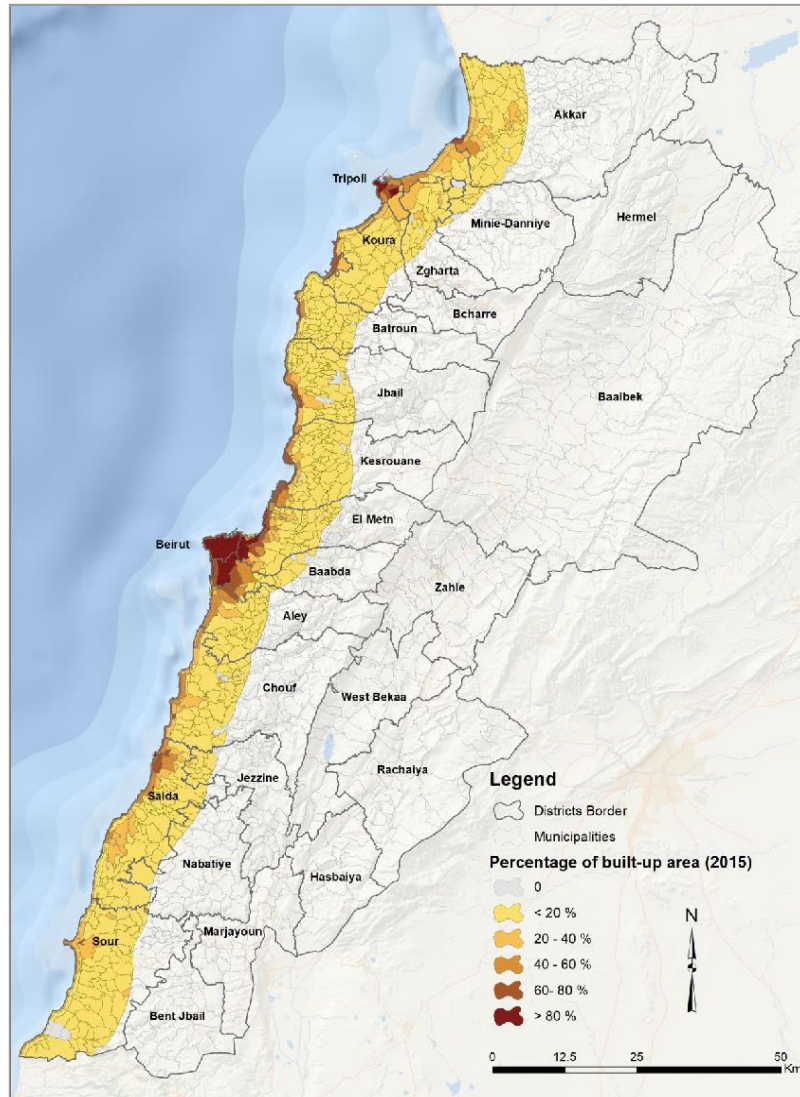


Figure 104: Overview map showing percentages of built up area in the lowest level of administrative units overlaid with coastal strips (author: Samah Termos)

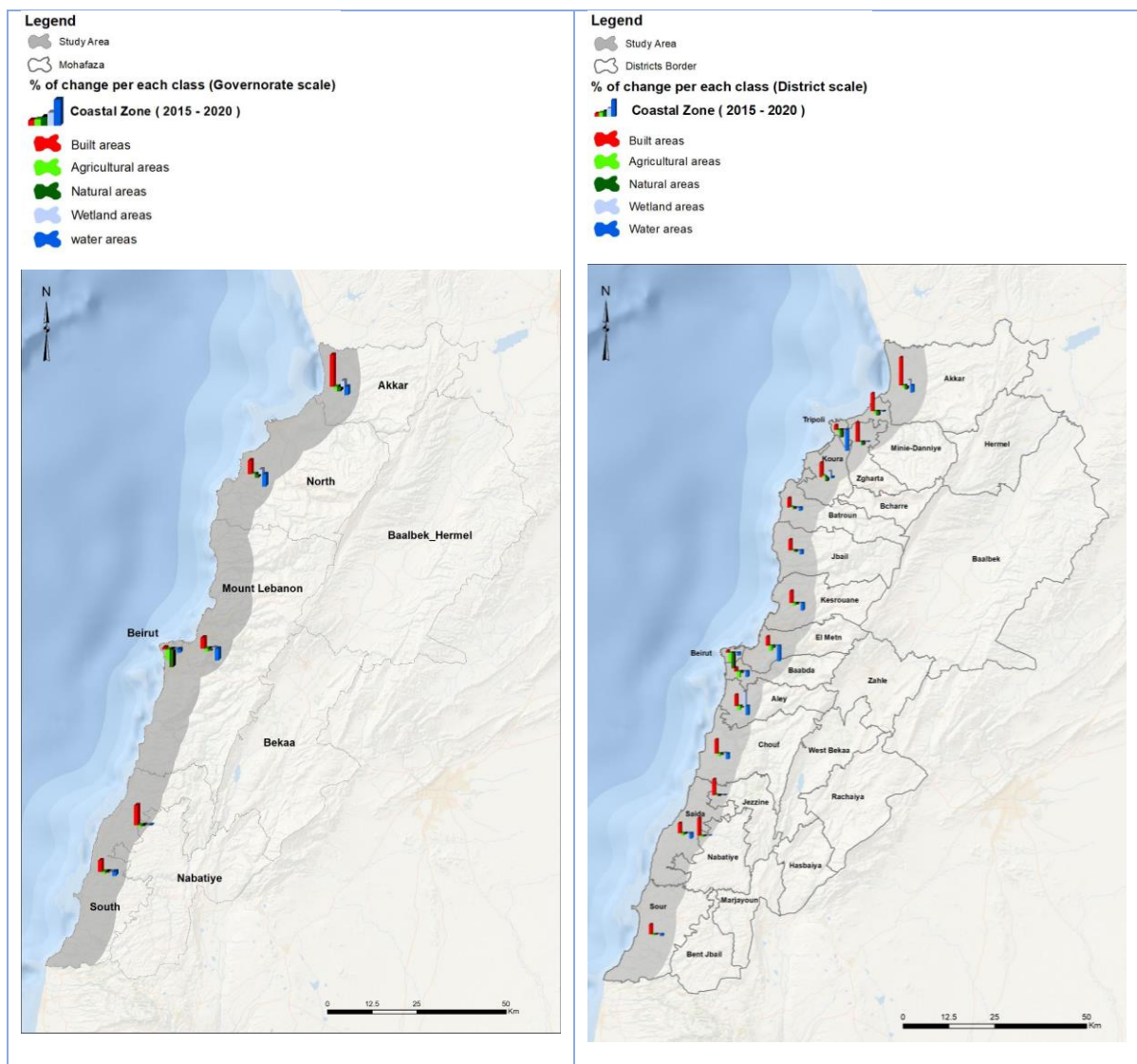


Figure 105: Diagram maps showing percentages of land cover change on the governorate (left map) and district level (right map) (author: Samah Termos)

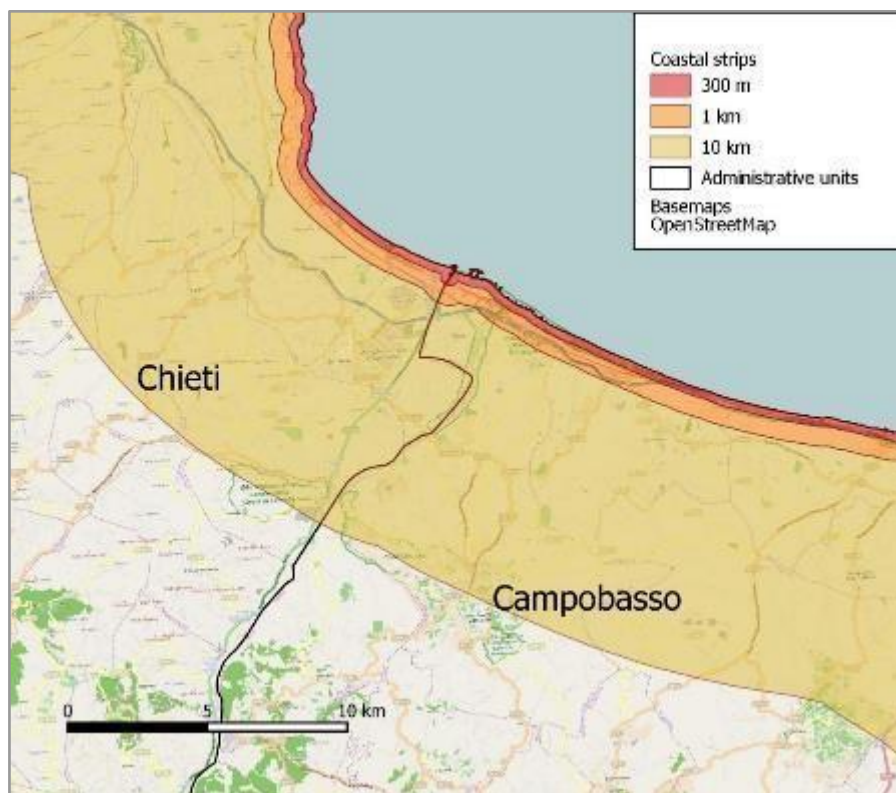


Figure 106: Detailed map showing reporting units layer (combination of coastal strips and administrative units)

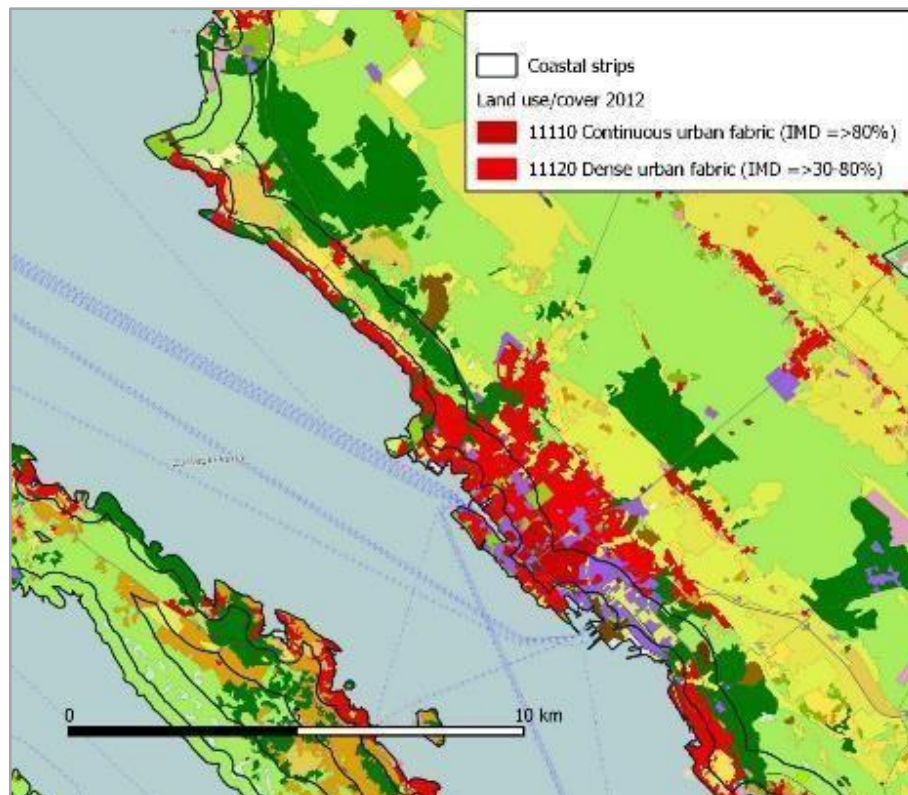


Figure 107: Detailed map showing Built up areas along the narrower coastal strip in Croatia (areas around the city of Zadar)

4.5 Validation steps

When performing GIS operations, it is always a good practise to validate obtained results after each processing step. This can be done, for example, by brief visual inspection or by performing some simple checks on aggregated results (e.g., total areas of reporting units should match to sums of areas of specific land cover classes). To avoid situations that some errors in initial processing steps are propagated to the last steps, suggested “checkpoints”, or control steps, are the following:

1. Initial validation of acquired input data (visual inspection, level of uncertainty, suitability for CCI25 calculations, etc.);
2. Control steps after challenging processing stages (e.g., construction of coastal strips and reporting units);
3. Control step after reclassification of initial LCLU classes to CCI25 classes (visual inspection, comparison with other sources, especially for classes that have ambiguous definitions);
4. Control step aimed at ensuring that attribute data from GIS layers have been correctly joined;
5. Control steps for calculations performed in spreadsheet application (for example, aggregating results and comparing totals).

REFERENCES

- [1] UN Environment/MAP, "Integrated Monitoring and Assessment Programme of the Mediterranean Sea and Coast and Related Assessment Criteria." 2017. Accessed: Sep. 22, 2022. [Online]. Available: https://wedocs.unep.org/bitstream/handle/20.500.11822/17012/imap_2017_eng.pdf
- [2] UNEP(DEPI)/MED IG.22/28, "Decision IG.22/7," p. 34.
- [3] QGIS Development Team, "QGIS project." <https://www.qgis.org> (accessed Jul. 19, 2022).
- [4] *Calculate Area in QGIS 3 - Planimetric and Ellipsoidal*, (May 05, 2020). Accessed: Jul. 22, 2022. [Online Video]. Available: <https://www.youtube.com/watch?v=eHn540xFkHg>
- [5] "EPSG Geodetic Parameter Dataset." <https://epsg.org/home.html> (accessed Jul. 20, 2022).
- [6] Esri, "Quick Notes on Map Projections in ArcGIS." Accessed: Jul. 21, 2022. [Online]. Available: <https://www.arcgis.com/sharing/rest/content/items/e8b85d508d2c4f21a3dec4e52dc7d9c4/data>
- [7] U.S. Department of the Interior U.S. Geological Survey, "USGS map projection poster." Accessed: Jul. 20, 2022. [Online]. Available: <https://d9-wret.s3.us-west-2.amazonaws.com/assets/palladium/production/s3fs-public/atoms/files/Map%20projections.pdf>
- [8] Microsoft Corporation, "Microsoft Excel Spreadsheet Software." <https://www.microsoft.com/en-ww/microsoft-365/excel> (accessed Jul. 19, 2022).
- [9] The Document Foundation, "LibreOffice office suite." <https://www.libreoffice.org/> (accessed Jul. 19, 2022).
- [10] Google, "Google Sheets: Online Spreadsheet Editor." <https://www.facebook.com/GoogleDocs/> (accessed Jul. 19, 2022).
- [11] "OGC GeoPackage." <https://www.geopackage.org/> (accessed Jul. 26, 2022).
- [12] M. Baučić, A. Morić Španić, and F. Gilić, "Upgraded LCC Indicator 25 proposal." Aug. 2022.
- [13] Van De Kerchove, R., Zanaga, D., Xu, P., Tsendbazar, N.E., Lesiv, M., 2022. Product User Manual - ESA WorldCover 10 m 2021 v200
- [14] European Space Agency and Airbus, "Copernicus DEM." European Space Agency, 2021. doi: 10.5270/ESA-c5d3d65.
- [15] L. Hawker et al., "A 30 m global map of elevation with forests and buildings removed," *Environ. Res. Lett.*, vol. 17, no. 2, p. 024016, Feb. 2022, doi: 10.1088/1748-9326/ac4d4f.
- [16] Airbus Defence and Space GmbH., "Copernicus DEM - Product Handbook." 2020. Accessed: Sep. 28, 2021. [Online]. Available: https://spacedata.copernicus.eu/documents/20126/0/GEO1988-CopernicusDEM-SPE-002_ProductHandbook_I1.00.pdf/082dd479-f908-bf42-51bf-4c0053129f7c?t=1586526993604
- [17] "OpenStreetMap," *OpenStreetMap*. <https://www.openstreetmap.org/> (accessed Jul. 21, 2022).
- [18] UNEP/MED WG.549/5, "The Guiding Factsheet for the Candidate CI 25 "Land cover change", p. 22, FEB. 2023.
- [19] *Regulation (EC) No 1059/2003 of the European Parliament and of the Council of 26 May 2003 on the establishment of a common classification of territorial units for statistics (NUTS)*. 2019. Accessed: Jul. 25, 2022. [Online]. Available: <http://data.europa.eu/eli/reg/2003/1059/2019-11-13/eng>
- [20] "Administrative Units / Statistical Units - GISCO - Eurostat." <https://ec.europa.eu/eurostat/web/gisco/geodata/reference-data/administrative-units-statistical-units> (accessed Jul. 27, 2022).
- [21] "Protected Areas (WDPA)," *Protected Planet*. <https://www.protectedplanet.net/en/thematic-areas/wdpa> (accessed Jul. 21, 2022).
- [22] S. Kay, "Answer to 'QGIS Clipping raster with vector-getting all touching pixels,'" *Geographic Information Systems Stack Exchange*, Aug. 03, 2017. <https://gis.stackexchange.com/a/250903/203065> (accessed Jul. 29, 2022).