SUITABILITY AND CHALLENGES OF *OPEN MAPS FOR EUROPE* DATA FOR CREATING A GENERAL PURPOSE SMALL-SCALE MAP OF CROATIA

A. Kuveždić Divjak [1]*, K. Kević [1], M. Viličić [1] , V. Hlatki [1]

[1] Faculty of Geodesy, University of Zagreb, 10000 Zagreb, Croatia -
(ana.kuvezdic.divjak, karlo.kevic, marina.vilicic, valentina.hlatki)@geof.unizg.hr

KEY WORDS: Mapmaking, Open Maps for Europe, Open Geospatial Data, Government Data, General Purpose Map.

ABSTRACT:

The adoption of the Open Data Directive in 2019 compelled the launch of the *Open Maps for Europe* project, aiming to provide accessible and harmonized geospatial data from over 40 European countries. This research investigates the suitability of *Open Maps for Europe* data for creating a general purpose small-scale map of Croatia. The study applies digital cartographic procedures to produce the map, while assessing data quality and fitness for this task. The methodology for map creation involved seven key steps: (1) extracting data from the 1:250,000 scale *EuroRegionalMap* dataset, (2) performing geometric, topological, and attribute conversions, (3) applying cartographic generalization to adapt the map content to a 1:500,000 scale, (4) conducting data quality checks, (5) addressing exceptions, (6) symbolizing and placing names, and (7) designing a printable map. The resulting general-purpose map of Croatia at a 1:500 000 scale demonstrates that *Open Maps for Europe* data is generally suitable for map creation at this scale. However, challenges such as data heterogeneity among countries, data gaps in certain areas, inappropriate levels of generalization, and disordered geometry may arise. The map created should be considered an intermediate, rather than a reliable and trustworthy final product since rigorous quality control measures should be undertaken to produce the final map.

1. INTRODUCTION

In 2019, the European Commission adopted the Directive on open data and the re-use of public sector information, also known as the Open Data Directive (Directive (EU) 2019/1024, 2019), which requires public sector data to be available as open data. Open data is defined as data without legal or technical barriers to access and (re)use. The Directive recognizes geospatial data, i.e., data with a strong spatial component, as one of the high-value datasets and links their openness and reuse to important benefits for society, the environment, and the economy. These data are considered suitable for creating a wide range of value-added products and services.

In response to this directive, the *Open Maps for Europe* project was launched – a project that brings together national cadastral and cartographic authorities from more than 40 European countries to provide public access to their geospatial data. The goal of *Open Maps for Europe* is to provide a harmonised, pan-European dataset of topographic data (at global and regional scale), digital elevation models, satellite imagery, cadastral data and the regional register of geographic names that can be used to create a wide range of value-added products and services (URL1). The project also strives to ensure that the geospatial datasets are available as open data without legal or technical barriers to access and (re)use.

In this context, our research focuses on investigating the suitability of *Open Maps for Europe* data for the creation of a general purpose small-scale map of Croatia, while examining the quality, completeness and fitness for use of *Open Maps for Europe* data for this task.

A general purpose map is a geographic map with a large amount of local information showing relief, vegetation, water, settlements, roads, and administrative boundaries, all represented with equal importance and accompanied by a description of the map. In the last 30 years, four editions of 1:500 000 scale general purpose maps for the territory of the Republic of Croatia have been published, the last one in 2008 by the Ministry of Armed Forces of the Republic of Croatia.

When creating a general purpose map at a scale of 1:500 000, several factors must be considered, including data quality, completeness, and adherence to scientific cartographic principles. This study encompasses two key objectives: (1) to apply automated digital cartographic procedures to produce a general purpose map of Croatia, and (2) to evaluate the quality and suitability of *Open Maps for Europe* data for this purpose.

Open data plays a critical role in facilitating the production of maps by providing mapmakers and cartographers the necessary information and resources. Under the *Open Maps for Europe* project, topographic data is declared as a harmonised pan-European data from official sources (URL1), available at two predefined scales, 1:250 000 and 1:1 000 000, as semi-finished cartographic data accessible through the *EuroRegionalMap* and *EuroGlobalMap* products. Additionally, it is declared that "these maps are for anyone who requires small scale harmonised data from official sources" (URL1).

Given this information, it is to be expected, that the accessibility and homogeneity of the *Open Maps for Europe* data should make the process of map production a straightforward task through (1) the extraction of data from the *EuroRegionalMap*

* Corresponding author

dataset and (2) the application of automated cartographic generalisation techniques.

By investigating the map creation process, assessing data quality, addressing exceptions, and analysing the resulting map, this research aims to shed light on the suitability *of Open Maps for Europe* data for small-scale map production. The findings will highlight the implications for improving the quality of the project and offer insights for policymakers and stakeholders involved in open data and geographic information systems initiatives. Ultimately, this study aims to contribute to a broader understanding of the benefits and challenges associated with open geospatial data, and support future efforts in this field.

2. BACKGROUND

This chapter describes the significance of high-value geospatial datasets, including their wide-ranging benefits in societal, environmental, and economic domains. It highlights the role of open geospatial data in promoting citizen engagement and participatory governance, emphasizing collaborative mapping initiatives like *OpenStreetMap*. The chapter also explores the role of cartography in harnessing open geospatial data, focusing on data visualization, contextualization, generalization, customization, and user engagement. Additionally, it discusses the *Open Maps for Europe* project, a government initiative, which ensures accessibility and openness of geospatial data for mapmaking purposes.

2.1 Leveraging Open Geospatial Data

High-value datasets, including geospatial data, have been identified as particularly significant due to their wide-ranging societal, environmental, and economic benefits (Regulation (EU) 2023/138, 2023). Due to their ability to provide spatial context and enable informed decision-making across multiple sectors, these datasets can serve as foundational resources for numerous applications and value-added services. For example, in urban planning, geospatial information can aid in designing efficient transportation networks, identifying suitable locations for infrastructure development, and assessing environmental impacts. In disaster management, geospatial data can facilitate emergency response planning, risk assessment, and post-disaster recovery efforts. Furthermore, geospatial information is vital in fields such as environmental monitoring, natural resource management, agriculture, public health, and tourism.

Moreover, open geospatial data promotes citizen engagement and participatory governance (Purwanto et al., 2020). By making geospatial information accessible to the public, it enables citizens to actively participate in decision-making processes, provide feedback, and contribute to the improvement of their communities. Open geospatial data can empower individuals and communities to understand their surroundings, advocate for their needs, and collaborate with governments and organizations to address local challenges effectively. Through initiatives like *OpenStreetMap*, citizens can actively contribute to mapping by providing local knowledge, updating information, and correcting errors.

2.2 Exploring Open Geospatial Data Sources: Collaborative Mapping and Government Initiatives

Many open geospatial data sets are the result of collaborative mapping. Today, citizens voluntarily take an active role in mapping various types of features on the Earth's surface, either through field surveys or by obtaining data from other sources such as aerial or satellite imagery. Different terms are used in the literature to describe such citizen-driven activities, including volunteered geographic information (VGI), crowdsourcing, and collaborative mapping.

The most popular among such initiatives is *OpenStreetMap* (OSM), a crowdsourced vector database of geospatial objects with a global extent and available under the open access Open Database License (ODbL) (Goodchild, 2007) – users are free to copy, distribute, transmit and adapt OSM data, as long as they credit *OpenStreetMap* and its contributors. OSM includes a wide range of geographic features, such as roads, buildings, points of interest, and natural landmarks, making it the most popular map service on the Internet and currently arguably the most valuable source of free geoinformation.

On the other hand, open government data represents a rich source of open geospatial data, generated and maintained by public sector bodies. Governments collect and manage geospatial information, including transportation networks, environmental data, census information, and administrative boundaries. Government open data portals and websites serve as repositories for accessing these datasets.

National mapping agencies often provide open access to a variety of geospatial datasets, such as topographic maps, land cover data, elevation models, and administrative boundaries. The data provided by national mapping agencies is typically authoritative and reliable, serving as valuable resources for cartographic purposes.

Organizations such as the National Aeronautics and Space Administration (NASA), the European Space Agency (ESA), and commercial satellite providers make satellite imagery openly available to the public. For example, Copernicus data products are by definition free of charge and provided through an open license (Legal notice (EU), 2019). These Earth observation datasets can be utilized in cartography to create basemaps, assess land cover and land use, monitor environmental changes, and support disaster response and planning.

By leveraging these sources, mapmakers can access diverse and valuable geospatial datasets. There are no legal or technological restrictions on their use, which means that these datasets can be used in creative, productive and unexpected ways.

2.3 The Role of Cartography in Harnessing Open Geospatial Data

Cartography plays an important role in the context of open geospatial data reuse by transforming raw geospatial data into meaningful and visually appealing maps that can facilitate data exploration, analysis, and decision-making. As open geospatial data becomes more accessible, cartography acts as a bridge between the data and its effective utilization by various stakeholders, including researchers, policymakers, businesses, and the general public.

Through effective data visualization, contextualization, generalization, customization, and user-focused design, cartography can help in maximising the value and usability of open geospatial data, enabling its wide range of applications across various domains.

2.3.1 Data Visualization and Communication: Cartography is responsible for visually representing geospatial data in a way that is easily understandable and informative. By employing various techniques such as symbolization, colour coding, and visual hierarchy, cartographers create maps that effectively communicate spatial patterns, relationships, and trends. Through clear and intuitive map design, cartography enables users to grasp complex information and make informed decisions based on the data.

2.3.2 Contextualization and Spatial Analysis: Cartography provides a means to contextualize open geospatial data by integrating it with other relevant datasets. By overlaying different layers of information, cartographers can create maps that reveal spatial relationships and facilitate spatial analysis. This allows users to gain a comprehensive understanding of the data, identify patterns, and derive valuable insights from the combination of diverse datasets.

2.3.3 Generalization and Simplification: Open geospatial datasets often contain detailed and extensive information, which may need to be generalized or simplified for specific mapping purposes. Cartography applies techniques such as generalization, aggregation, and scale adjustments to reduce complexity and create maps that are suitable for the intended audience and purpose. Generalization ensures that maps effectively portray the desired level of detail while maintaining visual clarity and legibility.

2.3.4 Customization and Tailored Maps: Cartography allows for the customization and tailoring of maps based on specific user needs and requirements. With open geospatial data, cartographers have the flexibility to select relevant attributes, adjust map elements, and emphasize specific features to create maps that address the unique requirements of different applications and user groups. This customization enables users to focus on the information most pertinent to their needs and facilitates effective decision-making.

2.3.5 User Experience and Engagement: Cartography plays a crucial role in enhancing the user experience and engaging map users. By considering design principles, including aesthetics, usability, and interactivity, cartographers create maps that are visually appealing, intuitive to navigate, and provide meaningful interactions. This can enhance user engagement, encourage exploration and discovery, and facilitates the effective communication of geospatial information.

2.4 The *Open Maps for Europe* Project: Ensuring Accessibility and Openness

Initiated in 2021, the *Open Maps for Europe* project enables free use (and reuse) and regular updating of high-quality small-scale harmonised datasets by connecting users to official national spatial data sources compliant with the Open Data and Public Sector Information (PSI) Directive. A new version of the project called *Open Maps for Europe 2* is underway (announced in March 2023), aiming to develop a new production process and technical specification for open and harmonised large-scale datasets for several European countries under a single open licence (URL1).

From a cartographic perspective, the *Open Maps for Europe* project provides cartographers with a valuable resource for comprehensive, up-to-date, and consistent cartographic products. The project's aim to create a homogeneous dataset should ensure consistency in data quality, standards, and formats, which is essential for producing accurate and reliable maps (URL1).

2.4.1 Content and coverage: The *Open Maps for Europe* project includes six datasets: two topographic datasets – *EuroGlobalMap* at 1:1 000 000 scale and *EuroRegionalMap* at 1:250 000 scale, *EuroDEM, Open Gazetteer, Pan-European Imagery*, and *Open Cadastral Map*.

The first release was in September 2021 and includes topographic datasets, a digital elevation model, satellite imagery, and a regional register of geographic names. The second release was in May 2022 and includes the *Open Cadastral Map* prototype covering four countries (Poland, the Netherlands, the Czech Republic, and Spain) at large scale (1:10 000). In November 2022, the third and final release was published, with contributions from North Macedonia and Switzerland to topographic datasets, while Denmark and Slovenia added their data to the *Cadastral Index Map* prototype (URL1).

Open national data included in these datasets are provided by *EuroGeographics* members, who make their data available in accordance with a standard set of specifications for *EuroRegionalMap*. Harmonization and quality assurance is performed by *EuroGeographics*, which generalizes the *EuroRegionalMap* data (last update November 2022) for the production of *EuroGlobalMap* (last update March 2023) via the production system. Both datasets contain administrative boundaries, hydrography, named location, settlements, and transport, while *EuroRegionalMap* additionally contains two more: vegetation and soils, and various thematic objects (tourist attractions, transmission lines, mines, etc.) (URL2).

The *Open Gazetteer* provides authoritative geographic names, and it is compliant with the INSPIRE Data Specification on Geographical Names. It is created from *EuroRegionalMap* data in combination with *EuroGeographic's EuroBoundaryMap* dataset. The last layer update was in October 2022 (URL2).

The *Pan-European Imagery* was created in 2018 from data collected by the European Union's Copernicus Earth Observation Program and covers the area of Europe at a ground resolution of 10 meters (URL2).

EuroDEM was created using official national databases at a scale of approximately 1:100 000 and was last updated in April 2022 (URL2).

Open Cadastral Map allows users to explore available national cadastral data in four data types: Administrative Units, Cadastral Parcels, Buildings, and Addresses. The data in this dataset is currently available for six EU countries: Czech Republic, Denmark, Netherlands, Poland, Slovenia and Spain. The last update was in November 2022 (URL2).

2.4.2 Data access: The datasets are available through the *Open Maps for Europe* service which allows users to search, view, and download open datasets (URL2). To connect to the service, users must select the desired datasets, read and accept the licence terms, and provide their e-mail address. After that, the service will send a download link and/or instructions for connecting to the service.

Open Maps for Europe provides users with detailed insight into the specifications of all available datasets: last update, themes (except for *EuroDEM*, *Pan-European Imagery* and *Open Gazetteer*), scales (except for *Pan-European Imagery* and *Open Gazetteer*), image resolution (only for *Pan-European Imagery*), coordinate system, available formats and/or web services for downloading and documentation of the datasets. (URL2)

EuroGlobalMap, *EuroRegionalMap* and the *Open Gazetteer* datasets can be downloaded as shapefiles or geopackages. *EuroRegionalMap* can also be downloaded as a FileGeoDatabase. The *EuroDEM* dataset can be downloaded as Tiff, while the *Pan-European Imagery* and the *Open Cadastral Map* are only available via the web service because of the large file size (URL2).

2.4.3 Licence and copyright: *Eurogeographics* uses the open data licence accepted by its members and requires users to acknowledge the source. The licence allows commercial use and applies only to *EuroGlobalMap*, *EuroRegionalMap*, *EuroDEM*, and the *Open Gazetteer* dataset. When using other datasets, users should check the terms and conditions of the providers of those datasets (URL2).

2.4.4 Existing case studies demonstrating the use of *Open Maps for Europe* datasets: Several practical examples of using data from *Open Maps for Europe* have been documented on the project website. Following the creation of a tactile map for the Netherlands, the launch of *Open Maps of Europe* enabled the Netherlands' Cadastre, Land Registry and Mapping Agency to use *EuroRegionalMap* to create tactile maps for other European countries. Other examples of *Open Maps for Europe* use cases also use *EuroRegionalMap*. This dataset has been used by the *European Ground Motion Service* data viewer as a selectable background map, in the development of web solutions to support the *United Nations System* for analysis and visualisation of decision processes and data actions, and by the *European External Action Service* for planning military mobility and investment programmes (URL1).

3. METHODS

This chapter describes the methodology for creating a small-scale general purpose map of Croatia using *Open Maps for Europe* datasets. The methodology involved two phases: map planning phase (content, format, presentation medium and mathematical elements) and map production phase (data preparation and preprocessing, quality control, dealing with exceptions and designing a map suitable for printing).

3.1 Map planning – content, format, presentation medium and mathematical elements (map projection, scale)

In the last 30 years, four editions of 1:500 000 scale general purpose topographic maps for the territory of the Republic of Croatia have been published, the last one in 2008 by the Ministry of Defence of the Republic of Croatia.

This last official overview topographic map of the Republic of Croatia was preceded by overview topographic maps at a scale of 1:500 000 prepared for the territory of the former Yugoslavia, to which Croatia belonged. One map dates from 1947-1950 and the second from 1979, with latter been updated in 1983 and 1989. In 1994, the Faculty of Geodesy of the University of Zagreb prepared on two sheets the topographic overview map at the scale of 1:500 000, published by the Ministry of Defence of the Republic of Croatia. In 1997, the map was reissued in two different versions – one with county boundaries, the other with municipal boundaries.

For the needs of the Ministry of Defence, Cartographic Laboratory Križovan prepared a topographic overview map of the Republic of Croatia at a scale of 1:500 000 in 1999. A new edition of this map was prepared on one sheet in 2008, and the map is used as an operational-strategic map of the Armed Forces of the Republic of Croatia (Ćosić et al., 2012).

A general purpose map of a proposed area of interest shows topographic information (vegetation, water, settlements, roads, and administrative boundaries) on a base map of terrain representation (relief).

To create such a map, suitable datasets and appropriate data geometry types are needed. *EuroRegionalMap* at 1:250 000 scale was selected as a primary source for map content, since it provides topographic data organized in seven thematic categories: Administrative boundaries (BND), Hydrography (HYDRO), Named Location (NAMES), Miscellaneous (MISC), Settlement (POP), Transportation (TRANS), and Vegetation and Soils (VEG) (EuroGeographics, 2022). Each of these categories includes a number of theme-related datasets with data available in different geometrical forms (points, lines, polygons). As not all the available datasets, nor the geometry forms, are needed (or suitable) to create a general purpose map, the choice of datasets to be used in the map creation process needs to be made. For instance, administrative boundaries data in *EuroRegionalMap* is available in two geometrical forms, lines and polygons. Since boundaries on a general purpose map are represented with lines and not polygons, a dataset with line geometry representation was used for this purpose. Having in mind the requirement of the general purpose map, which is to provide general information about the area of interest, we focused on topographic data available in the *EuroRegionalMap*, while inferring that the remaining datasets could be useful for creating other types of maps, i.e., thematic maps. Also, while getting deeper into the *Open Maps for Europe* datasets, we found that in terms of generalization, there are no significant differences in data geometry between *EuroRegionalMap* and *EuroGlobalMap*. This makes *EuroGlobalMap* datasets usable in the creation of a map at the proposed 1:500 000 map scale. The decision on datasets to be used was made based on the criteria of completeness and spatial accuracy, determined through visual comparison with existing and official topographic maps. A list of datasets used to create a proposed general purpose map of Croatia at 1:500 000 map scale is provided in Table 1.

EuroRegionalMap uses vector data structure to represent discreet objects on the surface of the Earth. However, to represent relief (continuous phenomenon) as a base map on a general purpose map, a digital elevation model *EuroDEM* was selected. Available at 1:100 000 scale, this model is suitable to create a relief base map in the proposed map scale of 1:500 000.

In order to cover the entire territory of the Republic of Croatia, the map extents were set from 42° to 47° north latitude and from 13° to 20° east longitude with a grid density of 1°. The map is primarily intended for digital display on a computer or some other medium, however, in the case of printing, it would be conditioned by a scale of 1:500 000, and as such it would be best corresponded to the B0 format (100.0 × 141.4 cm). Scale is a parameter of the automated procedure and affects only cartographic generalization operators.

The coordinate system of normal Lambert conformal conic projection, with standard parallels 43°05’ and 45°55’ north was selected (abbreviated HTRS96/LCC, EPSG:3766). This projection for Croatia is based on the ellipsoid GRS80 and it was officially determined as coordinate system of the Republic of Croatia for small scale official maps (Official Gazette, 2004). Small linear distortions, good preservation of surface shapes and universality of its usage are the main reasons of its suggestion for small-scale official maps.

Theme	Dataset	Description	Form
EGM: BND	POLBNDA	Admin. Bound.	Polygon
EGM: HYDRO	LANDMASK	Land area	Polygon
ERM: HYDRO	COASTL	Coastline	Line
	ISLANDS	Islands	Polygon
	LAKERESA	Lakes	Polygon
	WATRCRSA	Rivers wid. ≥125m	Polygon
	WATRCRSL	Rivers wid. ≤125m	Line
ERM: POP	BUILTUPA	Settlements, pop>5000	Polygon
	BUILTUPP	Settlements, pop<5000	Point
EGM: TRANS	ROADL	Road network	Line
ERM: TRANS	EXITC	Borders	Point
	RAILRDL	Railways	Line
ERM: NAME	GNAMEL	Toponyms	Line

Table 1. List of topographic datasets used to create general purpose map of Croatia at 1:500 000 scale.

3.2 Map production phase

The methodology for map creation involved seven key steps (represented in Figure 1): (1) extracting data from the 1:250 000 scale *EuroRegionalMap* dataset (and 100 000 scale *EuroDEM*), (2) performing geometric, topological, and attribute conversions, (3) applying cartographic generalization to adapt the map content to a 1:500 000 scale, (4) conducting data quality checks, (5) addressing exceptions, (6) symbolizing and placing names, and (7) designing a printable map. These steps can be classified into two main stages in the map creation process, data preprocessing (covering (1), (2) and (4)) where the data is prepared for cartographic visualization, and map making (including (2), (3), (4), (5), (6) and (7)) where cartographic principles are applied to data to create a map.

Open-source programmes and modules for spatial data (GRASS GIS and QGIS) were used for preprocessing, cartographic visualisation and external map elements design.

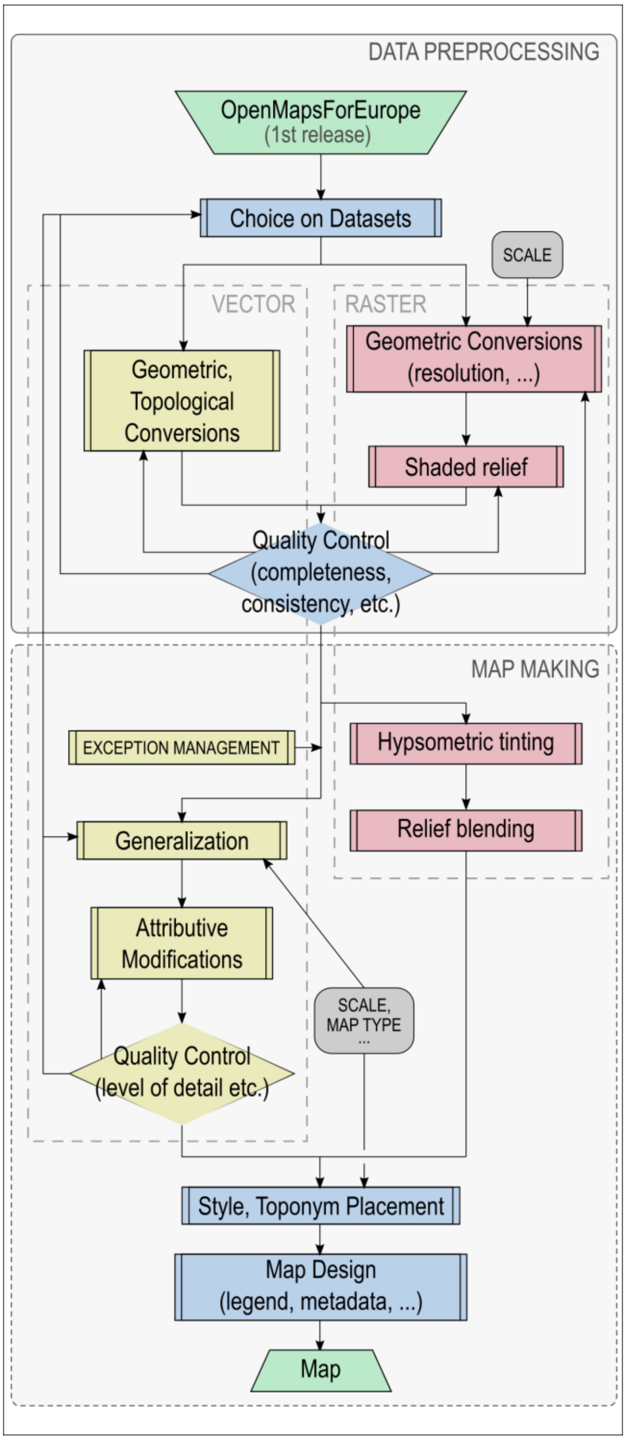

Figure 1. Flowchart of the map creation procedure.

The first step towards a map product was to model the data to fit the map's purpose. This included geometric and topological conversions of the original data. For topographic (vector) data, geometric conversion included reprojecting data from a predefined geographic coordinate system (ETRS89, EPSG:4258) to a selected map projection (HTRS96/LCC, EPSG:3766) and removing features outside of the map extent (geometrical cleaning). These procedures ensured that the topographic data is properly represented and limited to the map extent. On the other hand, topological conversions refer to topological principles and include topological editing, such as removing duplicates and joining line segments. Adhering to topological principles will ensure consistency and preserved spatial relations among topographic data on a map. For raster data, preprocessing included geometric conversions such as reprojection, resampling, interpolation and filtering. Same as topographic data, elevation data are provided in fit-for-sharing geographic coordinates (ETRS89 with vertical datum EVRS), which makes reprojecting a necessary step in the map creation process. Also, *EuroDEM* data is provided with a 60m resolution which is not optimised for maps printed on a predefined paper format (300dpi resolution, B0 format) and 1:500 000 map scale. For optimal relief representation on a printed map, the elevation model was resampled to a spatial resolution of 42m. Finally, DEM model showed inconsistency as some pixels had no assigned value while others had illogical value. This required interpolation and filtering which removed such outliers and softened the model through reducing unnecessary details (Figure 2). After preprocessing, DEM was used to create shaded relief. Shaded relief is a mathematical simulation of how light and shadow might fall on a surface. Illuminating terrain with a simulated light source, modelled by its latitude and height, it is possible to create realistic terrain representations.

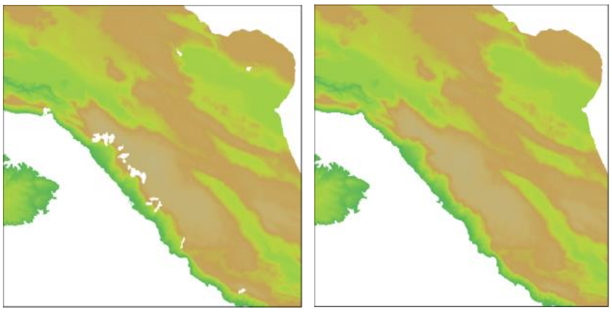

Figure 2. DEM data gap modelling: before interpolation (left), after interpolation (right)

After performing geometric and topological conversions it was necessary to control the quality of the results, usually by means of visual identification of the content. For raster data (shaded relief), quality control referred to layer overlap, e.g., rivers flowing through valleys and not along mountain peaks. If any issues were found, topological conversions and/or shaded relief were redone. For vector data, quality control concerned data completeness or topological inconsistencies. In the case of administrative boundaries, the proposed line dataset showed topological limitations (e.g., self-intersection) and data gaps (Figure 3). For these reasons, additional datasets, such as the polygon boundary dataset or boundary dataset from another *Open Maps for Europe service*, was considered.

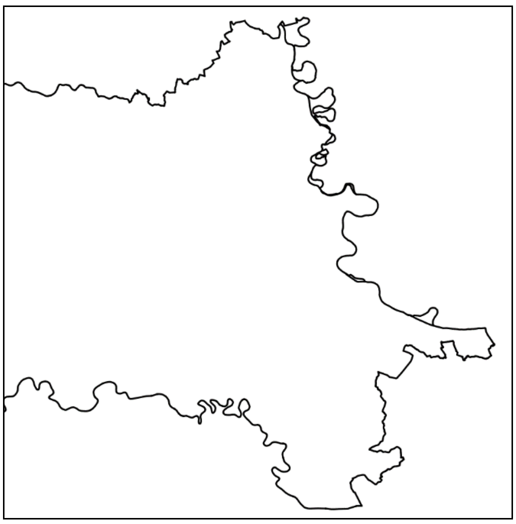

Figure 3. Topological inconsistency – self intersection of administrative boundary line dataset in *EuroRegionalMap*.

Once the data was ready, cartographic rules were applied to create a map. For topographic vector data, this phase started with exception management. Identification of e.g., features with no attribute values can result in features being omitted from the map. Exception management was followed by generalization procedures. As the map scale goes from 1:250 000 to 1:500 000, there is less space to show all the relevant content, so the generalization aims to adjust the level of details and adapt the content to a general purpose 1:500 000 scale map. Generalization included six different generalization methods which were applied to some or all the data on the map: selection, simplification and smoothing, aggregation, exaggeration, displacement and orientation, and symbolisation. For line objects such as rivers, roads and railways, generalization included selection method that filters data to be visualized, simplification and smoothing methods that remove unnecessary line curvatures, exaggeration that makes lines visible, and displacement and orientation, as a consequence of exaggeration, that put lines in correct mutual relation. While some methods were performed manually (e.g., displacement), others included automated processes. For instance, simplification and smoothing of roads were performed using Douglas–Peucker algorithm that reduces nodes density based on a map scale parameter to create a similar curve with simplified geometry (Tutić, 2022). This way, road's characteristic curvature will be preserved on a map. On the example of settlements, a 1:500 000 map scale caused polygon representation to be replaced by a point (symbolisation as generalization method) in cases when the population of the settlement was less than 5 000 people (e.g., city of Delnice). Based on the population profile of Croatia's settlements, a population of 5 000 was set as a threshold between polygon and symbol representation to ensure appropriate phenomena visual distribution that will better reflect the character of settlements in Croatia.

Attribute modifications were a follow-up step in the map making process. While generalization mostly impacted the geometry of data, attribute modifications affected their attributes. Attributes (e.g., population in settlement dataset) are important in the later stages of the process, when applying styles, so it is important that all the data have assigned all the relevant attribute values. If some attribute values are missing, external data sources should be consulted to bridge the gap. After generalization and attribute modifications have been done, quality control ensures that data is adequately generalized, and that no relevant data is omitted. Again, visual identification through comparison with external map sources may reveal the conformance level. If any issues persist (e.g., too curved roads), it is necessary to adjust generalization parameters or change attribute modifications approach.

For raster data, map making process includes hypsometric tinting and relief blending. For small-scale maps such as general purpose 1:500 000 scale map, hypsometric tinting was used to represent terrain heights. In the colour palette, green colour was used to represent lower altitudes (up to 200m), and it changes to yellowish and reddish hues as the altitude rises. Hypsometric tinting (colour ranges) and shaded relief (greyscale) were overlayed to create a realistic relief representation. This process is called relief blending and is used in modern cartography to create relief basemap for general purpose maps. There exist different blending modes with multiply being the most used one. It multiplies colour values of the shaded relief with values of the hypsometric scale and divides it with 250. This way shaded areas get darker while bright ones are less affected, making it effective in representing shades.

Creating and applying style for visual representation of data geometries and toponyms placement was the next stage in map making process. Visualization style includes multiple variables, such as colour, size, and shape. In some cases, visualization style is tightly connected with generalization processes, especially exaggeration and symbolisation. For example, the size, shape, and colour of the settlement symbols can be influenced by the classification of settlements based on population size. More populated settlements usually have a more complex symbol style. This way, their greater relevance for the map is depicted through symbol style. Also, the true size of objects represented on a map is usually too small to be seen which is why they are shown bigger than they are (exaggeration method of generalization). When deciding on colours for topographic data, hue choice must be aligned with cartographic principles (e.g., blue colour for rivers, red/yellow for roads, black for railroads), while saturation and luminance must work with the colours of the base map and other data. Toponym placement was the final step in the map making process before adding the description of the map. In this stage toponyms, including populated places, administrative areas/regions, lakes, rivers, mountains, seas, etc. are placed on the map. Toponym placement must follow cartographic principles, i.e., for linear objects, the name must be placed above the line and stretched along the object while following its shape, for areal objects, the name must be placed on the surface of the object while showing its stretching, and for point objects, the name must be put horizontally to the right and above the point. There must not be overlapping of toponyms, different font types (serif and sans serif) should be used to distinguish different types of objects represented, names of water objects, such as river and lake names should be written in the colour of the object itself (e.g., blue) (Figure 4).

Figure 4. Placement of map toponyms adjusted to cartographic principles.

In the final stage, a map legend explaining the symbology of the map was added along with additional metadata information such as the name of the map, scale, map projection, data sources, attribution of the source, the author of the map, etc. All this information is found outside the map body and contributes to a better understanding of the data represented. A preview of the result of map creation process – general purpose map of Croatia at 1:500 000 scale is presented in Figure 5.

Figure 5. Preview of the result of map creation process – general purpose map of Croatia at 1:500 000 scale.

4. CONCLUSIONS

The result of this research was a general purpose map of Croatia created exclusively from *Open Maps for Europe* data using open-source software (QGIS and GRASS GIS). The map was created at the scale of 1:500 000 in Lambert Conformal Conic projection showing topographic information (water, settlements, roads, and administrative boundaries) on a terrain representation (hypsometric and shaded relief). While small scale topographic maps might not be suitable for detailed navigation or specific site analysis, they play a crucial role in providing an overview of the terrain, understanding regional topography, and identifying key geographic elements over large areas.

Utilizing semi-automated digital cartography procedures enabled efficient map creation and the ability to update it easily with new data. The resulting general-purpose map of Croatia at a 1:500,000 scale demonstrates that *Open Maps for Europe* data is generally suitable for map creation at this scale. However, challenges such as data heterogeneity among countries, data gaps in certain areas, inappropriate levels of generalization, and disordered geometry may arise.

The resulting map presented in this research served primarily to test the completeness and fitness for use of *Open Maps for Europe* data for this task and to accelerate map production of this type. Therefore, it should be considered an intermediate product, rather than a reliable and trustworthy final product. Rigorous quality control measures should be undertaken to produce the final map.

Since this map was produced right after the first release of *Open Maps for Europe* project, the methodology developed for creating the general purpose small-scale map of Croatia should be tested and adapted to assess its applicability on latest available *Open Maps for Europe* release. Furthermore, the seven key steps described in this research were applied specifically to create the general purpose map for Croatia. To facilitate broader applications and promote reproducibility, this methodology should be adapted and extended to other countries participating in the *Open Maps for Europe* project. This would enable the evaluation of the generalization techniques and data quality for different geographical regions and datasets, providing valuable insights into the scalability and versatility of the approach.

To enhance transparency and facilitate future analyses, it would be valuable to provide a set of reproducible steps or even open-source code that can be shared with the cartographic community. This would enable other researchers and mapmakers to apply similar analyses and procedures in their respective countries or adapt the methodology to future iterations of the *Open Maps for Europe* project, ultimately contributing to the improvement of geospatial data in the region.

A comprehensive comparison between the maps generated using *Open Maps for Europe* data and other existing products, such as *Overture Maps* and *OpenStreetMap*, would be beneficial. This evaluation should consider aspects like data quality, thematic coverage, update frequency, and cartographic design. Such a comparison will help stakeholders understand the strengths and limitations of *Open Maps for Europe* relative to alternative mapping solutions and identify areas for improvement.

ACKNOWLEDGEMENTS

This research is part of the Twinning Open Data Operational project that has received funding from the European Union’s Horizon 2020 research and innovation program under grant agreement no. 857592.

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