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Challenges in Integrating Global Environmental Data with GISCO Administrative Layers: A GIS Perspective

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Contents

Abstract

The Geographic Information System of the Commission (GISCO) manages the European Commission's geographical reference database, providing key geospatial datasets. These datasets support various Commission services, with regular use by several Directorates-General (DG), including the Joint Research Centre (JRC). This report presents a number of challenges experienced by two JRC units (D.1 and D.6) working on global issues when using GISCO's country-level administrative boundaries and Exclusive Economic Zones (EEZ) datasets across different services. A variety of global datasets are used by the Digital Observatory for Protected Areas (DOPA) of the EC Knowledge Centre for Biodiversity, the EU Observatory on Deforestation and Forest Degradation (EUFO), and the Copernicus Land Monitoring Service (CLMS) in support to global EU policies and we share here a few observations and challenges faced when integrating GISCO's global products with other global environmental spatial datasets. This report should therefore help improve data, methods and processes when delivering global information.

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1 Introduction

The Geographic Information System of the Commission (GISCO) is a permanent service of Eurostat (ESTAT) that provides reference geographical information and related services for use within Eurostat and the European Commission (EC). It is responsible for maintaining the EC's geographical reference database, known as the GISCO reference database, which contains key geographical datasets used by the Commission. This database stores a wide range of geospatial data, such as administrative boundaries at the country level and Exclusive Economic Zones (EEZ) including their boundaries and areas. Several Directorates-General (DG), comprising the Joint Research Centre (JRC), are regular users of GISCO's data and services.

The JRC has been instructed to align its standard outputs as closely as possible with the Commission's geographical datasets. To ensure compliance with these guidelines, various working groups at the JRC have been incorporating GISCO datasets in the development of different tools. As an example, working groups have used GISCO's EEZ and/or administrative boundaries at the country level datasets in the context of the following services:

- The **Digital Observatory for Protected Areas** (DOPA) supports the EU's efforts to mobilize and utilize biodiversity data, ensuring it is accessible to policymakers, managers, researchers, and other stakeholders. It is a tool that documents global biodiversity by calculating metrics and indicators on biodiversity, human pressures, ecosystem services, and funding at the country, ecoregion, and protected area levels. GISCO's country boundaries and EEZ datasets have been used to update DOPA's administrative baseline layer, which plays a key role in its back-end approach by enabling the reporting of metrics and indicators at the country level (see Section 2).
- The **EU Observatory on Deforestation and Forest Degradation** (EUFO) monitors changes in global forest cover and the underlying drivers of these changes. It delivers access to global forest maps and spatial data related to forests and forestry activities. As part of its role in supporting the implementation of the EU Regulation on Deforestation-free Supply Chains (EUDR), the EUFO produced the Global Forest Cover map for 2020 (GFC2020). The Observatory relies on GISCO's country boundaries dataset for the extraction of forest-related indices aggregated by country from the GFC2020 product (see Section 3).
- The **Copernicus Land Monitoring Service** (CLMS) delivers high-quality environmental information by integrating satellite, in situ, and other data sources to support a wide range of policy areas across various governance levels. It focuses on EU policy priorities and meets the needs of various DGs and Member States. As part of CLMS' global component, the Copernicus Global Land Cover and Tropical Forest Mapping and Monitoring service (LCFM) introduces a high-resolution (10m) dynamic global land cover service, generating global annual land cover maps and tropical forest monitoring products for 2020–2026. A comparison was carried out between the GISCO country boundaries and the processing blocks that include "land" for the production of the forthcoming LCFM (see Section 4).

These services rely on global datasets to deliver information that supports EU policies. This report documents key observations and challenges encountered when integrating GISCO's global products (versions available at the time the activities were carried out) with other global environmental spatial datasets.

GISCO's global datasets offer key and valuable information, and their quality continues to improve with each new release, as illustrated in the case analysis conducted by the working group

supporting the CLMS. Working groups responsible for the DOPA and EUFO services encountered technical challenges when using GISCO's products for integration with other global datasets, within the contexts of their respective EC services, mainly due to inconsistencies in spatial data alignment and country coding standards.

The aim of this report is to support the Commission’s ongoing efforts to align GISCO’s global datasets with current operational needs, ultimately contributing to higher-quality global information provided by services like those referenced above in support of EU policies.

2 Digital Observatory for Protected Areas

Science-driven conservation relies on comprehensive information about biodiversity and the factors contributing to its decline to effectively evaluate and prioritize actions. The European Union (EU) is committed to protect nature and reverse the degradation of ecosystems through the EU Biodiversity Strategy for 2030 (European Commission, 2020). Following the Strategy's mandate, the EC established the Knowledge Centre for Biodiversity (KCBD) in 2020, in close cooperation with the European Environment Agency (EEA). Hosted by the JRC, the KCBD has the mission to support EU Biodiversity policies by enhancing access, consistency and transparency of relevant biodiversity data and information. While its primary focus is on the EU, the KCBD also supports the implementation and monitoring mechanism of the global dimension of the EU Biodiversity Strategy by contributing to global biodiversity knowledge.

The KCBD fulfils its mission through the provision of services such as Digital Observatory for Protected Areas (DOPA), JRC's global biodiversity information system, which serves as the backbone of JRC's capacity to provide the EC with scientific and technical knowledge on global biodiversity (Dubois et al., 2013). This tool also assists institutions like the Convention on Biological Diversity (CBD) Secretariat, United Nations Environment Programme (UNEP), and United Nations Development Programme (UNDP) in tracking progress on global biodiversity targets, including Aichi Target 11 (until 2022) and the Kunming Montreal Global Biodiversity Framework (KM-GBF).

Upon its creation in 2013, DOPA annually produces metrics and indicators focusing on biodiversity, anthropogenic pressures, ecosystem services and funding, calculated at country, ecoregion and protected area level (Bastin et al., 2017; Dubois et al., 2016). Despite of its name, it has evolved since 2016 from being protected area-focused to becoming an area-based conservation service. As such, DOPA now produces indicators and metrics on both protected and non-protected areas, acting as a conservation support tool. DOPA's back-end system currently processes over 1,200 metrics, for more than 270,000 protected areas, in all countries, and terrestrial, marine, and pelagic ecoregions. Information is distributed through 50 REST services that support various web applications, including the DOPA Explorer[1], front-end to the DOPA database and soon to be replaced by the KCBD Global Biodiversity Data Viewer[2]. For a more detailed description of the back-end workflow, please refer to Juffe-Bignoli et al. (2024).

2.1 Biodiversity metrics and indicators

To compute metrics and indicators, DOPA relies exclusively on publicly available global datasets to allow for independent, transparent and replicable policy support. Using global reference datasets, the DOPA contributes to global assessments while providing a wide range of consistent and comparable indicators at the country, ecoregion and protected area level.

In each calculation round, DOPA updates most datasets to their latest versions. However, two key baseline datasets - the administrative and ecoregions datasets - are updated less frequently. For

1 https://dopa-explorer.jrc.ec.europa.eu/

2 https://dopa.jrc.ec.europa.eu/gbdv/

the 2024 calculations, both were updated, with the administrative baseline layer specifically reviewed to meet the EC's requirement to use GISCO-provided geographical data.

The administrative baseline layer plays a crucial role in the DOPA back-end approach, as it is used for reporting metrics and indicators at country level. This layer is typically created by integrating an administrative boundaries at the country level dataset ("country boundaries" [CNTR] dataset) with an EEZ dataset. DOPA has been using globally recognized datasets, including UN-endorsed administrative boundaries, to maintain consistency with other global datasets used by the UN and the broader scientific community. In previous indicator releases, DOPA used the Global Administrative Unit Layers (GAUL) (FAO, 2015) and the EEZ v. 9 dataset (Flanders Marine Institute, 2019) to produce the internal version of the administrative baseline layer necessary for computing metrics at the country level.

For accurate and reliable metric calculations, DOPA's back-end system needs an administrative baseline layer that covers the global surface (i.e., CNTR+EEZ+Areas Beyond National Jurisdiction [ABNJ]), which is topologically correct, with harmonized coastlines and boundaries (i.e., free of overlaps and gaps). Additionally, the layer must include harmonised names and codes for countries and territories that follow international standards, along with a clear policy on disputed territories that identifies the parties involved. When updating the baseline dataset using GISCO layers, the aim was to avoid manually correcting inconsistencies internally, as this could result in data that is "correct" but not universally shareable (i.e., DOPA's approach is not to correct input data, but to report biodiversity metrics). Addressing the request to align with GISCO's products was an opportunity to address the discontinuation of the GAUL dataset.

2.2 Updating the administrative baseline dataset using GISCO products

DOPA explored various combinations of GISCO datasets to update the administrative baseline layer.

Initially, the latest versions available were tested: GISCO's 2024 country boundaries at a 1:1,000,000 scale (CNTR_1M_2024) alongside the 2020 EEZ at a 1:1,000,000 scale (EEZ_1M_2020) datasets. The first introduces improvements in the geometries compared to the GAUL dataset. Nevertheless, the process of updating DOPA's administrative baseline layer encountered challenges - such as geometric mismatches and inconsistencies in country codes - that generally persisted when attempting to use higher-resolution versions of the datasets i.e., GISCO's 2024 country boundaries at a 1:100,000 scale (CNTR_100K_2024) and 2020 EEZ at a 1:100,000 scale (EEZ_100K_2020), as detailed in Sections 2.2.1 and 2.2.2. Considering these difficulties, the decision was made to test another version of the country boundaries.

Consequently, another attempt was made using GISCO's 2020 country boundaries at a 1:100,000 scale (CNTR_100K_2020) and the 2020 EEZ at a 1:100,000 scale (EEZ_100K_2020). While this resolved some geometric issues, others persisted, prompting another trial (see Section 2.2.1).

GISCO's 2020 country boundaries at a 1:1,000,000 scale (CNTR_1M_2020) and the 2020 EEZ at a 1:1,000,000 scale (EEZ_1M_2020) datasets were tested and ultimately selected for use.

For clarity, Table 1 provides an overview of the GISCO products explored and the shorthand references used for them in this section about DOPA.

Table 1. GISCO datasets used during the process of updating DOPA's administrative baseline layer.

Type	Year	Scale	Feature class name ([1])	Short name	Reference
Administrative boundaries	2024	1:1,000,000	CNTR_RG_01M_2024	CNTR_1M_2024	Eurostat/GISCO, 2024a
Administrative boundaries	2024	1:100,000	CNTR_RG_100K_2024	CNTR_100K_2024	Eurostat/GISCO, 2024b
Coastline	2020	1:1,000,000	COAS_RG_01M_2020	COAS_1M_2020	Eurostat/GISCO, 2020a
Administrative boundaries	2020	1:1,000,000	CNTR_RG_01M_2020	CNTR_1M_2020	Eurostat/GISCO, 2020b
Administrative boundaries	2020	1:100,000	CNTR_RG_100K_2020	CNTR_100K_2020	Eurostat/GISCO, 2020c
EEZ	2020	1:1,000,000	EEZ_RG_01M_2020	EEZ_1M_2020	Eurostat/GISCO, 2020d
EEZ	2020	1:100,000	EEZ_RG_100K_2020	EEZ_100K_2020	Eurostat/GISCO, 2020e

[1] GISCO datasets mentioned in this report were used alongside the corresponding CNTR_AT table.

Source: Own elaboration using data from Eurostat/GISCO (2024a; 2024b; 2020a-e)

The following sections outline the main challenges encountered during the update of the administrative baseline dataset.

2.2.1 Challenges with the geometries

Roughly, the process of producing an updated DOPA's administrative baseline dataset that covers the global surface (i.e., CNTR+EEZ+ABNJ) consist of:

- Definition of a bounding box that covers the global surface (i.e., covering ± 90° latitude and ± 180° longitude).
- Conduct the union of the country boundaries and EEZ datasets.
- Obtain the portion of the world relative to ABNJ by subtracting the CNTR+EEZ union from the global bounding box.

This process should return a dataset containing all the objects from the input country boundaries and EEZ layer, plus an additional object corresponding to ABNJ.

However, when using the latest GISCO's country boundaries datasets (i.e., CNTR_1M_2024 and CNTR_100K_2024) alongside EEZ (i.e., EEZ_1M_2020 and EEZ_100K_2020) as inputs the resulting output dataset adds three new objects instead of one:

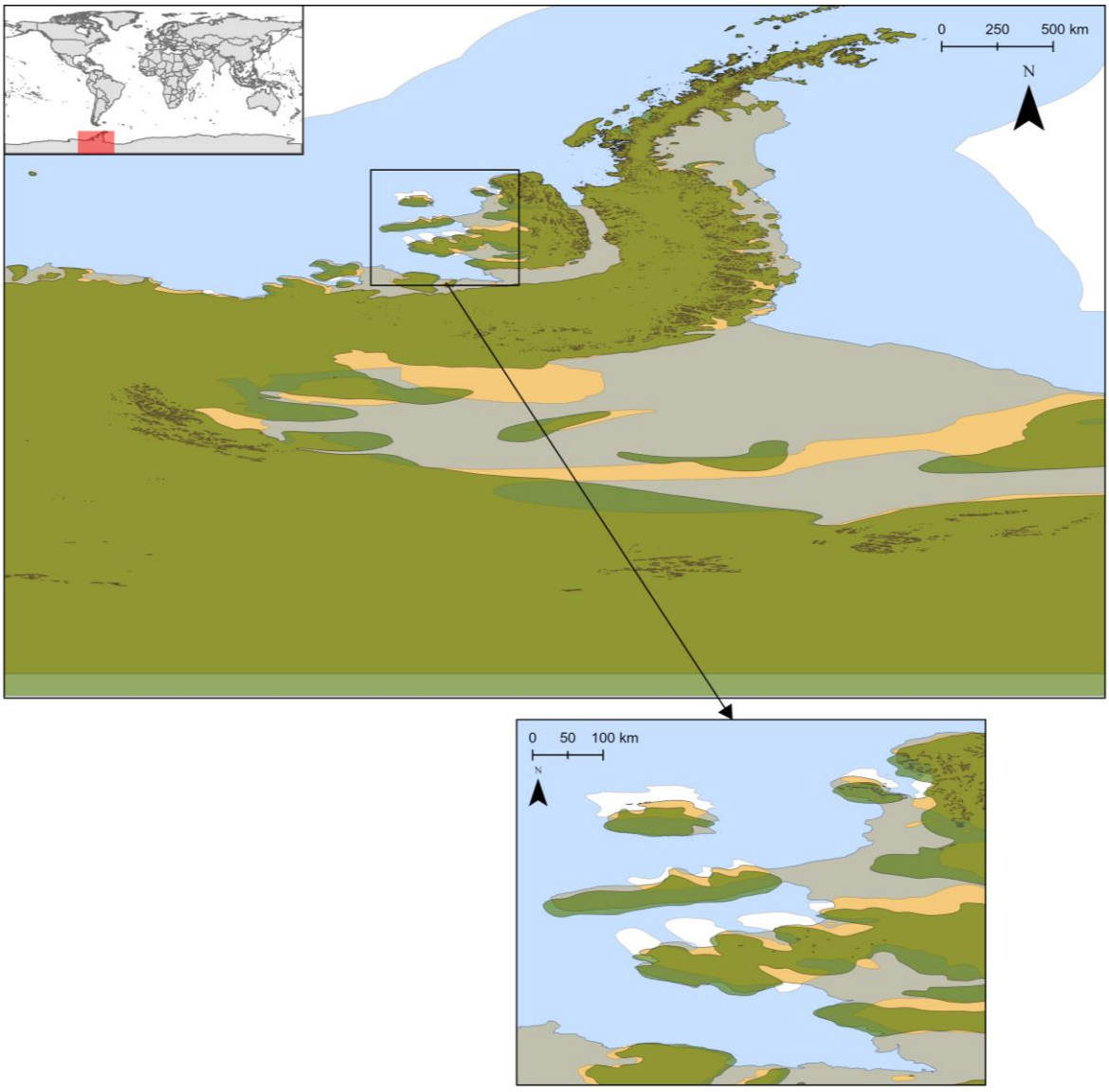
- ABNJ.

— Inconsistent coastline (hereafter “INCO”): the output layer has numerous “holes” and overlaps along the coastline because the coastline of the input country boundaries dataset is not harmonised (i.e. does not match) with that of the input EEZ dataset (Fig. 1).

— Missing Coverage (hereafter “MICO”): the output layer does not reach the limit of the global bounding box (Antarctic and Pacific areas), as seen in the example in Figure 1. This is because neither CNTR_1M_2024 nor CNTR_100K_2024 layers reach the limit of the bounding box.

The main map in Figure 1illustrates shifts in the coastlines (INCO) of the CNTR_1M_2024 layer (brown) and the EEZ_1M_2020 dataset (blue), highlighted by white gaps along the coastline on the left. Different shades of green represent terrestrial ecoregion coverage: olive green and dark green show the overlap of terrestrial ecoregions with CNTR_1M_2024 and CNTR_1M_2024+EEZ_1M_2020, respectively, while the light green strip at the bottom represents terrestrial ecoregion coverage only, as the CNTR_1M_2024 layer does not extend to the global bounding box boundary (MICO). Grey areas indicate overlaps between CNTR_1M_2024 and EEZ_1M_2020.

Figure 1. Missing coverage and inconsistent coastline using the 2024 country boundaries.



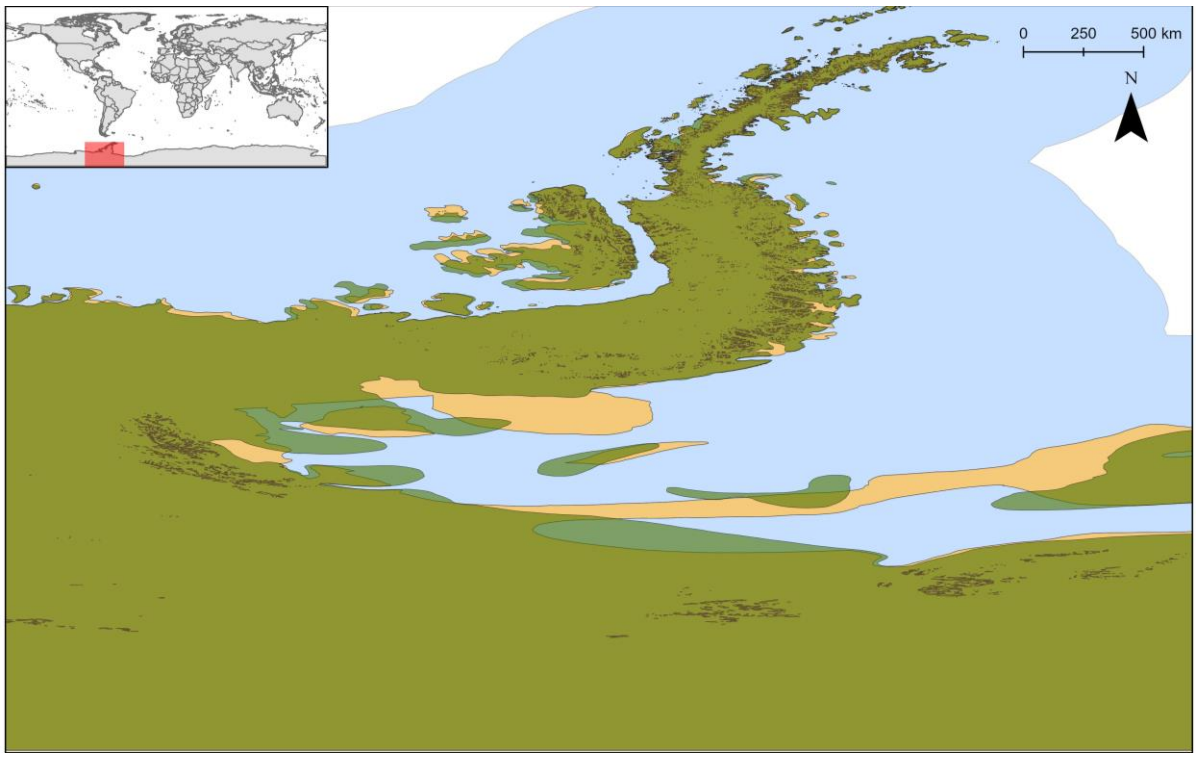
Source: JRC using data from Eurostat/GISCO (2024a; 2020d) and Dinerstein et al., (2017)

While the MICO issue is easily manageable, INCO represents a major challenge. The presence of these inconsistencies would significantly slow down each intersection operation necessary for calculating indicators. As an alternative, attempts were made to harmonize the coastlines of GISCO's 2024 country datasets and 2020 EEZ datasets with the coastline boundaries provided by GISCO (COAS_1M_2020), but they do not align either. Harmonizing country boundaries and EEZ coastlines across datasets requires extensive manual digitization, making it a time-consuming and resource-intensive task.

Given the issues outlined above, DOPA tested GISCO's 2020 country boundaries at a 1:1,000,000 and 1:100.000 scales, hereafter CNTR_1M_2020 and CNTR_100K_2020, respectively. Although these are less recent versions, they offer certain advantages over the 2024 datasets. First, both 2020 layers extend to the edge of the global bounding box, avoiding the MICO issue (Fig. 2). Second, The INCO issue is improved as they have a higher degree of coastline harmonization with the corresponding scales of the EEZ datasets (Fig. 3). This last aspect is particularly notable in the case of CNTR_100K_2020.

The main map in Figure 2 shows how MICO is addressed by combining the CNTR_1M_2020 dataset (brown) with the EEZ_1M_2020 dataset (blue). Terrestrial ecoregion coverage is now represented in olive green (overlap with CNTR_1M_2020) and dark green (overlap with CNTR_1M_2020+EEZ_1M_2020). Additionally, the alignment between the coastlines of both GISCO layers has improved significantly, reducing the INCO issues observed in Figure 1.

Figure 2. Missing coverage and inconsistent coastline using the 2020 country boundaries.



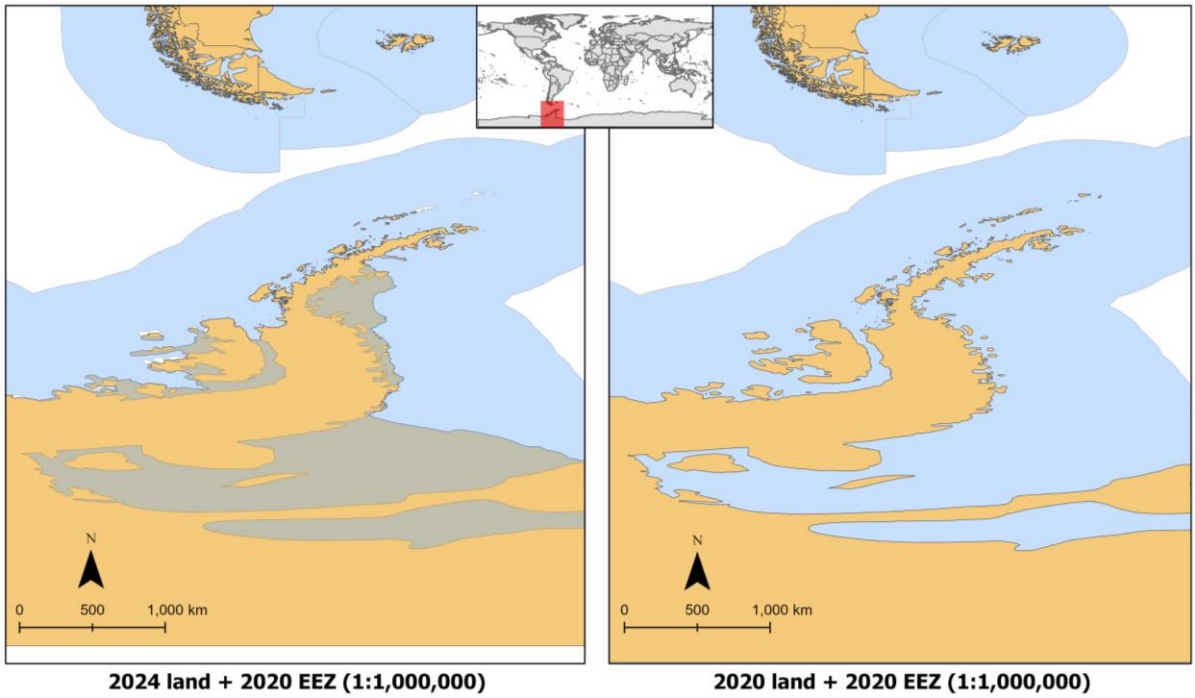
Source: JRC using data from Eurostat/GISCO (2020b; 2020d) and Dinerstein et al., (2017)

Despite the advantages in GISCO's 2020 country geometries, certain amount of work is still required on the user side to harmonise their coastlines with EEZ as some gaps remain when combining them, though they are significantly more manageable. In Figure 3, the map on the left highlights overlaps (in grey) between country boundaries (brown) and EEZ (blue) using the

CNTR_1M_2024 layer and the EEZ_1M_2020 dataset. The map on the right, using the CNTR_1M_2020 layer, shows no overlaps with the EEZ.

Since CNTR_100K_2020 shows a higher degree of coastline harmonization with its corresponding EEZ (i.e., EEZ_100K_2020), it was decided to proceed with updating DOPA's administrative baseline dataset testing these two layers.

Figure 3. Coastline alignment comparison: 2024 vs. 2020 country boundaries.



Source: JRC using data from Eurostat/GISCO (2024a; 2020b; 2020d)

While using the CNTR_100K_2020 datasets resolve some of the previously described issues, it also introduces other challenges. For instance, working with a dataset at a 100,000 scale instead of a dataset at a 1,000,000 scale significantly increases the computational workload. Additionally, during the initial intersections between CNTR_100K_2020, EEZ_100K_2020 and the terrestrial ecoregions layer (Dinerstein et al., 2017) in PostGIS, the function failed to intersect certain geometries. The problem was traced to a bug in the system (i.e., not a user error), and was eventually resolved by upgrading PostGIS, GEOS, and PROJ.

Intersections were reprocessed before proceeding to aggregate the World Database on Protected Areas (WDPA) and World Database on Other Effective Area-based Conservation Measures (WD-OECM) datasets.

DOPA may currently operate at a scale that exceeds the needs of its intended outputs, as well as the resolution of other global datasets used in calculations and by partners such as the UN Environment Programme World Conservation Monitoring Centre (UNEP-WCMC), which manages the WDPA and WD-OECM and relies on a global country dataset at a 1:1,000,000 scale. For example, the boundaries of thousands of small islands do not align with terrestrial ecoregions, and the high density of nodes in the geometries adds complexity to calculations and slows processing without providing significant informational value. To address this, DOPA considered lower-resolution scales

before transitioning to production and reprocessed CNTR_1M_2020 and EEZ_1M_2020 using the same methods as with previous versions.

The final output is a simplified one, where "holes" caused by geometric inconsistencies are no longer classified as MICO or INCO but are instead labelled as "problematic." These gaps may result from mismatched coastlines between CNTR and EEZ data or geometries that do not extend to the ± 90° latitude and ± 180° longitude limits.

2.2.2 Challenges with the attributes

Unique country codes are crucial for computing and reporting country-level metrics in DOPA. Its functions rely on internationally recognized country codes, including alpha-2 and alpha-3 codes as per ISO 3166 standard[3] and M49 numerical codes as per the United Nations (UN)[4]. Using these officially assigned codes ensures compatibility with global datasets like the WDPA, the baseline dataset in DOPA necessary for calculating protected area coverage, that also use internationally recognized country codes.

This approach worked well with the previous administrative baseline layer based on FAO (2015) and Flanders Marine Institute (2019) datasets. However, the GISCO''s products (both 2024 and 2020 versions) present new country codes. Below is a non-exhaustive list of relevant characteristics that impact the current DOPA back-end process:

1. **Use of different codes**: although unique official codes exist for countries and territories, the GISCO datasets use the sovereign state's code for several overseas territories. For example, internationally recognized codes exist for Guadeloupe, French Guiana, Martinique, and Réunion (“GP”, “GF”, “MT”, and “RE” ISO-2 codes, respectively). While the GAUL dataset uses these codes, the GISCO dataset assigns the “FR” ISO-2 code for France to these territories instead. Since DOPA calculates indicators and metrics at the country/territory level, this coding approach hinders the ability to calculate separate values for these territories.
2. **Presence of non-officially assigned codes**: some of the country codes used in the GISCO datasets do not match any officially assigned codes. In most cases, these non-officially assigned codes correspond to disputed territories (e.g., the code “XH” in the CNTR_ID field, which corresponds to the disputed territory of Jammu and Kashmir, does not exist in the list of ISO-2 codes as per ISO 3166 standard). In addition to using unofficial codes, there is no documentation of the officially assigned codes for the countries involved in territorial disputes in a standardized format (e.g., IN/PK, for the Jammu and Kashmir territory disputed between India and Pakistan).
3. **Different number of characters than those expected in a field**: in a few cases, values in fields containing country codes have more/less characters than specified. For example, the CNTR_ID field is described as holding two-character ISO-codes for countries, but two territories have three characters values (i.e., "XJL”, “XXS” and “XXR”). Conversely, the ISO3_CODE field, which expects three-character ISO codes, contains some objects with two-character ISO codes.

[3] https://www.iso.org/obp/ui/#home

[4] https://unstats.un.org/unsd/methodology/m49

4. **Different codes used for the same country or territory in the land and EEZ layers**: in some instances, the codes assigned to the same country or territory in the GISCO country boundaries and EEZ products do not match. For example, the land area of the United States Minor Outlying Islands has its officially assigned ISO-2 code ("UM") in the CNTR_ID field of the 2024 GISCO country boundaries dataset, but its corresponding EEZ is assigned the code for the United States ("US") in the EEZ_ID field of the GISCO 2020 EEZ dataset.

The discrepancies above regarding country codes, especially 1-3, can have an important impact in the DOPA back-end approach and the accuracy of computed indicators (tables detailing the codes with discrepancies are provided in Annex 1).

On one hand, indicators calculated with the updated administrative baseline layer based on the GISCO's datasets might not be comparable with previous DOPA releases. Furthermore, the accuracy of metrics and indicators could be compromised, as demonstrated by a recent exercise evaluating the impact of replacing the GAUL dataset with GISCO's CNTR_1M_2024 product for calculating DOPA's Protected Connected (ProtConn) indicator. ProtConn, a component indicator of Target 3 of the KM-GBF, measures terrestrial protected and conserved area connectivity using the WDPA and WD-OECM datasets. A country-level comparison revealed that some of the countries with highest discrepancies (i.e., relative difference > ±10%) were those that had their unique officially assigned codes in GAUL but were assigned the sovereign state's country code in CNTR_1M_2024 (Table 2). This suggests that using GISCO's dataset may reduce accuracy and lead to incorrect results. The findings highlight the need for consistent ISO-3 country codes across WDPA, WD-OECM, and administrative boundary datasets for reliable ProtConn calculations.

Table 2. Comparison of ProtConn indicator results using two different country boundaries datasets.

Country name	ProtConn indicator using GAUL dataset (%)	ProtConn indicator using GISCO 2024 country boundaries dataset (%)	Relative difference (%)
France	20.73	17.73([1])	-14.48
Guadeloupe	69.11	99.98([2])	44.67
Réunion	67.61	100.00([2])	47.90
Martinique	62.48	99.97([2])	60.00
Saint Martin (French part)	0.00	100.00([2])	100.00
French Guiana	48.00	98.85([2])	105.94
Taiwan, Province of China	18.53	100.00([3])	439.67
Mayotte	9.98	100.00([2])	901.53

1 All Overseas France territories are assigned to sovereign state (France).

2 Assigned country code is that of the sovereign state (France).

3 Assigned country code is that of the sovereign state (China).

Source: JRC based on data from UNEP-WCMC and International Union for Conservation of Nature (IUCN) (2024), FAO (2015) and European Commission (2024a).

On the other hand, all functions used in DOPA's calculation workflow and REST (Representational State Transfer) services would need to be adapted to reflect changes in country codes in GISCO's datasets. Additionally, these updates would need to address the absence of certain fields previously used in function development (e.g., UN M49 country codes, which are not included in the GISCO's products).

In general, the tabular discrepancies regarding country and territory codes described above affect both the 2024 and 2020 versions of GISCO's country boundaries datasets. While the 2024 version may offer some improvements over the 2020 version, challenges encountered with its geometries (see previous section 2.2.1) led to the decision to use the CNTR_1M_2020 version instead for updating DOPA's administrative baseline dataset.

3 EU Observatory on Deforestation and Forest Degradation

The EU Observatory on deforestation and forest degradation (EUFO, COM 2023a) aims to monitor changes in the world's forest cover and related drivers. It provides access to global forest maps and spatial forest and forestry-related information. Moreover, this Observatory facilitates access to scientific information on supply chains, linking deforestation, forest degradation and changes in the world's forest cover to EU demand for commodities and products. The EUFO is one of the items announced in the Commissions Communication to step-up action to protect and restore the World's forests (COM 2019). The EU Regulation on Deforestation-free supply chains (EUDR; EU, 2023) also refers to the Observatory as one of the support tools for the implementation. The EUDR lays down rules and obligations for seven commodities (cattle, cocoa, coffee, oil palm, rubber, soya, wood) and derived products. Operators need to ensure due diligence, including geographic coordinates about the sourcing location, and assessment of the risk of deforestation or forest degradation after the cut-off date (31 December 2020). However, data and information provided on the EUFO do not assure compliance or imply non-compliance with EU Regulations, other legal frameworks or commitments, or international agreements.

3.1 Global Forest maps for year 2020

An important product for the EUDR implementation is the Global Forest Cover map for the year 2020 (GFC2020, COM 2023b; Bourgoin et al., 2024, Bourgoin et al., 2025). This global map indicates at 10 m spatial resolution forest cover presence or absence for the year 2020 following the definition of forest as set out in the EUDR. GFC2020 is produced from a large set of global layers that indicate the potential presence or the absence of forest. There are three distinct steps: 1) mapping the maximum potential extent of forest cover for year 2020 globally, 2) apply rules to reduce the maximum potential forest cover extent according to the EUDR forest definition, and 3) post processing with minor corrections and applying a minimum mapping unit of 0.5 ha (Bourgoin et al., 2025). The map has an overall accuracy of 91% with an error of 8% for omission and a commission error of 18% (Colditz et al., 2025).

The GFC2020 is displayed on the EUFO Web Platform. The platform also includes an interactive web map of Global Forest Attributes, which provides the forest cover and three additional indices derived from forest pattern analysis (Vogt et al., 2022) - porosity, network coherence, and connectivity - for every country (reporting unit). These four indicators are normalized within the range of 0-100%, providing an intuitive and neutral reporting summary for status and trend assessments, as well as allowing for direct comparison between individual reporting units.

To define the countries used to compute the indices, and the associated country names and codes, the Global Forest Attributes analysis is based on the most up-to-date Eurostat's GISCO products, version 2024.

3.2 Modifying GISCO 2024

The extraction of forest indices aggregated by country from Remote Sensing (RS)-derived datasets with high-resolution, such as GFC2020, has revealed significant limitations of the existing GISCO products. The current GISCO products (2024 version), with their best available scale of 1:100,000, are not compatible with the GFC 2020 dataset, which has a resolution of 10m. This difference in spatial precision leads to substantial discrepancies at the coastline level, where the boundaries

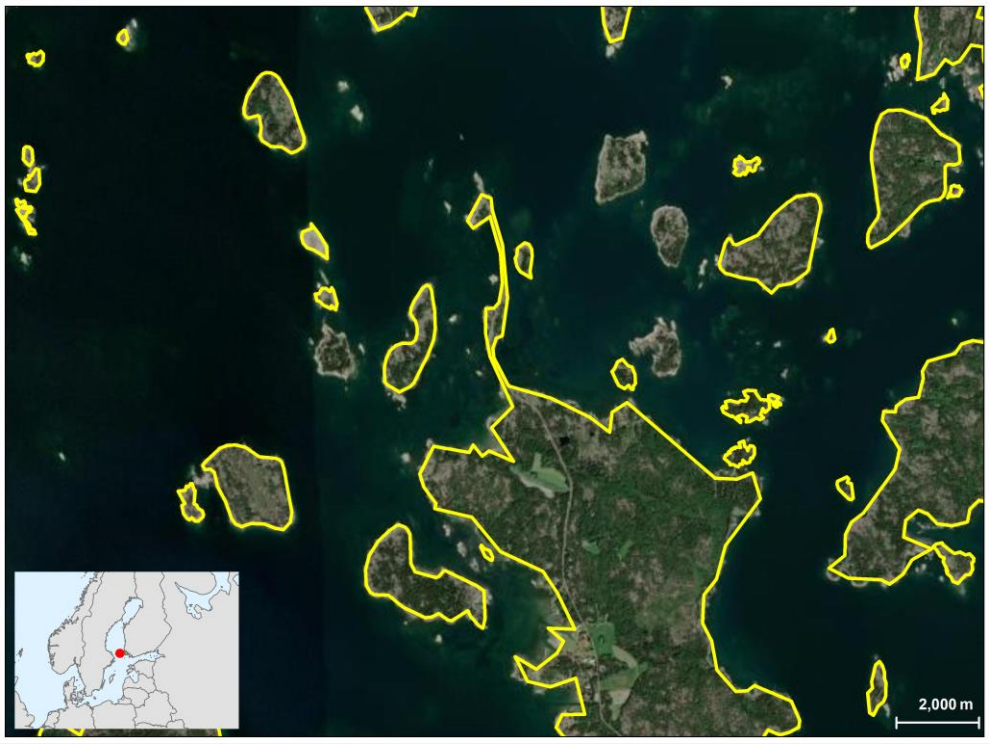
between land and sea are defined. As a result, significant coastal land areas and also small islands are not accurately represented or are missing altogether from the GISCO country boundaries.

Box 1. The Finnish Islands in the Baltic Sea.

The difference in precision between high-resolution satellite imagery and the GISCO vector products is particularly pronounced in the area of the south-western Finnish Islands in the Baltic Sea. This region is characterized by a complex and fragmented archipelago, comprising thousands of islands of varying sizes, from small rocky outcrops to larger landmasses. The unique geography of this area, with its numerous islands, islets, and skerries, poses significant challenges for mapping and boundary definition. The GISCO country boundaries, available at a scale of 1:100,000, are currently the best available products from Eurostat. However, due to the inherent limitations of scale, not all the boundaries of the Finnish islands are precisely mapped and tiny islands or rocks are omitted due to their small area. Specifically, the simplification process used to create the GISCO country boundaries at this scale can result in the loss of detailed information, leading to inaccuracies in the representation of island coastlines, shapes, and sizes. In some cases, small islands are entirely missing from the GISCO layer, while others may be incorrectly represented or merged with neighbouring islands. This can have significant implications for applications that rely on accurate and detailed boundary definitions.

Figure 4 illustrates a notable example from an area of the Finnish Islands, where a high-resolution satellite image is compared with the GISCO country boundaries 2024 (outlined in yellow). A visual inspection of the figure reveals that the GISCO country boundaries, while generally accurate, exhibit some significant limitations. Specifically, some coastlines are highly simplified, resulting in the exclusion of portions of the coastal land. This simplification can be seen in the form of straightened or smoothed coastlines, which deviate from the actual complex geometry of the islands. Furthermore, the figure shows that some small islands are entirely missing from the GISCO country boundaries, highlighting the challenges of accurately representing complex archipelagos at a scale of 1:100,000.

Figure 4. Comparison between a high-resolution satellite image and the 2024 GISCO country boundaries in the Finnish Islands.



Source: JRC using data from Eurostat/GISCO (2024b) and ESRI World Imagery

The exclusion of significant areas from the country boundaries can affect the accuracy of forest index extraction. To address the limitations of the current GISCO products, we proposed expanding country coastlines using EEZ. By combining GISCO country boundaries (CNTR) with EEZ (CNTR+EEZ), we could create a more comprehensive and complete representation of country boundaries, extending up to 200 nautical miles from the coastline. This expanded boundary includes all land surfaces detected through RS analysis.

3.2.1 Merging GISCO and EEZ

To create an expanded country boundary dataset, CNTR+EEZ, we merged the GISCO country boundaries version 2024 (Eurostat/GISCO, 2024b) with the EEZ dataset v. 12 (Flanders Marine Institute, 2023). However, this process was not straightforward due to the incompatibility between the EEZ coastlines, defined using the ESRI world country boundaries, and the GISCO coastlines. The ESRI world country dataset (and the related EEZ) differs from the GISCO country dataset not only in terms of geometries (coastlines and country boundaries) but also in country definitions, nomenclatures and codes, as discussed in detail in chapter 2.2.2. For example, in the 2024 version of the GISCO country boundaries dataset, the CNTR_UR field contains codes that do not conform to the ISO 3166-1 alpha-3 standard for Belarus, Greece, and Slovakia (see Table 4 in Annex 1).

Although GISCO had previously provided an EEZ product harmonised with the country coastlines version 2020 (Eurostat/GISCO, 2020e), a similar dataset is not available for the version 2024. For this reason, we created an internal version of CNTR+EEZ using the latest versions of both GISCO and EEZ datasets.

The procedure for creating the internal CNTR+EEZ involved the following steps (**Figure 5**):

- Download of EEZ land union v. 4 dated October 2024 (Flanders Marine Institute, 2024), which provided EEZ already merged with ESRI world country polygons, resulting in a dataset with expanded country polygons but with a different nomenclature and code identification compared to GISCO.
- Clip and inserted the GISCO countries 2024 into EEZ land union layer, ensuring consistency in the land country coastline geometries.
- Union of the EEZ polygons with the GISCO countries, retaining the GISCO codes and nomenclature.
- Create new EEZ polygons for countries or regions not present in the original EEZ, including Hong Kong, Macao, and several islands in the South China Sea.

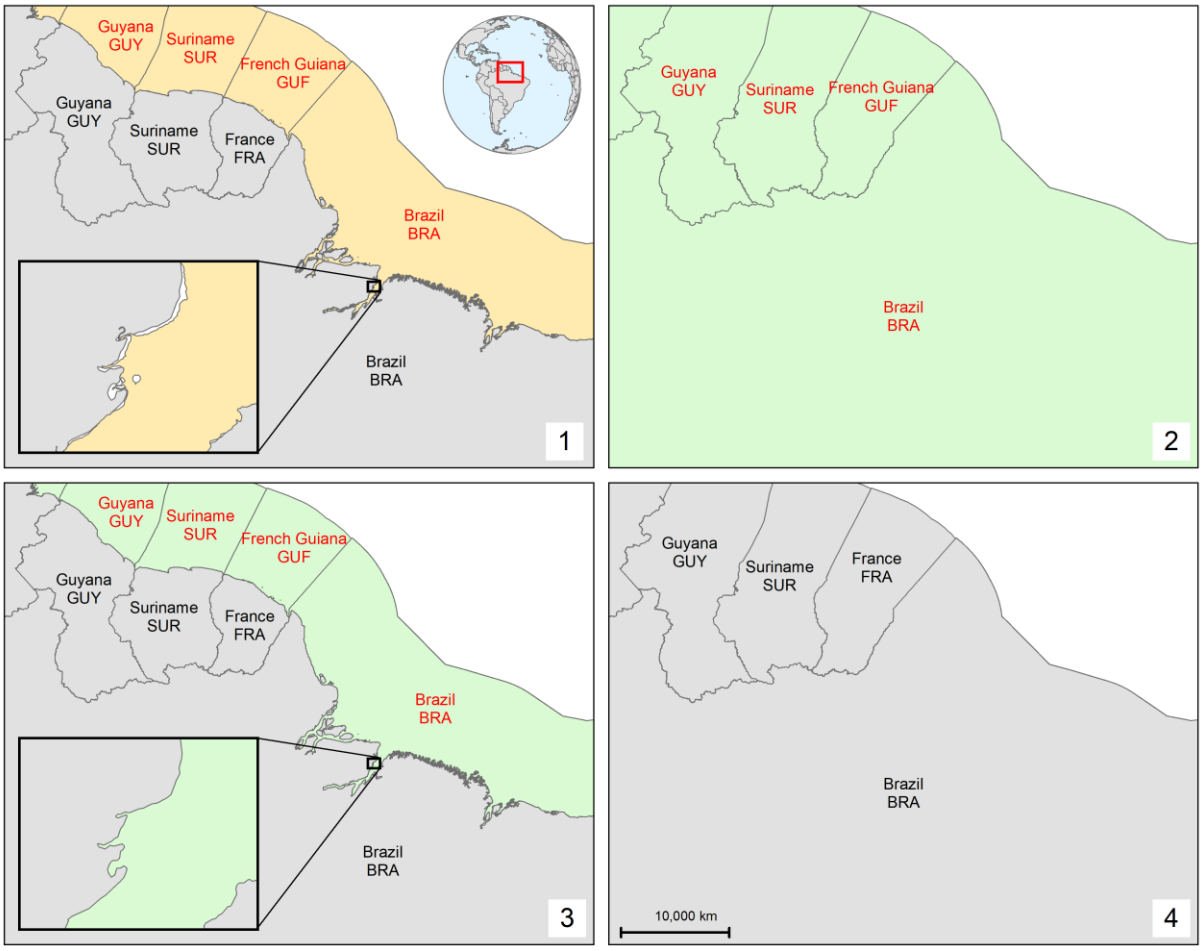
After completing the CNTR+EEZ procedure, we conducted a review of the resulting dataset and identified inconsistencies between the GISCO and EEZ datasets. Specifically, we found that several small islands from the GISCO dataset were incorrectly assigned to the wrong country due to falling outside their corresponding EEZ (see the full list in Annex 2).

To correct these inconsistencies and ensure the accuracy of the CNTR+EEZ dataset, we first conducted an online research to verify the country origins of the affected islands, consulting a range of reliable sources. This step enabled us to determine the correct country attribution for each island and ensure that our corrections were based on accurate and up-to-date information. Secondly, we manually re-attributed the islands to their correct countries, updating the CNTR+EEZ dataset.

By taking these steps, we were able to ensure that the CNTR+EEZ dataset accurately reflected the country boundaries and provided a reliable foundation for our analysis and applications.

The maps in Figure 5 illustrate the procedure used to merge the country polygons and attributes (country names and ISO3 codes) of the GISCO country boundaries 2024 at a 1:100,000 scale with the EEZ v. 12 dated October 2023 to obtain the expanded country boundaries CNTR+EEZ. The maps are displayed for an area in South America. **Map 1** (top left) shows the incompatibility between the two datasets (EEZ in orange, GISCO in grey), both in terms of geometry (see the zoomed area with non-matching coastlines) and country codes (e.g., French Guiana is classified by GISCO as part of France). **Map 2** (top right) displays the EEZ land union v. 4 in green. **Map 3** (bottom left) shows the GISCO layer clipped and inserted into the EEZ land union, with matching coastlines. **Map 4** (bottom right) presents the resulting CNTR+EEZ boundaries with the GISCO country coding.

Figure 5. CNRT+EEZ procedure**.**



Source: JRC using data from Eurostat/GISCO (2024b) and the Flanders Marine Institute (2023; 2024)

4 Copernicus Land Monitoring Service

The Copernicus Land Monitoring Service (CLMS) provides users in the field of environment and other terrestrial applications with high quality information based on space data combined with other sources of in situ and other ancillary data. It addresses the data and information needs of a wide range of policies such as environment including biodiversity, climate change, agriculture and forestry, regional and urban planning, as well as water management, transport, energy or neighbourhood policy, at global, European, national and local level. The CLMS focuses on the EU policy priorities and responds therefore to the needs of multiple policy DGs, i.e. thematic directorates-general of the EC and furthermore serves the needs of the EU Member States.

4.1 Copernicus Global Land Cover and Tropical Forest Mapping and Monitoring

The Copernicus Global Land Cover and Tropical Forest Mapping and Monitoring service (LCFM), part of the global component of the Copernicus Land Monitoring Service, aims to continue the time series of the existing 100 m Copernicus Global Land Cover layers (available for 2015-2029) but also to enhance the existing service by providing a high resolution (10 m), dynamic global land cover service. LCFM will generate frequent, sub-annual land surface features and categories and consolidate these into global annual land cover maps and tropical forest monitoring products at 10/100 m resolution for the years 2020-2026.

4.2 Comparison of GISCO countries to land area processed for Global Component of the Copernicus Land Monitoring Service

We compared GISCO country boundaries to land areas mapped by the global component of the CLMS. Specifically, this analysis focuses on processing blocks that include “land” for the production of the forthcoming LCFM (COM 2024, VITO 2024). This is a vector file containing the outlines of all the processing blocks used during the production of the ESA WorldCover product (Zanaga et al., 2021). Sentinel-2 (S2) data is organized into MGRS tiles in JPEG 2000 format (10,980 x 10,980 pixels at 10 m resolution). Each MGRS tile also contains 121 internal blocks of 1,024 x 1,024 pixels. In the block grid, overlapping blocks (from neighbouring S2 tiles and UTM zones) and blocks that are fully covered by water (e.g., blocks consisting entirely of ocean or inland water) were removed.

We compared the block grid against the following GISCO country boundaries products in projection EPSG:4326 (WGS 84 datum):

- GISCO 2020 at 1:1,000,000: CNTR_RG_01M_2020_4326.shp downloaded from Countries - GISCO - Eurostat;
- GISCO 2024 at 1:1,000,000: CNTR_RG_01M_2024_4326.shp downloaded from Countries - GISCO - Eurostat;
- GISCO 2024 at 1:100,000: GISCO.CNTR_RG_100K_2024.shp obtained directly from ESTAT.

The number of blocks which are not water and did not intersect with a respective GISCO country boundaries dataset, hence contain land that is missing in GISCO products, are:

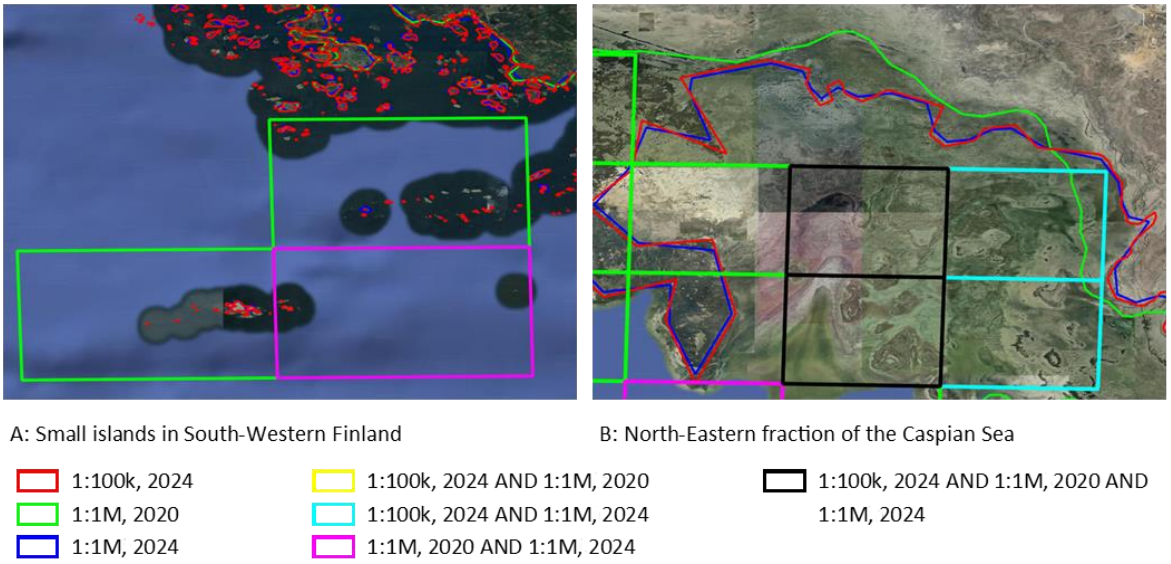
- 4,472 blocks for GISCO 2020 at 1:1,000,000
- 2,992 blocks for GISCO 2024 at 1:1,000,000

— 1,108 blocks for GISCO 2024 at 1:100,000

The number of blocks decreased with the newest release of GISCO data for the same scale (1:1,000,000) which suggests an improvement in the delineation of land. The analysis also indicates that the identification of blocks depends on the scale of the GISCO data, with a decrease in identified blocks for scales that depict more spatial detail.

Figure 6 shows close ups for examples of blocks (rectangles) that were identified to contain land (and thus will be processed for LCFM) but do not intersect with one or several GISCO data (the datasets are indicated by the colour). The colour of irregular polygons in the background indicates the country boundary in GISCO: red for GISCO 2024 at 1:100,000 (1:100k), green for GISCO 2020 at 1:1,000,000 (1:1M) and blue for 2024 at 1:1,000,000. In Figure 6-A for islands off the Finnish coast shows two green rectangles that indicate processing blocks that contain land which does not intersect with GISCO 2020 at 1:1,000,000. The purple block only intersects with GISCO 2024 at 1:100,000. Example B in Figure 6 shows land boundaries at the Caspian Sea shoreline. Green blocks to the left indicate that GISCO 2020 at 1:1,000,000 misses land, black rectangles in the centre shows that no GISCO dataset intersects, and turquoise blocks on the right show that both GISCO products for 2024 do not intersect.

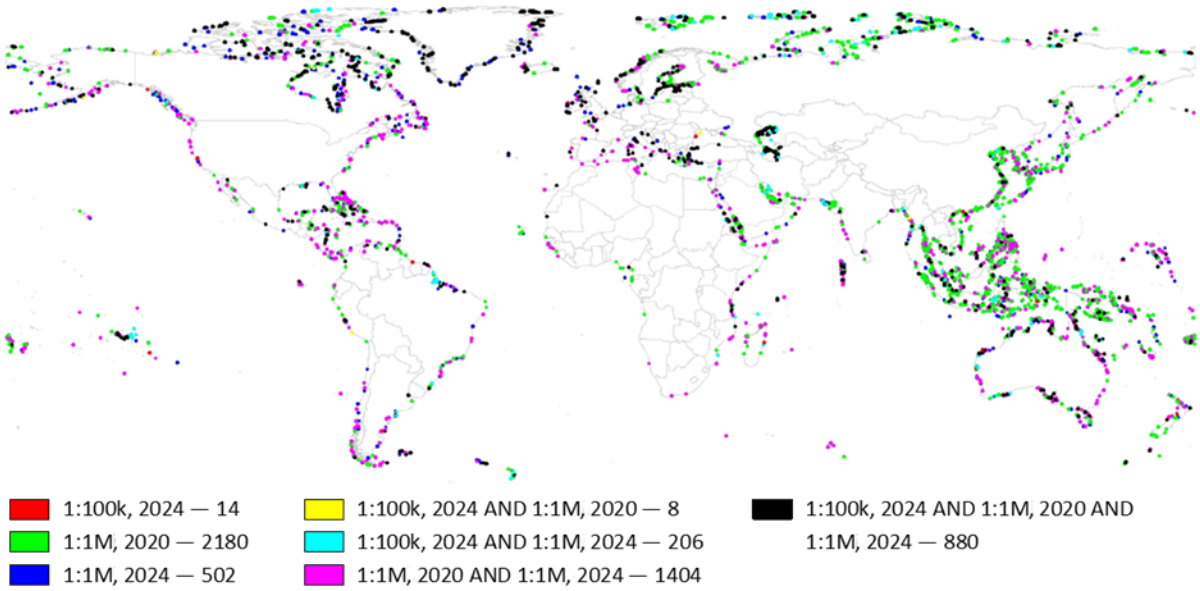
Figure 6. Close up for South-Western Finland and the North-Eastern Caspian Sea for LCFM processing blocks that were not fully covered by water and do not intersect with GISCO country boundaries data for 2020 or 2024 at 1:1,000,000 or 1:100,000.



Source: JRC based on data from Google, © 2024 Maxar Technologies (background image), VITO – Flemish Institute for Technological Research (LCFM processing blocks) and Eurostat/GISCO (country boundaries).

Figure 7 shows LCFM processing blocks that were not fully covered by water and do not intersect with GISCO country data for 2020 and 2024 at 1:1,000,000 or 1:100,000. The colour indicates if one or a combination of several GISCO datasets missed a block. The size of the blocks is exaggerated to make them visible at global level. The number after the hyphen indicates the amount of unique processing blocks for this category (dataset combination); in total there are 5,194 unique blocks identified by any of the three datasets. The high number of only GISCO 2020 at 1:1,000,000 scale (green) confirms the assumption that improved in the 2024 data release; high number of GISCO at 1:1,000,000 compared to data or combinations that include 1:100,000 indicates the before mentioned relationship to mapping scale.

Figure 7. LCFM processing blocks that were not fully covered by water and do not intersect with GISCO country data for 2020 or 2024 at 1:1,000,000 or 1:100,000.



Source: JRC based on data from VITO – Flemish Institute for Technological Research (LCFM processing blocks) and Eurostat/GISCO (country boundaries). Note: The size of the blocks is exaggerated to make them visible at global level. The number after the hyphen in the legend indicates the amount of unique processing blocks for this category (dataset combination).

Figure 7 indicates that all identified blocks are located along continental outlines either coastlines or shorelines for interior water bodies like the Caspian Sea that GISCO does not allocate to a specific country. The figure also indicates some geographic patterns with regards to individual GISCO datasets.

- Africa, which the exception is the Red Sea, depicts only a few locations with identified blocks. This result is likely linked to 1) steeper coasts with little ambiguity to identify the water/land boundary 2) a relatively low complexity of the coastline i.e. elongated shorelines with few bends and small radius, and 3) few small coastal islands.
- Asia indicates blocks predominantly identified for GISCO 2020 at 1:1,000,000 (green). This suggests that the country boundaries improved in terms of completeness for GISCO 2024.
- Complex shorelines show a dominance of blocks for GISCO data at 1:1,000,000 for both 2020 and 2024 (purple). Shorelines are characterized by a high fragmentation and low compactness. Reasons for shoreline complexity may be due to former presence of fjords in formerly glaciated regions (Chile, Tierra del Fuego, Canadian East and West Coast) or high frequency of small islands or low coast (Caribbean, Southeast Asia, the Pacific Islands).
- Nordic lands in Europe, Canada, Greenland and Russia show a higher frequency of missing blocks for any of the datasets. This may be partly related to complexity but mainly also to shifting ice, retreating glaciers and unclear definitions of the land-sea boundary.
- The Indus and the Amazon Delta and parts of the Caspian Sea show clusters of missing blocks for GISCO data from 2024 at 1:100,000 and 1:1,000,000. This pattern suggests shifting water levels and moving deltaic sediments.

From this analysis we concluded that the GISCO improved the quality of country delineations along shorelines in the 2024 data release. Also, we demonstrated that the level of spatial detail (the scale of the map) matters when assessing completeness of land identification along shorelines. For areas with low shorelines and fluctuating water levels, e.g. the Caspian Sea, there is ambiguity in the exact delineation, which foremost depends on the time of data collection.

5 Conclusions

GISCO's products continue to improve in quality over time, as demonstrated in Section 4 on the CLMS service. These datasets have proven to be useful and provided valuable information to the EC services in this report, underscoring the significance of GISCO's work. While these products can serve as essential components in the development of JRC's scientific tools such as DOPA and the EUFO, the current need to adapt and harmonize these datasets downstream - often using different methodologies – for use with other global datasets reveals an opportunity for further standardization. The operational use of GISCO's product versions referenced in this report has highlighted several constraints:

- Geometric inconsistencies between country boundaries and EEZ layers (e.g., coastline misalignments, missing coverage at global bounding box extents) affected the construction of globally complete and topologically correct administrative layers.
- Attribute discrepancies, particularly in country codes and naming conventions, reduced interoperability with global datasets such as the WDPA and ISO 3166-based references, affecting data relationships, metric calculations and indicators reproducibility.
- Differences in spatial resolution between GISCO products and high-resolution raster datasets used in remote sensing analyses (e.g., GFC2020) created misalignments or omission of small land features and could lead to reduced accuracy in derived spatial indicators.

These challenges required considerable user-side corrections and custom harmonization workflows, often involving manual spatial and attribute reconciliation. Ensuring consistency across end-users, allowing them to retain the datasets' integrity as much as possible, would help the Commission obtain improved global information for policy support.

Since the time of the DOPA and EUFO documented activities in this report, new versions of both GISCO's country boundaries and EEZ datasets have been released. It would be important to assess whether the issues identified in this report have been addressed in these updated versions.

Looking ahead, further insight from GISCO into upcoming scenarios would support the working groups in making decisions on the use of these products that are sustainable over the medium term. For example, a number of targeted enhancements could help improve the usability of GISCO's global products and support their integration into operational workflows. For instance, aligning more closely with international coding systems - such as ISO 3166 or UN M49 - could streamline interoperability with other global environmental datasets. Where deviations exist, including clear documentation or a correspondence table would improve integration. In parallel, it may be interesting to explore the adoption of open-source products, including the Natural Earth[5] administrative boundaries dataset, or more spatially detailed options such as the Database of Global Administrative Areas (GADM)[6] or OpenStreetMap (OSM)[7] administrative data.

[5] https://www.naturalearthdata.com/

[6] https://gadm.org/

[7] https://www.openstreetmap.org/

Global products that reduce the need for user-side modifications would enable more efficient workflows, improve the reproducibility and comparability of results. This would also encourage the use of GISCO datasets and help prevent users from turning to alternative spatial products (e.g., GADM) due to technical challenges like those shown in this document. This report aims to provide end-user feedback to help the EC enhance the usability of GISCO's global reference datasets for obtaining higher-quality global information that support EU policies.

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List of abbreviations and definitions

Abbreviations	Definitions
ABNJ	Areas Beyond National Jurisdiction
CBD	Convention on Biological Diversity
CLMS	Copernicus Land Monitoring Service (CLMS)
CNTR	Country boundaries
DG	Directorate-General
DOPA	Digital Observatory for Protected Areas
EC	European Commission
EEA	European Environment Agency
EEZ	Exclusive Economic Zone
ESTAT	Eurostat
EU	European Union
EUDR	EU Regulation on Deforestation-free Supply Chains
EUFO	EU Observatory on Deforestation and Forest Degradation
GAUL	Global Administrative Unit Layers
GADM	Database of Global Administrative Areas
GISCO	Geographic Information System of the Commission
GFC2020	Global Forest Cover map for 2020
INCO	Inconsistent coastline (INCO):
IUCN	International Union for Conservation of Nature
JRC	Joint Research Centre
KCBD	Knowledge Centre for Biodiversity
KM-GBF	Kunming Montreal Global Biodiversity Framework
MICO	Missing Coverage
OECMs	Other Effective Area-based Conservation Measures
OSM	OpenStreetMap
ProtConn	Protected Connected
REST	Representational State Transfer
RS	Remote Sensing
S2	Sentinel-2
TEOW	OneEarth Terrestrial Ecoregions
UN	United Nations
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNEP-WCMC	UN Environment Programme World Conservation Monitoring Centre
VITO	Flemish Institute for Technological Research
WD-OECM	World Database on Other Effective Area-based Conservation Measures
WDPA	World Database on Protected Areas

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Annexes

Annex 1. Discrepancies between country codes in GISCO datasets and the international ISO 3166 standard

Table 3. Mismatches between country codes in GISCO datasets and the officially assigned ISO 3166 (alpha-2) codes.

ISO-2 codes missing in GISCO[1]	GISCO codes missing in ISO standard[2]
AX	CP
GB	EL
GF	UK
GP	XA
GR	XB
MF	XC
MQ	XD
RE	XE
YT	XF
	XG
	XH
	XI
	XJ
	XL
	XM
	XN
	XO
	XU
	XV

[1] Country codes missing in GISCO data i.e. present in ISO 3166 standard but not in GISCO

[2] Country codes missing in official ISO 3166 standard i.e. present in GISCO data but not in ISO 3166 standard

Table 4. Mismatches between country codes in GISCO datasets and the officially assigned ISO 3166 (alpha-3) codes.

ISO-3 codes missing in GISCO[1]	GISCO codes missing in ISO standard[2]
ALA	BYS[3]
GLP	CPT
GUF	GRE[3]
MAF	SKM[3]
MTQ	XXA
MYT	XXB
REU	XXC
	XXD
	XXE
	XXF
	XXG
	XXH
	XXJ
	XJL
	XXL
	XXM
	XXN
	XXO
	XXR
	XXS
	XXU
	XXV
	XXZ

1 Country codes missing in GISCO data i.e. present in ISO 3166 standard but not in GISCO

2 Country codes missing in official ISO 3166 standard i.e. present in GISCO data but not in ISO 3166 standard

3 GISCO country codes included in the COUNTRY_UR field of the 2024 administrative boundaries

Annex 2. List of territories with incorrect country assignments in the GISCO Country Layer 1:100,000 version 2024.

Table 5. Territories with misassigned countries in the GISCO 1:100,000 Country Layer (2024 version)

Territory	Coordinates for localization [lat, lon]	GISCO assignment	Correct assignment
3 islands	-12.253181, 123.036849	Indonesia	Australia
4 islands	-21.261634, 155.755513	New Caledonia	Australia
Atoll	11.492555, 162.228559	Micronesia	Marshall Islands
Atoll	9.824402, 160.895744	Micronesia	Marshall Islands
3 islands	18.436502, -64.837732	US Virgin	British Virgin
Island	25.894676, 124.567418	Japan	Senkaku Islands (disputed)
2 islands	27.740653, 50.016438	Iran	Saudi Arabia
Island	25.668356, 52.415237	UAE	Qatar
Island	25.028281, 52.232018	UAE	Qatar

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