Cartographic evaluation of the ecological background of a group of sites on an international scale - Methodological framework

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PATRINAT
CENTRE D'EXPERTISE ET DE DONNÉES
OFB·MNHN·CNRS·IRD

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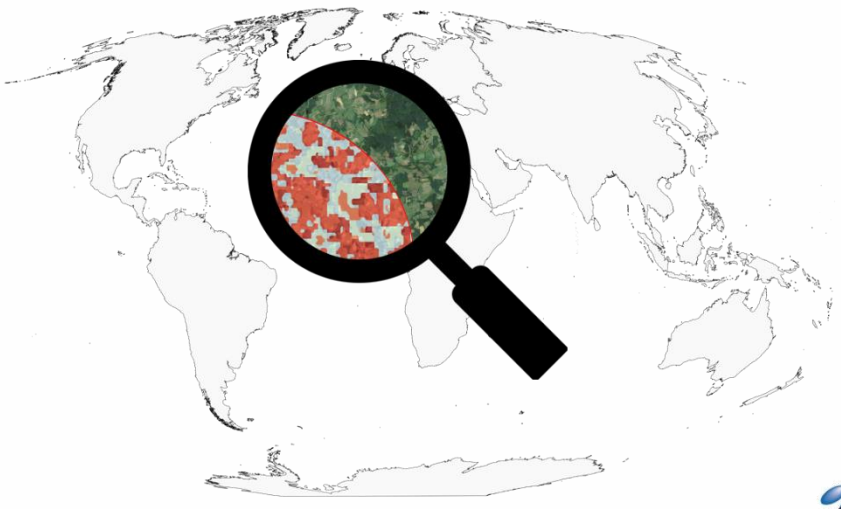

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IMERYS

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Centre of expertise and data on natural heritage

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PatriNat

Centre of expertise and data on natural heritage

As a scientific unit bringing together engineers, experts and data specialists, PatriNat consolidates the skills and resources of its four core institutions: the OFB, the MNHN, the CNRS and the IRD.

PatriNat coordinates national knowledge acquisition programmes to map ecosystems, species and protected areas, monitor trends in terrestrial and marine biodiversity, list key areas for nature conservation (Znieff), and produce scientific and technical reference systems (TaxRef, HabRef, etc.). These programmes involve numerous partners and bring citizens together through participatory science observatories (such as Vigie-Nature, INPN espèces or Vigie-terre).

PatriNat develops information systems for standardizing, sharing, discovering, synthesizing and archiving data for both public policy (SIB, SINP) and research (PNDB) purposes, ensuring links with international systems (GBIF, CDDA, etc.).

PatriNat provides its expertise in interpreting data to support stakeholders and help decision-makers guide their policies: production of indicators, in particular for the National Biodiversity Observatory (ONB) and booklets of key figures, preparation of Red Lists of threatened species and ecosystems, systematic reviews, preparation of reports for European directives, development of biodiversity diagnostic tools for local stakeholders, and assessment of the effectiveness of restoration measures. PatriNat also organizes the CITES scientific authority for France.

All the information (from raw data to summary data) is made public on the NatureFrance, INPN and Compteur BIOM portals.

For more information: www.patrinat.fr

Directors: Laurent PONCET and Julien TOUROULT

Naturefrance

The public biodiversity information service

Naturefrance is the public information service for public policy on biodiversity in France. It is available through several information portals, including the general portal naturefrance.fr. Aimed at a wide a readership, it provides key information on the major issues relating to biodiversity and its development, the pressures it is under and society's responses. Naturefrance presents key figures, indicators developed within the framework of the ONB (National Biodiversity Observatory), articles and publications based on the scientific analysis of data from public conservation policies or socio-economic activities that are favorable or unfavorable to biodiversity.

As part of this mission entrusted by the OFB, PatriNat manages this portal and participates in the processing, analysis and interpretation of some of the data posted on Naturefrance: for example, data from the Natural Heritage Inventory Information System (SINP) and the Information System of the Convention on International Trade in Endangered Species of Wild Fauna and Flora (SI CITES).

For more information: naturefrance.fr

National inventory of natural heritage

The portal to French biodiversity and geodiversity, in mainland and overseas France

As part of Naturefrance, the National Inventory of Natural Heritage (INPN) is the portal for French biodiversity and geodiversity, both in mainland France and overseas (www.inpn.fr). It brings together and disseminates information on the state and trends of France's natural heritage on land and at sea (current and ancient animal, plant, fungal and microbial species, natural habitats, protected areas and geology) in mainland France and the French overseas territories.

The data comes from the Natural Heritage Inventory Information System (SINP) and all the associated networks. PatriNat organizes the management, validation, centralization and dissemination of this information at national level. The resulting consolidated inventory is the culmination of work involving scientists, local authorities, naturalists and nature protection associations, with a view to establishing a regularly updated summary of France's natural heritage.

The INPN is the French benchmark for naturalist knowledge, expertise, macroecology research and the development of effective conservation strategies for natural heritage. All this information is available to professionals, amateurs and the general public.

For more information: www.inpn.fr

Overseas Biodiversity Counter

The indicators, issues and initiatives portal on biodiversity in overseas France

As part of Naturefrance, the Overseas Biodiversity Counter (BiOM) is developing an entry dedicated to France's overseas territories, which are home to a significant proportion of the world's biodiversity. An accessible, up-to-date and permanent portal, it brings together citizens and biodiversity stakeholders, with three objectives: to share scientific knowledge, to promote the actions of the overseas territories, and to encourage everyone to take action. This approach aims to relate the cultural contexts and highlight the specific challenges of each territory, in response to a commitment made in the Overseas France Blue Book.

The initiative is complemented by surveys of the general public: for example, the first overview of participatory science programmes in local areas, and a survey on the perception of nature and the use of digital tools.

PatriNat is responsible for implementing the project, with the participation of stakeholders in the French overseas departments and territories, in three areas: production of biodiversity indicators (knowledge, endangered species, protected areas, etc.), support for initiatives to encourage participation and science (eco-actions, participatory inventories, etc.) and technical management of the portal.

For more information: biodiversite-outre-mer.fr

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1. Introduction

1.1. Context

The Natural Heritage Support and Research Unit (UAR PatriNat) works in close collaboration with public and private partners operating landholdings in France and abroad. Used for their natural resources or simply for the space they provide for economic or strategic activities, these sites are home to local biodiversity that coexists in these locations and that can be vulnerable to some operations. In order to reconcile human activities and environmental issues on these sites, PatriNat works alongside its public and private partners to develop strategies for preserving and restoring biodiversity. These strategies need to be built on an adequate knowledge of the ecological characteristics of the partners' land and their surrounding landscape, as well as on the development and use of evaluation, awareness-raising and communication tools.

In this context, a method has been developed to assess the ecological background of landholdings on an international scale. It uses spatial data sets to produce cartographic and statistical results. Based on the case study of a French mining company operating throughout the world, an initial cartographic study was carried out on a national level in France: CARPO (Cartographie de Potentialités Ecologiques), aimed at assessing the levels of ecological potential of several sites, using fine, synthetic indicators (Forero S., 2021). The methodological framework presented in this document is a continuation of this national work: it has been transposed to a global scale, with the adaptations that this entails. It was developed in collaboration with Imerys, as part of the scientific collaboration partnership between the MNHN and Imerys, which led to the development and testing on Imerys sites worldwide.

What does this guide contain? This user guide presents a cartographic analysis method that provides a global overview of the ecological context of several sites around the world. It describes the general approach, the resources to be used, the processing to be carried out, the results that can be obtained and the limitations of the cartographic assessment method. Information sheets and technical details are provided in the appendix.

Who is it intended for? This guide is aimed at private or public organizations that own or rent land throughout the world and are seeking to characterize it from an environmental point of view using a uniform method. This work can be part of the elaboration of a Corporate Social Responsability (CSR) strategy.

1.2. Objective: a tool at the interface between knowledge, awareness and communication

The study of biodiversity provides a clear insight into the richness of the living world, but also reveals the extent of the biodiversity erosion caused by human activities, enabling the identification of appropriate protection and conservation measures (Triplet P., 2021). Characterizing the ecological context of activity sites means determining and spatializing the potential for biodiversity, so that it can be preserved (avoiding negative impacts) or even restored. This tool makes it possible to identify, not only the geographical sectors that contain elements that are favorable to biodiversity and which constitute a priority for conservation or management actions, but also, the degraded sectors representing opportunities for restoration to a suitable state and for management to maintain this state.

Mapping the ecological context of sites is therefore an essential step in improving knowledge of ecological stakes, assessing the sensitivity of sites, anticipating the impacts of the various phases of operations and adapting the site's response to impacts according to the local context. This knowledge mobilization will ultimately make it possible to produce cartographic atlases and lay the foundations for creating or reinforcing biodiversity action plans at site

level, but also to consolidate an impact mitigation hierarchy approach (avoid-minimize-restore-offset) that is consistent at the level of an organization managing land on a global/international scale.

The advantage of this tool is that it provides access to a general diagnosis of the ecological context of a group of sites in a relatively rapid, consistent way across the globe, which can be updated. The methodological framework proposed in this document is intended to be accessible, free and reproducible.

It should be noted that the diagnosis provided remains simplified and partial. In this sense, beyond its contribution in terms of knowledge of the ecological context, this work is above all a tool for raising awareness of environmental challenges, and for communicating about the existing or potential natural heritage within a defined geographical perimeter . It can therefore be used as a basis for discussions with stakeholders on the ecological features of a site and the location of actions taken or to be taken. Thus, this mapping can be helpful to an organization's consultants, customers and investors who are interested in the ecological issues and risks associated with the organization's land holdings.

2. General methodological approach

2.1. Resources required

This work is based on a method that makes full use of IT tools and digital data. The method, which focuses on processing spatial data sets, requires Geographic Information System (GIS) software and data processing software[1]. The following box describes some of the vocabulary used in this document relating to the GIS environment.

Definitions

Spatial dataset: a coherent set of geographical data relating to the same object of study, the graphical representation of which can be viewed in GIS software. The dataset takes the form of a set of data files: shapefiles, tabular information and metadata (IRD, 2023). The data can be vector or raster, among other types.

Vector data: in GIS, vector data are layers of spatial data represented by points, lines or polygons. Vector layers are made up of entities, each of which has a spatial representation (geometry) and alphanumeric characteristics (attribute information) entered by the operator. Vector data offers excellent graphic resolution, as well as a wide range of editing and creation options.

Raster data: in contrast, "rasters" are fixed images made up of a set of pixels. Raster attribute information is limited to one type of data: the value of each pixel. This quantitative value corresponds to the object of study represented by the raster. The resolution of the layer is given by the size of a pixel.

Tabular data and attribute tables: attribute data is the quantitative and/or qualitative information that characterizes the entities in a data layer. All this information is grouped together in the form of spreadsheets: attribute tables. These terms are used mainly for vector layers.

The resources required to implement this cartographic diagnostic tool are as follows:

Spatial data The GIS software QGIS, a free, open and royalty-free tool for viewing, managing, processing and analyzing cartographic data, is perfectly suited to the needs of this method. Another software package that can be used is ArcGIS, a complete and professional geographic information system, available by paying license.

Tabular data Although the majority of operations are carried out via the GIS interface, spreadsheet software such as Excel or Libre Office Calc can be useful for some additional operations.

Skills This work requires skills in IT and data management. GIS operations require knowledge of spatial data integration, processing and export. The main GIS operations carried out as part of this method are as follows: collection, display and organization of several datasets, geoprocessing of vector layers, processing of rasters, management of attribute tables, joins, page layout tool.

Time Despite the large size of the spatial data layers and their sometimes substantial weight, with good computer equipment, most GIS processing is relatively quick (ranging from instantaneous to around twenty minutes for each). General work planning: depending on the operator's level of GIS expertise, the number of sites to be assessed and the desired output, this project can take

[1] The software and versions used in these experiments were: QGIS 3.28.6 Firenze, ArcGIS Desktop 10.8, Microsoft Office Suite Professional Plus 2019, Libre Office 6.4.7.2.

around 3 months to complete (half the time should be spent collecting and processing the data and the other half putting together the atlases and carrying out the analysis).

2.2. General approach

The purpose of this section is to provide a general overview of the process. Each stage is then detailed in the rest of the document.

The method for mapping ecological potential presented in this guide was developed as part of a cartographic project on industrial sites worldwide. Based on this specific case, it is a general approach that can be transposed to other projects of various kinds.

In line with the objectives and requirements set out in section 1.2, the resources mobilized for this work are digital spatial datasets that can be consulted and downloaded online free of charge. This set of datasets is at the core of the method; they have been rigorously selected and made available in this approach (section 3.2.).

The steps involved in mapping this environmental data are as follows (Figure 1):

1. **Data preparation**. This stage consists of gathering the cartographic input data for the project, i.e. the study area data to be obtained (points or polygons locating the sites), and the data sets (provided by the method) to be collected. The speed with which this stage is completed depends on :
   - existing and available site data (which may need to be compiled, added to or modified),
   - and the desired environmental themes (selection of a subset of the datasets or possible addition of other data to the initial group of datasets proposed by the method).

   ⚠ Particular attention must be paid to the projection and coordinate systems during this stage, to ensure that the rest of the work runs smoothly (detailed in section 2.3).

   Outputs: creation of a database (Database V1) with one folder per dataset, containing GIS layers, metadata and user manuals.

   For more details: see section 2.3. for information on projection system issues; then refer to :
   - section 3.1. for the creation of the layer of study sites and areas;
   - section 3.2. for the presentation and collection of the data sets proposed by the method;
   - section 3.3. for the cartographic cross-referencing of these two data sets;
   - Appendix 2 to consult the environmental dataset sheets, for more information on the content, processing, limitations (etc.) of each dataset.

2. **Cartographic cross-referencing and attribute information**.
   - Spatial and geometric processing: the GIS layers (raster and vector) of the previously selected and downloaded datasets are intersected with the perimeters of the study sites, in order to extract data on the target area. This process is carried out in GIS, using cutting and extraction tools. Once extracted, the raster data is vectorized, so that only one type of data is used for the rest of the project. The GIS processing chain and technical details are described in section 3.3.1.
   - Cleaning up attribute tables: the attribute information describing the data varies from one dataset to another, some having almost none at all, while others are more detailed and/or precise. So, for each dataset, it is necessary to identify the fields in the attribute table that are of interest to use and display in the context of the project, and possibly delete those that seem less useful, rename them, etc. (suggestions of fields to use for each dataset are given in the sheets in Appendix 2).
   - Creation of simple indicators: they are calculated for each dataset in order to assess the importance of an ecological element on each site. These are mainly surface areas, in hectares and surface

proportions, or the number of entities per site (for example, the potential number of threatened species on a site). In practical terms, these indicators are added directly from the attribute tables in the GIS datasets. *Please note that these metrics are calculated using GIS software based on theoretical data. They should therefore be used as estimates.*

Outputs: creation of a second database (Database V2), again with one file per data set, containing the vector layers cut out from the study sites and their associated attribute tables filled in with quantitative or qualitative information on the mapped entities (including indicators).

For more details: see section 5.1. on the limitations of indicators calculated using GIS; section 3.3.1. for information on the GIS tools and processing steps; and the *processing*, *fields* and *indicators* section of the datasets sheets in Appendix 2.

3. **Results and analysis.** Once the cross-referencing has been completed, the graphical and statistical results can be formatted into cartographic atlases using GIS software.

Outputs: production of cartographic atlases (one for each study area, containing the different themes covered by the datasets; and one overall, giving an overview of all the study areas), and of a GIS database made up of the datasets specific to the study areas.

For more details: refer to section 4. for the results structuring (suggested representation, example of an atlas plate, organization of GIS data).

For a complete approach, a final stage of dissemination and communication of the elaborated mapping should be considered. As mentioned in the introduction, this project also has an instructive and educational purpose; it is therefore important to consider the appropriate tools for informing people about the meaning and usefulness of such a cartographic analysis, and to communicate the results obtained in order to make employees aware of the ecological challenges of the sites (see section 5.2).

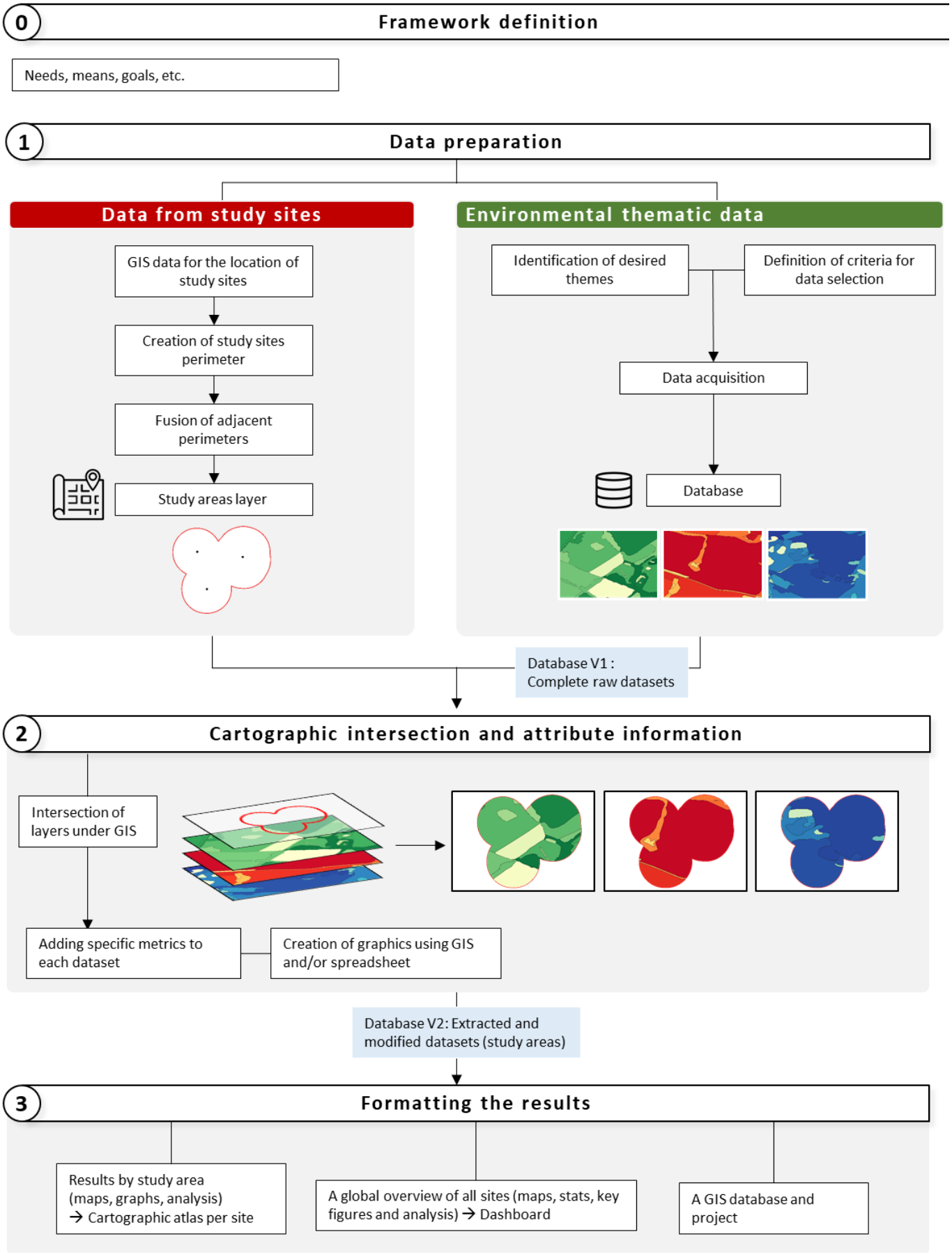


Figure 1. General methodological framework

2.3. The spatial reference system: projection and coordinates

This entire methodological framework has been built and tested on QGIS software. The use of other GIS software may involve rules, functions or vocabulary terms other than those described in this document.

2.3.1. Theoretical elements

Representation models

In cartography, there is a major bias, which must be discussed before any handling: the reference system that defines the projection and coordinates used. There are two types of representation of the Earth's surface: the globe, in the form of a 3D sphere, ellipsoid or geoid, and the planisphere, a 2D flat surface (Figure 2). The globe is the geometric model best suited to reproducing the characteristics associated with the Earth's rotundity in its true proportions (Lapaine M., *et al.*, 2014). On the other hand, the transition from 3D to 2D alters reality and leads to deformations of the features mapped.

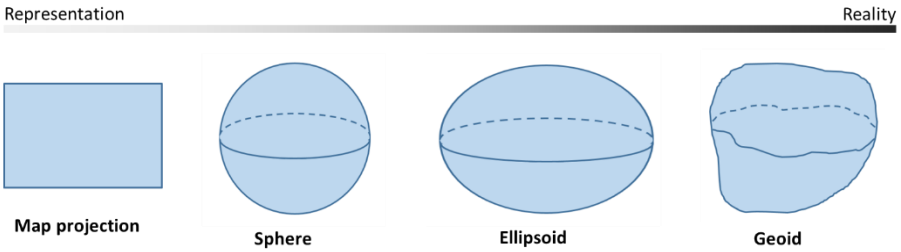


Figure 2. Evolution of models of the shape of the Earth (modified, Github).

Reference systems

This transformation from a globe to a flat surface is achieved through a process of cartographic projection, which transposes the spherical terrestrial envelope onto a flat map, and a geographic coordinate system, which provides the link between the actual terrestrial locations and the cartographic representation. The combination of projection and coordinates constitutes the Coordinate Reference Systems (CRS)[2], a parameter that must be defined and set up into the GIS.

Projections

There are three main ways of projecting an image of the Earth onto a flat surface (Figure 3):

- azimuth projection (according to a plan),
- conical projection (along a cone),
- and the cylindrical projection (on a cylinder).

Deformations

Whatever the projection adopted, the transition from volume to plane poses numerous mathematical and geometric problems, such as distortions of angles, distances and surfaces. These parameters can be attenuated individually and locally, but deformations are still unavoidable: the aim is to find the best compromise to meet the needs of the map. Depending on what is preferred, the map can be :

- equivalent (preserving surfaces),
- conformal (preserving angles and shapes),
- or equidistant (preserving distances).

[2] Name used by the QGIS software.

"*Cylindrical projections are often used for world maps; the latitude is deliberately limited to the south and north to avoid the excessive distortion of the polar regions that this projection method entails*" (Lapaine M., *et al.*, 2014).

The Tissot indicator is a visual model that shows these progressive deformations from the equator to the poles, with the same object represented at different latitudes (Figure 4).

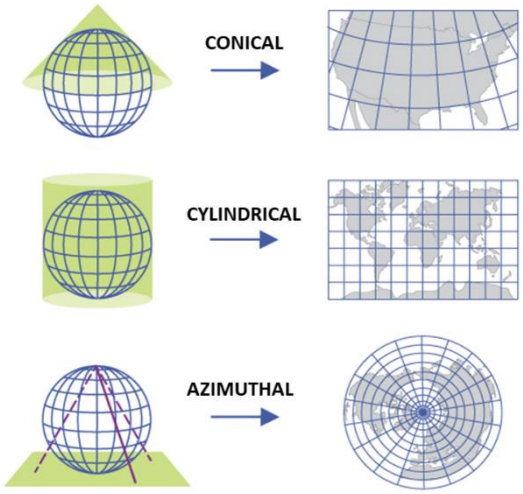


Figure 4. The 3 types of projection. (Maxicours)

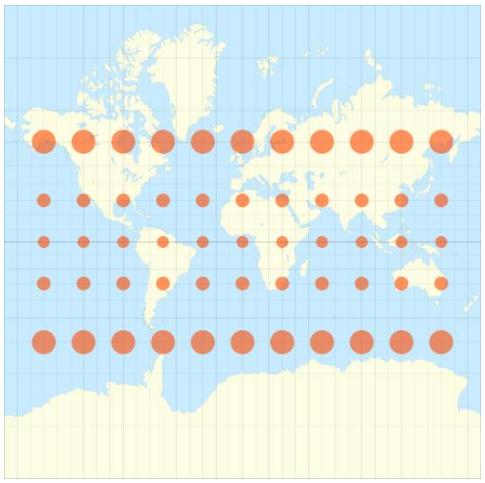


Figure 3. Tissot indicator for Mercator projection - Progressive surface deformation, shape preservation. (Eric Gaba - Wikimedia Commons)

There are dozens of reference coordinate systems. Their choice depends on the purpose of the mapping, its scale and the region of the world being studied. The smaller the study area (sites located in a few sectors of the globe), the more it is possible to adapt the CRS locally, thereby minimizing distortions and obtaining an accurate representation. On the contrary, the larger the scale (sites located in several sectors of the globe), the greater the distortions between the extreme points of the zone and the more compromises will have to be made in terms of cartographic representation.

2.3.2. Methodological approaches identified

Two possibilities were considered:

- **A local solution**, with the reference system adapted to each geographical area, based on the UTM zone grid[3] (Figure 5). This grid divides the world into 100 km squares, each with its own projection and coordinate systems. In this way, this method makes it possible to give each localized area of the world the appropriate CRS, enabling mapping to be carried out without the problem of deformations.

[3] Universal Transverse Mercator

This solution would therefore involve identifying all the UTM zones intersected by the project data (the study zones), listing the corresponding CRSs, splitting all the datasets according to these UTM zones and reprojecting each dataset and each zone into the correct CRS. This solution quickly proves to be time-consuming and tedious in large-scale projects (wide global distribution of study sites) involving a large number of datasets.

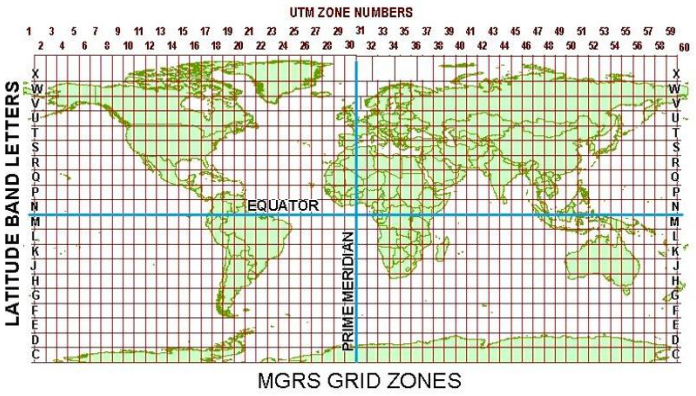


Figure 5. Global UTM zones (bel-horizon.eu)

- **A global solution**, with the adoption of a single reference system for the entire project. Easier, quicker and more reproducible than the previous solution, this solution involves accepting mapping compromises. As explained above, there is no single correct CRS for the whole world. If such a choice is applied, it is necessary to accept distortions in the angles, areas and/or distances of the spatial data sets processed. Here are some CRS s that have been considered, adapted and recommended for global mapping*:*

  - Mercator WGS84 | EPSG:4326 projection: the oldest standard used for planispheres (1569), this projection is now the global standard for mapping (Lapaine *et al.,* 2014) . It is used in particular by Google and OpenStretMaps, and in general for all global datasets. It is a conformal cylindrical projection and its measurement system is decimal.
  - World Mollweide projection | ESRI:54009: this projection is used for thematic maps of the world, where the preservation of areas is necessary. This equivalent pseudo-cylindrical projection has the advantage of being relatively faithful to the real proportions of the earth's surface, and thus preserves areas with little distortion, even near the polar regions (Sillard, P., 2000). Its measurement system is metric.
  - Sphere Eckert IV projection | ESRI:53012: useful in world cartography, particularly for thematic maps such as climate maps, the Eckert IV projection has the advantage of being optimized to minimize distortions over the whole globe. This projection, which is equivalent in nature, slightly stretches the equatorial regions, but the proportion with the polar regions is relatively well respected (Sillard, P., 2000).
  - Sphere Winkel Tripel projection | ESRI:53042: used in particular by the *National Geographic Society*, this projection is one of the most widely used for producing general maps of the world (ESRI, n.d.). Neither conformal nor equivalent, it was constructed to minimize surface, distance and shape distortions, with the exception of certain areas close to the polar regions (Lapaine *et al.*, 2014).

2.3.3. Selected solution and application in the GIS

Given the global nature of cartographic analysis and the amount of datasets to be processed, the global solution proved to be optimal for this global mapping method.

Mercator projection

After documentary research, tests and discussions with professionals on the subject, and in the interests of simplicity and consistency, the projection chosen is the Mercator projection, combined with the WGS84 coordinate system, corresponding to the EPSG:4326 code. The main reason for this choice is the universal use of this projection:

- By default, the majority of the world's spatial data is encoded natively in Mercator WGS84, and it is preferable to use the dataset in its original CRS, as reprojecting a layer can be risky (lack of transparency on reprojection parameters in some GIS software, risk of only modifying the projection system without the coordinate system, misleading "on-the-fly" projection settings, etc.). Opting for the Mercator WGS84 CRS therefore offers simplification and a degree of reliability in the management and processing of spatial data.

  Of the 17 datasets selected for this method, the majority are originally in Mercator WGS 84. Only 2 datasets are available in another CRS: World Mollweide (for the *Global Distribution of Seagrasses* and *Global Human Footprint* datasets).

- Opting for a universal CRS also means that the method can be more easily transposed to different projects.
- In addition, the distortion compromises of this CRS seem acceptable for the project, given that the objective is not to compare results between sites, but to have a vision of the ecological context site by site. In addition, the fact that the mapped surfaces are analyzed in proportion (percentage of the study area covered by the data sets) and not in absolute values, it contributes to eliminating the effects of surface distortion.

  Depending on the project, it is possible that other CRS choices will prove more optimal. Please refer to section 5.2. on prospects for identifying possible improvements.

Definition of the CRS in the GIS

Throughout the project, it is important to pay attention to the projections used for the data, the GIS and the map layouts.

Project layers The datasets used must be in a common CRS, chosen beforehand (in this case Mercator WGS 84). If this is not the case, the data layers encoded in another CRS will have to be reprojected using GIS software.

The GIS project The GIS interface makes it possible to view geographic data in a wide variety of CRSs. In addition to the data layers, the GIS software viewer itself is equipped with a configurable CRS (Figure 6). This must be configured to define the projection with which to display data layers, and the coordinate system to be used for geographic coordinates and the calculation of metrics (area, distance, etc.).

⚠ **Warning**: QGIS projects data "on the fly", which means that in the event of different projections between data layers, the software will display the layers in the CRS indicated by the project, automatically transposing between the CRSs of the layers and that of the project. This parameter is useful when the aim is to display several data layers with different CRSs quickly and easily in the same reference system: the user only needs to enter the project's CRS, and the layers will be projected in line with it.

However, when GIS software is used for more advanced purposes than simple visualization, this parameter can be misleading. In fact, when data layers are actually being processed, such as for calculating metrics, it is very important to set up the layers in the correct CRS. For example, visual verification of the geographical location of data in the viewer must be complemented by verification of the layer's native CRS in the parameters. If the latter does not correspond to the desired CRS for the project as a whole, it is possible to reproject the layer using GIS (exporting a new data layer using a reprojection tool integrated into GIS).

Originally an option that could be disabled in early versions of QGIS, on-the-fly transformation has now become a permanently activated default parameter.

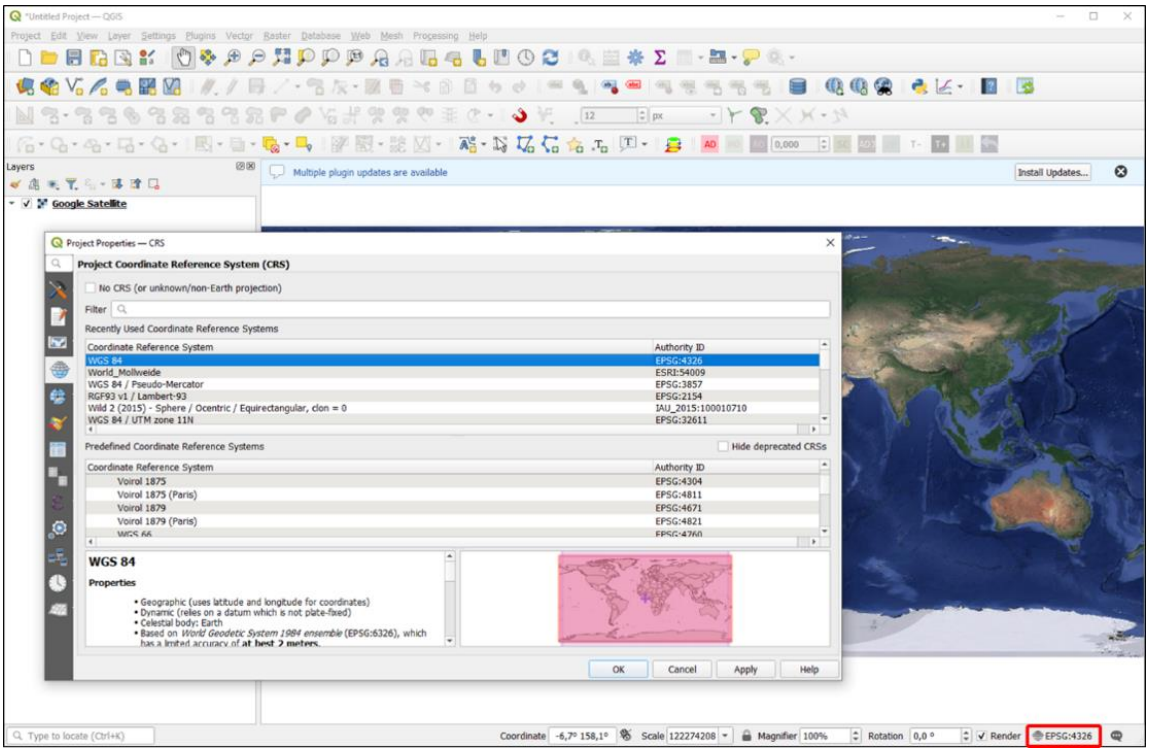


Figure 6. Setting up the project's CRS in QGIS.

Calculation of spatial metrics using GIS

The calculation methods used by GIS vary from one software package to another and may not be clearly detailed in the parameters. Broadly speaking, there are 2 procedures:

- The GIS software performs the calculations according to the flat map; the measurements are therefore linked to the cartographic representation displayed: an area that is flattened and shrunken because of the projection will have a smaller surface area than an area whose geometry has been stretched.
- The GIS software performs calculations on the ellipsoid, so it does not depend on the parameterized projection or the deformations visible to the eye on the map, but on the actual measurement of the earth's surface.

Unlike most other GIS software, QGIS calculates metrics (area, distance, etc.) based on the ellipsoid. They are therefore correct because, as shown in the box below, they are based on calculations on the sphere, which are more accurate than those based on the flat map.

"Apart from the problems of identifying reference systems, a difficulty can arise with the calculation of distances. Let's imagine two points with their coordinates in projection, expressed in a certain reference system. The exact distance separating these two points should normally be calculated on the sphere (or better still on the ellipsoid). However, given the complexity of the algorithms used to calculate geodesics, it may be tempting for the software manufacturer to perform the calculations in projection.

This information is generally not available in the software documentation (...). The problem lies in the choice of projection. If the projection does not alter the distances too much (i.e. it is adapted to the area being processed), and if the distance between the two points considered is not too great, then the distance calculated in projection will be close to the exact value. On the other hand, if the user adopts a projection that causes significant distortion, then there is a high risk of ending up with totally incorrect distance measurements. If the GIS performs calculations on the sphere, then in all cases the calculations are correct". (Sillard, P., 2000).

General methodological approach

Recap

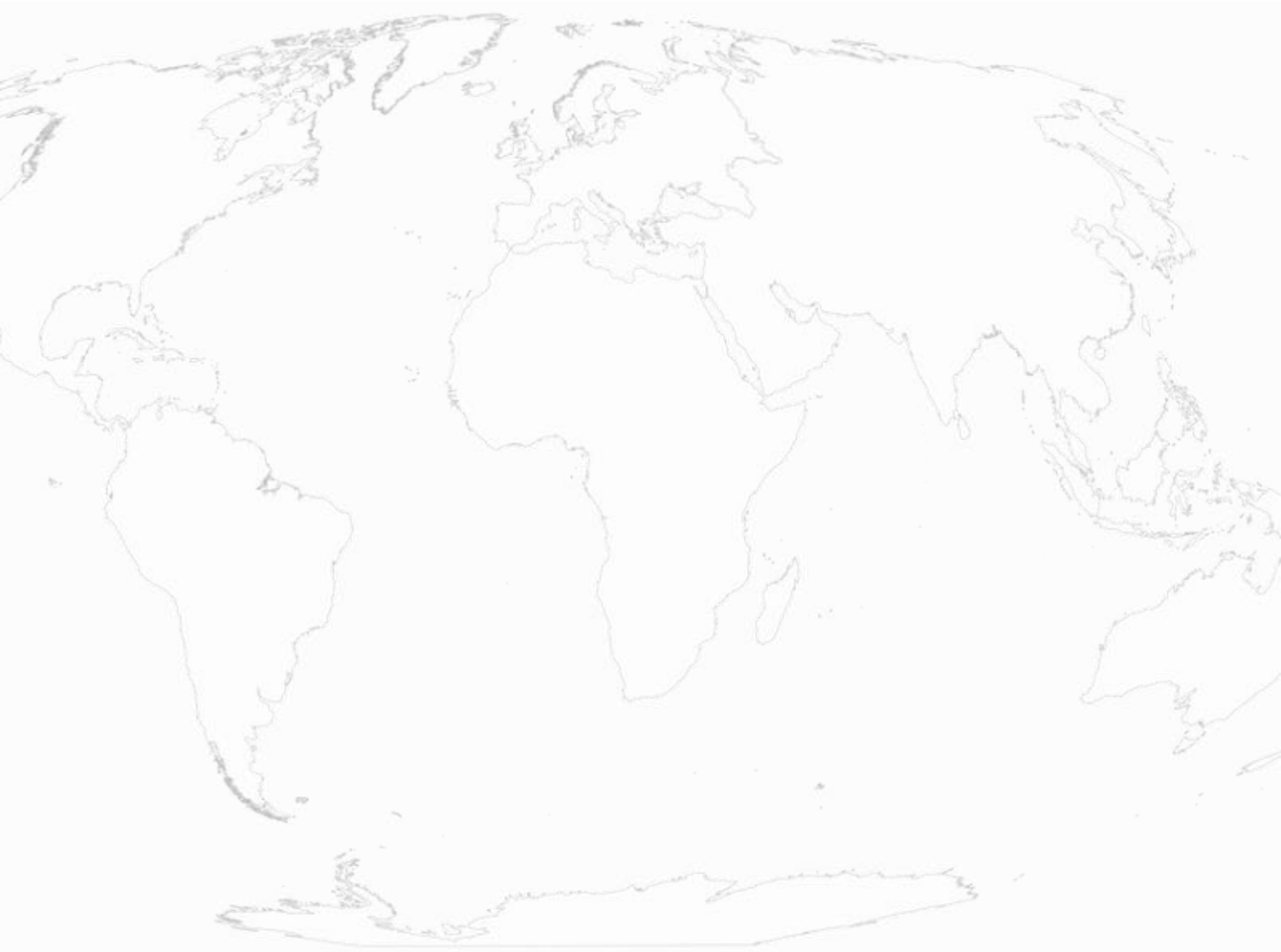
This global mapping of ecological potential requires computer resources and familiarity with **GIS** and **spreadsheet software**.

It is based on the use of several **global spatial datasets**, which can be downloaded online and processed using GIS software.

The steps in the method (detailed in subsequent chapters) are as follows:

- preparing spatial data (compiling, creating)
- spatial cross-referencing (intersection of data by GIS processing)
- create a complete attribute table (identify useful information, add metrics)
- formatting and analyzing results (producing maps, graphs and atlases)

Throughout all these stages, pay particular attention to the **projection and coordinate reference system (CRS)** adopted and the GIS calculation method used, especially when calculating metrics.



3. Mapped data

The core of this project is the cross-referencing of environmental data sets with the study sites. The aim of the following section is to present these two main groups of data and describe how they are created, obtained and selected.

3.1. Definition of study areas

This methodological framework is designed to respond to projects that are similar in terms of their global scope, but where the configuration of the sites to be studied may vary in terms of:

- amount (from a few sites to several hundred),
- size (from a few meters to square kilometers),
- and geographical distribution and location.

Sites refer to all the activity sites or landholdings of an organization, which are the subject of this ecological analysis. They may be sites currently in operation (active sites) or sites where activity has ceased temporarily or permanently (inactive sites), planned sites (future extensions or new activities), restored sites, sectors protected from the impact of an activity (avoidance) or compensation sites (offsets).

The study areas include the perimeters of the sites, plus zoning around these sites (Figure 7). They designate the areas studied as part of this method: the ecologically characterized spatial context (see part 3.1.2.).

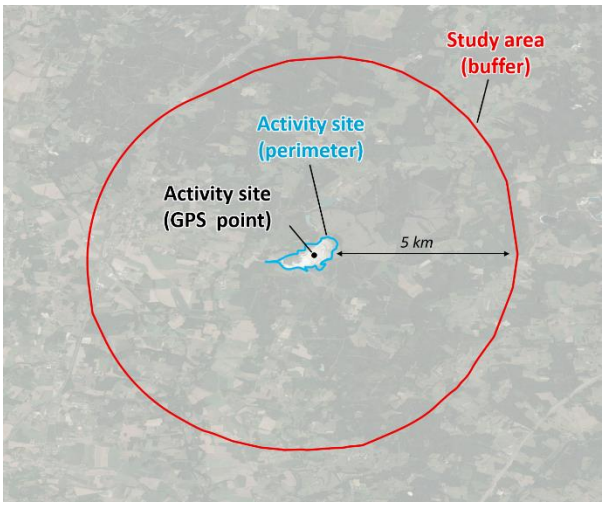


Figure 7. Diagram of a business site and its study area.

Consequently, before starting any processing, it is important to:

1. clearly identify the sites targeted by this project,
   (which may be landholdings, parcels, administrative units, etc.);
2. and define the study areas to be analyzed by this cartographic analysis.

3.1.1. Site data collection

The first step is to search for the most complete, accurate and up-to-date spatial resources likely to contain the spatial extent of the sites to be studied. This information can be found in the organization's GIS, online, or must be created from the data reported by the sites. The spatial dataset containing all the sites to be studied can take various forms:

- Geographical coordinates (spreadsheet), to be transformed into a vector layer of points,
- GPS points (vector layer of points corresponding to the centroids of the sites or to a characteristic point on the site),
- Site perimeters (vector layer of polygons demarcating site boundaries).

It is strongly recommended to use a layer of polygons composed of the exact contours of the sites, particularly in the case of sites with a surface area of more than several dozen hectares or a group of sites with very different surface areas. This will contribute to more accurate results when creating the study area than the approach using a layer of GPS points, as it allows us to take into account the precise extent of the sites and their representativeness in the landscape structure.

This raw dataset may require an intermediate clean-up stage using GIS or spreadsheet software, resulting in a simple, clean dataset containing only the sites targeted by the study. The attribute table for the layer of points or polygons containing the sites must contain at least one field enabling each site to be identified (the full name of the site or an alphanumeric identifier). It may also contain other fields such as the geographical location (municipality, region, country, continent), the type of activity within the site or its status (active, inactive, restored, preserved, etc.), the affiliation of the site to a sub-group of sites, the surface area, etc.

3.1.2. Creation of study areas

The second stage consists of creating a second "buffer" layer, corresponding to the study areas, from the previously obtained/created sites layer. To do this, a "buffer" layer of the sites layer must be generated in GIS, applying a distance of 5 km, corresponding to approximately 0.045° to the equator (Figure 7).

The advantage of studying a wider area around each site is that it provides an overview of the ecological context in which the site is located. Ecosystems and environmental issues have no spatial boundaries, and are subject to dynamics and interactions that extend beyond the site itself. Therefore, considering an area at least 10 km wide means that these dynamics can be taken into account locally, and edge effects in the immediate vicinity of the site perimeter can be limited.

The WGS84 coordinate system uses degrees, so it is the distance in degrees that must be entered in the GIS. Please refer to the appendices for the geoprocessing tools used.

⚠ Buffer deformation and choice of reference system

After initial tests to create the buffer layer in QGIS, the generated features were found to be out of alignment with the base map and to have geometric anomalies.

Indeed, with the reference system chosen (Mercator WGS84), as mentioned in section 2.3.1, spatial deformations are expected during global mapping, due to the projection which inevitably stretches the earth's surface (Figure 3). Geometrically, the buffers created should therefore follow this increasing deformation towards the poles and should themselves be slightly stretched.

However, by creating the buffer layer in QGIS, perfectly circular features appear around all the GPS points of the sites, at any point on the globe (Figure 8). If the same exercise is carried out using ArcMap software from the ArcGIS suite, the buffers generated conform to the deformation caused by the projection, locally. At the equator, for example, the buffers are circular (because there is no projection deformation), and gradually stretch as they get closer to the poles.

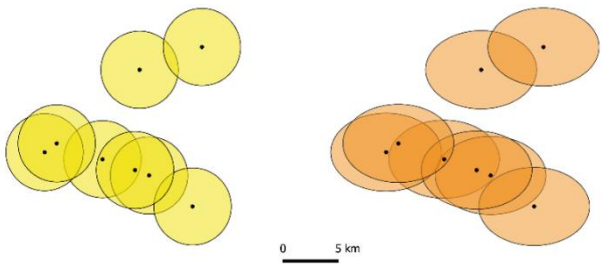


Figure 8. Results of the creation of the buffer layer for the study area.
Comparison of buffers created in QGIS using the planar method on the left and buffers created in ArcMap using the geodetic method on the right.

This difference between the two GIS software packages is due to a buffer layer construction parameter, set by default in QGIS, but adjustable in ArcMap. The latter allows the user to choose the layer creation method: planar or geodesic. The geodesic option creates more precise and accurate buffers, taking into account the shape of the Earth (ellipsoid or geoid, Figure 2); unlike buffers based on the planar method, with measurements taken on a flat surface (ArcGIS Pro, n.d.).

➔ For the purposes of this work, therefore, the geodetic method should be used. To do this, and wherever possible, use ArcMap software, which, unlike QGIS, allows you to set the parameters for this method.

Figure 9 illustrates these CRS and buffer layer issues, on a random point. In the first case (Figure 9-A), the map is produced using a local projection system: the base map is accurate and undistorted, so the buffer is undistorted too. In the second case (Figure 9-B), the map is produced using the Mercator global projection system, which causes progressive stretching from the equator to the poles: the base map is therefore stretched. It is therefore normal for the buffer to undergo the same deformations, in order to follow the base map underneath. Applying a perfectly circular buffer, which has not been transformed, would be irrelevant and would not intersect the correct real land surface underneath.

Figure 9. Deformation and buffer layer: comparison of a local (A) and global (B) projection system.

The third and final stage in defining the study areas is the merging of adjacent entities (Figure 10). This is because some sites may be very close to each other spatially, so that the buffer zones (study areas) intersect, sometimes with significant or even total spatial overlap (Figure 10-A). In order to carry out a single map cross-reference and to avoid extracting duplicate data on the part overlapped by the two (or more) study zones, the perimeter of these study zones is merged to form a single large study zone (Figure 10-B).

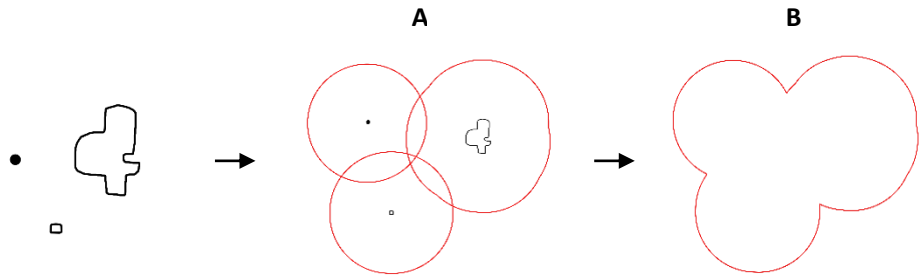


Figure 10. Creation of the study areas GIS layer (in red) from the activity sites layer (in black). A: individual study areas | B: grouped study areas.

It is therefore possible to work with two types of study area layers. Cross-mapping with layer A provides results for each individual study area, whereas with layer B the results are at the scale of the large grouped study area, thus losing the detail per site.

The study area layers must include unique alphanumeric identifiers for each study area. In the case of layer A (Figure 10), the user needs to make sure that two identifier fields are filled in: the first indicating the identifier of each individual study area ("ID_indiv" Table 1), the second indicating the identifier of the large study area in the case of grouped adjacent sites ("ID_group" Table 1). Here is an example of an attribute table for layer A, Figure 10 :

Table 1. Example of an attribute table for the GIS layer of the study areas

ID_indiv	ID_group
1	1
2	1
3	1

Considering the GIS queries and processing to be carried out, this will make it possible to call up the entities separately or designate the overall study area.

3.2. Compilation of environmental datasets

The search for and selection of datasets was a major preliminary phase in the construction of this methodological mapping framework. Indeed, mobilizing global spatial data for environmental analysis requires a rigorous and methodological selection process. This section presents the criteria used to select the data, as well as the datasets themselves.

3.2.1. Data selection criteria

The survey of available environmental datasets was carried out in 3 phases:

1. Online searches of all global spatial data likely to provide relevant information on the ecological context of sites,
2. List all the data identified in a multi-criteria spreadsheet and fill in a set of pre-defined information fields for each dataset;
3. Sort and prioritized the listed datasets using filters.

This multi-criteria table is a decision-making tool that enables all the identified datasets and their metadata to be compiled, centralized, sorted and managed.

In order to build up a knowledge base on the ecological context of a group of sites on a global scale, the spatial datasets used for this work were selected on the basis of 7 main criteria:

- **A global geographical coverage** of the data, in order to have a complete and homogeneous coverage on the whole globe and to be able to analyze sites from one continent to another.
- **Producers or suppliers of reliable data,** such as institutions, NGOs, recognized associations and research bodies. Most of the data are among the most comprehensive sources of information commonly used in cartographic analysis projects.
- **Themes relevant to the needs of the study**, i.e. biodiversity-related themes that provide an overview of ecological issues (ecosystems, species, protected areas, pressures, etc.). The themes have been chosen according to the type of activity and location of the company, but can be adapted to most contexts.
- **Open data datasets**, i.e. free public data available online, easily accessible and downloadable in a format that allows the data to be reused and distributed (James, 2013).
- **A format that can be downloaded, used and modified in GIS** so that the data can be revised and adapted to each project, and then formatted in a personalized way.
- **A correct spatial resolution,** adapted to the size of the study sites: fine spatial resolutions have been preferred (of the order of a few tens or hundreds of meters), and resolutions that are too coarse (greater than one kilometer) have been avoided.
- **Ideally, frequent updates.** This parameter should be considered if the environmental diagnostic project is to be carried out over time, with a temporal analysis of the ecological context of the sites. With frequent updates announced for the datasets, the mapping work can be repeated and updated over the long term. Not all datasets offer this advantage, but that does not mean they cannot be used.
- **A recent data acquisition date.** Ideally, datasets dating from the last decade were prioritized. In the absence of recent data, older datasets have been selected, taking into account the limitations that this may entail. The importance of this criterion depends on the temporality of the objects mapped, which present more or less rapid change dynamics (carbon storage, forest extent, observation of endangered species, etc.).

By complying with these criteria, it is possible to select the right data for the project and to compile datasets that are homogeneous and comparable. In addition to these main discriminating criteria, other information relating to the datasets has been entered in the multi-criteria table, as follows:

- Name
- Producer/supplier
- Theme
- Geographical reach (scope)
- Date
- Update and time reference
- Spatial resolution
- Projection system
- Acquisition/production method
- Internet address
- Accessibility
- Guide/metadata availability
- Licence
- Type (vector/raster)
- Format
- File, download, processing

The complete layout of the multi-criteria table used for this method is presented in Appendix 1 (view of the spreadsheet, description of the fields, and example of a filled-in dataset). It can be consulted for information purposes, or can be used when adding new data.

This methodological guide proposes a selection of ready-to-use environmental data sets, but this selection can be supplemented, if necessary, by other thematic data, particularly in the context of more specific projects. The template provided in the appendix means that the same method can be used if new data is added.

3.2.2. Data presentation

The table below summarizes the spatial datasets selected and proposed by this methodological framework (Table 2). For more information on each dataset (information, method, interpretation, limitations, GIS processing required, etc.), please refer to the dataset sheets in Appendix 2.

The metadata for the fields in Table 3 are presented in Appendix 2. Full citations of the datasets are available in the bibliography.

Theme	Name	Producer	Overview	Data date	Spatial resolution	Acquisition/production method	Update	Format	Licence	Dataset download link*
Ecoregions	**Global Ecological Zones**	FAO FOM Forestry Department	The 19 global ecological zones refer to the main large-scale biomes, based on climate and vegetation.	2010	/	**Compilation & modification** Several data sources used by continent (cf the metadata manual).	*No update announced*	Vector (ESRI shapefile)	Commercial use prohibited	Link to resource
	Marine Ecoregions	The Nature Conservancy	Biogeographic classification of the world's coastal and continental shelf waters, following a nested hierarchy of realms, provinces and ecoregions.	2012	/	**Production & compilation** This dataset combines two separately published datasets: the "Marine Ecoregions Of the World" and the "Pelagic Provinces Of the World".	*No update announced*	Vector (ESRI shapefile)	Commercial use prohibited	Link to resource
Biodiversity areas	**Biodiversity Hotspots**	Hoffman M. *et al.*	Identification of the 36 biodiversity hotspots in the world, which are the Earth's most biologically rich, yet threatened, terrestrial regions.	2016	/	**Production**	*No update announced*	Vector (ESRI shapefile)	Unrestricted use (CC BY 4.0)	Link to resource
	World Database on Protected Areas (WDPA)	UNEP-WCMC, IUCN	Compilation of the world's marine or terrestrial protected areas and their classification according to the 7 IUCN management categories	2023	Variable	**Compilation** Data have been obtained from nearly 500 sources.	Monthly update	Vector (OGC geopackage)	Commercial use prohibited	Link to resource
	Key Biodiversity Areas (KBA)	BirdLife International	Most important places in the world for species and their habitats, based on elements of biodiversity across genetic, species and ecosystem levels. KBAs have outstanding ecological integrity, globally important ecosystems or significant populations of animals, fungi and plants.	2014	Variable	**Compilation & modification** Compilation of several existing perimeters/sites about taxonomic, ecological and thematic subsets of biodiversity, including for example: Important Bird and Biodiversity Areas (IBAs), Alliance for Zero Extinction sites (AZE).	KBAs should be reviewed and updated nationally every 8-12 years	Vector (ESRI shapefile)	Commercial use prohibited	Link to resource

Theme	Name	Producer	Overview	Data date	Spatial resolution	Acquisition/production method	Update	Format	Licence	Dataset download link*
Ecosystems	**Terrestrial Habitats types**	Jung M., *et al.*	Spatially characterization of 47 terrestrial habitat types, as defined in the IUCN habitat classification scheme.	2015	100 m	**Modelling** Habitat map produced by creating a global decision tree that intersects the best currently available global data on land cover, climate and land use.	*Future updates mentioned*	Raster (TIF)	Unrestricted use (CC BY 4.0)	Link to resource
	Global Forest Change	Hansen M.C., *et al.*	Forest decline over the period 2001-2019 (deforested areas).	2019	30 m	**Modelling** Results from time-series analysis of Landsat images (Landsat 8 OLI) characterizing forest extent and change.	*No update announced*	Raster (TIF)	Unrestricted use (CC BY 4.0)	Link to resource
	Forest Landscape Integrity Index	Grantham H.S., *et al.*	Forest extent in 2019, with indicators of human pressures and alteration of forest connectivity.	2020	300 m	**Compilation and modification** Four datasets were combined representing: the forest extent, 'observed' pressure from high impact, 'inferred' pressure associated with edge effects, anthropogenic changes in forest connectivity due to forest loss.	*Future updates mentioned*	Raster (TIF)	Unrestricted use (CC BY 4.0)	Link to resource
	Global Lakes and Wetlands Database	WWF	Different wetland types, lakes, reservoirs, and rivers.	2004	1 km	**Compilation** Data based on the combination of seven digital maps and attribute data sets, like MGLD[4] or GLCC[5] .	*No update announced*	Vector (ESRI shapefile)	Commercial use prohibited	Link to resource
	Natural Earth Rivers, lakes and reservoirs	Natural Earth	Main rivers and lakes ranked by relative importance, coordinating with river ranking.	n.d.	/	**Modification** Rivers primarily derive from World Data Bank 2 and additional sources like recent satellite imagery.	*No update announced*	Vector (ESRI shapefile)	Unrestricted use	Link to resource
	Global Distribution of Saltmarshes	Mcowen C., *et al.*	Distribution of saltmarsh (ecosystems located in the intertidal zone of sheltered marine and estuarine coastlines - marine habitat), drawing from occurrence data.	2015	/	**Production & modelling** Surveyed and/or remotely sensed.	*No update announced*	Vector (ESRI shapefile)	Commercial use prohibited (CC BY-NC 4.0)	Link to resource

Theme	Name	Producer	Overview	Data date	Spatial resolution	Acquisition/production method	Update	Format	Licence	Dataset download link*
Ecosystems	**Global Distribution of Seagrasses**	UNEP-WCMC, Short FT	Distribution of seagrasses (marine habitat).	2020	/	**Compilation**	*No update announced*	Vector (ESRI shapefile)	Commercial use prohibited	Link to resource
	Global Distribution of Coral Reefs	UNEP-WCMC, WorldFish Centre, WRI, TNC	Distribution of coral reefs (marine habitat) in tropical and subtropical regions.	2018	30 m	**Compilation** From a number of sources, include the Millennium Coral Reef Mapping Project (and the World Atlas of Coral Reefs.	*No update announced*	Vector (ESRI shapefile)	Commercial use prohibited	Link to resource
	Global Mangrove Watch	Bunting P., *et al.*	Mangrove map: distribution and extent change of various types of salt-tolerant plant species (trees or shrubs).	2020	25 m	**Modelling** The GMW has generated a global baseline map of mangroves using ALOS PALSAR and Landsat (optical) data.	*No update announced*	Vector (ESRI shapefile)	Unrestricted use (CC BY 4.0)	Link to resource
Threatened species	**IUCN Red List Maps**	IUCN	Distribution area of fauna and flora threatened species (known range of each species) according their conservation status and based on IUCN Red List of Threatened Species™. Four taxa were chosen for this study: plants, amphibians, reptiles and mammals.	2022	/	**Compilation** Data provided by several experts around the world, constitution of maps and distribution areas from occurrence data (IUCN imposes data standards, attributes, format).	Red List is updated at least twice each year.	Vector (ESRI shapefile)	Commercial use prohibited	Link to resource
Human impacts and carbon resources	**Global Human Footprint**	Venter O., *et al.*	Level of direct and indirect human pressures on the environment globally, based on a compilation of 8 variables[6] .	2009	1 km	**Production & modification** Gathering of the 8 variables and creation of a human pressure score within a 0-10 scale.	*No update announced*	Raster (TIF)	Unrestricted use (CC0 1.0)	Link to resource
	Vulnerable carbon	Noon M., *et al.*	Mapping of carbon sinks: extent of potential carbon loss in the event of disturbance/exploitation.	2018	300 m	**Compilation & modification** These datasets are based on input maps collected from published literature.	*No update announced*	Raster (TIF)	Commercial use prohibited (CC BY-NC 4.0)	Link to resource

Table 2. Summary table of selected thematic datasets.

*The hyperlinks were consulted and integrated in August 2023.

[4] MGLD (MSSL Global Lakes Database, Birkett and Mason 1995)

[5] GLCC (Global Land Cover Characterization, Loveland et al. 2000, in 'Global Ecosystem' classification)

[6] The 8 variables: built-up areas, human population density, electrical infrastructure, cultivated land, pastureland, roads, railways and waterways.

3.3. Cartographic cross-referencing

Once the layer of sites has been created (cf. 3.1.) and the environmental datasets collected (cf. 3.2.), these two sets of data can be cross-mapped using GIS. The data will then be enhanced with simple indicators to quantify the presence of specific features within the sites.

3.3.1. Cross-referencing layers in GIS

Cross-mapping consists of creating a spatial and attribute intersection between the sites and the environmental datasets. Figure 11 illustrates the methodological diagram detailing the steps involved in this cross-referencing, along with explanations of the processing chains.

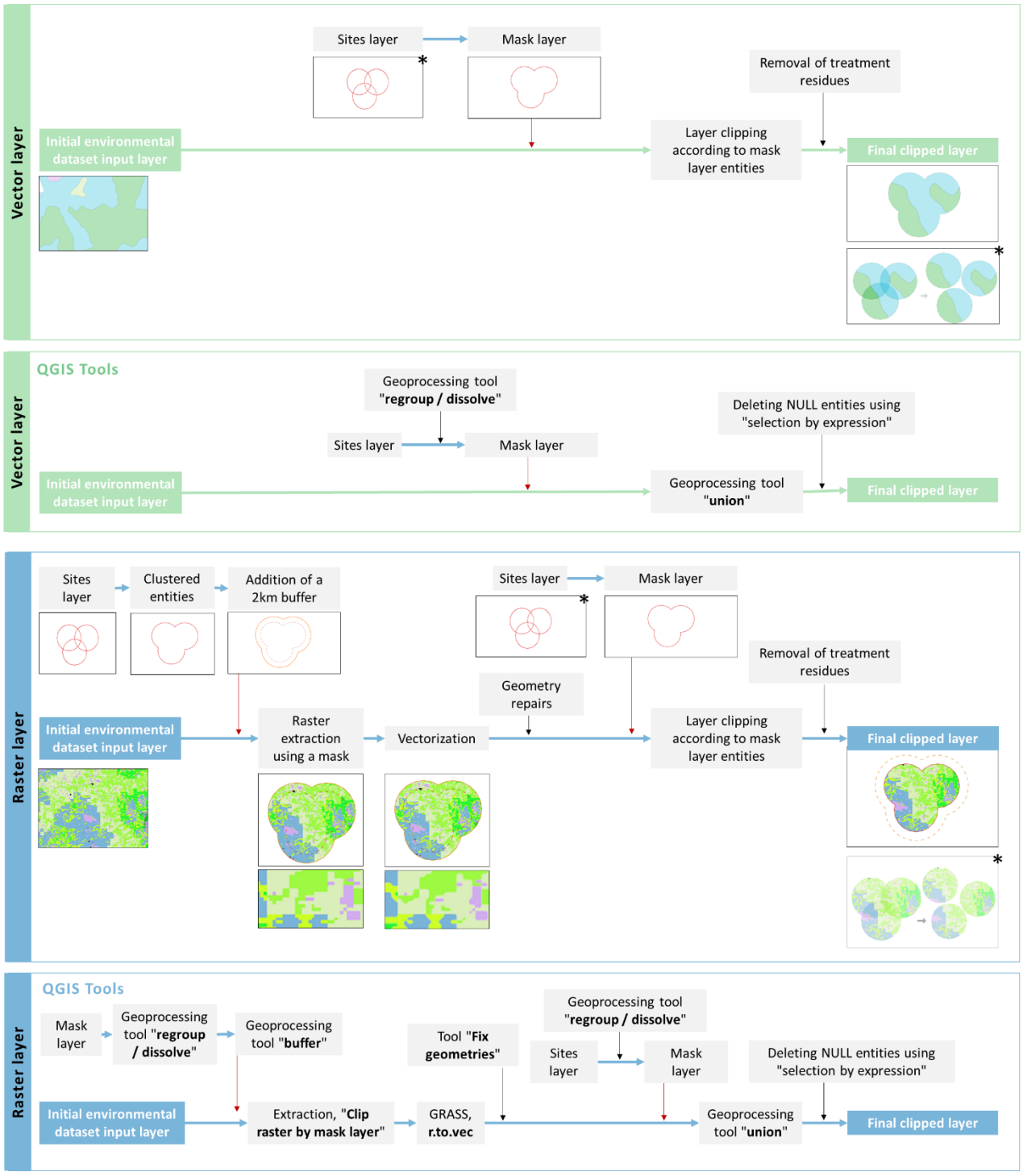


Figure 11. Cartographic cross-referencing processing chain and QGIS tools used

In Figure 11, the initial data layer refers to the downloadable raw data proposed by the method, and the mask layer refers to the layer of study areas previously created (sites layer with the 5km buffer). The raw data in the environmental datasets are GIS layers in vector or raster format. The processing of these two types of data differs slightly, so they are presented in two separate boxes.

Vector data

1. Each GIS layer in the environmental datasets is intersected with the mask layer. This clipping, carried out using the QGIS *union* tool, enables the data to be cross-referenced:
   - Spatially: subdivision of the data layer according to the study areas,
   - and at attribute level: the attribute tables of the "dataset" layer and the "mask" layer are cross-referenced and combined into one.

   As indicated at the end of section 3.1.2, the map intersection can be performed with the mask layer for individual study areas (Figure 10-A), or with the mask layer for grouped study areas (Figure 10-B). The first case is identified by an asterisk in Figure 11.

2. Following this geoprocessing, the layer needs to be cleaned up, because unwanted entities are contained in the layer, known as "processing residues". The *union* tool can be used to spatially separate entities present in one layer, in the other one, or in both at the same time. It is this last configuration that is sought in the context of cross-mapping: the entities that are part of the environmental dataset and that are included in the study areas.

   Entities located in either layer in isolation should therefore be deleted. In the attribute table of the newly created layer, these entities are identified by their content marked "*NULL*" (Figure 12). In order to remove these geoprocessing residues :
   - identify two fields linked respectively to each of the two original layers (dataset layer and mask layer)
   - select *NULL* entities using the field calculator : "field_name1" IS NULL
   - delete selection
   - then repeat the operation with "field_name2" IS NULL

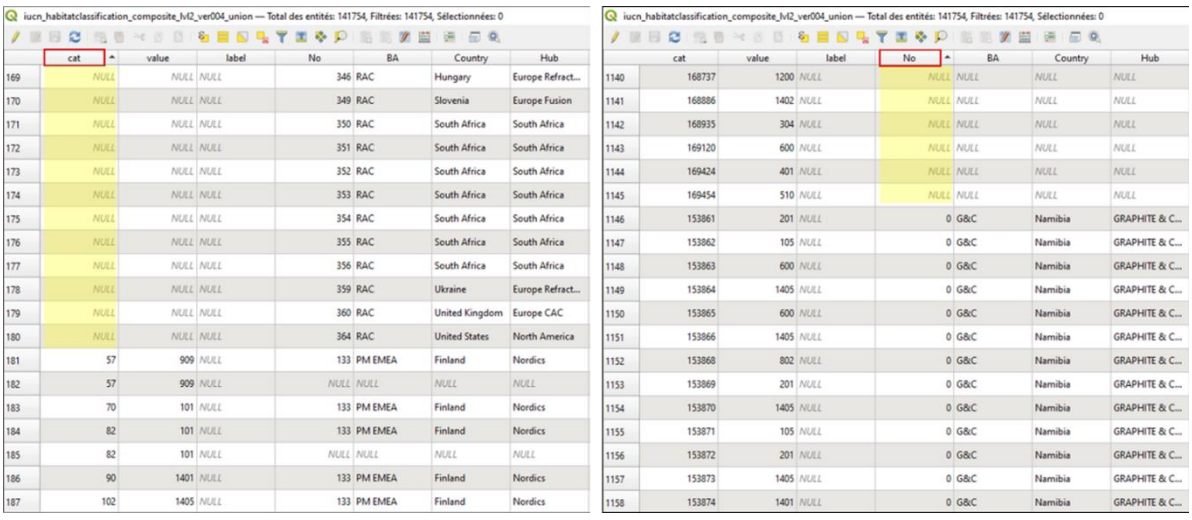


Figure 12. Deletion of "NULL" entities following "union" geoprocessing.
Example of an attribute table for a layer resulting from the union between a dataset layer and the mask layer.

The new data layer is now complete,
- representing the spatial entities of the dataset encompassed in the study areas,
- which includes environmental data in its attribute table, as well as identifiers and other information relating to the study areas.

Raster data

Raster data follows the same processing chain as that described above for vector data, but requires an additional preliminary step. This is the conversion of the raster format into a vector format, known as "vectorization". Vectorising raster data enables better data interoperability for the rest of the project: working with the same data format for all GIS data, cross-referencing GIS data, being able to edit data in terms of attributes and geometry, adding indicators, etc.

Vectorising a raster in GIS can be a fairly time-consuming task, especially for rasters with a global coverage. Therefore, it is best to clip the raster according to the mask layer first, then vectorize the extracted raster portions.

Cropping a raster requires two different mask layers: the initial mask layer and an enlarged mask layer with a 2 km buffer. The raster is first clipped according to the enlarged mask layer, then vectorized, and finally the vector layer obtained is clipped a second time according to the initial mask layer (Figure 13-B).

This method makes it possible to compensate for the edge effects associated with the pixel structure of the raster (Figure 13-A). The 2 km threshold was chosen considering the raster resolutions of the datasets processed as part of this method. As the highest resolutions are 1 km, opting for a margin of 2 km ensures that all the pixels in the study area are included when cropping.

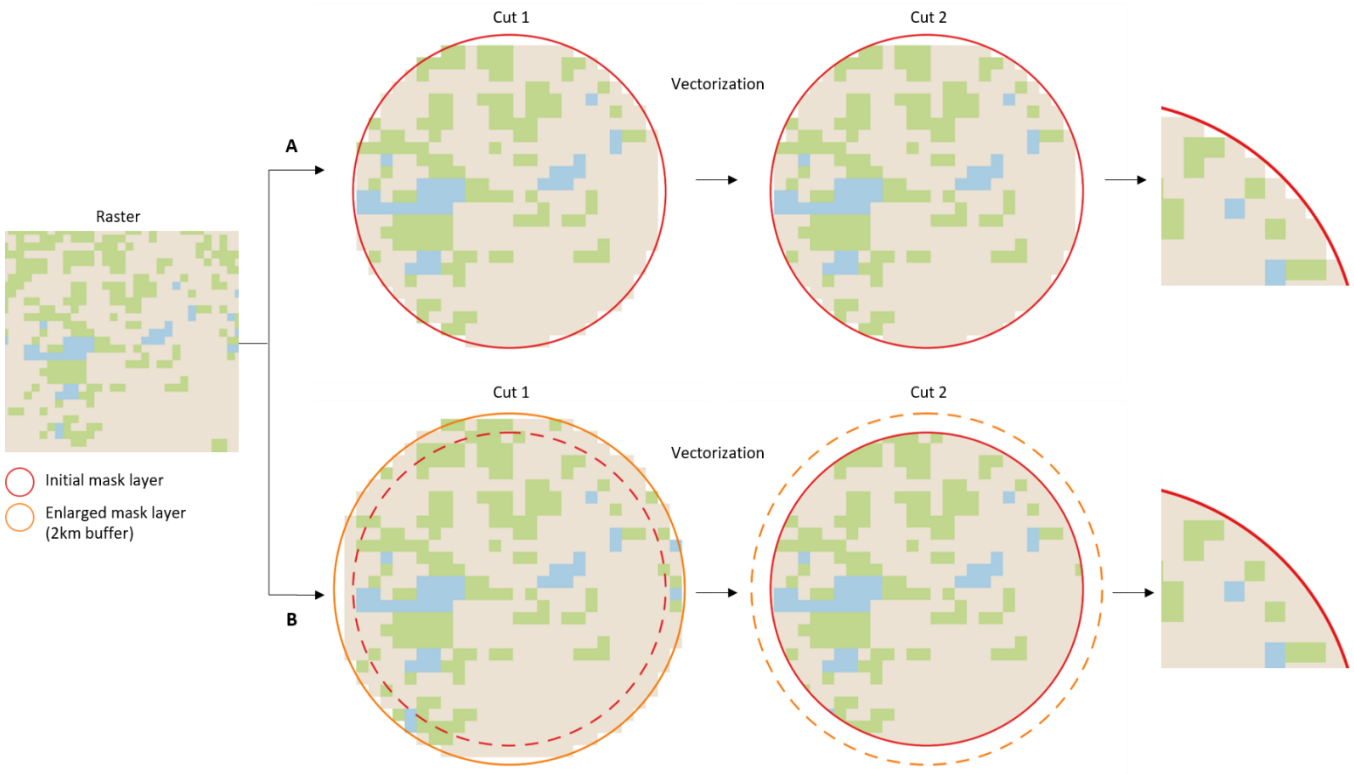


Figure 13. Comparison of raster clipping methods based on an initial mask layer (A) or an enlarged mask layer (B).

3.3.2. Adding indicators

Once the layers have been cross-referenced, the final stage involves adding indicators to the data layers obtained. The addition of these simple indicators makes it possible to quantify the representation of the environmental features within each study area. They can be metrics (surface area, length, etc.) or statistical figures (count, sum, average, etc.).

These indicators can be calculated using GIS, via the attribute table for each layer. Once the figures have been generated, they can be summarized and represented on the atlas's map sheets, through graphs in particular.

For each dataset, a suggested indicator is given in the sheets in Appendix 2.

For example, the layer of the World Database of Protected Areas (WDPA, from UNEP-WCMC and IUCN) can be used to identify and spatialize the protected areas within each study area. The relevant indicators can be a count of the number of protected areas included in the study area, as well as their respective surface areas. The surface areas can be represented in the form of a graph showing the sum of the proportions of surface area by level of protection (Figure 14).

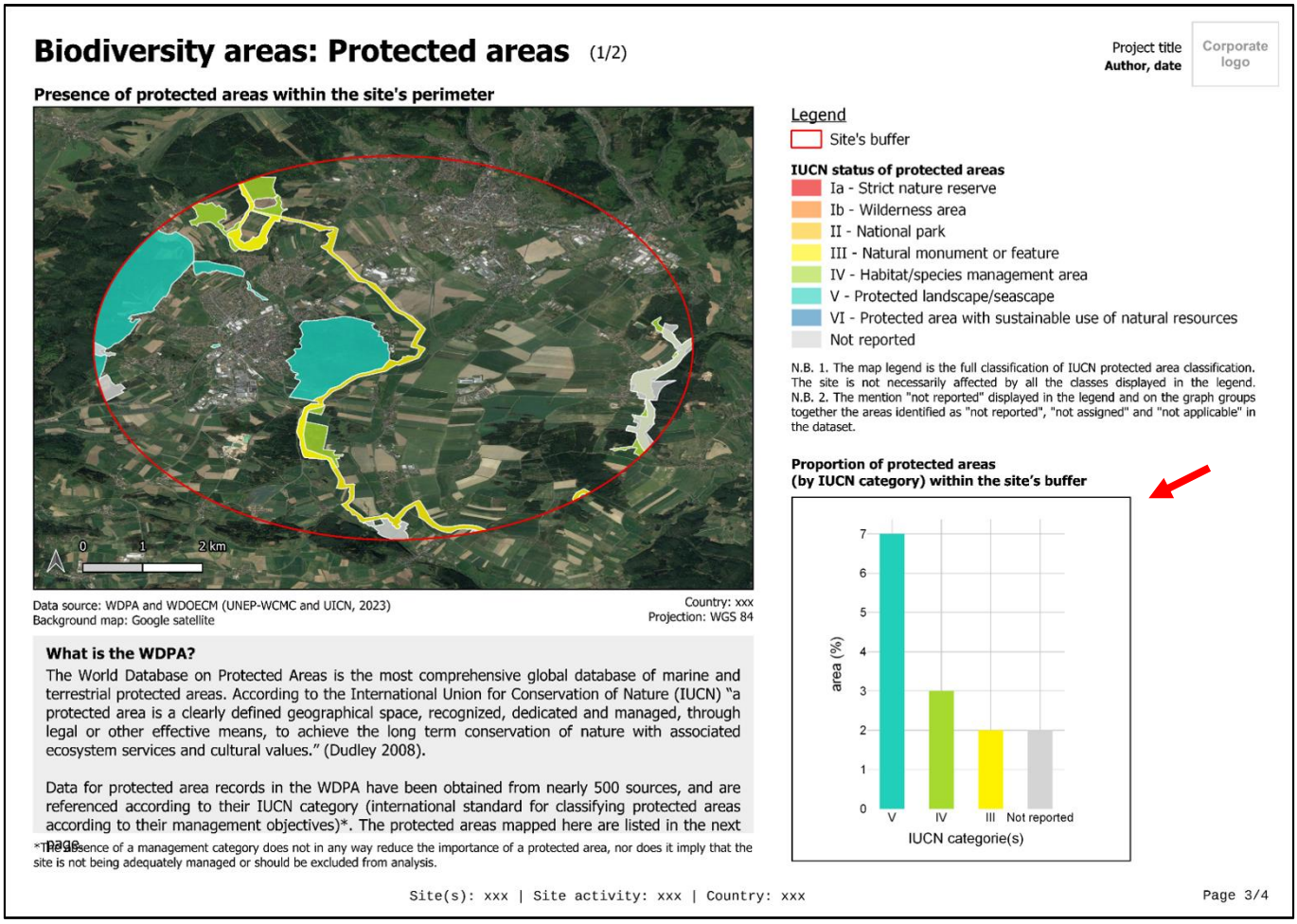


Figure 14. Example of how indicators from a dataset are represented on an atlas plate

This type of graph can be created using the QGIS Data Plotly extension , which can be used to generate different types of statistical graphs, integrated directly into the map sheets, and automated for all the sites using the QGIS "atlas" function (see section 4.1.2.).

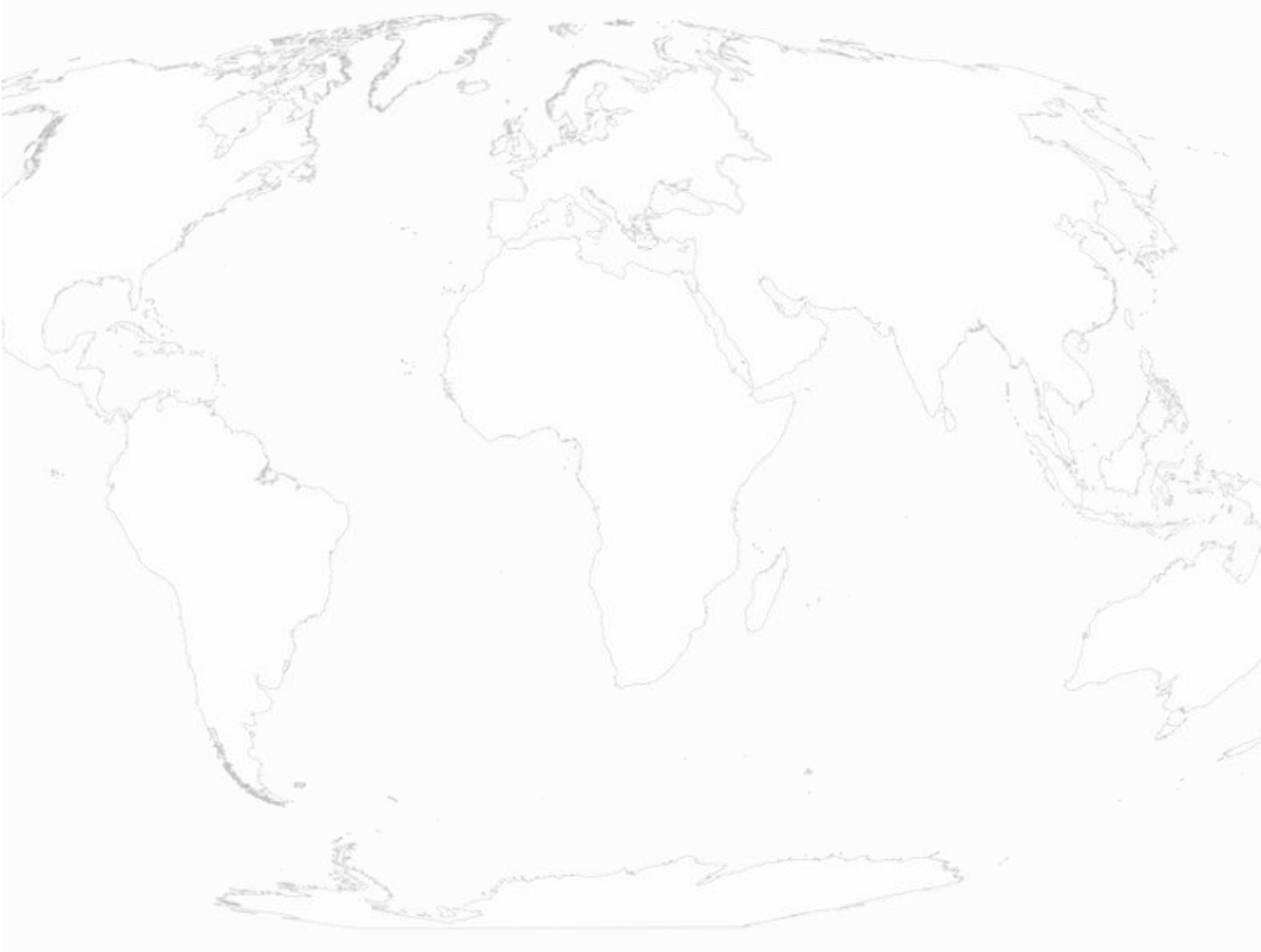
Mapped data

Recap

Cartographic cross-referencing is carried out in several stages:

- Definition of the **study sites and areas**, and creation of the corresponding GIS layers (circular buffers with a radius of **5 km**, i.e. 0.045° for the study areas layer).
- Collection of the **datasets** proposed by the method; and addition of other datasets as required.
- **Cartographic cross-referencing** using GIS.
- Addition of the desired **indicators.**

→ Throughout this cartographic work: refer to the **dataset sheets** (Appendix 2) to find out about their content, their purpose, the indicators to be associated, the processing to be carried out, the fields in the attribute table to be studied, and the limitations they entail.



4. Presentation of results: possible outputs

This mapping project has the dual advantage of providing, for the same amount of work, a local analysis, by study area, but also a global and synthetic overview, on the scale of all the study areas. This section presents the three main outputs that can be obtained from the cartographic cross-referencing.

4.1. Individual atlases

4.1.1. Presentation of the atlas format

The atlas is a visual tool designed to help the user discover the environmental heritage through a geographical approach, to make it easier to share data, and to carry out some analysis. The atlas is made up of a collection of cartographic plates representing the different geographical information in the datasets used.

As part of this methodological approach,

- A map sheet (plate) is an image illustrating a theme, i.e. a dataset (Figure 15);
- An atlas refers to all the map sheets for a study area. The atlas therefore comprises as many pages as there are datasets in the study area in question. As some sites do not intersect spatial entities for some datasets (i.e. a study area with no protected areas or no marine habitats of interest), their atlases will lack the geographical plates for these themes.

This format is well suited to cross-referencing maps, providing a complete overview of the characteristics of each study area, by theme. The purpose of the map sheets is to present the mapped data on the one hand, and to illustrate the summary results on the other. Below is a suggested configuration for a map sheet (Figure 15), with :

1. The map represents a set of data on a given study area, accompanied by the essential components: a title, a scale, an orientation, and the source of the mapped data.
2. The legend, adapted to the content of each map, depending on the study area.
3. A description of the dataset mapped (definition of the ecosystems or themes represented, information on the data acquisition method, interpretation, etc.).
4. A statistical representation for certain data sets (figure, key figure), to show a quantitative result of what is found in the study area (surface areas, surface proportions, number of elements).

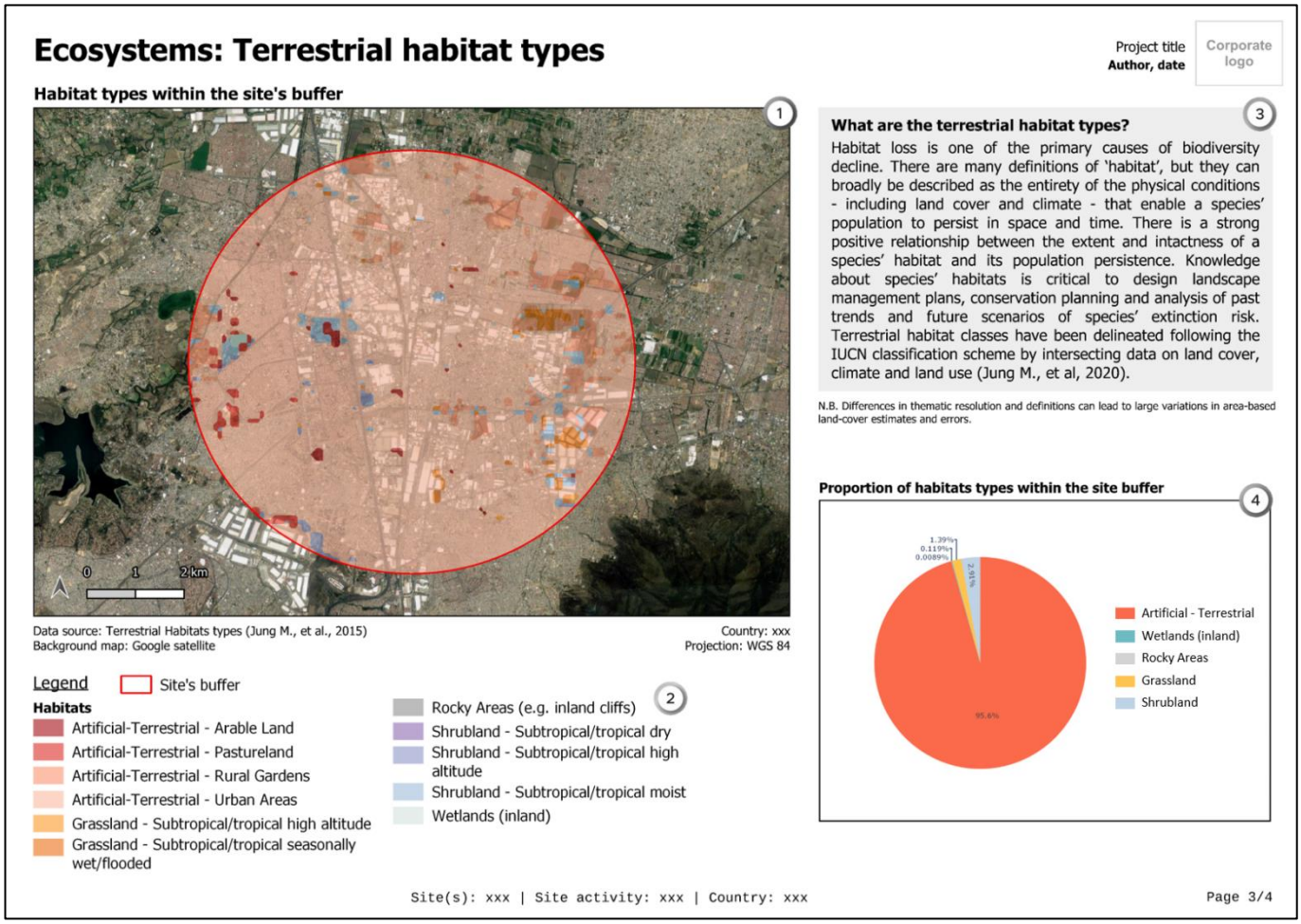


Figure 15. Typical composition of a map sheet

4.1.2. Mapping in QGIS

The map sheets can be produced one by one (in the case of a small group of sites to be analyzed) or their production can be automated, making it possible to create a large number of them quickly and easily, particularly in the case of a large number of sites to be analyzed.

The QGIS *atlas* tool can be used to create plate layout frames, and then to generate plates for each study area. With a good knowledge of the software, it is possible to make fairly precise and personalised settings. Figure 16 shows the steps involved in building an atlas in QGIS.

1. Create page layouts

QGIS Project ▸ Layout Manager ▸ Create

2. Activate *atlas* functionality

A page setup window opens Atlas ▸ Atlas stettings

3. Configure the atlas settings

A tab Atlas is added. Check Generate atlas

▸ Configuration ▸ Coverage layer:

Each feature in this layer will generate a map sheet.
Here, choose the study areas layer.

▸ Page name:

Name given to each map sheet.
Here, assign the names or unique identifiers of the study areas.

▸ Filter with:

This option allows you to filter the perimeters of the study area to be processed, and therefore the maps to be produced, or not. This filtering makes it possible to avoid generating map sheets for sites not intersected by a dataset, which represents a considerable saving of time when assembling the sheets subsequently. The information must first have been entered in the cover layer.

▸ Output ▸ Uncheck Single file export when possible

▸ Output file name expression:

Name of each file (map sheet) in output. In order to automate the naming and simplify file management subsequently, indicate the following name: "ID"||'.1'||'_name', with *ID :* the unique identifier of the site (table field attributor), .n° : the number of the theme, then *name :* the name of the theme.

Example of output file titles

1.1_marine
1.2_forest
2.1_marine
2.2_forest
3.1_marine
3.2_forest
...

▸ Check Single file export

▸ Image export format: png

4. Compose the layout of the map sheet

Addition of map, legend, scale, text box, graphics etc. For each element, in the tab Item properties make sure to check Controlled by atlas in order to link them to the atlas in a dynamic way.

5. Generate the maps

This button launches the production of the atlas. The map sheets of the theme in question are displayed, composed of dynamic content depending on the site displayed on the screen. The drop-down menu next to it allows you to view all the sites, and the side arrows allow you to move from one site to the next.

6. Export atlas

This button allows you to export all the generated maps at once. The plates can be exported in image or PDF format, in the same file or in separate files (see the atlas parameters Atlas ▸ Output)

Figure 16. Creating an atlas in QGIS

All the files generated for each thematic layout can be placed in the same folder. By naming the files beforehand, as shown in Figure 16, the plates are organized and grouped by study area, with the same order of thematic plates.

To sum up, producing an atlas involves: creating a layout by theme, then generating plates for each study area within each thematic layout, exporting all the plates by theme, and finally assembling them into an atlas (Figure 17).

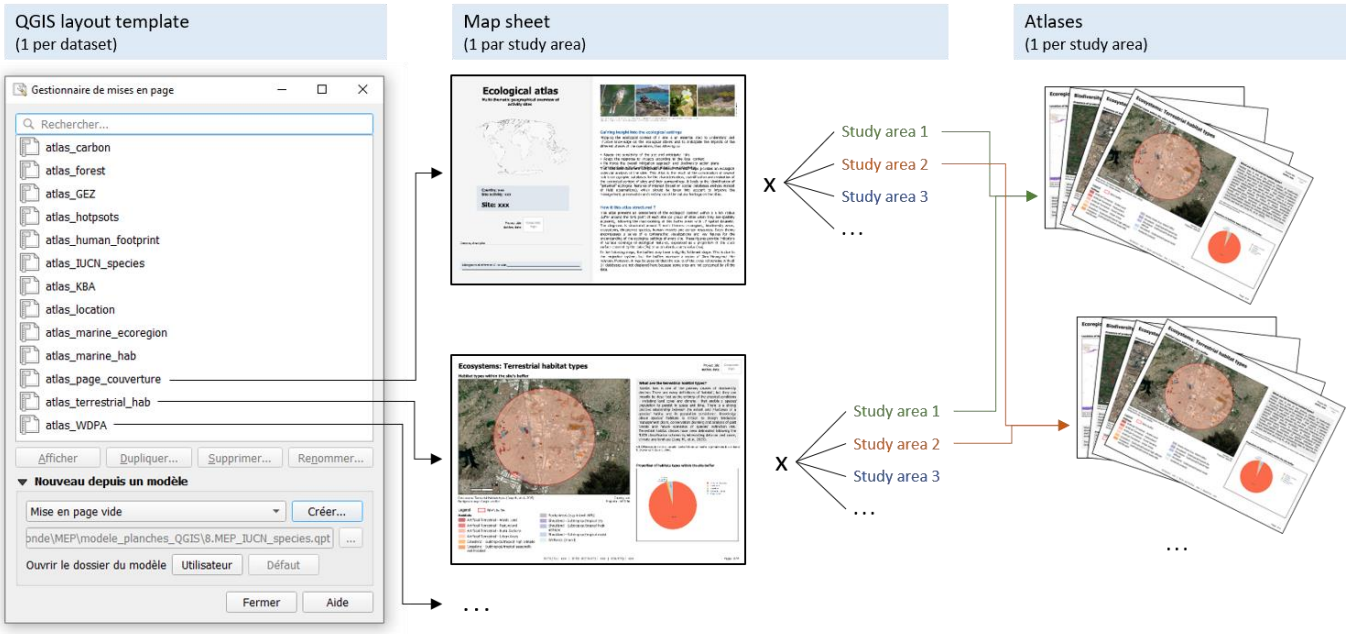


Figure 17. Map atlas composition

4.1.3. Assembling map sheets into an atlas

Once all the map sheets have been produced, they need to be assembled in a single document for each study area. This phase can also be facilitated or even automated by computer tools. Here is a suggestion of the steps to follow in compiling the atlases:

1. **Creating a presentation layout template**
   Create a blank document using presentation software such as Microsoft PowerPoint, which will contain the atlas map sheets. Include in this template any elements that are invariable for all the study areas and that will be common to all the atlases (i.e. a cover page, bibliography, table of dataset metadata, pagination, etc.). Provide a sufficient number of blank slides (the maximum number of plates to be included in the largest atlas, for example): this will make it easier to import the plates (step 4). Save and close the document.

2. **Duplicate the "template" document**
   Copy and paste the file you have created to obtain as many files as atlases you require.

3. **Renaming files**
   Rename all the files created with the names of the study areas. This can be done automatically using Excel and the additional tool Kutools for Excel, which must be installed. A tutorial on renaming a list of files contained in a folder using a spreadsheet program is available online[4] .

4. **Integrating and assembling the plates**
   This is the most time-consuming and repetitive stage, as it involves manually integrating the map sheets into the corresponding blank atlases. There are two possible options:
   - copy/paste the images (map sheets) one by one into each document ;

[4] Extend Office, https://www.extendoffice.com/documents/excel/2339-excel-rename-files-in-a-folder.html, consulted in September 2023.

- use PowerPoint's photo album function when creating the first document, in step 1. It will then be used to add images in batches to each atlas.

5. **Exporting atlases in PDF format**
   Finally, all the documents are converted to PDF format for distribution. When a large number of documents need to be converted, a quick and simple programming script can be used to automate the conversion. An example of an R-language script is provided in Appendix 3.

Appendix 4 shows examples of the map sheets produced as part of the methodological framework experiment.

4.2. A global atlas

A second type of document can be produced on the basis of the map cross-referencing: a general atlas, presenting a summary of the results for all the sites. This global atlas may include :

- A table summarizing all the datasets used and their metadata
- One page per thematic dataset, including :
  - The number of sites covered by the dataset (i.e. 5/100 or 90/100 sites).
  - A map showing the complete dataset and the location of the study sites overlaid on the dataset, to give a visual idea of the spatial overlap between the dataset and the sites.
  - A graph representing the distribution of the dataset or a summary of its content.
  - Some statistical indicators reflecting the parameters of the thematic data at the scale of all the sites, such as the average surface area of forest, the average number of protected areas, or the sum of threatened species in the study areas.
- This global atlas can also be an opportunity to reposition the project of cross-mapping, to clarify its interest, scope and purpose, as well as the limits associated with each dataset and with the exercise as a whole.

4.3. A spatial GIS database

As a result of this work, a large amount of raster and vector spatial data has been collected and created. These data layers can be integrated into the organization's GIS, in order to complete the technical land monitoring tool with data on the ecological context of the sites. The initial and complete data can be kept and possibly used for other projects, as well as the modified and clipped layers for the needs of this analysis can be archived and possibly reused to modify, improve or update the project.

As shown in the diagram of the general methodological approach (Figure 1), data processing results in several versions of the data, constituting different databases. The spatial data tree in Figure 18 shows the evolution of the datasets from their download in their raw state to their cross-referencing with the study areas and the grouping of adjacent buffers.

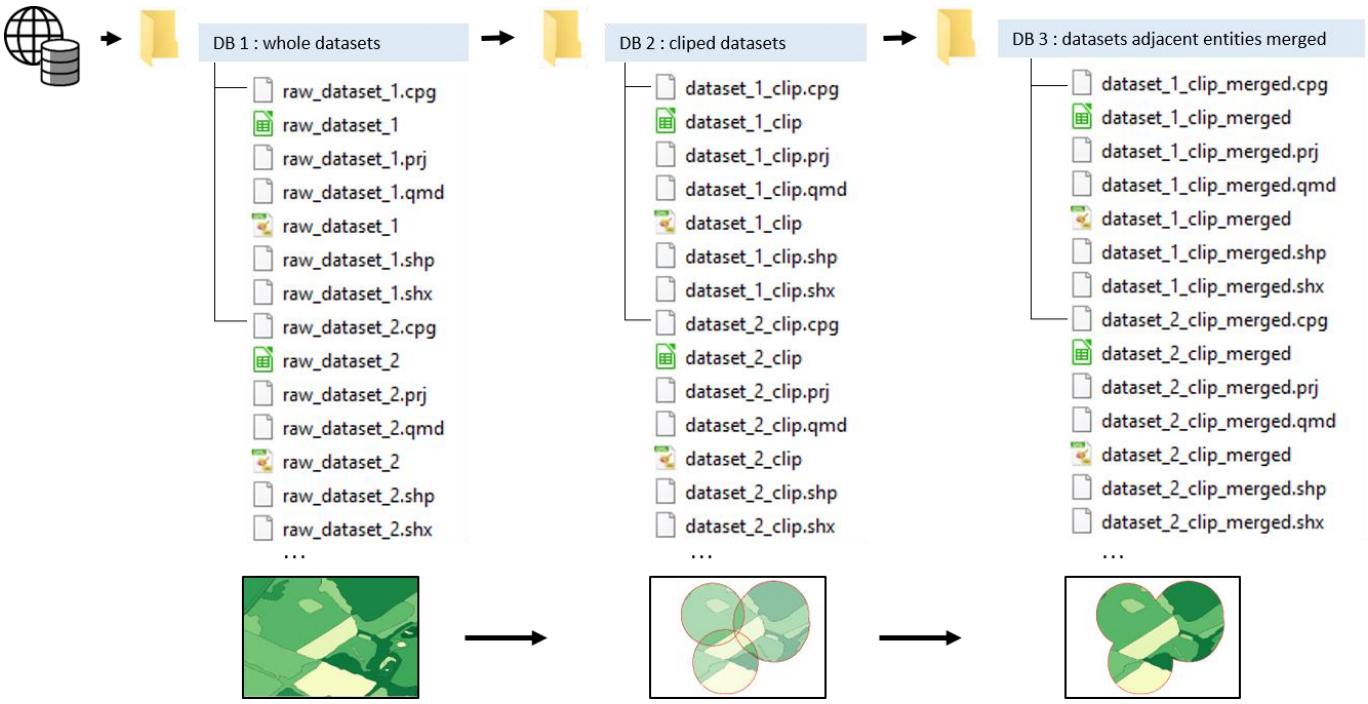


Figure 18. GIS tree: generated databases

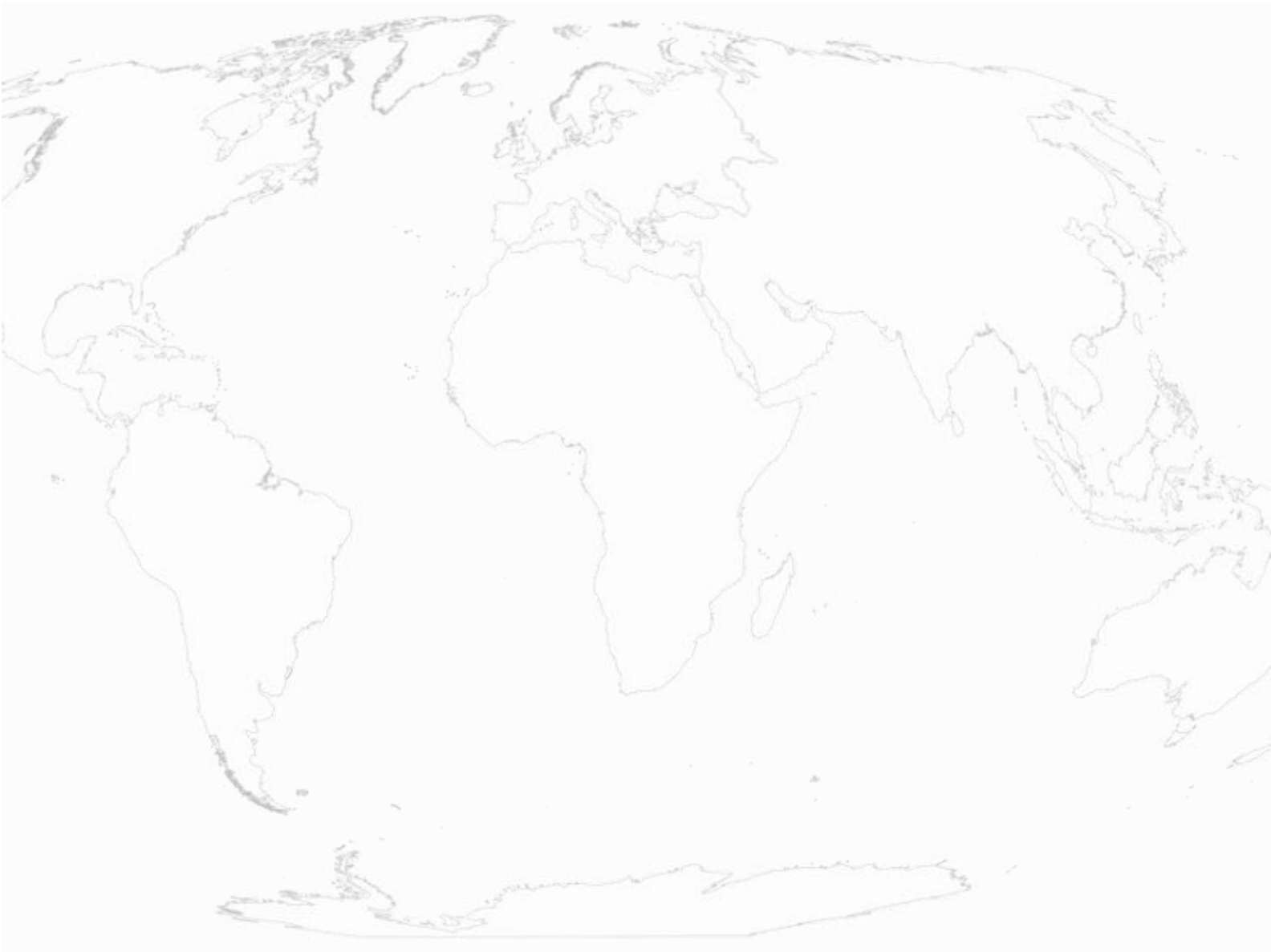
Presentation of results

Recap

The final deliverable best suited to this work is the **cartographic atlas**, accompanied by a few statistical parameters. Thanks to GIS processing, these results can easily be produced at 2 levels:

- **local**, at the scale of the study area, in order to have details of the ecological context by theme
- and **global**, at the level of all the sites, with global indicators making it possible to assess the environmental challenges at Group level.

In addition to these media for presenting data and results, a **GIS database** can be set up following the downloading and processing of data layers, and can integrate the organization's GIS.



5. Limits and perspectives

5.1. Limits and warning points

The method for mapping the ecological context of international sites presented in this document contains a number of methodological limitations, which are addressed in the following points and which should be taken into account when applying this method (both upstream and when communicating the results):

The method :

- This is a generic methodological framework using generalist datasets. This makes the method highly adaptable and transposable, with the advantage of being suitable for any study area and a wide variety of projects. On the other hand, it is precisely this standardized and generalist aspect of the method that needs to be taken into account when using it: the analysis it delivers remains de facto general, and does not necessarily take into account the uniqueness and specificities of each project for which it is used. To remedy this, a few points on the transposability and improvement of the method are raised in the next section (5.2. perspectives). In addition, it should be noted that this is a global method, using large-scale datasets to study sites on a very local scale. This means that care must be taken when interpreting the data, although particular attention was paid to the spatial resolution of the datasets during the data selection phase.
- Analysis of the ecological context of the study areas on the basis of publicly available datasets leads to the identification of ecological potential. The latter should not be confused with the real ecological issues within the sites (or the areas adjacent to the sites), which require the availability and integration of inventory data produced at local level (wildlife surveys or other studies on the sites and their surroundings).
- This identification of ecological potential makes it possible to define priority guidelines for preserving, restoring or managing certain ecological features within the sites, which can form the basis for drawing up a biodiversity action plan. However, these action plans need to be refined with recommendations that respond to the real ecological challenges of the site, which are identified using biodiversity inventories.
- The results of the mapping analysis for each site should not be compared with the results for another site. This methodological framework is therefore not intended to establish comparisons between the ecological context of the sites.

The datasets: although selected according to a rigorous approach and a desire for consistency, the datasets selected for this method remain heterogeneous in several respects: dates and methods of data acquisition, spatial resolutions, data producers, etc. Not all the datasets provide the same level of information, with the same reliability, and are therefore not comparable with each other.
These results therefore depend on the precision and finesse of these datasets. Depending on the dataset, there may be :

- Minor discrepancies between the perimeters of certain elements, which may lead to overestimates or underestimates of certain indicators.
- Some differences between the nature attributed to an object in a map layer and the reality on the ground, e.g. a sector noted with a land use mode that is not exactly that which is actually present on site (by mistake, by change, etc.).

Please refer to the "datasets" sheets for more details on the limits of each dataset (Appendix 2).

⚠ **Dataset licenses:** like many data sets available online, the datasets offered by this method are licensed for use and distribution. Licenses define the framework for reusing, modifying and sharing data. They may be free or restrictive. Of the 17 datasets selected, 10 are subject to restrictions on use (Table 3). It is essential to consult the conditions of use of these datasets before any manipulation. These licenses often state that commercial use of the

data is prohibited. Thus, no data presented in this document may be used commercially without the prior written authorization of the data producers.

Refer to the Bibliography to contact data producers if necessary.

Study areas :

- The correct operation of the cross-referencing and calculation tools depends on the correct structure and standardization of the data. The user must ensure that the GIS of the sites to be analyzed is properly formatted prior to any analysis.
- This methodological framework is applicable to groups of sites located on a global scale. For analyses of a group of sites on a supranational (a continent in particular) or even national or regional scale, other datasets and other methodological choices than those proposed in this document may prove more relevant.
- When creating the study area layer, the decision to merge the buffers of geographically adjacent sites may be questioned, as this operation prevents the production of results at the scale of each site (in the case where several sites are grouped together). For example, if study zones 1 and 2 form a large study zone 3, cartographic analyses will be produced for zone 3 only, and the results for zones 1 and 2 will not be accessible.

This document presents a prototype of the method which has undergone some testing, but which needs to be rolled out to other groups of sites in order to extend the tests to other contexts. Based on feedback from experience, this method may evolve, which would lead to changes in this version.

5.2. Perspectives

5.2.1. Transposing and adapting the methodological framework to other projects

- **Datasets:** as this method is intended to be applied to sites of various types, the group of datasets proposed can be modified and added to as required. In fact, the selection proposed in this method was based on the activity of a French industrial company operating sites on every continent. It is possible that other projects will require the mobilization of other datasets on other specific themes specific (data on birds or soils, for example), or, on the contrary, that datasets deemed unnecessary for the project (such as marine habitats, for example) will be discarded.

- **The projection and coordinate system (CRS) :**

  For sites concentrated in one (or a few) parts of the world

  Two methodological approaches to the CRS issue were discussed in section 2.3.3: a local solution and a global solution. For the purposes of this method, the global solution was deemed more relevant, but depending on the project, the local solution may prove more appropriate. This is particularly the case if the business sites being studied are concentrated in one geographical region of the world (or in a few different geographical regions), in which case it is possible to search for UTM zones and reproject feasible data layers. This choice depends on the geographical distribution of the sites, but also on the quantity of spatial data to be processed, the needs and purposes of the mapping, and the time and resources available.

  If you choose the global solution

  In the case of the global solution, the Mercator WGS 84 CRS has been recommended. However, depending on the project and the desired mapping objectives, other CRSs may be chosen (see the proposals in section 2.3.2.).

While the Mercator projection has the advantage of allowing a simple and easily transposable application of the methodological framework, other CRSs may be more appropriate for analyzing surfaces, in particular projections equivalent to conformal projections.

For sites at high latitudes

In particular, the Mercator projection needs to be changed if sites are located - or even concentrated - close to the poles, where this projection has the most shortcomings. While it is acceptable for projects covering equatorial, tropical and temperate latitudes, it becomes unsuitable for sub-polar and polar regions.

- **Study areas :**

The size of the buffers

The radius defined to form the study areas has been set at 5 km, in order to take into account the immediate environment of the sites, and to be able to put their ecological potential into a local context and limit edge effects. However, this distance can be adapted for each project, depending on the size of the initial site perimeters, the type and intensity of the activity carried out on these sites (notion of possible environmental impacts) and, once again, the mapping objectives.

Merging study areas

The grouping of adjacent study areas is proposed in cases where study areas overlap partially or even completely. However, this step can be bypassed if deemed unnecessary. As previously mentioned (section 5.1.), this will enable site-by-site results to be obtained instead of the results for the grouping of buffers.

5.2.2. Next steps

- **Updates:** the mapping of ecological potential can be updated over time, according to the needs and updates specific to each dataset. Updating the GIS project involves repeating the mapping cross-references and recalculating the metrics. This may involve updating the datasets proposed in this methodological framework, as well as adding new relevant datasets (or even replacing current datasets) that may emerge in the future. As far as layouts are concerned, if they are based on layout templates and produced automatically by the GIS software (which is possible with the "atlas" function in QGIS, for example), this stage will not require any additional work.

- **Dissemination:** the results of this mapping project are intended to be shared in order to raise awareness of the ecological stakes on the organization's landholdings. To ensure that the results are properly understood and communicated, it is important to consider how they will be disseminated. For example :
  - share maps and analysis using PDF documents ;
  - setting up a webinar to explain the approach and method, present the results and share ways of using the results to improve biodiversity management on land;
  - make the results available to the teams on an interactive display platform.

- In-depth study: as mentioned at the beginning of this document, this framework provides an initial knowledge base on the ecological context of a group of sites. It offers a general environmental overview and highlights, in part, the main ecological potential.
  In order to make more sense from a biodiversity point of view and to be anchored in a more local reality, it is recommended that this work be deepened and enriched by more detailed data on a local scale, with, for example, the mobilization of datasets with continental, or even national or regional, coverage. For the purposes of this generic method, only global datasets have been used, but other datasets may be added, as

long as they cover the entire area of distribution of the study areas, to obtain homogeneous results for all the sites.

Limits and perspectives

Recap

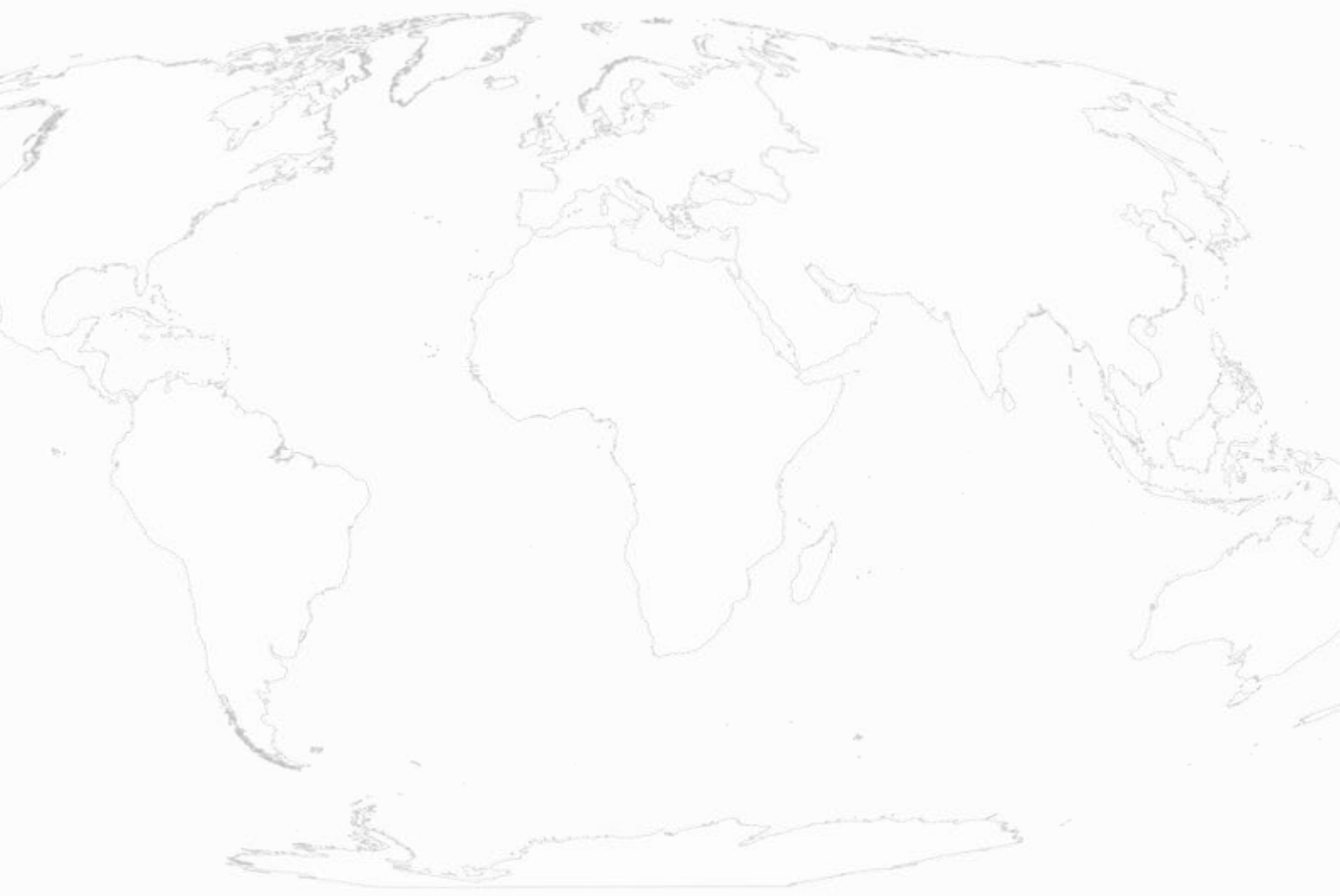
There are a number of points to bear in mind throughout the implementation of the methodological framework, as well as when disseminating the results:

- A **global method** for local application
- A **general-purpose method** for a wide range of application projects
- Heterogeneous **data sets**
- Restrictive **licenses** for the use of datasets
- The creation of simplified **study areas** and the non-comparison of results between sites

The method detailed in this document is intended to be generic and transposable. Thus, for a more specific and customized application, several parameters can be adapted:

- **Selecting the data sets** used for cross-mapping
- The relevant **CRS(s)** and method (local or global) for projecting the datasets
- The size and configuration of the **study areas**

The outputs can then be **disseminated** via various communication tools, **updated over** time, and **expanded** using more local data (if possible) to make the results even more precise and accurate.



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Venter O., Sanderson E.W., Magrach A., Allan J.R., Beher J., Jones K.R., Possingham H.P., Laurance W.F., Wood P., Fekete B.M., Levy M.A., Watson J.E.M., (2016). Global Human Footprint dataset. *Global terrestrial Human Footprint maps for 1993 and 2009*. Dryad, data link: https://doi.org/10.5061/dryad.052q5; visited on March 2023.

WWF, (2004). Global Lakes and Wetlands dataset. Paper link: https://www.sciencedirect.com/science/article/pii/S0022169404001404; data link: https://www.worldwildlife.org/pages/global-lakes-and-wetlands-database; visited on March 2023.

Appendices

Appendix 1: Multi-criteria table for data sets

Fields	Content	Example
Name	Dataset name	**Forest Landscape Integrity Index**
Producer/provider	Name of authors or name of the scientific structure	Grantham H.S., *et al.*
Prioritization	Ranking of the interest of the dataset for the project (from A: major interest, to D: minor interest or to be excluded)	A
Theme	Topic of the dataset	Forest. Score assigned to each forest pixel, from the lowest integrity (0) to the most intact (10).
Overview	Abstract of the dataset (content, method, etc.)	FLII corresponds to the global forest extent in 2000, with the addition of indicators of human pressure and alteration of forest connectivity. By combining these parameters, a score is assigned to each pixel, the FLII, on a scale from 0 (lowest integrity) to 10 (most intact).
Geographical extent	Region of the world covered by the dataset (country/continent/world)	World
Release date	Date of publication/update of the dataset or associated paper. Date indicated by the recommended bibliographic reference.	2020
Data date	Date of acquisition of the data contained in the GIS layer.	2000
Update and time reference	Information relating to the date of creation of the dataset and the announced frequency of its updates.	Not yet effective. "The index we provide here could be easily updated annually and utilized by nations as a way to report the state of their forests" (cf. paper)
Spatial resolution	Provides information about the spatial detail of the map (corresponds to the actual size of the smallest element represented in the dataset).	300 m
Coordinate reference system	Native coordinate system and map projection of the dataset	EPSG:4326 - WGS 84
Acquisition /production method	How the data is produced. **Production**: data created from scratch **Compilation**: gathering and collating existing data **Modification**: reworking/adapting existing data **Modelling**: data creation based on remote sensing products and automated learning	**Compilation and modification** Based on four data sets were combined representing: (i) forest extent (2019, Université de Maryland, Global Forest Change); (ii) 'observed' pressure from high impact, localized human activities for which spatial datasets exist, specifically: infrastructure, agriculture, and recent deforestation; (iii) 'inferred' pressure associated with edge effects, and other diffuse processes; iv) anthropogenic changes in forest connectivity due to forest loss.
Internet address	Internet link(s) presenting the dataset (website, scientific paper, viewer)	**Viewing:** https://www.forestlandscapeintegrity.com/ **Article:** https://www.nature.com/articles/s41467-020-19493-3
Accessibility	Link to the dataset download platform (if different from the previous field)	**Downloading:** https://www.forestlandscapeintegrity.com/download-data
Guide/user manual/metadata	Availability of a user guide and metadata documents, and links to access them	**Yes**. https://www.nature.com/articles/s41467-020-19493-3
Licence	Licence and constraints on the use/dissemination of the data as stated by the producer/supplier of the data	Attribution 4.0 International (CC BY 4.0). "You are free to: share (copy and redistribute the material in any medium or format) and adapt (remix, transform, and build upon the material for any purpose, even commercially)
Avantages	Identification of the particular advantages of the dataset for the work	/
Limits	Identification of the limitations, defects and constraints of the dataset for the work	Small Google Form to fill out to access the data Drive (surname, first name, institution, email)
Note	Free comment space	/
Indicator	Relevant indicator for qualifying/quantifying data in the context of cross-mapping. Can be used for analysis.	Area (ha)
Quotation	Citation of the dataset and/or associated scientific paper recommended by the data producer/provider	Grantham, H.S., Duncan, A., Evans, T.D. et al. Anthropogenic modification of forests means only 40% of remaining forests have high ecosystem integrity. Nat Commun 11, 5978 (2020). https://doi.org/10.1038/s41467-020-19493-3
Type	GIS data type (vector, raster)	Raster
Format	Data format (TIF, shp, gpkg, etc.)	TIF
File, download, processing	Configuration of the dataset (several layers for example), indication on the file sizes, comments on downloading (difficult, long, heavy, or not), and any processing required to be able to read/use it	/
Data collecting	Procurement status (downloaded or not)	Downloaded
Use/processing	Processing and modifications applied to the parent data (especially GIS processing)	Extraction of data (clipped according to study area perimeters)

Appendix 2: Dataset sheets

Mapping user guide annexes

Global mapping of ecological potential
Database identity sheets

Dataset	Global Ecological Zones

Description

The Global Ecological Zones (GEZ) recognize **19 ecological zones**, which refer to the **main large-scale biomes**, based on **climate and vegetation**, similar to the Köppen-Trewartha climatic groups. The GEZ classification and maps categorize FAO (Food and Agriculture Organization of the United Nations) forest statistics into broad forest types, gathered in five major domains : tropical, subtropical, temperate, boreal, and polar. An Ecological Zone is defined as "*a zone or area with broad yet relatively homogeneous natural vegetation formations, similar (not necessarily identical) in physiognomy*" (Rakonczay Z., 2002).

The GEZ were obtained by compiling several datasets, whose sources by continent can be found in the FAO report (FAO FOM Forestry Department, 2013).

Producer/supplier	FAO FOM Forestry Department
Theme	Ecoregions
Data date and update	2010, no update announced
Spatial resolution	From 1:15 000 000 to 1:1 500 000
Projection	Mercator WGS 84 (EPSG:4326)
Method	Compilation & modification
Manual/metadata	Yes
Format	Vector (shapefile)
Accessibility	Free and downloadable
Licence	Commercial use prohibited
Internet link	https://data.apps.fao.org/map/catalog

Limitations

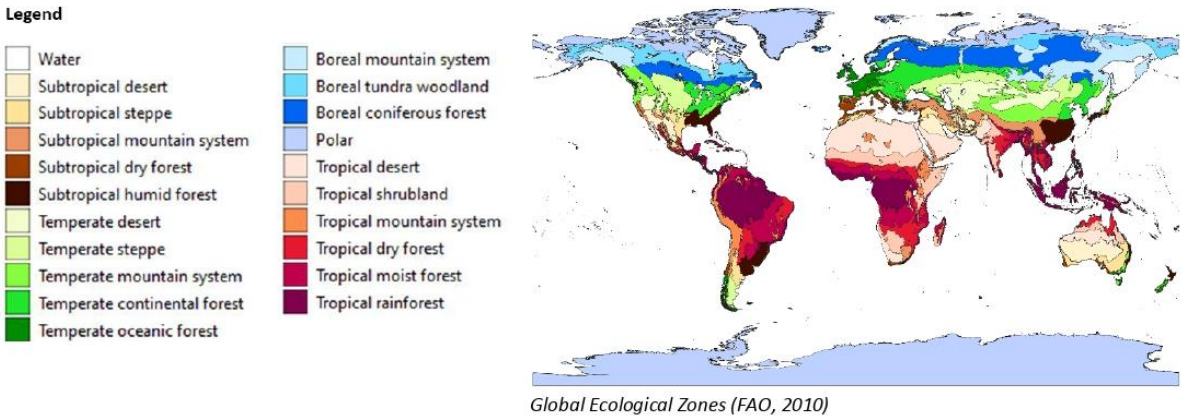
The GEZ classification is a **general typology,** which doesn't take into account all aspects of the local climate and vegetation. It is therefore advisable to supplement the analysis with other sources specific to the region under study, such as local meteorological data or regional climatic zoning.

Analysis

The data layer only provides the names and geographical extent of the GEZs. The FAO report provides additional information, such as the **GEZ criteria**, which are equivalent to Köppen-Trewartha Climatic groups and types, in combination with vegetation physiognomy and one orographic zone within each domain. Recognizing the ecological zone of a site helps to understand the major climatic and ecological trends in which it fits.

- **Biodiversity**. Climate has a direct influence on the biodiversity of a site. By grasping the climatic conditions, it can be possible to interpret local ecosystems, the species that live there and the threats they face.
- **Climate change**. Understanding a site's climate helps to anticipate and adapt to climate change (implementing conservation measures that take into account the challenges related to variations in temperature, rainfall, wind, etc).

For each study area, simply **identify the GEZ** to which it belongs, and refer to the descriptions in the article to



Global Ecological Zones (FAO, 2010)

Dataset **Marine Ecoregions**

Description

This dataset from the Ocean database combines two separately published datasets: the "Marine Ecoregions Of the World" (MEOW) and the "Pelagic Provinces Of the World" (PPOW). For the purposes of this study, only MEOW data are used, as they relate to marine waters close to continents. Indeed, the regions aim to capture generic patterns of biodiversity across habitats and taxa, with regions extending from the coast (intertidal zone) to the 200 m depth contour. The classification was partly derived from existing classifications.

The MEOW dataset shows a biogeographic classification of the world's coastal and continental shelf waters, following a nested hierarchy of realms, provinces and ecoregions. It describes 232 ecoregions, which lie within 62 provinces and 12 large realms (see list on the next page).

Producer/supplier	The Nature Conservancy
Theme	Ecoregions
Data date and update	2012, no update announced
Spatial resolution	Not defined
Projection	Mercator WGS 84 (EPSG:4326)
Method	Production & compilation
Manual/metadata	Yes
Format	Vector (shapefile)
Accessibility	Free and downloadable
Internet link	https://data.unep-wcmc.org/datasets/38

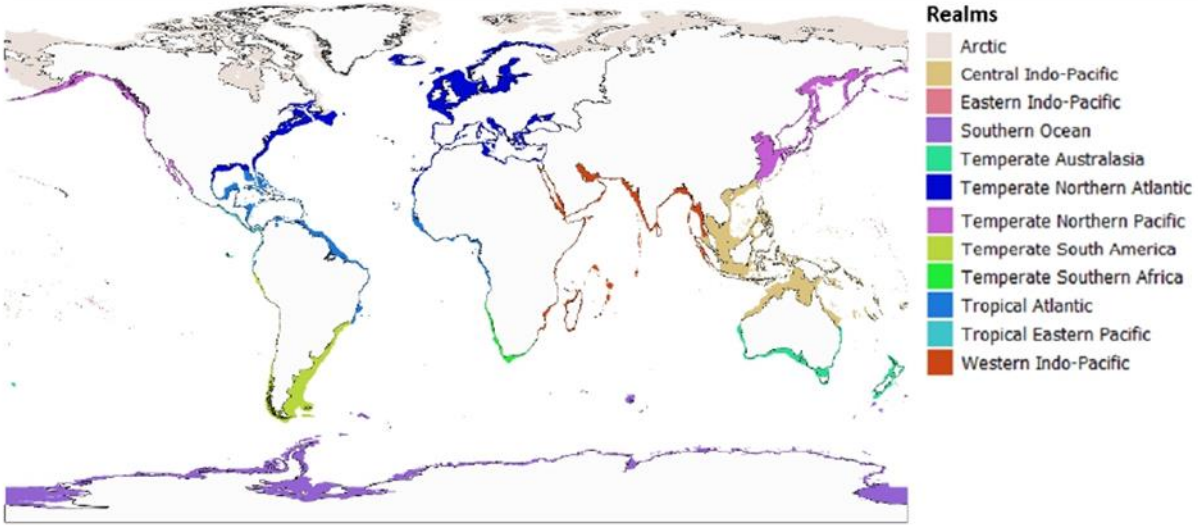
Analysis

This dataset complets the Global Ecological Zones (GEZ dataset), in order to also characterize coastal sites in terms of the global biogeographic context and the ecological patterns. For each study area, simply **identify the marine ecoregion** to which it belongs.

Geographic information fields

In the vector layer "ECOREGION", "REALM" and "PROVINCE" fields describe each marine ecoregion.

- A realm is the broadest level of classification in the MEOW dataset. Realms represent large and distinct oceanographic regions based on factors such as ocean temperature, salinity, and productivity.
- Provinces are the next level of classification, providing a more detailed subdivision within each realm. Provinces are based on additional factors such as biogeography, species composition, and oceanographic features.
- Ecoregions are the finest level of classification. Ecoregions represent distinct ecological units within provinces, characterized by specific species compositions and ecological processes.



Marine Ecoregions (MEOW) (The Nature Conservancy, 2012)

Realms and provinces	Number of ecoregions
Arctic	**19**
Arctic	19
Central Indo-Pacific	**40**
Eastern Coral Triangle	4
Java Transitional	2
Lord Howe and Norfolk Islands	1
Northeast Australian Shelf	2
Northwest Australian Shelf	2
Sahul Shelf	4
South China Sea	3
South Kuroshio	1
Sunda Shelf	4
Tropical Northwestern Pacific	4
Tropical Southwestern Pacific	5
Western Coral Triangle	8
Eastern Indo-Pacific	**12**
Central Polynesia	3
Easter Island	1
Hawaii	1
Marquesas	1
Marshall, Gilbert and Ellis Islands	2
Southeast Polynesia	4
Southern Ocean	**21**
Continental High Antarctic	6
Scotia Sea	5
Subantarctic Islands	7
Subantarctic New Zealand	3
Temperate Australasia	**17**
East Central Australian Shelf	2
Northern New Zealand	3
Southeast Australian Shelf	3
Southern New Zealand	4
Southwest Australian Shelf	3
West Central Australian Shelf	2
Temperate Northern Atlantic	**25**
Black Sea	1
Cold Temperate Northwest Atlantic	5
Lusitanian	3
Mediterranean Sea	7
Northern European Seas	7
Warm Temperate Northwest Atlantic	2
Temperate Northern Pacific	**17**
Cold Temperate Northeast Pacific	6
Cold Temperate Northwest Pacific	6
Warm Temperate Northeast Pacific	3
Warm Temperate Northwest Pacific	2
Temperate South America	**15**
Juan Fernandez and Desventuradas	1
Magellanic	5
Tristan Gough	1
Warm Temperate Southeastern Pacific	4
Warm Temperate Southwestern Atlantic	4
Temperate Southern Africa	**5**
Agulhas	2
Amsterdam-St Paul	1
Benguela	2
Tropical Atlantic	**25**
Gulf of Guinea	6
North Brazil Shelf	2
St. Helena and Ascension Islands	1
Tropical Northwestern Atlantic	9
Tropical Southwestern Atlantic	5
West African Transition	2
Tropical Eastern Pacific	**11**
Galapagos	3
Tropical East Pacific	8
Western Indo-Pacific	**25**
Andaman	3
Bay of Bengal	2
Central Indian Ocean Islands	2
Red Sea and Gulf of Aden	3
Somali/Arabian	4
West and South Indian Shelf	2
Western Indian Ocean	9

Dataset **Biodiversity Hotspots**

Description

Biodiversity hotspots are regions characterized both by exceptional levels of plant endemism and serious levels of habitat loss. These are Earth's most biologically rich - yet threatened - terrestrial regions. To qualify as a biodiversity hotspot, an area must meet two strict criteria (CEPF, 2023):

- Contain at least 1,500 species of vascular plants found nowhere else on Earth (known as "endemic" species).
- Have lost at least 70 percent of its original surface area.

The definition of these hotspots makes it possible to identify the major regions of the world where biodiversity issues are particularly high, and in fact where conservation action is a priority.

Producer/supplier	Hoffman, M. *et al.*
Theme	Biodiversity areas
Data date and update	2016, no update announced
Spatial resolution	Not defined
Projection	Mercator WGS 84 (EPSG:4326)
Method	Production
Manual/metadata	Yes
Format	Vector (shapefile)
Accessibility	Free and downloadable
Licence	Unrestricted use (CC BY 4.0)
Internet link	https://zenodo.org/record/3261807#.YTD8_I4zaUn

Developed in 1988 at the University of Oxford by Normand Myers' team, the concept of biodiversity hotspots was then taken up by the NGO Conservation International (CI), which expanded its outlines and popularized it for funders (Geoconfluences, 2023). Thus, the Critical Ecosystem Partnership Fund (CEPF) is today the conservation funder for 25 of the 36 hotspots (see list on next page).

Analysis

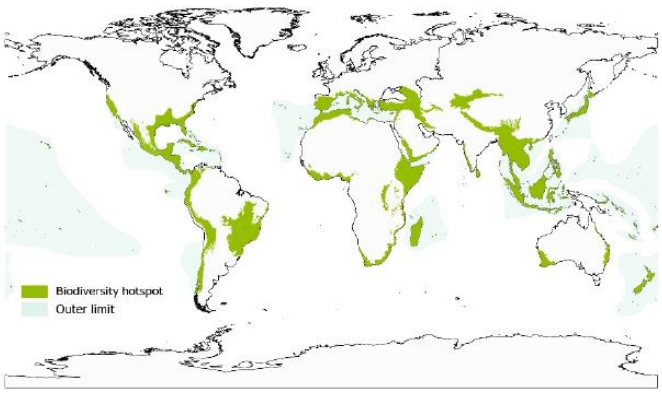
The vector layer consists of 2 types of entities:

- the "hotspot areas": they refer to the 36 official biodiversity hotspots, and
- the "outer limits": correspond to the geographical extension of these official areas, in order to include the insular environment in the biodiversity hotspot they belong to.

This dataset is used to identify which study areas are located within a biodiversity hotspot, thus areas very likely to host important biodiversity levels that need to be preferentially preserved, managed and restored or with particularly strong global environmental issues. For each study area concerned by the dataset, **identify the intersected biodiversity hotspot** and refer to the descriptions on the website to identify local biodiversity, the history of the area, the links between biodiversity and human societies, or planned management objectives (https://www.cepf.net/node/1996).

Limitations

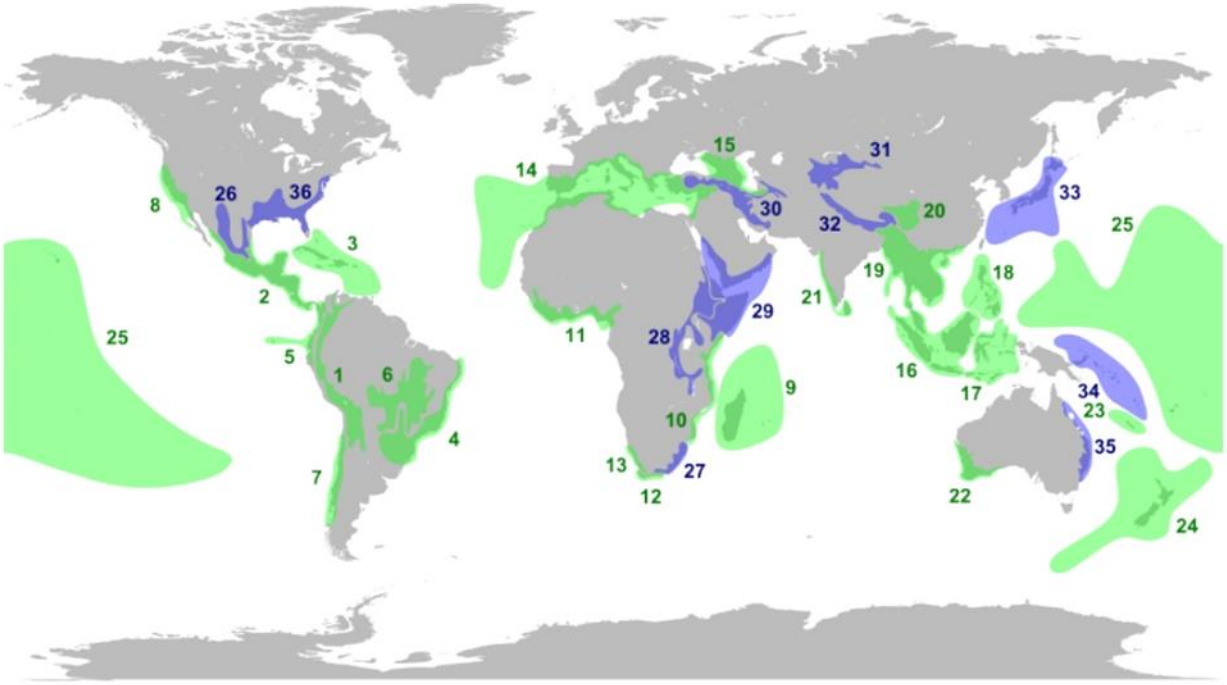
These zoning allows to identify major areas of global interest. In fact, there are a multitude of **other locations** not identified by this mapping where biodiversity issues are also very high (because criteria or scale of analysis are different for example). Thus, the fact that a site is not located in a global biodiversity hotspot does not mean that it is not linked to a rich biodiversity or a strong threat, or that it holds a reduced environmental interest.



Biodiversity Hotspots (Hoffman, M. et al., 2016)

List of 36 Biodiversity Hotspots:

1. The Tropical Andes
2. Mesoamerica
3. The Caribbean Islands
4. The Atlantic Forest
5. Tumbes-Chocó-Magdalena
6. The Cerrado
7. Chilean Winter Rainfall-Valdivian Forests
8. The California Floristic Province
9. Madagascar and the Indian Ocean Islands
10. The Coastal Forests of Eastern Africa
11. The Guinean Forests of West Africa
12. The Cape Floristic Region
13. The Succulent Karoo
14. The Mediterranean Basin
15. The Caucasus
16. Sundaland
17. Wallacea
18. The Philippines
19. Indo-Burma
20. The Mountains of Southwest China
21. Western Ghats and Sri Lanka
22. Southwest Australia
23. New Caledonia
24. New Zealand
25. Polynesia and Micronesia
26. The Madrean Pine-Oak Woodlands
27. Maputaland-Pondoland-Albany
28. The Eastern Afromontane
29. The Horn of Africa
30. The Irano-Anatolian
31. The Mountains of Central Asia
32. Eastern Himalaya
33. Japan
34. East Melanesian Islands
35. The Forests of East Australia
36. North American Coastal Plain



Dataset

WDPA: Word Database On Protected Areas

Description

The World Database on Protected Areas (WDPA) is the most comprehensive global database of marine and terrestrial protected areas.

According to the International Union for Conservation of Nature (IUCN) "a protected area is a clearly defined geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the **long-term conservation of nature** with associated **ecosystem services and cultural values**." (Dudley 2008)

Data for protected area (PA) records in the WDPA have been obtained from nearly 500 sources, and are referenced according to their **IUCN management category** (international standard levels of nature protection for classifying protected areas, more or less restrictive in terms of regulations, according to their management objectives).

Producer/supplier	UNEP-WCMC (ONU) and IUCN
Theme	Biodiversity areas
Data date and update	2023, monthly update
Spatial resolution	Variable*
Projection	Mercator WGS 84 (EPSG:4326)
Method	Compilation
Manual/metadata	Yes
Format	Vector (shapefile)
Accessibility	Free and downloadable
Internet link	https://www.protectedplanet.net/en

Preliminary treatments

The WDPA data is delivered in 3 separate vector layers. The data in these layers can be extracted according to the study areas and then merged to form a single layer.

**The data in the WDPA database come from a wide range of sources, often using different scales and techniques to generate their data.*

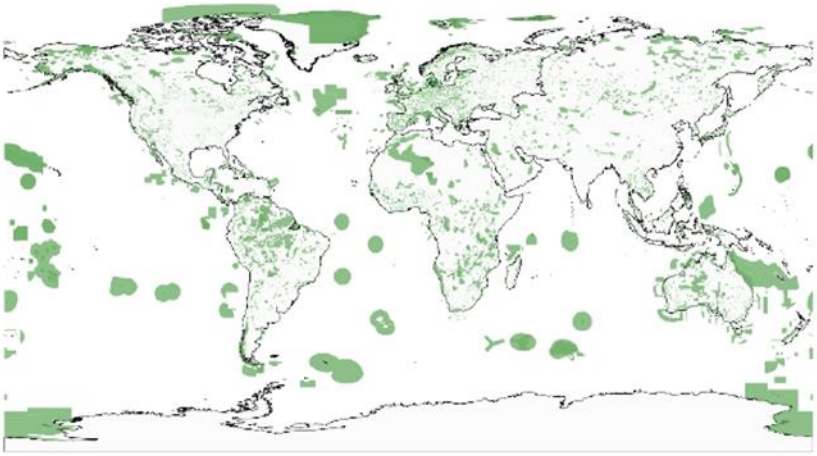
Analysis and indicator

WDPA dataset makes it possible to identify the geographic limits and the number of protected areas within the study zone, where special attention should be paid to avoid impacts or to reinforce synergic management within the site and the PA.

There are several parameters to characterise a site in terms of protected areas: the **number of protected areas** it contains, the **total surface/proportion** of protected areas, the **IUCN categories**(to assess the degree of protection and regulation of the area), the management authority (potential partner to improve management objectives within sites). This baseline information allows to identify no-go areas or restoration opportunities aligned with surrounding PA objectives.

Geographic information fields

- ORIG_NAME: name of the PA submitted by data provider in the original language.
- DESIG_TYPE: PA type designation
- DESIG_ENG: PA type designation, in english
- MANG_AUTH: person or group managing the PA.
- IUCN_CAT: IUCN PA level category
- area_ha: PA surface area within the study zone (indicator to be added)



WDPA and WDOECM (UNEP-WCMC and IUCN, 2023)

Limitations

- Although very complete and regularly updated, this dataset may omit some zoning. It may be useful to cross-reference and complete it with **more local databases on PA**.
- Some PA may lack certain information (IUCN category, management authority, etc.)
- The data providers in this dataset represent a wide range of stakeholders: environmental professionals, institutions, associations, etc. Thus, the spatial resolution and updating of the data may be **quite disparate** from one PA to another.

IUCN Management Categories

Category	Definition of Management Objective
Category Ia Strict Nature Reserve	Strictly protected areas set aside to protect biodiversity and also possibly geological or landform features, where human visitation, use and impacts are strictly controlled and limited to ensure protection of the conservation values. Such protected areas can serve as indispensable reference areas for scientific research and monitoring.
Category Ib Wilderness Area	Protected areas are usually large unmodified or slightly modified areas, retaining their natural character and influence, without permanent or significant human habitation, which are protected and managed so as to preserve their natural condition.
Category II National Park	Protected areas are large natural or near natural areas set aside to protect large-scale ecological processes, along with the complement of species and ecosystems characteristic of the area, which also provide a foundation for environmentally and culturally compatible spiritual, scientific, educational, recreational and visitor opportunities.
Category III Natural Monument/ Feature	Protected areas are set aside to protect a specific natural monument, which can be a landform, sea mount, submarine cavern, geological feature such as a cave or even a living feature such as an ancient grove. They are generally quite small protected areas and often have high visitor value.
Category IV Habitat/Species Management Area	Protected areas aim to protect particular species or habitats and management reflects this priority. Many category IV protected areas will need regular, active interventions to address the requirements of particular species or to maintain habitats, but this is not a requirement of the category.
Category V Protected Landscape/Seascape	A protected area where the interaction of people and nature over time has produced an area of distinct character with significant ecological, biological, cultural and scenic value: and where safeguarding the integrity of this interaction is vital to protecting and sustaining the area and its associated nature conservation/ other values.
Category VI Protected Area with Sustainable Use of Nature Resources	Protected areas conserve ecosystems and habitats, together with associated cultural values and traditional natural resource management systems. They are generally large, with most of the area in a natural condition, where a proportion is under sustainable natural resource management and where low-level non-industrial use of natural resources compatible with nature conservation is seen as one of the main aims of the area.

Dataset	**KBA: Key Biodiversity Area**

Description

The Key Biodiversity Areas (KBA) are the most important places in the world for species and their habitats, based on elements of biodiversity across genetic, species and ecosystem levels. KBAs have outstanding ecological integrity, globally important ecosystems or significant populations of animals, fungi and plants. The conservation of KBAs help safeguard the most critical zones for nature.

KBA compiles several datasets: Important Bird and Biodiversity Areas (IBA), Alliance for Zero Extinction sites (AZE), Important Fungus Areas, Important Plant Areas, Prime Butterfly Areas. Among these data, sites qualify as global KBAs if they meet one or more of 11 criteria, clustered into five higher level categories (table).

KBAs are recognised by the International Finance Corporation *Performance Standard 6* and by the Equator Principles as likely Critical Habitat. The *Banks and Biodiversity* coalition recognise KBAs as No-Go areas under their policy area 3. Several banks have developed their own safeguarding standards that recognise KBAs as critical habitat or no-go areas ».
For more information on the links between the private sector and KBAs, see: https://portals.iucn.org/library/node/47660

Producer/supplier	BirdLife International
Theme	Biodiversity areas
Data date and update	2014, should be reviewed and updated nationally every 8-12 years
Spatial resolution	Variable*
Projection	Mercator WGS 84 (EPSG:4326)
Method	Compilation & modification
Manual/metadata	Yes
Format	Vector (shapefile)
Accessibility	Free and downloadable
Licence	Commercial use prohibited
Internet link	https://www.keybiodiversityareas.org/

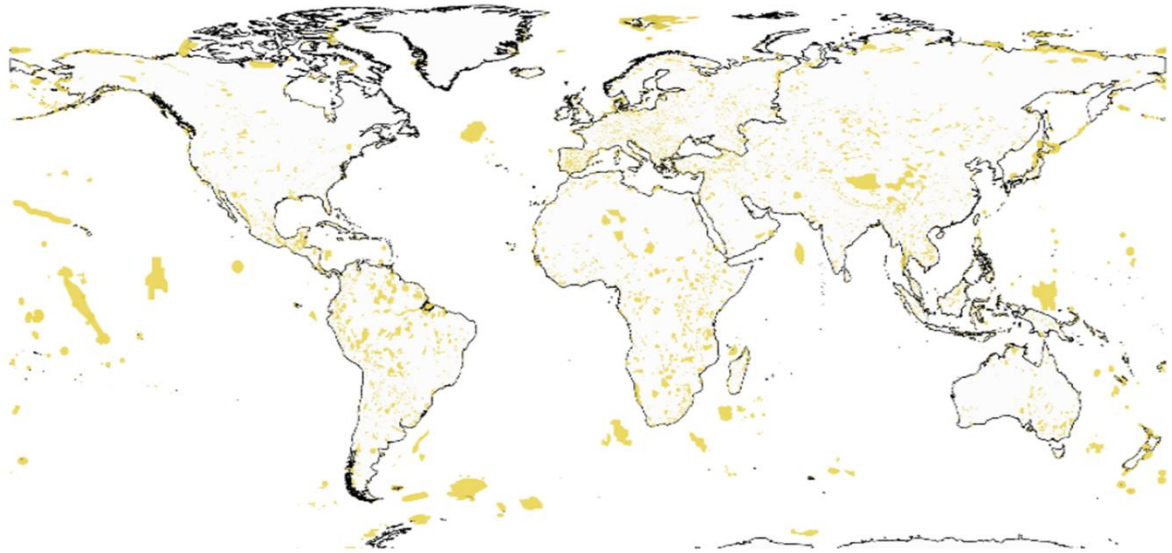
**The data in the KBA dataset come from a wide range of sources, often using different scales and techniques to generate their data.*

Geographic information fields

- NATNAME: name for Site used nationally
- SOURCE: origin of data
- IBASTATUS: if site is a confirmed IBA
- AZESTATUS: if site is a confirmed AZE

Preliminary step

The data is available for download **on request** and sent by e-mail within a few days.



(BirdLife International, 2014)

KBA higher level	KBA criteria
A. Threatened biodiversity	Threatened species
	Threatened ecosystem types
B. Geographically restricted biodiversity	Individually geographically restricted species
	Co-occurring geographically restricted species
	Geographically restricted assemblages
	Geographically restricted ecosystem types
C. Ecological integrity	Sites of ecological integrity
D. Biological processes	Demographic aggregations
	Ecological refugia
	Recruitment sources
E. Irreplaceable sites	Irreplaceable sites through quantitative analysis

Analysis

The purpose of the KBAs criteria is to locate and highlight sites that make significant contributions to the global persistence of biodiversity.. The IBAs are used to identify the most favorable areas for the conservation of wild birds; and the AZEs are the sites that sites that hold the last-remaining populations of 1,483 of the Earth's most threatened species. Special attention should be paid to avoid impacts in these areas, where restoration actions or ecological connectivity operations can also take place.

For each study area, calculate the **total area (or proportion) covered by KBA zoning**, then characterize the KBAs by their name, source, and whether they are also identified as IBAs or AZEs.

Limitations

The data providers in this dataset represent a wide range of stakeholders: environmental professionals, institutions, associations, etc. Thus, the spatial resolution and updating of the data may be **quite disparate** from one KBAa to another. Also, the absence of KBAs within the study zones does not mean that the site is in an ecologically poor location.

Dataset **Terrestrial habitats types**

Description

The database "terrestrial habitat types" developed by Martin Jung and his team offers a **mapping of land use, oriented to natural habitats**. Delineated following the IUCN classification scheme, this classification is derived from remote sensing data modelling and based on a global decision tree that intersects the best currently available global data on land cover, climate and land use. For metadata, refer to Jung M. *et al*., 2020.

The database consists of several layers of data. For the purposes of this study, the most relevant dataset is the global composite image at native 100m Copernicus resolution, level 2 with **82 types of terrestrial habitats** (see table on next page).

There are many definitions of 'habitat', but they can broadly be described as the entirety of the physical conditions - including land cover and climate - that enable a species' population to persist in space and time (Kearney, M., 2006).

Producer/supplier	Jung M., *et al.*
Theme	Ecosystems
Data date and update	2015, future updates mentioned
Spatial resolution	100 m
Projection	Mercator WGS 84 (EPSG:4326)
Method	Modelling
Manual/metadata	Yes
Format	Raster (TIF)
Accessibility	Free and downloadable
Licence	Unrestricted use (CC BY 4.0)
Internet link	https://zenodo.org/record/4058819#.Y--hIYSZOUk

Preliminary treatments

Download file entitled "iucn_habitat classification_composite_lvl2_ver004.zip".

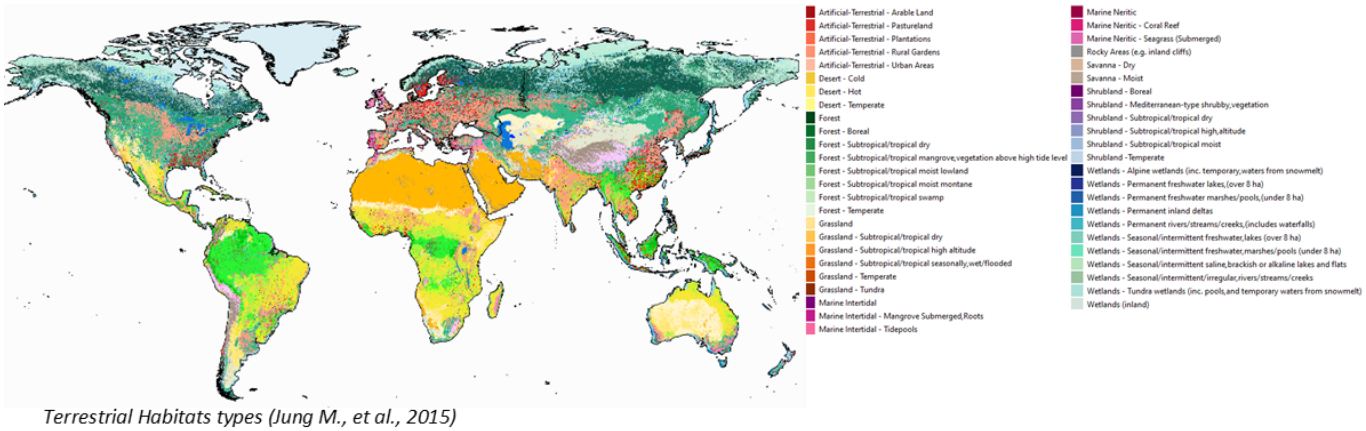
Once downloaded, the data is first clipped according to the perimeter of the study area, then vectorized (in order to minimize the size of the processed files).

Associate the raster pixel values with the legend of the corresponding habitat types (refer to the website).

Analysis

Habitat loss is one of the primary causes of biodiversity decline. There is a strong positive relationship between the extent and intactness of a species' habitat and its population persistence. Knowledge about species' habitats is critical to design site biodiversity management plans, conservation planning actions and to track changes on land use.

For each study area, determine the **proportion of area covered by each habitat**.



Terrestrial Habitats types (Jung M., et al., 2015)

Limitations

- Based on spatial image modeling, it is possible that the dataset contains **classification errors** (omission or commission).
- The data layer dates back to 2015, thus change in land use (artificialization of soils, decline/advancement of agriculture, forests, erosion, etc.) can lead to differences in

IUCN habitat typology

Level 1	Level 2
1. Forest	1.1. Boreal
	1.2. Subarctic
	1.3. Subantarctic
	1.4. Temperate
	1.5. Subtropical/tropical dry
	1.6. Subtropical/tropical moist lowland
	1.7. Subtropical/tropical mangrove vegetation above high tide level
	1.8. Subtropical/tropical swamp
	1.9. Subtropical/tropical moist montane
2. Savanna	2.1. Dry
	2.2. Moist
3. Shrubland	3.1. Subarctic
	3.2. Subantarctic
	3.3. Boreal
	3.4. Shrubland –Temperate
	3.5. Subtropical/tropical dry
	3.6. Subtropical/tropical moist
	3.7. Subtropical/tropical high altitude
	3.8. Mediterranean-type shrubby vegetation
4. Grassland	4.1. Tundra
	4.2. Subarctic
	4.3. Subantarctic
	4.4. Temperate
	4.5. Subtropical/tropical dry
	4.6. Subtropical/tropical seasonally wet/flooded
	4.7. Subtropical/tropical high altitude
5. Wetlands (inland)	5.1. Permanent rivers/streams/creeks (includes waterfalls)
	5.2. Seasonal/intermittent/irregular rivers/streams/creeks
	5.3. Shrub dominated wetlands
	5.4. Bogs, marshes, swamps, fens, peatlands
	5.5. Permanent freshwater lakes (over 8 ha)
	5.6. Seasonal/intermittent freshwater lakes (over 8 ha)
	5.7. Permanent freshwater marshes/pools (under 8 ha)
	5.8. Seasonal/intermittent freshwater marshes/pools (under 8 ha)
	5.9. Freshwater springs and oases
	5.10. Tundra wetlands (inc. pools and temporary waters from snowmelt)
	5.11. Alpine wetlands (inc. temporary waters from snowmelt)
	5.12. Geothermal wetlands
	5.13. Permanent inland deltas
	5.14. Permanent saline, brackish or alkaline lakes
	5.15. Seasonal/intermittent saline, brackish or alkaline lakes and flats
	5.16. Permanent saline, brackish or alkaline marshes/pools
	5.17. Seasonal/intermittent saline, brackish or alkaline marshes/pools
	5.18. Karst and other subterranean hydrological systems (inland)
6. Rocky Areas (e.g., inland cliffs, mountain peaks)	
7. Caves & Subterranean Habitats (non-aquatic)	7.1. Caves
	7.2. Other subterranean habitats
8. Desert	8.1. Hot
	8.2. Temperate
	8.3. Cold

Level 1	Level 2
9. Marine Neritic	9.1. Pelagic
	9.2. Subtidal rock and rocky reefs
	9.3. Subtidal loose rock/pebble/gravel
	9.4. Subtidal sandy
	9.5. Subtidal sandy-mud
	9.6. Subtidal muddy
	9.7. Macroalgal/kelp
	9.8. Coral Reef (9.8.1. Outer reef channel ; 9.8.2. Back slope ; 9.8.3. Foreslope (outer reef slope) ; 9.8.4. Lagoon ; 9.8.5. Inter-reef soft substrate ; 9.8.6. Inter-reef rubble substrate)
	9.9 Seagrass (Submerged)
	9.10 Estuaries
10. Marine Oceanic	10.1 Epipelagic (0–200 m)
	10.2 Mesopelagic (200–1,000 m)
	10.3 Bathypelagic (1,000–4,000 m)
	10.4 Abyssopelagic (4,000–6,000 m)
11. Marine Deep Ocean Floor (Benthic and Demersal)	11.1 Continental Slope/Bathyl Zone (200–4,000 m)
	11.1.1 Hard Substrate
	11.1.2 Soft Substrate
	11.2 Abyssal Plain (4,000–6,000 m)
	11.3 Abyssal Mountain/Hills (4,000–6,000 m)
	11.4 Hadal/Deep Sea Trench (>6,000 m)
	11.5 Seamount
	11.6 Deep Sea Vents (Rifts/Seeps)
12. Marine Intertidal	12.1 Rocky Shoreline
	12.2 Sandy Shoreline and/or Beaches, Sand Bars, Spits, etc.
	12.3 Shingle and/or Pebble Shoreline and/or Beaches
	12.4 Mud Shoreline and Intertidal Mud Flats
	12.5 Salt Marshes (Emergent Grasses)
	12.6 Tidepools
	12.7 Mangrove Submerged Roots
13. Marine Coastal/ Supratidal	13.1 Sea Cliffs and Rocky Offshore Islands
	13.2 Coastal Caves/Karst
	13.3 Coastal Sand Dunes
	13.4 Coastal Brackish/Saline Lagoons/Marine Lakes
	13.5 Coastal Freshwater Lakes
14. Artificial - Terrestrial	14.1 Arable Land
	14.2 Pastureland
	14.3 Plantations
	14.4 Rural Gardens
	14.5 Urban Areas
	14.6 Subtropical/Tropical Heavily Degraded Former Forest
15. Artificial - Aquatic	15.1 Water Storage Areas [over 8 ha]
	15.2 Ponds [below 8 ha]
	15.3 Aquaculture Ponds
	15.4 Salt Exploitation Sites
	15.5 Excavations (open)
	15.6 Wastewater Treatment Areas
	15.7 Irrigated Land [includes irrigation channels]
	15.8 Seasonally Flooded Agricultural Land
	15.9 Canals and Drainage Channels, Ditches
	15.10 Karst and Other Subterranean Hydrological Systems [human-made]
	15.11 Marine Anthropogenic Structures
	15.12 Mariculture Cages
	15.13 Mari/Brackish-culture Ponds
16 Introduced Vegetation	17 Other
	18 Unknown

Dataset **Global Forest Change**

Description

Global Forest Change (GFC) database offers several datasets on the world's forest cover by period, as an evolution map of gain/loss/extent of forest cover between 2000 and 2019,based on time-series analysis of Landsat satellite images (Landsat 8 OLI). Trees are defined as vegetation taller than 5m in height. 'Forest Loss' is defined as a stand-replacement disturbance, or a change from a forest to non-forest state, by annual time scales. Encoded as either 0 (no loss) or else a value in the range 1–17, representing loss detected primarily in the year 2001–2019, respectively (Hansen M.C., *et al.*, 2019*)*

Producer/supplier	Hansen M.C., *et al.*
Theme	Ecosystems
Data date and update	2019, no update announced
Spatial resolution	30 m
Projection	Mercator WGS 84 (EPSG:4326)
Method	Modelling
Manual/metadata	Yes
Format	Raster (TIF tiles)
Accessibility	Free and downloadable
Licence	Unrestricted use (CC BY 4.0)
Internet link	https://earthenginepartners.appspot.com/science-2013-global-forest/download_v1.7.html

Preliminary treatments

The GFC dataset is divided into 504 raster tiles measuring approximately 1000 km x 1000 km each, covering the world. Considering the files size (around 10 GB) and the download and process timeframes, it is suggested to download only those tiles on which sites are located. Using GIS, assemble the tiles into a virtual raster, clip the virtual raster according to the perimeters of the study areas layer, then vectorise the cliped raster (this operation can take several hours).

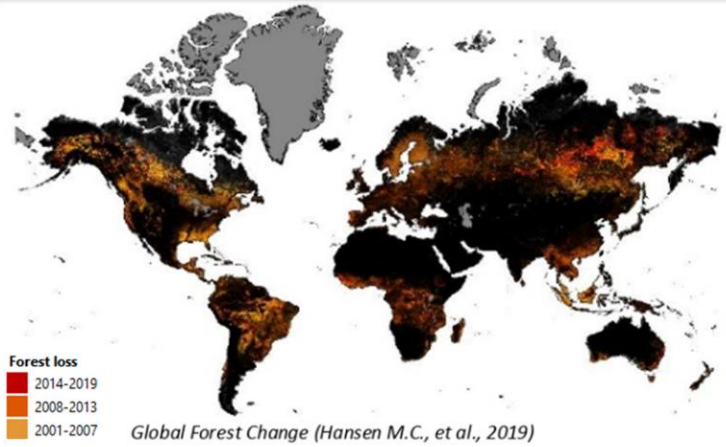
Analysis

Each pixel in the raster indicates the date on which the area it represents was deforested. The metric that can be calculated and analysed is **the area covered by pixels** in each study area, in order to **estimate the proportion of forest habitat lost**. The map display of this data also provides information on **the date of this destruction**, in order to estimate the current state of forest cover.

Areas with forest loss could represent reforestation opportunities. It is important to preserve and restore forests, not only for their intrinsic value, but also for the biodiversity they host, and the ecosystem services they provide like local temperature regulation, carbon sink, water quality, wood supply, soil formation and stabilisation, or educational and recreational functions.

Limitations

Although the data is precise (very fine resolution), the accuracy may be limited in some locations. Satellite image **modelling can include pixel classification errors** (omission or commission), which should be taken into account when interpreting the results.



Global Forest Change (Hansen M.C., et al., 2019)

Dataset **Forest Landscape Integrity Index**

Description

The Forest Landscape Integrity is an index showing the forest extent in 2000*, indicating, in addition, degrees of forest integrity (low, medium and high forest integrity). The integrity is based on human pressures and alteration of forest connectivity. To produce the Forest Landscape Integrity Index (FLII), four data sets were combined representing (Grantham H.S., et al., 2000):

- forest extent (2000, University of Maryland, Global Forest Change);
- 'observed' pressure from high impact, localized human activities for which spatial datasets exist, specifically: infrastructure, agriculture, and recent deforestation;
- 'inferred' pressure associated with edge effects, and other diffuse processes, (e.g. activities such as hunting and selective logging) modelled using proximity to observed pressures;
- anthropogenic changes in forest connectivity due to forest loss.

** Tree cover in the year 2000, defined as canopy closure for all vegetation taller than 5m in height.*

Producer/supplier	Grantham H.S., *et al.*
Theme	Ecosystems
Data date and update	2000, future updates mentioned
Spatial resolution	300 m
Projection	Mercator WGS 84 (EPSG:4326)
Method	Compilation and modification
Manual/metadata	Yes
Format	Raster (TIF)
Accessibility	Free and downloadable
Licence	Unrestricted use (CC BY 4.0)
Internet link	https://www.forestlandscapeintegrity.com/download-data

Preliminary treatments

The data is available for download on **request** (**fill in a Google Form** allowing access to a Drive folder with the data).

Once downloaded, the data is first clipped according to the perimeter of the study area, then vectorized (in order to minimize the size of the processed files).

Analysis

The crossing of the human pressures and alteration of forest connectivity parameters leads to the attribution of a **score for each pixel**, the FLII, according to a gradient going from 0 to 10. This range is discretized to define three broad illustrative categories: low integrity (≤6.0), medium integrity (>6.0 and <9.6), and high integrity (≥9.6). Details on the calculation and the classes are provided on the next page.

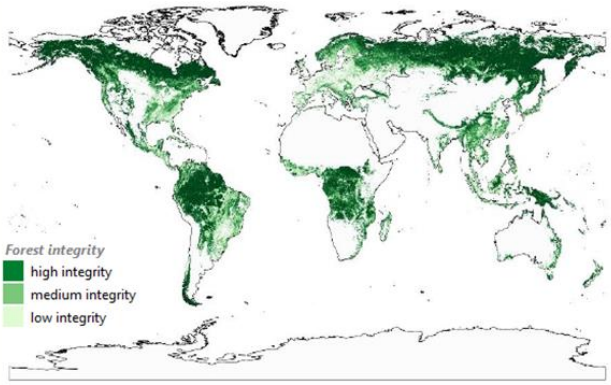
For each study area, calculat the FLII area provides an indication of the **forest cover surface**, and information on its **ecological quality**. Areas with medium to high integrity indexes could be preserved, while areas with a low index could represent a forest restoration opportunity.

Limitations

The limitations of this layer are mainly due to the the forest cover data that:

- may not be up to date since the forest cover dates from 2000
- produced by **modelling satellite images**, which leads to potential classification errors

Furthermore, this variable aggregation approach offers the advantage of combining and summarizing information but has the disadvantage of uncertainty linked to the reliability of the overlaying of different indicators from eventually heterogeneous sources.



Forest Landscape Integrity Index (Grantham H.S., et al., 2000)

Calculating the Forest Landscape Integrity Index

The FLII for forest pixel *i* is calculated as:

FLIIi=[10/3](3−min(3,[Pi+Qi+LFCi])), where

Pi = observed human pressures within a pixel

Qi = aggregate effect from inferred pressures (Q) on pixel i

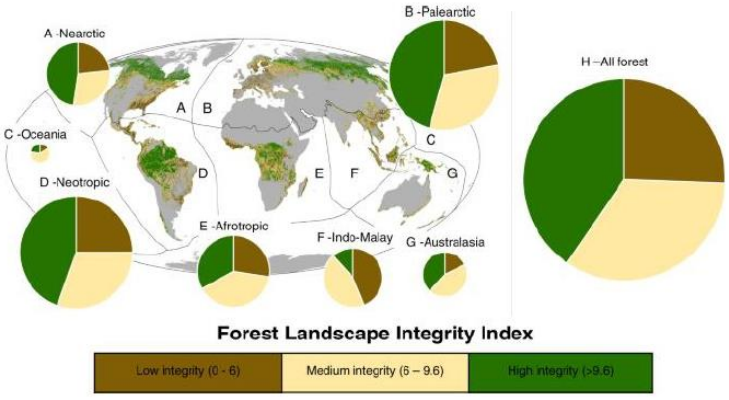
LFCi = Lost Forest Configuration (LFC) on pixel i

The three constituent metrics, LFC, P, and Q, all represent increasingly modified conditions the larger their values become. To calculate a forest integrity index in which larger values represent less degraded conditions, therefore, the sum of those components is substracted from a fixed large value (here, 3). Three was selected as assessment indicates that values of LFC + P + Q of 3 or more correspond to the most severely degraded areas. The metric is also rescaled to a convenient scale (0-10) by multiplying by an arbitrary constant (10/3)

$FLII_i$ ranges from 0 to 10, forest areas with no modification detectable using our methods scoring 10 and those with the most scoring 0

Forest integrity classes:

- High Forest Integrity (scores ≥ 9.6): Interiors and natural edges of more or less unmodified naturally regenerated (i.e., non-planted) forest ecosystems, comprised entirely or almost entirely of native species, occurring over large areas either as continuous blocks or natural mosaics with non-forest vegetation; typically little human use other than low-intensity recreation or spiritual uses and/or low-intensity extraction of plant and animal products and/or very sparse presence of infrastructure; key ecosystem functions such as carbon storage, biodiversity, and watershed protection and resilience expected to be very close to natural levels (excluding any effects from climate change) although some declines possible in the most sensitive elements (e.g., some high value hunted species).
- Medium Forest Integrity (scores > 6.0 but <9.6): Interiors and natural edges of naturally regenerated forest ecosystems in blocks smaller than their natural extent but large enough to have some core areas free from strong anthropogenic edge effects (e.g., set-asides within forestry areas, fragmented protected areas), dominated by native species but substantially modified by humans through a diversity of processes that could include fragmentation, creation of edges and proximity to infrastructure, moderate or high levels of extraction of plant and animal products, significant timber removals, scattered stand-replacement events such as swidden and/or moderate changes to fire and hydrological regimes; key ecosystem functions such as carbon storage, biodiversity, watershed protection and resilience expected to be somewhat below natural levels (excluding any effects from climate change).
- Low Forest Integrity (score ≤ 6.0): Diverse range of heavily modified and often internally fragmented ecosystems dominated by trees, including (i) naturally regenerated forests, either in the interior of blocks or at edges, that have experienced multiple strong human pressures, which may include frequent stand-replacing events, sufficient to greatly simplify the structure and species composition and possibly result in significant presence of non-native species, (ii) tree plantations and, (iii) agroforests; in all cases key ecosystem functions such as carbon storage, biodiversity, watershed protection and resilience expected to be well below natural levels (excluding any effects from climate change).



Source : Grantham, H.S., Duncan, A., Evans, T.D. *et al.* Anthropogenic modification of forests means only 40% of remaining forests have high ecosystem integrity. *Nat Commun* **11**, 5978 (2020). https://doi.org/10.1038/s41467-020-19493-3

Dataset

Global Lakes and Wetlands Database

Description

The Global Lakes and Wetlands Database (GLWD) database created by the WWF contains 3 datasets: level 1 - large lakes and reservoirs*; level 2 - smaller water bodies ; level 3 - wetlands. The three levels of GLWD are based on the combination of seven digital maps and attribute datasets as described on WWF, 2004). In order to study wetlands, level 3 is the most appropriate, comprising lakes, reservoirs, rivers and different wetland types in the form of a global raster map compiling previous data: "*The GLWD-3 raster map of wetland areas, largely based on the wetlands map of the 1993 UNEP World Conservation Monitoring Centre. Only one class of GLWD-3 is based on remote sensing data* (satellite imagery), (WWF, 2004).

**Lakes, reservoirs and rivers are can sometimes be considered wetlands, depending on their feautures and the criteria used to define wetlands.*

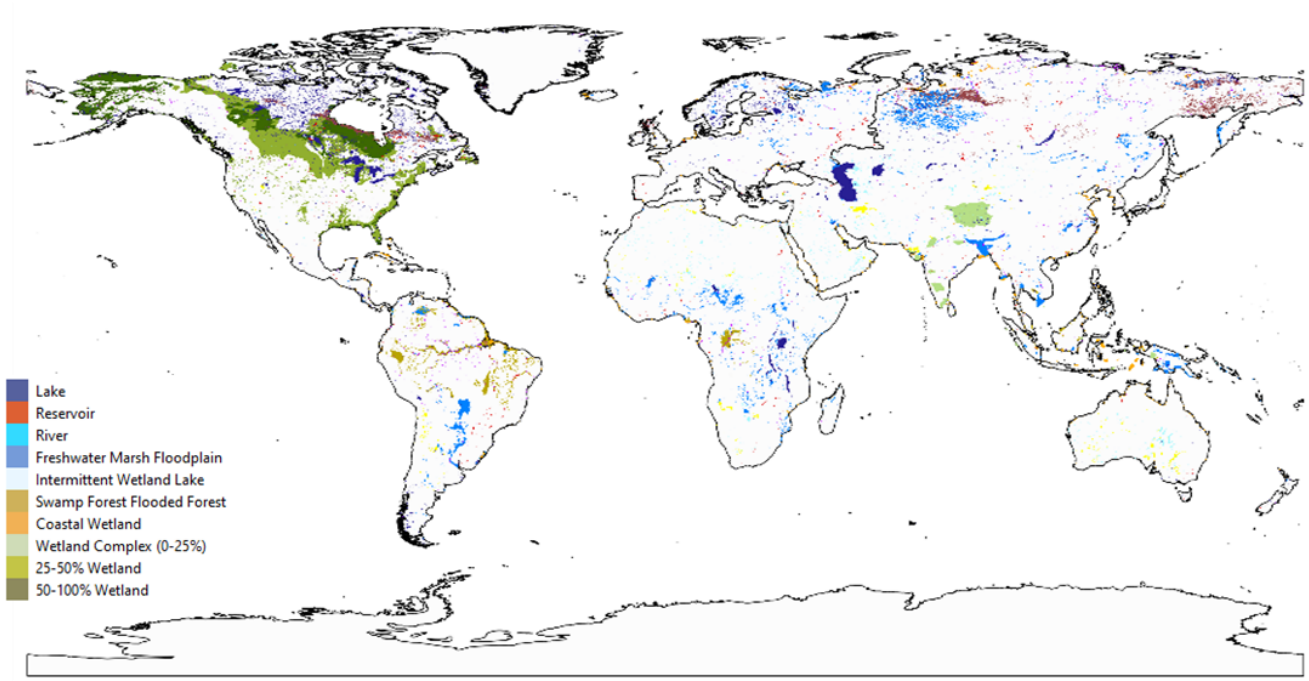
Producer/supplier	WWF
Theme	Ecosystems
Data date and update	n.d., no update announced
Spatial resolution	1 km
Projection	Mercator WGS 84 (EPSG:4326)
Method	Compilation
Manual/metadata	Yes
Format	Raster (TIF)
Accessibility	Free and downloadable
Licence	Commercial use prohibited
Internet link	https://www.worldwildlife.org/pages/global-lakes-and-wetlands-database

Preliminary treatments

The raw data contains an *avl* file. To use it in QGIS, previously open it with ArcGIS, then export it as a TIF raster. Once converted, clipp the data according to the perimeter of the study area, then vectorize the raster.

Geographic information fields

The data describes a typology of 12 categories. The raster pixel values can be associated with the legend of the corresponding wetland types, (correspondence in the WWF, 2004).



Global Lakes and Wetlands Database (WWF)

Analysis

Wetlands are areas where **water is the primary factor** controlling the environment and the associated plant and animal life. They are among the world's most productive environments and support high concentrations of birds, mammals, reptiles, amphibians, fish and invertebrate species. Wetlands **provide many ecosystem services** like fish and fiber, water supply, water purification, climate regulation, flood regulation, coastal protection, recreational opportunities and tourism. Wetland ecosystems **host remarkable biodiversity**, since 40% of all species live or breed in wetlands (IUCN, 2020), yet over 85% of the world's wetlands have been lost in 300 years (UNEP, 2022). Identifying the location of wetlands allows to prioritize areas to be preserved or hydrological connections to be created or restored.

For each study area, calculate the **total area of wetlands** that it includes, and possibly study the detail by wetland type.

Limitations

- For methodological reasons, the sharp decline of wetlands in previous centuries has not necessarily been taken into account in this dataset. Thus, this leaves some lakes and wetlands being represented in their **historic instead of recent outlines**.
- The resolution of the dataset is relatively **coarse for a local scale** (1 km). This data is used to identify the largest wetlands and to understand the general context of the site, but cannot be used as a mapping of proven wetlands.
- It could be useful to supplement these results with other wetland datasets, such as RAMSAR data (wetlands of international importance, with a finer and more reliable layout, but data layer currently incomplete), and more local wetland maps.
- It is recommended to use this dataset for informational purposes only, without making it a map sheet and derive interpretations from this information, because the data is of too coarse a resolution and the inventory is too concise to allow this analysis. Suggested integration into documents: present wetlands data in another thematic map sheet describing land use (terrestrial habitats for example), as secondary information.

Dataset

Natural Earth : Rivers, lakes and reservoirs

Description

Natural Earth database provides two datasets on hydrographic features. These are two vector data layers:

- rivers and lake centerlines: single-line drainages including optional lake centerlines, and
- lakes and reservoirs: natural and artificial lakes waterbodies.

Datasets are derived from World Data Bank 2 and additional sources like recent satellite imagery.

Producer/supplier	Natural Earth
Theme	Ecosystems
Data date and update	n.d., no update announced
Spatial resolution	1:10m
Projection	Mercator WGS 84 (EPSG:4326)
Method	Modification
Manual/metadata	Yes
Format	Vector (shapefile)
Accessibility	Free and downloadable
Licence	Unrestricted use
Internet link	https://www.naturalearthdata.com/

Geographic information fields

Rivers

- FEATURECLASS: the type of waterway (river, canal, lake centerline)
- NAME: name of the waterway (available in many languages)
- SCALERANK: level of branch in the hydrographic network, gives the importance of the waterway

Lakes

- FEATURECLASS: the type of water body (lake, alkaline lake or reservoir)
- NAME: name of the water body (not provided for all entities, but available in many languages)

Analysis

The hydrographic network (rivers and lakes) is an essential compartment in environment. It is one of the main ecosystems on the planet, home to many species, provides important ecological continuities and ecosystem services such as water supply, fisheries or navigation (transport).

- **Lakes**. Calculate the surface of waterbodies contained in the study area, identify the type, and name.
- **Rivers**. Calculate the length of the waterway that passes through the study area, identify the scale rank. and name.

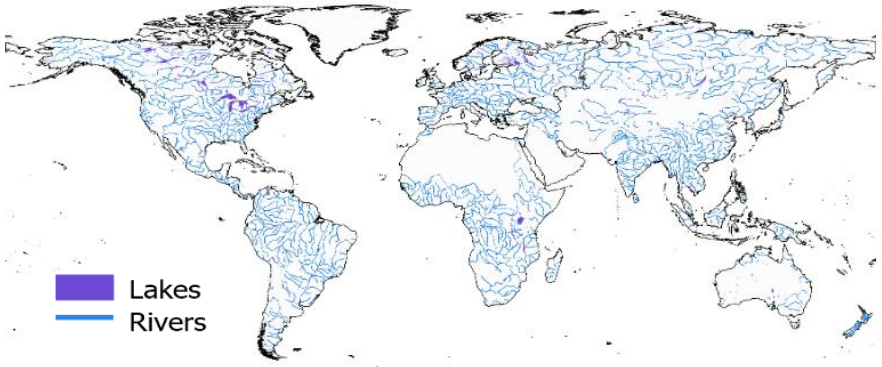
Limitations

These two datasets are quite limited for local use, due to the scale of resolution of the datasets but also to the method of data collection.

- **Lake** data: this is not an exhaustive inventory of waterbodies (main ones only).
- **River** data: contains only major rivers, and omits much of the global hydrographic network. The layout of the shape file is very simplified and does not follow the real watercourses perfectly. This induces 1 to 2 km shifts, which is not negligible for the study area analysis of a few hundred meters.

These limitations should be taken into account when interpreting results.

- It is recommended to use this dataset for informational purposes only, without making it a map sheet and derive interpretations from this information, because the data is of too coarse a resolution and the inventory is too concise to allow this analysis. Suggested integration into documents: present wetlands data in another thematic map sheet describing land use (terrestrial habitats for example), as secondary information.



Natural Earth Rivers, lakes and reservoirs (Natural Earth)

Dataset | **Saltmarshes and mangroves**

Description (saltmarshes)

This dataset displays the extent of the knowledge regarding the distribution of saltmarsh globally, drawing from occurrence data (surveyed and/or remotely sensed), (Mcowen, C. et al, 2015). Saltmarshes are areas of low-lying ground along a coast, which are regularly flooded by seawater, and where salt-tolerant plants grow (Park C., et al., 2013).

Producer/supplier	Mcowen C., *et al.*
Theme	Ecosystems
Data date and update	2015, no update announced
Spatial resolution	Between 1:10 000 and 1:100 000
Projection	Mercator WGS 84 (EPSG:4326)
Method	Production & modelling
Manual/metadata	Yes
Format	Vector (shapefile)
Accessibility	Free and downloadable
Licence	Commercial use prohibited (CC BY-NC 4.0)
Internet link	https://data.unep-wcmc.org/datasets/43

Geographic information fields

The "NAME" field gives English name of the feature as provided by the data provider. This may provide some additional information about the type of saltmarshes.

Description (mangrove)

A mangrove is a tropical evergreen tree or shrub which grows in coastal areas, particulary on tidal flats and estuaries (Park C., et al., 2013).The primary objective of the Global Mangrove Watch (GMW) has been to provide countries lacking a national mangrove monitoring system with first cut mangrove extent and change maps, to help safeguard against further mangrove forest loss and degradation (Bunting P., et al., 2020). The GMW has generated a global baseline map of mangroves in 2010 using ALOS PALSAR and Landsat (optical) data, and changes appeared with the updates (2020).

Producer/supplier	Bunting P., *et al.*
Theme	Ecosystems
Data date and update	2020, no update announced
Spatial resolution	25 m
Projection	Mercator WGS 84 (EPSG:4326)
Method	Modelling
Manual/metadata	Yes
Format	Vector (shapefile)
Accessibility	Free and downloadable
Licence	Unrestricted use (CC BY 4.0)
Internet link	https://data.unep-wcmc.org/datasets/5

Analysis (both)

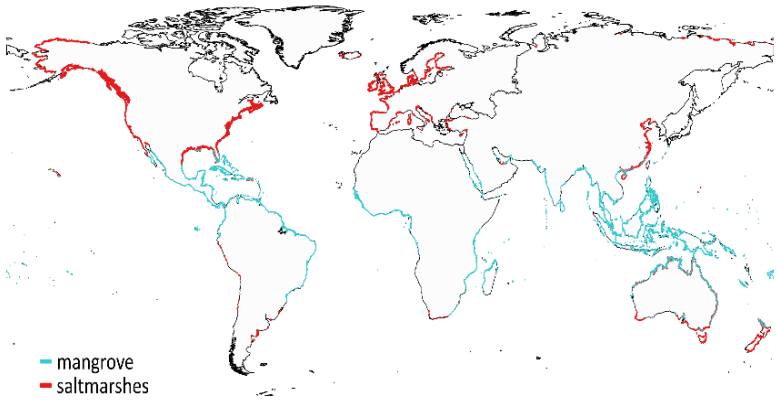
The biodiversity of marine habitats depends on these particular ecosystems, which is why it is important to preserve them.

These two datasets concern the study areas located on the shoreline. Calculate the **area of each habitat** (mangrove and saltmarshes) within the study areas.

Covering a vast area if earth, marine and coastal ecosystems are essential to the proper fuctionning of the planet. They provide several services, including nutrition for wildlife and humans, life cycle maintenance for flora and fauna, and carbon sequestration (Océan et Climat, s.d.). Thus, special attention should be given to the preservation or restoriation of these habitats.

Limitations (both)

Both types of habitats provide insight into the ecological richness of coastal areas but are not representative of coastal biodiversity and ecosystems. For coastal study sites with a strong marine/coastal component, complete with other habitat datasets likely to be found in the study areas.



Global Mangrove Watch (Bunting P., et al., 2020) and Global Distribution of Saltmarshes (Mcowen, C. et al, 2015)

Dataset **Seagrasses and coral reefs**

Description (seagrasses)

This dataset shows the **global distribution** of seagrasses, and is composed of two subsets of point and polygon occurrence data (UNEP-WCMC, 2020).

Seagrasses are the only flowering plants that can live underwater. They grow in sediment on the sea floor with erect, elongate leaves and a buried root-like structure (rhizome) (Seagrass-Watch, 2023).

Producer/supplier	UNEP-WCMC (ONU)
Theme	Ecosystems
Data date and update	2020, no update announced
Spatial resolution	1:1 000 000
Projection	World Mollweide (ESRI:54009)
Method	Compilation
Manual/metadata	Yes
Format	Vector (shapefile)
Accessibility	Free and downloadable
Licence	Commercial use prohibited
Internet link	https://data.unep-wcmc.org/datasets/7

Geographic information fields

The "scientifc" and "vernacular" fields give the scientific and vernacular names of the species identified in the polygon (not always reported).

Preliminary treatments

The data, initially in World Mollweide, must be re-projected in Mercator WGS 84 using GIS tools.

Description (coral reefs)

This dataset shows the **global distribution** of coral reefs in tropical and subtropical regions. It is the most comprehensive global dataset of warm-water coral reefs to date, acting as a foundation baseline map for future, more detailed, work (UNEP-WCMC, 2018).

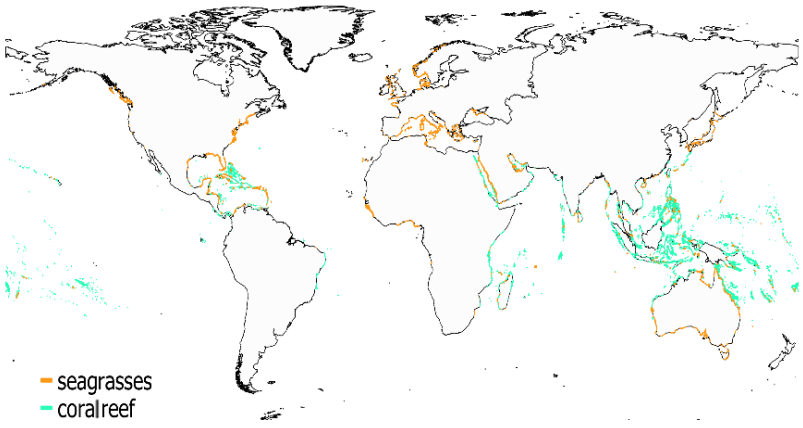
Coral are small colonial invertebrates that live in shallow seas found in the coastal zones of warm tropical and subtropical ocean (Park C., et al., 2013).

Producer/supplier	UNEP-WCMC (ONU)
Theme	Ecosystems
Data date and update	2018, no update announced
Spatial resolution	30 m
Projection	Mercator WGS 84 (EPSG:4326)
Method	Compilation
Manual/metadata	Yes
Format	Vector (shapefile)
Accessibility	Free and downloadable
Licence	Commercial use prohibited
Internet link	https://data.unep-wcmc.org/datasets/1

Analysis (both)

Both compiled from multiple data sources (sources in the respective metadata documents), these two datasets provide a fairly recent overview of two major marine habitats. They are important for the balance of ecosystems, and are home to tens of thousands of marine and terrestrial species.

These two datasets concern the study areas located on the shoreline. Calculate the **area of each habitat** (seagrasses and coral reefs) within the study areas.



Global Distribution of Seagrasses (UNEP-WCMC, 2020), Global Distribution of Coral Reefs (UNEP-WCMC, 2018)

Dataset

IUCN Red List Maps

Description

Established in 1964, the IUCN Red List of Threatened Species has evolved to become the world's most comprehensive information source on the global conservation status of animal, fungi and plant species. Threatened species are any species which are vulnerable to extinction in the near future. Among the different categories of species vulnerability established by the IUCN, only species in the "critically endangered" (CR), "endangered" (EN) and "vulnerable" (VU) categories are considered here as "threatened".

The dataset is composed of the distribution area of fauna and flora threatened species (known range of each species) according their conservation status. Four taxa were chosen for this study: plants, amphibians, reptiles and mammals. Data are provided by several experts around the world, constitution of maps and distribution areas from occurrence data (IUCN imposes data standards, attributes, format).

Producer/supplier	UICN
Theme	Threatened species
Data date and update	2022, Red List is updated at least twice each year
Spatial resolution	Not defined
Projection	Mercator WGS 84 (EPSG:4326)
Method	Compilation
Manual/metadata	Yes
Format	Vector (shapefile)
Accessibility	Free and downloadable
Licence	Commercial use prohibited
Internet link	https://www.iucnredlist.org/resources/spatial-data-download

Geographic information fields

- CLASS: species taxonomic group (plants, mammals, amphibians, reptiles)
- SCI_NAME: species scientific name
- CATEGORY: conservation status (category of vulnerability) according to the IUCN Global Red List
- PRESENCE: status (present/past) of the species in this area (presence codes: 1-extant, 2-probably extant, 3-possibly extant, 4-possibly extinct, 5-extinct, 6-presence uncertain)

Please refer to the paper for more metadata (IUCN, 2022).

Analysis

The Red List is a critical indicator of the health of the world's biodiversity. For each study area, **list the potential species** and their conservation status, calculate **the total number of threatened species** with a range comprising the site's buffer, calculate the **details by taxonomic group and threat level** (this can take the form of a stacked bar chart). Sites that have identified the potential threatened species within their territories can implement actions targeting the preservation or the restoration of their habitats.

Preliminary treatments

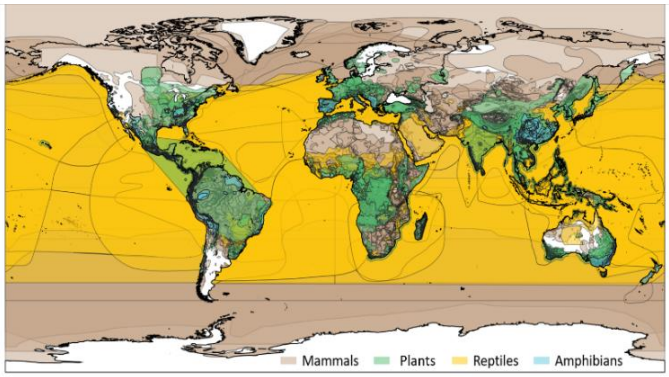
- Download the 4 datasets. Some datasets are in 2 parts: clip the vector layers according to the perimeters of the study area, then merge the 2 parts to make only one layer per dataset.

Information: some layers are quite heavy (> 1. 5 GB each) and may take some time to display in a GIS software.

- Sort through the attribute table of the layer, keeping entities that meet the following criteria only:
  - Category: Threatened species (CR, EN, VU)
  - Presence: species with a high probability of occurrence, referred to as "existing" (code 1/2/3)

Limitations

- This dataset provides an overview of the potential main threatened species of a territory, but it is important to note that only 4 taxonomic groups are represented here (a large number of **taxa are missing**, like birds or aquatic species).
- The distribution maps **are a depiction of a taxon's distribution**; this doesn't equate to either the spread of extinction risk or the occupied range area. The maps simply intend to: inform Red List assessments, help to identify conservation priorities, visualize a representation of geographical area within which species can be found (IUCN, 2022).



IUCN Red List Maps (IUCN, 2022)

Dataset

Global Human Footprint

Description

Human pressures on the environment are changing spatially and temporally, with profound implications for the planet's biodiversity and human economies. They result in land changes that have a direct impact on biodiversity: degradation of ecosystems, fragmentation of habitats, disturbance of species, environmental pollution, etc. The human footprint database locates and quantifies the **direct and indirect human pressures** on the environment globally, based on **8 variables**: built environments, population density, electric infrastructure (night-time lights), crop lands, pasture lands, roads, railways, navigable waterways (metadata of variables available in Venter O., *et al.*, 2016).

Producer/supplier	Venter O., *et al.*
Theme	Human impacts and carbon resources
Data date and update	2009, no update announced
Spatial resolution	1 km
Projection	World Mollweide (ESRI:54009)
Method	Modification & production
Manual/metadata	Yes
Format	Raster (TIF)
Accessibility	Free and downloadable
Licence	Unrestricted use (CC0 1.0)
Internet link	https://datadryad.org/stash/dataset/doi:10.5061/dryad.052q5

Preliminary treatments

Once downloaded, the data is first clipped according to the perimeter of the study area, then vectorized (in order to minimize the size of the processed files).

The data, initially in World Mollweide, must be re-projected in Mercator WGS 84 using GIS tools.

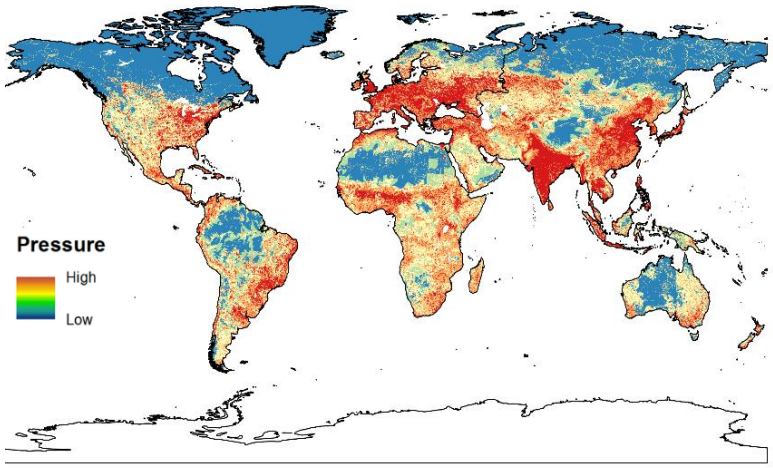
Analysis

The 8 variables of pressure were overlaid to create the standardized Human Footprint map indicating the degree of pressure in an area, from 0 to 50: 0 - no pressure, 1-2 - low pressure, 3-5 - moderate pressure, 6-11 - high pressure, 12-50 - very high pressure (Venter O. et al., 2016). Areas with reduced level of pressures should be primarily preserved, while areas with high level of pressures can be restored. The **surface proportions of the different pressure levels** that compose every study area can be calculated.

Limitations

- The Human Footprint is a **static and dated view** of human pressures on the environment (calculated over the period 1993-2009). Given the pace of change in societies and territories, there is a strong need for an up-to-date understanding of the spatial and temporal trends in human pressures (Venter O. et al., 2016).
- The **spatial resolution** is quite coarse (1 km).
- This **variable aggregation approach** offers the advantage of combining and summarizing information but has the disadvantage of uncertainty linked to the reliability of the overlaying of different indicators from eventually heterogeneous sources.

However, the data provides a general indication of the human footprint, and remains contextual.



Global Human Footprint (Venter O., et al., 2009)

Dataset **Vulnerable carbon**

Description

These datasets provide global **maps of carbon density** (aboveground, belowground biomass carbon and soil organic carbon stocks) for the year 2010 and 2018 at ~300-m spatial resolution. Input maps were collected from published literature, and where necessary, updated to cover the focal time period.

The database consists of three main thematic layers:

- **Manageable** carbon: carbon in terrestrial and coastal ecosystems that could experience an anthropogenic land-use conversion event.
- **Vulnerable** carbon: carbon that would be released in a typical land-use conversion.
- **Irrecoverable** carbon: carbon that, if lost, would not recover by mid-century.

In the context of an environmental potential analysis, the selected relevant data layer is **vulnerable carbon**. It corresponds to the amount of carbon lost and released in the event of disturbance/exploitation or if the reserves were destroyed (e.g. by logging, land clearing or forest fire) (Noon, M.L., et al., 2021).

Producer/supplier	Noon M., *et al.*
Theme	Human impacts and carbon resources
Data date and update	2018, no update announced
Spatial resolution	300 m
Projection	Mercator WGS 84 (EPSG:4326)
Method	Compilation & modification
Manual/metadata	Yes
Format	Raster (TIF)
Accessibility	Free and downloadable
Licence	Commercial use prohibited (CC BY-NC 4.0)
Internet link	https://zenodo.org/record/4091029#.Y_dmX4SZOUk

Preliminary treatments

Download file entitled "Vulnerable_Carbon_2018.zip".

Once downloaded, the data is first clipped according to the perimeter of the study area, then vectorized (in order to minimize the size of the processed files).

The raster pixel values can be associated with the legend of the corresponding carbon rate (please refer to Noon M., *et al.*, 2021).

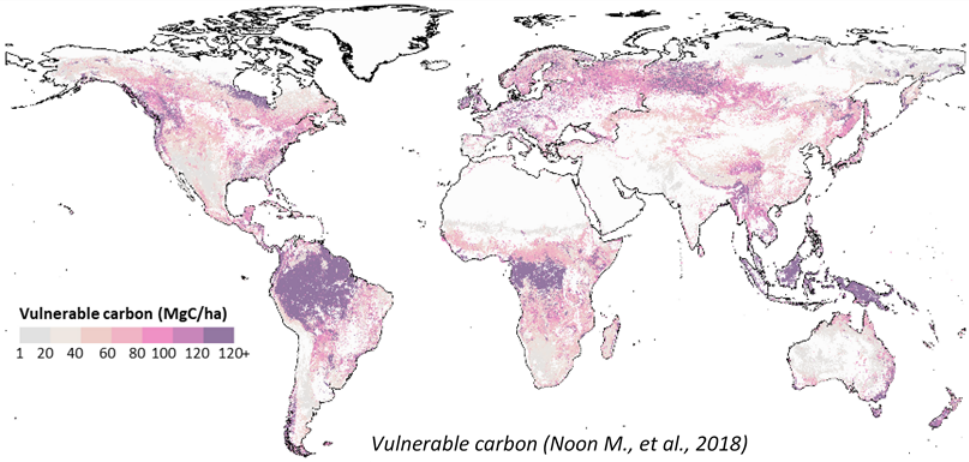
Analysis

Carbon sinks absorb more carbon than they release. Protecting carbon sinks within the site's territory is essential for tackling climate change and keeping climate stable.

Each pixel of the raster represents a carbon density, expressed as the megagrams (Mg) of carbon (C) potentially stocked per hectare (ha) of land. For each study area, calculate **the total amount of vulnerable carbon** (MgC/ha), and the **areas of carbon sinks by density category** (ha), (see the scale presented in Noon M., *et al.*, 2021).

Limitations

This data provides an **approximate estimate** of the carbon content of ecosystems (non-exhaustive inventory) : some ecosystems were not included in the methodology.



Vulnerable carbon (Noon M., et al., 2018)

Calculating the Vulnerable carbon values

To assess the vulnerability criterion, we quantified average carbon losses from biomass and soils due to the most common anthropogenic disturbances: conversion to agriculture in grasslands, wetlands and tropical forests; forestry in boreal and temperate forests; and aquaculture or built infrastructure in coastal ecosystems. We considered the feasible loss events that would alter the land cover (for example, forest to soy field) as opposed to activities that might reduce the carbon content but not constitute full conversion (for example, forest degradation due to charcoal collection or selective logging). Vulnerable carbon is therefore the portion that would be lost in a hypothetical but typical conversion event; it does not characterize the likelihood of that conversion event. Note that directly incorporating irrecoverable carbon into climate mitigation strategies would require further assessing the likelihood of disturbance or conversion due to direct anthropogenic pressures or climate shifts.

Details on the calculations and assumptions summarized in Table S5 *(Noon M., et al., 2018)*.

Table S5. Approaches for calculating vulnerable SOC by ecosystem

Ecosystem	Primary driver of anthropogenic conversion (assumption)	Vulnerable SOC: how calculated (standard error in parentheses)	Source / explanation
Tropical & subtropical forests (all types)	Agriculture	Initial C x 21.3% (+/- 4.1%)	Emissions factor from Don et al 2011, normalized to 30 cm based on Sanderman methodology.
Tropical & subtropical grasslands	Agriculture	Initial C x 25.2% (+/- 3.3%)	
Montane grasslands	Agriculture	Modeled	In the absence of montane grassland-specific data, we used a Carbon Response Function (CRF) for temperate grasslands from Poeplau et al. 2011 [23].
Tropical & subtropical wetlands (non-peat, both forested and herbaceous)	Agriculture/ development	Initial C x 100% or 450 (+/- 67) MgC ha^{-1} (whichever is smaller)	Sjogersten et al 2014[31] find no significant difference in CO2 fluxes between tropical wetlands on organic (peat) and mineral soils; we therefore treat non-peat tropical wetlands the same as tropical peatlands.
Temperate forests (all types)	Forestry	Initial C x 0%	In a meta-analysis of 75 studies reporting 432 SOC response ratios for harvested temperate forests, Nave et al. (2010) report no significant SOC change in forest mineral soils[53].
Temperate grasslands	Agriculture	Modeled	We used a Carbon Response Function (CRF) for temperate ecosystems' conversion to cropland from Poeplau et al. 2011 to model the SOC response of this transition[23].
Temperate wetlands (non-peat, both forested and herbaceous)	Agriculture/development	Initial C x 42% (+/- 16.8%)	Estimate from Nahlik & Fennessy 2016[30].
Boreal forests (all types)	Forestry	Initial C x 0%	Studies suggest that forestry/ timber has no meaningful effect on mineral SOC stocks in boreal forests, therefore we assumed 0% change[55,56].
Boreal grasslands and shrublands	Agriculture/development	Initial C x 0%	We assumed the same CRF as for temperate grasslands.
Boreal wetlands (non-peat, both forested and herbaceous)	Agriculture/development	Initial C x 42% (+/- 16.8%)	In absence of a boreal-specific study, we applied the same loss as temperate wetlands.
Mangroves	Aquaculture/development	Initial C x 81% (+/- 15.7%)	Estimate from Kauffman et al. 2017[35]
Seagrasses	Aquaculture/development	Initial C x 72% (standard error not available)	Estimate from Macreadie et al. 2014[37]
Salt marshes	Aquaculture/development	Initial C x 60% (+/- 8%)	Estimate from Van de Broek et al. 2019[38]
Tropical peatlands	Agriculture	Initial C x 100% or 450 (+/- 67) Mg C ha^{-1} (whichever is smaller)	Estimate based on IPCC emissions factors.
Temperate & boreal peatlands	Agriculture	Initial C x 100% or 135 (+/- 33) Mg C ha^{-1} (whichever is smaller)	

Appendix 3: Exporting atlases in PDF format

The code in R language below can be used to batch convert several text or presentation documents into PDF, while maintaining satisfactory quality and active hyperlinks. Replace the path and formats with the desired parameters. Make sure you have Libre Office installed (free).

```
install.packages("docxtractr")
install.packages("stringr")
library(docxtractr)
library(stringr)

setwd("C:/acces_path_docs_folder_to_convert")

#Recover all files in the working directory
all_files <- list.files()

#Filter only files with the .pptx extension
pptx_files <- all_files[ which(stringr::str_detect(all_files, "\\.pptx"))]

# Convert all pptx files to pdf using the replace extension function
for(i in seq_along(pptx_files)) {
  convert_to_pdf(path = pptx_files[i], pdf_file = paste0(str_remove(pptx_files[i], "\.pptx"), ".pdf"))}
```

Appendix 4: Examples of thematic map sheets

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Ecological atlas

Multi-thematic geographical overview of activity sites

Country: xxx
Site activity: xxx

Site: xxx

Project title
Author, date

Corporate logo

Company description_____

Bilbiographical reference of the atlas_____

From left to right : Mistle Thrush (Turdus viscivorus) ; Seascape in the Lavezzi islands in Bouches de Bonifacio (Corsica, France) ; Field pansy (Viola arvensis) ; Quarry landscape in Imerys Clerac site (Brittany, France).

Gaining insight into the ecological settings

Mapping the ecological context of a site is an essential step to understand and improve knowledge on the ecological stakes and to anticipate the impacts of the different phases of the operations, thus allowing to:

- Assess the sensitivity of the site and anticipate risks
- Adapt the response to impacts according to the local context
- Reinforce the overall mitigation approach and biodiversity action plans
- Communicate with stakeholders and disseminate knowledge

This illustrated document composed of several thematic maps provides an ecological potential analysis of the sites. This atlas is the result of the combination of several public cartographic databases for the characterization, quantification and evaluation of the ecological context of sites and their surroundings. It leads to the identification of "potential" ecological features of interest (based on spatial databases analysis instead of field observations), which should be taken into account to improve the management, preservation and restoration of the natural heritage on the sites.

How it this atlas structured ?

This atlas presents an assessment of the ecological context within a 5 km radius buffer around the GPS point of each site (or group of sites when they are spatially adjacent), following the map-crossing of this buffer areas with 17 spatial datasets. The diagnosis is structured around 5 main themes: ecoregions, biodiversity areas, ecosystems, threatened species, human impacts and carbon resources. Every theme encompasses a series of a cartographic visualizations and key figures for the understanding of the ecological settings of every site. These figures provide indicators of surface coverage of ecological features, expressed as a proportion of the site's surface covered by the data (%) or as an absolute area value (ha).

In the following maps, the buffers may have a slightly flattened shape. This is due to the projection system, but the buffers measure a radius of 5km throughout the polygon. Moreover, it may be possible that the results of the cross-referencing with all 17 databases are not displayed here because some sites are not concerned by all the data.

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Metadata : themes and datasets

Theme	Name	Producer	Abstract	Date	Spatial resolution	Internet link
Ecoregions	Global Ecological Zones	FAO FOM Forestry Department	The 19 global ecological zones refer to the main large-scale biomes, based on climate and vegetation.	2010	/	Link to resource
	Marine Ecoregions	The Nature Conservancy	Biogeographic classification of the world's coastal and continental shelf waters, following a nested hierarchy of realms, provinces and ecoregions.	2012	/	Link to resource
Biodiversity areas	Biodiversity Hotspots	Hoffman M. et al.	Identification of the 36 biodiversity hotspots in the world. Biodiversity hotspots are Earth's most biologically rich, yet threatened, terrestrial regions.	2016	/	Link to resource
	World Database on Protected Areas (WDPA)	UNEP-WCMC, IUCN	Compilation of the world's protected areas, marine or terrestrial, and their classification according to the 7 IUCN categories (referring to levels of protection)	2023	Variable	Link to resource
	Key Biodiversity Area	BirdLife International	Most important places in the world for species and their habitats, based on elements of biodiversity across genetic, species and ecosystem levels.	2014	Variable	Link to resource
Ecosystems	Terrestrial Habitats types	Jung M., et al.	Spatially characterization of 47 terrestrial habitat types, as defined in the IUCN habitat classification scheme, based on land cover, climate and land use.	2015	100 m	Link to resource
	Global Forest Change	Hansen M.C., et al.	Forest decline over the period 2001-2019 (deforested areas).	2019	30 m	Link to resource
	Forest Landscape Integrity Index	Grantham H.S., et al.	Forest extent in 2019, with indicators of human pressures and alteration of forest connectivity.	2000	300 m	Link to resource
	Global Lakes and Wetlands Database	WWF	Different wetland types, and also lakes, reservoirs, and rivers.	n.d.	1 km	Link to resource
	Natural Earth Rivers, lakes and reservoirs	Natural Earth	Main rivers and lakes	n.d.	/	Link to resource
	Global Distribution of Saltmarshes	Mcowen C., et al.	Distribution of saltmarsh (marine habitat).	2015	/	Link to resource
	Global Distribution of Seagrasses	UNEP-WCMC, Short FT	Distribution of seagrasses (marine habitat).	2020	/	Link to resource
	Global Distribution of Coral Reefs	UNEP-WCMC, WorldFish Centre, WRI, TNC	Distribution of coral reefs (marine habitat).	2018	30 m	Link to resource
	Global Mangrove Watch	Bunting P., et al.	Mangrove map : various types of salt-tolerant plant species (trees or shrubs).	2020	25 m	Link to resource
Threatened species	IUCN Red List Maps	IUCN	Distribution area of fauna and flora threatened species, based on IUCN Red List of Threatened Species™.	2022	/	Link to resource
Human impacts and carbon resources	Global Human Footprint	Venter O., et al.	Level of direct and indirect human pressures on the environment globally, based on a compilation of 8 variables	2009	1 km	Link to resource
	Vulnerable carbon	Noon M., et al.	Mapping of carbon sinks: extent of potential carbon loss in the event of disturbance/exploitation.	2018	300 m	Link to resource
Study areas	Sites	? Company	Surrounding layer (5 km) of company's sites, produced from the GPS points layer of the sites, provided by the company.	2023	/	

N.B. 1. The dates provided in the table of datasets and on the atlas maps are those of the data (time of acquisition), while the dates given in the bibliographic references are those of the publication of the data or the associated article. "n.d." means "no date".
N.B. 2. For each thematic page of the atlas, an insert (grey box) provides a brief explanation of the dataset represented.For further information, please consult the dataset sheets, available in the mapping user guide appendix (Régnier A., Forero S., 2023).

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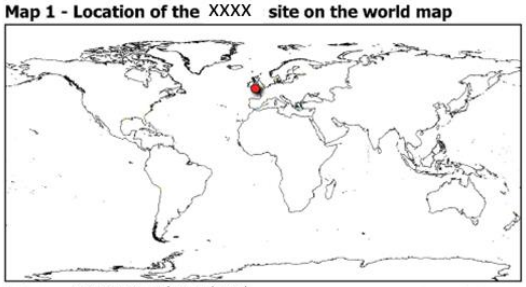
Site location

Project title
Author, date

Corporate logo

Map 1 - Location of the XXXX site on the world map



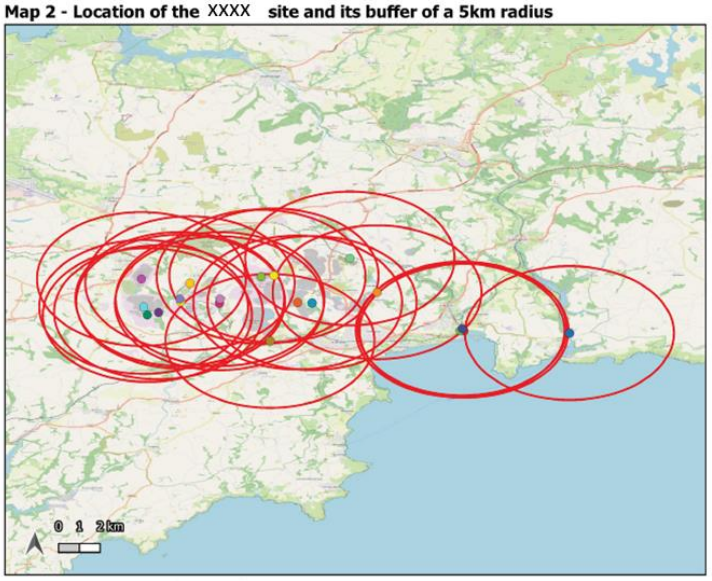
Data source: XXXX Company's sites (2023)
Background map: World Continents (ESRI, 2010)

Legend - Map 1
- XXXX site

Legend - Map 2
- Site's buffer(s)

Name(s) of IMERYS site(s)
- XXXX site Lab 1
- XXXX site Lab 2
- XXXX site Lab 3
- XXXX site Lab 4
- XXXX site Water treatment 1
- XXXX site Water treatment 2
- XXXX site Water treatment 3
- XXXX site Office building 1
- XXXX site Office building 2
- XXXX site Office building 2
- XXXX site Office building 3
- XXXX site Solid waste treatment 1
- XXXX site Solid waste treatment 2
- XXXX site Offset area
- XXXX site Plant 1
- XXXX site Plant 2
- XXXX site Plant 3
- XXXX site Plant 4
- XXXX site Rehabilitated area 1
- XXXX site Rehabilitated area 2

Map 2 - Location of the XXXX site and its buffer of a 5km radius



Data source: XXXX Company's sites (2023)
Background map: Open Street Map

Country:XXXXXXXXXXXX
Projection: WGS 84

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Ecoregions: Global Ecological Zones

Project title
Author, date

Corporate logo

Location of the site within the Global Ecological Zones

Data source: Global Ecological Zones (FAO, 2010)
Background map: Google satellite

Country: XXXX XX
Projection: WGS 84

Legend
- XXXX site

Global ecological zone (world)
- Water
- Subtropical desert
- Subtropical steppe
- Subtropical mountain system
- Subtropical dry forest
- Subtropical humid forest
- Temperate steppe
- Temperate mountain system
- Temperate oceanic forest
- Polar
- Tropical desert
- Tropical shrubland
- Tropical mountain system
- Tropical dry forest
- Tropical moist forest
- Tropical rainforest

What are the Global Ecological Zones?

An Ecological Zone (EZ) is defined as "a zone or area with broad yet relatively homogeneous natural vegetation formations, similar (not necessarily identical) in physiognomy" (Rakonczay Z., 2002).

The Global Ecological Zones recognize 20 ecological zones, gathered in five major domains (similar to the Köppen–Trew-artha climatic groups): tropical, subtropical, temperate, boreal, and polar. The Global Ecological Zones classification and maps categorize FAO (Food and Agriculture Organization of the United Nations) forest statistics into broad forest types.

Ecological zone: Tropical mountain system

All months without frost: in marine areas over 18°C. Approximate > 1000 m altitude (local variations).

(FAO, 2013)

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Ecoregions: Marine ecoregions

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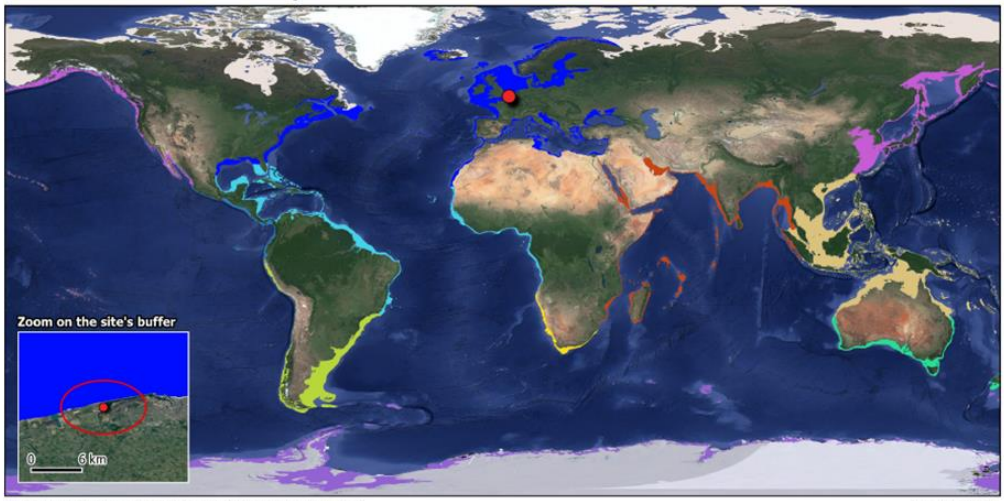
Author, date

Corporate logo

Location of the site within the major marine biomes



Legend

XXXX site

Marine ecoregions

- Arctic
- Central Indo-Pacific
- Eastern Indo-Pacific
- Southern Ocean
- Temperate Australasia
- Temperate Northern Atlantic
- Temperate Northern Pacific
- Temperate South America
- Temperate Southern Africa
- Tropical Atlantic
- Tropical Eastern Pacific
- Western Indo-Pacific

Data source: Marine Ecoregions (The Nature Conservancy, 2012)
Background map: World Continents (ESRI, 2010)

Country: XXXX
Projection: WGS 84

What are marine ecoregions?

The Marine Ecoregions Of the World dataset shows a biogeographic classification of the world's coastal and continental shelf waters, following a nested hierarchy of realms, provinces and ecoregions.

The regions aim to capture generic patterns of biodiversity across habitats and taxa, with regions extending from the coast to the 200m depth contour.

Realm	Province	Ecoregion
Temperate Northern Atlantic	Northern European Seas	North Sea

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Biodiversity areas: Biodiversity hotspots

Project title
Author, date

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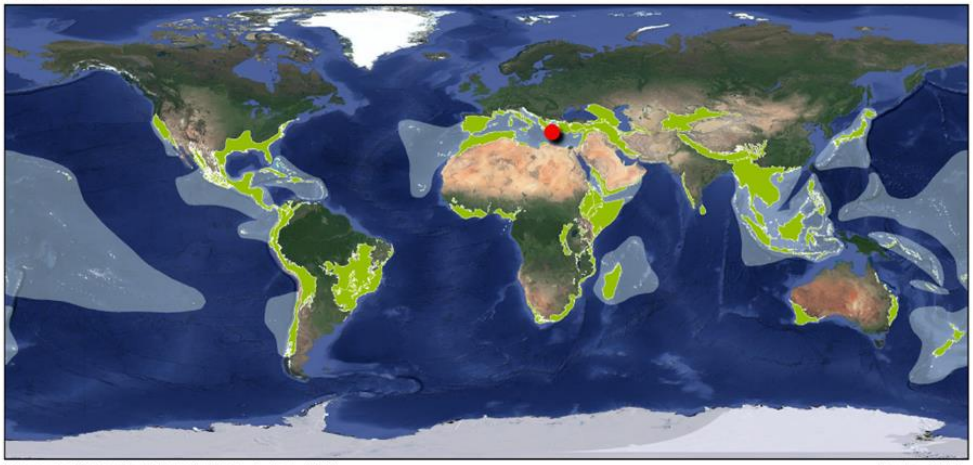
Location of the site within the world's biodiversity hotspots



Legend

XXXX site

Hotspots biodiversity

- Hotspot area
- Outer limit

• Hotspot area refers to the 36 official biodiversity hotspots
• Outer limit corresponds to the geographical extension of these official areas, in order to include the insular environments.

Data source: Biodiversity Hotspots (Hoffman, M. et al., 2016)
Background map: Google satellite

Country: XXXX
Projection: WGS 84

What are biodiversity hotspots?

Biodiversity hotspots are regions characterized both by exceptional levels of plant endemism and serious levels of habitat loss. These are Earth's most biologically rich - yet threatened - terrestrial regions.

To qualify as a biodiversity hotspot, an area must meet two strict criteria:

• Contain at least 1,500 species of vascular plants found nowhere else on Earth (known as "endemic" species).
• Have lost at least 70 percent of its original surface area.

(CEPF, 2023)

Hotspot: Mediterranean Basin

The Mediterranean Basin stretches from Cabo Verde in the west to Jordan and Turkey in the east, and from Italy in the north to Tunisia in the south. It also includes parts of Spain, France, the Balkan States, Greece, Turkey, and the nations of North Africa and the Middle East, as well as some 5,000 islands scattered around the Mediterranean Sea. West of the mainland, the hotspot includes a number of Atlantic islands: the Canaries, Madeira, the Selvages, the Azores and Cabo Verde.
Rivaling the natural diversity in the hotspot (which includes approximately 30,000 plant species), is its cultural, linguistic and socio-economic diversity. The region contains some of the world's first and greatest civilizations, and the oldest sovereign state of San Marino, which dates back to 301 A.D.
Many of the ecosystems reached an equilibrium long ago with human activity dominating the landscapes. However, this delicate balance is in a precarious state as many local communities depend on remaining habitats for fresh water, food and a variety of other ecosystem services.

(CEPF, 2023)

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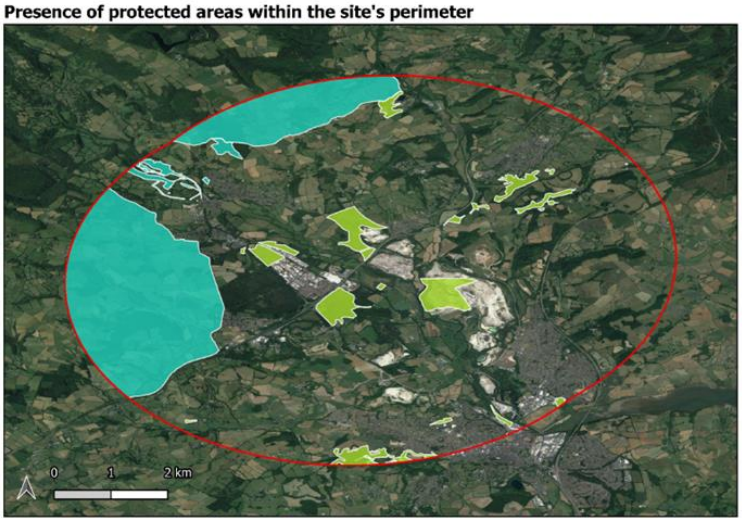
Biodiversity areas: Protected areas (1/2)

Project title
Author, date

Corporate logo

Presence of protected areas within the site's perimeter



Data source: WDPA and WDOECM (UNEP-WCMC and UICN, 2023)
Background map: Google satellite

Country: XXXX
Projection: WGS 84

Legend

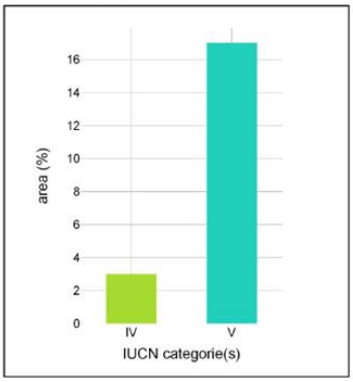
Site's buffer

IUCN status of protected areas

- Ia - Strict nature reserve
- Ib - Wilderness area
- II - National park
- III - Natural monument or feature
- IV - Habitat/species management area
- V - Protected landscape/seascape
- VI - Protected area with sustainable use of natural resources
- Not reported

N.B. 1. The map legend is the full classification of IUCN protected area classification. The site is not necessarily affected by all the classes displayed in the legend.
N.B. 2. The mention "not reported" displayed in the legend and on the graph groups together the areas identified as "not reported", "not assigned" and "not applicable" in the dataset.

Proportion of protected areas (by IUCN category) within the site's buffer



What is the WDPA?

The World Database on Protected Areas is the most comprehensive global database of marine and terrestrial protected areas. According to the International Union for Conservation of Nature (IUCN) "a protected area is a clearly defined geographical space, recognized, dedicated and managed, through legal or other effective means, to achieve the long term conservation of nature with associated ecosystem services and cultural values." (Dudley 2008).

Data for protected area records in the WDPA have been obtained from nearly 500 sources, and are referenced according to their IUCN category (international standard for classifying protected areas according to their management objectives)*. The protected areas mapped here are listed in the next page.

*The absence of a management category does not in any way reduce the importance of a protected area, nor does it imply that the site is not being adequately managed or should be excluded from analysis.

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Biodiversity areas: Protected areas (2/2)

Project title
Author, date

Corporate logo

Protected areas within the site's buffer

Name (original)	Designation (english)	Designation (original)	Management authority	IUCN category	Area (ha)
XXXX Park	Site Of Special Scientific Interest (Gb)	Site Of Special Scientific Interest (Uk)	Not Reported	IV	14
XXXX Marsh	Local Nature Reserve	Local Nature Reserve	Not Reported	IV	4
XXXX Prairie	Nature Reserve	Nature Reserve	National Trust	V	7
XXXX Caves and Oaklands	Site Of Special Scientific Interest (Gb)	Site Of Special Scientific Interest (Uk)	Not Reported	IV	28
XXXX Moor	Local Nature Reserve	Local Nature Reserve	Not Reported	IV	45
XXXX River	Site Of Special Scientific Interest (Gb)	Site Of Special Scientific Interest (Uk)	Not Reported	IV	41
XXXX Lake	Site Of Special Scientific Interest (Gb)	Site Of Special Scientific Interest (Uk)	Not Reported	IV	14
XXXX Peak	Nature Reserve	Nature Reserve	National Trust	V	47
XXXX Woodland	Local Nature Reserve	Local Nature Reserve	Not Reported	IV	23
XXXX Hills	National Park	National Park	Not Reported	V	1460
XXXX Farm	Site Of Special Scientific Interest (Gb)	Site Of Special Scientific Interest (Uk)	Not Reported	IV	26
XXXX Heathlands	Site Of Special Scientific Interest (Gb)	Site Of Special Scientific Interest (Uk)	Not Reported	IV	2
XXXX Royal Garden	Site Of Special Scientific Interest (Gb)	Site Of Special Scientific Interest (Uk)	Not Reported	IV	1
XXXX Ruins	Site Of Special Scientific Interest (Gb)	Site Of Special Scientific Interest (Uk)	Not Reported	IV	63
XXXX Old Growth Forest	Site Of Special Scientific Interest (Gb)	Site Of Special Scientific Interest (Uk)	Not Reported	IV	1
XXXX Rocky heights	Local Nature Reserve	Local Nature Reserve	Not Reported	IV	3
XXXX Covent	Site Of Special Scientific Interest (Gb)	Site Of Special Scientific Interest (Uk)	Not Reported	IV	51
XXXX Riverwalk	Site Of Special Scientific Interest (Gb)	Site Of Special Scientific Interest (Uk)	Not Reported	IV	46
XXXX Birds Haven	Local Nature Reserve	Local Nature Reserve	Not Reported	IV	3

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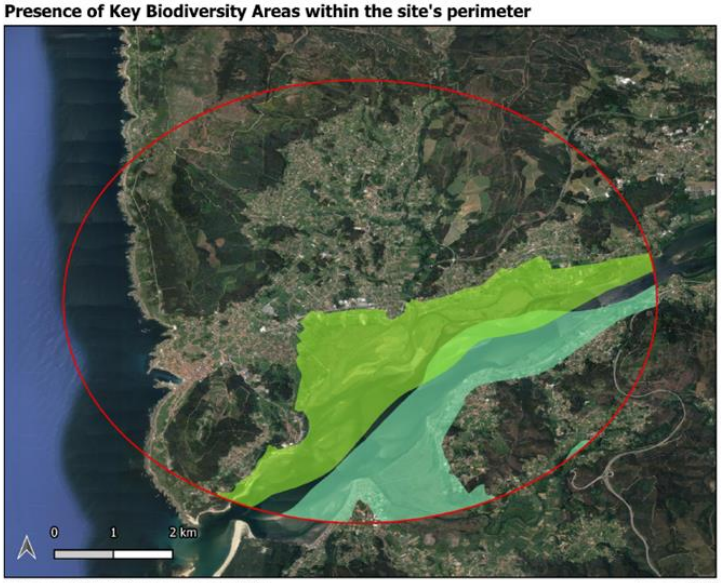
Biodiversity areas : Key Biodiversity Areas

Project title
Author, date

Corporate logo

Presence of Key Biodiversity Areas within the site's perimeter



Data source: KBA (BirdLife International, 2014)
Background map: Google satellite

Country: XXXX
Projection: WGS 84

What are KBAs?

The Key Biodiversity Areas are the most important places in the world for species and their habitats, based on elements of biodiversity across genetic, species and ecosystem levels. The conservation of KBAs help safeguard the most critical zones for nature.

KBA compiles several datasets: Important Bird and Biodiversity Areas, Alliance for Zero Extinction sites, Important Fungus Areas, Important Plant Areas, Prime Butterfly Areas.

Among these data, sites qualify as global KBAs if they meet one or more of 11 criteria, clustered into five higher level categories: threatened biodiversity, geographically restricted biodiversity, ecological integrity, biological processes and irreplaceability.

Additional data:
IBA areas: Important Bird Areas (Bird Life International)
AZE areas: threatened species areas (Alliance for Zero Extinction)

Legend
Site's buffer

KBA's names
XXXX Flood plains
XXXX Estuary

26% of the site's buffer is covered by KBAs

KBAs within the site's buffer

National name	Source	IBA status	AZE status
XXXX Estuary	BirdLife International: Global IBA Layer 13th June 2008	confirmed	no
XXXX Flood plains	Provided by Local Environmental NGO in June 2016, but initially prepared in 2011	confirmed	no

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Threatened species (1/2)

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IUCN Red List species: range of endangered amphibians, mammals, reptiles and plants

Data source: IUCN Red List Maps (IUCN, 2022)
Background map: Google satellite

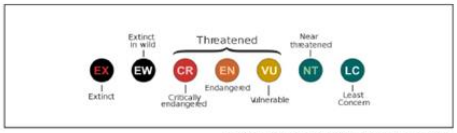
Country: XXXX
Projection: WGS 84

What is the IUCN Red List?

Established in 1964, the IUCN Red List of Threatened Species has evolved to become the world's most comprehensive information source on the global conservation status of animal, fungi and plant species.

What is a threatened species?

Threatened species are any species which are vulnerable to extinction in the near future. Among the different categories of species vulnerability established by the IUCN, only species in the "critically endangered" (CR), "endangered" (EN) and "vulnerable" (VU) categories are considered here as "threatened".
This assessment illustrates the known range of endangered amphibians, mammals, reptiles and plants.
The distribution maps are a depiction of a taxon's distribution; this does not equate to either the spread of extinction risk or the occupied range area. The maps simply intend to: informe Red List assessments, help to identify conservation priorities, visualize a representation of geographical area within which species can be found (IUCN, 2022). Species whose range is mapped here are listed on the following page.



IUCN 3.1 Red List Status by Peter Halasz

Legend
Site's buffer

IUCN categories
Vulnerable
Endangered
Critically endangered

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Threatened species (2/2)

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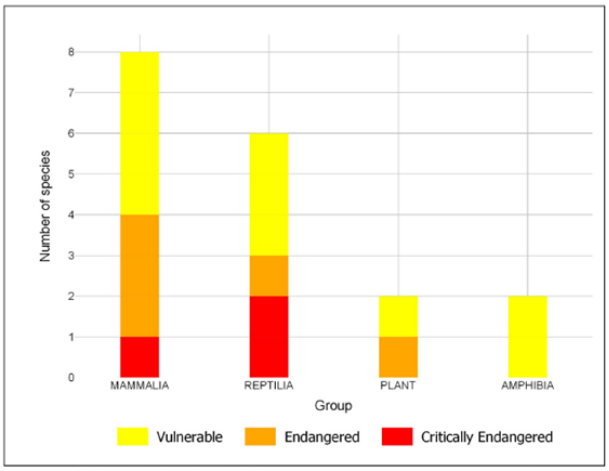
List of threatened animal and/or plant species with a range within the site's buffer

Plant/animal group	Scientific name	Threat status
AMPHIBIA	Rana iberica	VU
AMPHIBIA	Pelobates cultripes	VU
MAMMALIA	Balaenoptera musculus	EN
MAMMALIA	Balaenoptera borealis	EN
MAMMALIA	Balaenoptera physalus	VU
MAMMALIA	Nyctalus lasiopterus	VU
MAMMALIA	Arvicola sapidus	VU
MAMMALIA	Physeter macrocephalus	VU
MAMMALIA	Oryctolagus cuniculus	EN
MAMMALIA	Eubalaena glacialis	CR
PLANT	Rumex rupestris	VU
PLANT	Genista ancistrocarpa	EN
REPTILIA	Dermochelys coriacea	VU
REPTILIA	Chelonia mydas	EN
REPTILIA	Caretta caretta	VU
REPTILIA	Lepidochelys kempii	CR
REPTILIA	Eretmochelys imbricata	CR
REPTILIA	Vipera latastei	VU

Number of threatened species (by animal or plant group and by level of threat) with a range within the site's buffer



Data source: IUCN Red List Maps (IUCN, 2022)

Country:XXXX

Total number of threatened species with a range comprising the site's buffer: **18**

N.B. Please note that the species listed in the table are not necessarily present in the area of the site; these are probable ranges where the species are likely to be found.

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Ecosystems: Terrestrial habitat types

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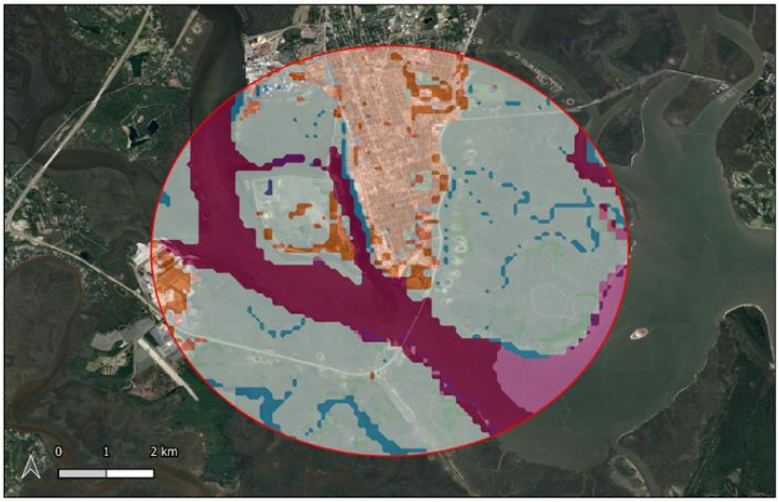
Habitat types within the site's buffer



Data source: Terrestrial Habitats types (Jung M., et al., 2015)
Background map: Google satellite

Country: XXXX
Projection: WGS 84

Legend — Site's buffer

Habitats

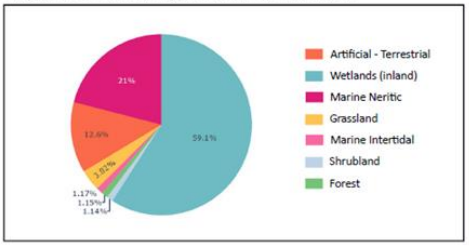
- Artificial-Terrestrial - Plantations
- Artificial-Terrestrial - Urban Areas
- Forest - Subtropical/tropical swamp
- Forest - Temperate
- Grassland - Temperate
- Marine Intertidal
- Marine Intertidal - Tidepools
- Marine Neritic
- Marine Neritic - Seagrass (Submerged)
- Shrubland -Temperate
- Wetlands - Permanent freshwater lakes (over 8 ha)
- Wetlands - Permanent inland deltas
- Wetlands - Seasonal/intermittent saline brackish or alkaline lakes and flats
- Wetlands (inland)

What are the terrestrial habitat types?

Habitat loss is one of the primary causes of biodiversity decline. There are many definitions of 'habitat', but they can broadly be described as the entirety of the physical conditions - including land cover and climate - that enable a species' population to persist in space and time. There is a strong positive relationship between the extent and intactness of a species' habitat and its population persistence. Knowledge about species' habitats is critical to design landscape management plans, conservation planning and analysis of past trends and future scenarios of species' extinction risk. Terrestrial habitat classes have been delineated following the IUCN classification scheme by intersecting data on land cover, climate and land use (Jung M., et al, 2020).

N.B. Differences in thematic resolution and definitions can lead to large variations in area-based land-cover estimates and errors.

Proportion of habitats types within the site buffer



Additional information on wetlands and the hydrographic system

Wetlands: 50-100% Wetland: 5382 ha (i.e. 68%)
Lake: 1309 ha (i.e. 16%)

Hydrographic network: No data or information

Data sources: Global Lakes and Wetlands Database (WWF), Natural Earth Rivers, lakes and reservoirs (Natural Earth)

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Ecosystems: Forest integrity and deforestation

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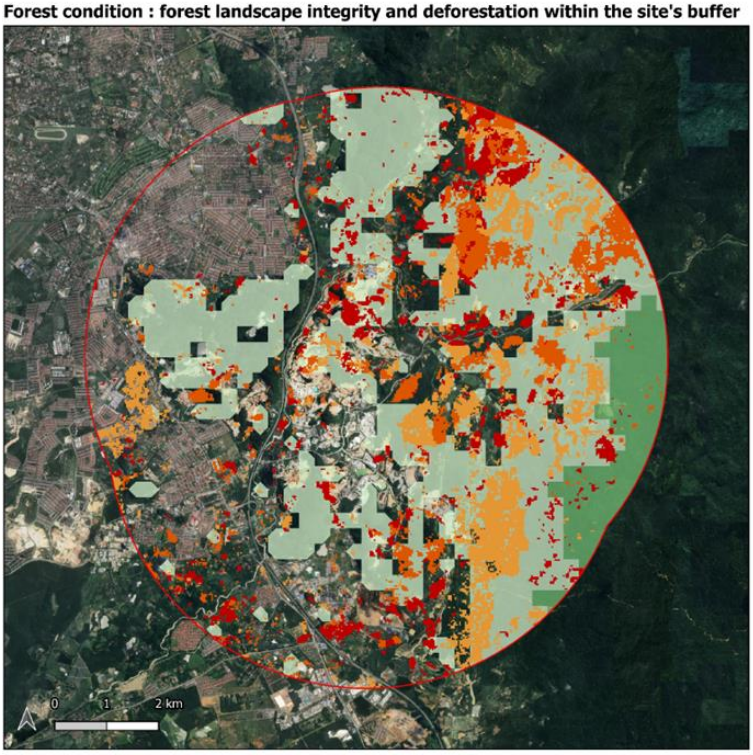
Forest condition : forest landscape integrity and deforestation within the site's buffer



Data sources: Global Forest Change (Hansen M.C., et al., 2019), Forest Landscape Integrity Index (Grantham H.S., et al., 2000)
Background map: Google satellite

Country: XXXX
Projection: WGS 84

What is the forest integrity?

The Forest Landscape Integrity is an index showing the forest extent in 2000, indicating, in addition, degrees of forest integrity. The integrity is based on human pressures and alteration of forest connectivity (Grantham H.S., et al., 2020).
Areas with medium to high integrity indexes could be preserved, while areas with a low index could represent a forest restoration opportunity.

And what about forest loss?

The Global Forest Change data shows the forest loss over the period 2001-2019. Each class in the legend thus indicates the time period of deforestation. Areas with forest loss could represent reforestation opportunities (Hansen M.C., et al., 2013).

Legend — Site's buffer

Forest integrity	Forest loss
low integrity	2001-2007
medium integrity	2008-2013
high integrity	2014-2019

Proportion of wooded and deforested area within the site's buffer, by integrity level (forest cover) and year of deforestation (forest loss)

Forest integrity area:		Forest loss area:	
low integrity:	4427 ha (i.e. 44 %)	2001-2007:	1026 ha
medium integrity:	522 ha (i.e. 5 %)	2008-2013:	434 ha
high integrity:	0 ha (i.e. 0 %)	2014-2019:	513 ha
Sum:	**4950 ha (i.e. 49 %)**	Sum:	**1974 ha**

N.B. 1. The map legends are the full legends of the databases. All the classes displayed in the legend are not necessarily on the map.
N.B. 2. It may be that some areas (particularly forest loss) are so small that items are not visible on the map. Please refer to the box above for the site's composition. (Figures are rounded; zeros can therefore simply mean values less than 1).
N.B. 3. These forestry datasets are derived from modelling. Approximations of location, type or area are therefore possible. The figures presented above, calculated by GIS, provide orders of magnitude rather than exact values.

Site(s): xxx | Site activity: xxx | Country: xxx

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Ecosystems: Marine ecosystems

Project title
Author, date

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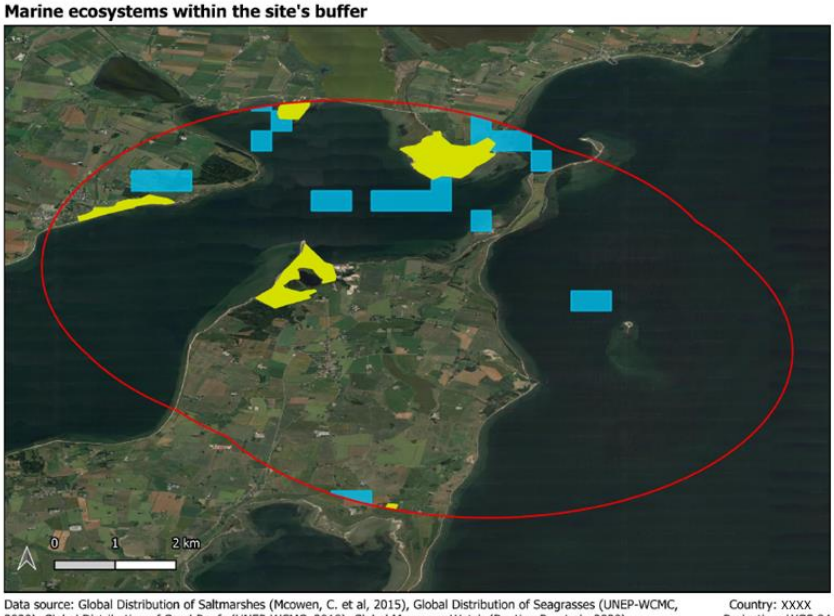
Marine ecosystems within the site's buffer



Data source: Global Distribution of Saltmarshes (Mcowen, C. et al, 2015), Global Distribution of Seagrasses (UNEP-WCMC, 2020), Global Distribution of Coral Reefs (UNEP-WCMC, 2018), Global Mangrove Watch (Bunting P., et al., 2020)
Background map: Google satellite

Country: XXXX
Projection: WGS 84

Legend
Site's buffer

Marine ecosystems
Saltmarshes
Seagrasses

Informations

Saltmarshes: 252 ha
Seagrasses: 409 ha

Seagrasses scientific name:Zostera marina
Seagrasses vernacular name: Eelgrass

What are marine ecosystems?

Marine ecosystems are saltwater aquatic ecosystems like estuaries and coastal areas, along with the open sea and oceans.

This includes but is not limited to:

Coral reefs: small colonial invertebrates that live in shallow seas found in the coastal zones of warm tropical and subtropical ocean (Park C., et al., 2013).

Mangrove: a tropical evergreen tree or shrub which grows in coastal areas, particulary on tidal flats and estuaries (Park C., et al., 2013).

Saltmarshes: an area of low-lying ground along a coast, which is regulary flooded by seawater at average high tide during the growing season, and where salt-tolerant plants grow (Park C., et al., 2013).

Seagrasses: they are the only flowering plants that can live underwater. They grow in sediment on the sea floor with erect, elongate leaves and a buried root-like structure (rhizome). There are about 60 species of fully marine seagrasses (Seagrass-Watch, 2023).

Covering a vast area of the earth, marine and coastal ecosystems are essential to the proper functioning of the planet. They provide several services, including nutrition for wildlife and humans, life cycle maintenance for flora and fauna, and carbon sequestration (Océan et Climat, s.d.).
Thus, special attention should be given to the preservation or restoration of these habitats.

Site(s): xxx | Site activity: xxx | Country: xxx

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Human impacts and carbon resources: Human footprint

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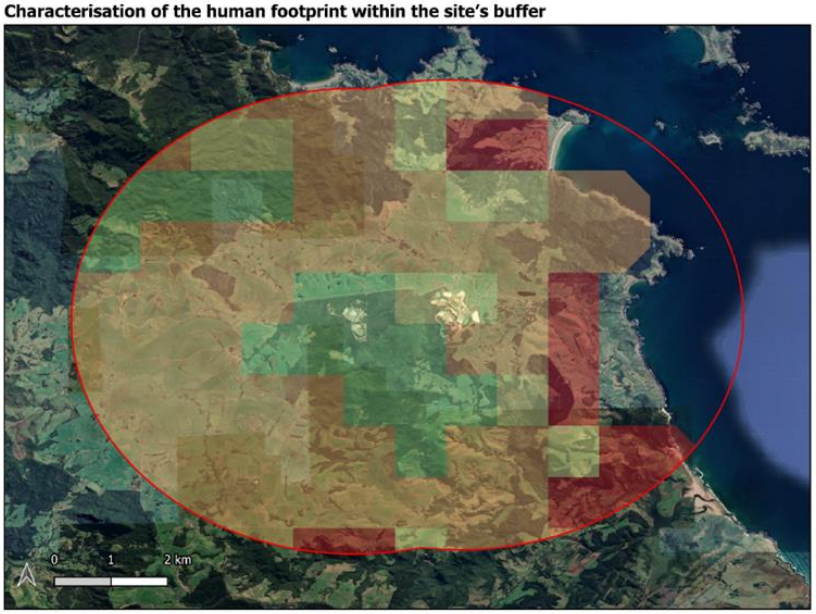
Characterisation of the human footprint within the site's buffer

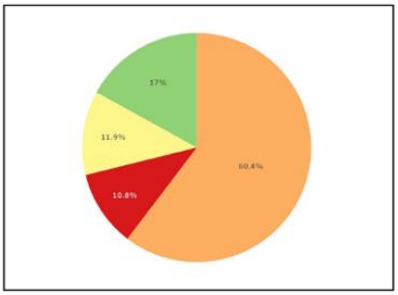


Legend
Site's buffer

Human pressure levels
no pressure
low pressure
moderate pressure
high pressure
very high pressure

N.B. Common legend for the map and graph

Proportion of different degrees of human pressures within the site



Data sources: Global Human Footprint (Venter O., et al., 2009)
Background map: Google satellite

Country: XXXX
Projection: WGS 84

What does the human footprint mean?

What does the human footprint mean? Human pressures on the environment are changing spatially and temporally, with profound implications for the planet's biodiversity and human economies. The human footprint refers to the direct and indirect human pressures on the environment globally, based on 8 variables : built environments, population density, electric infrastructure (night-time lights), crop lands, pasture lands, roads, railways, navigable waterways. These 8 pressures were overlaid to create the standardized Human Footprint map indicating the degree (low to very high) of pressure in an area. Areas with reduced level of pressures should be preserved (Venter O. et al., 2016).

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Human impacts and carbon resources: Vulnerable carbon

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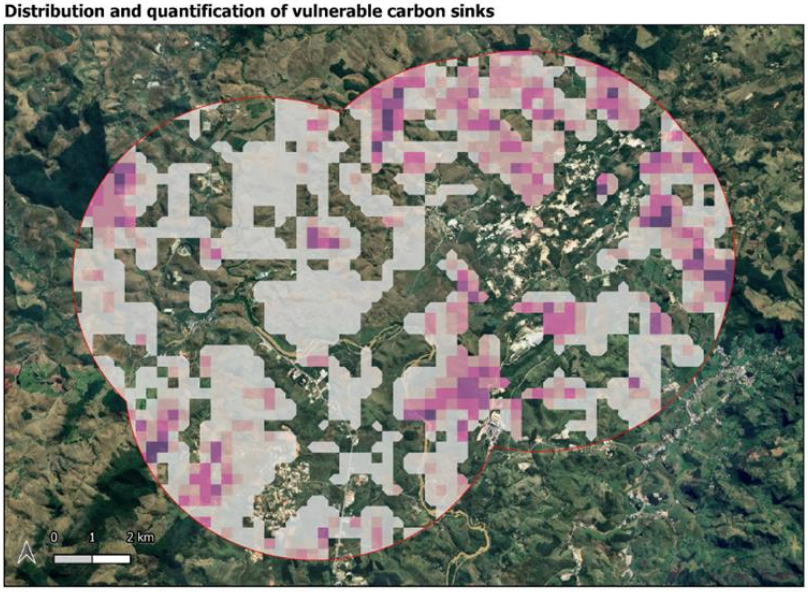
Distribution and quantification of vulnerable carbon sinks



Data sources: Vulnerable carbon (Noon M., et al., 2018)
Background map: Google satellite

Country: XXXX
Projection: WGS 84

Legend
Site's buffer

Vulnerable carbon (MgC/ha)

1 20 40 60 80 100 120 120 +

Average of vulnerable carbon value estimate within the site buffer: **40 MgC/ha**

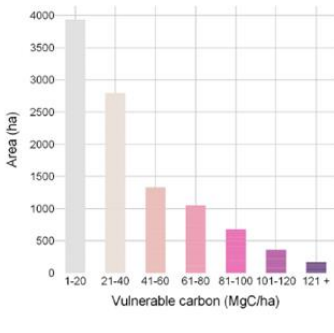
N.B. The map legend is the full legend of the database. All the classes displayed in the legend are not necessarily on the map. Please refer to the diagram on the right side for the site's composition.

What is vulnerable carbon?

Based on the global maps of carbon density in 2018, vulnerable carbon is the amount of carbon lost in the event of disturbance/exploitation. In other words, it corresponds to the amount of carbon that would be released if the reserves were destroyed (e.g. by logging or forest fire) or in a typical land-use conversion (Noon, M.L., et al.). It is expressed as the megagrams (Mg) of carbon (C) potentially stocked per hectare (ha) of land.

Carbon sinks absorb more carbon than they release. Protecting carbon sinks is essential for tackling climate change and keeping climate stable.

Area of carbon stocks on the site's buffer, according to the amount of carbon stored



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Disclaimer and limits

This cartographic work is based on the processing and analysis of global digital spatial data. This is a **general diagnosis** carried out on the Company'ssites worldwide, providing information on the main ecological stakes. It is important to use it as a tool for raising awareness and communicating, rather than an exact and exhaustive knowledge base. When analysing the cartographic work carried out, attention should be paid to three main points:

Data heterogeneity : the datasets used have variable parameters, including data date, data producer, acquisition method, and spatial resolution.

Data acquisition method: the content of a dataset may be based on different acquisition methods. Most of these are: **compilation** of several datasets from different sources, which results in a certain heterogeneity within the same dataset, such as spatial resolution, date or data producer; or **modelling**, using satellite images and artificial intelligence, and which may therefore result in mapping or identification errors.

Surface indicators: the surface areas (in hectares or percentages) displayed in the atlas are calculated using GIS software (calculations in WGS84 based on the ellipsoid). They gave an approximative overview of the extent of some ecological features and their values should be taken as a global indication.

For more information on the limits of each dataset, **please consult the dataset sheets, available in the mapping user guide appendix** (Régnier A., Forero S., 2023).

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Dataset references

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The dates provided in the table of datasets (p.1) and on the atlas maps are those of the data (time of acquisition), while the dates given in the bibliographic references are those of the publication of the data or the associated article.

SUMMARY

The creation of a cartographic atlas of the ecological context of a group of sites, based on the use of various datasets, enables organizations and economic players to gain a better understanding of the environment in which their activities are located. This first stage contributes to an overall analysis to be carried out across a network of sites, with the aim of anticipating potential risks on biodiversity, avoiding impacts or rehabilitating sites after use.

To conduct a cartographic assessment, a standardized methodological framework is proposed here, based on the use of accessible geographical datasets containing layers of information on the environment, such as sensitive areas, ecosystems and land use, range areas of endangered species, etc. The application of this methodological framework consists on the creation of a GIS project, using digital spatial and statistical data analysis tools, and comprising several stages ranging from data acquisition to its final representation, via its management, processing and analysis.

This project leads to the production of atlases (graphic and textual documents), which act as communication and awareness-raising tools, with the aim of raising awareness of the potential natural heritage in the area of the study sites.

Aimed at large geographical scales, this methodological framework has its advantages but also its limitations, which are discussed, along with prospects for improvement or adaptation to specific contexts.

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