
# Product Specification and Algorithm Theoretical Base Document: Nature-based recreation service account

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# 1. Introduction

## 1.1 Report objectives and approach

The objective of this report is to detail the technical requirements of the selected accounting pilot demonstrators for the PEOPLE-EA project, and hence covers the results of tasks in WP2.1 and WP2.2.

The report first describes the technical specification of the platform, whereafter for each demonstrator account is described:

- the technical specification (e.g., selection of condition indicators and reference levels)
- an overview of potential algorithms to be evaluated during an agile iterative co-design round-robin benchmarking.
- test areas and input datasets necessary to perform the round-robin benchmarking.
- results of the benchmarking, and justification of the selected algorithm

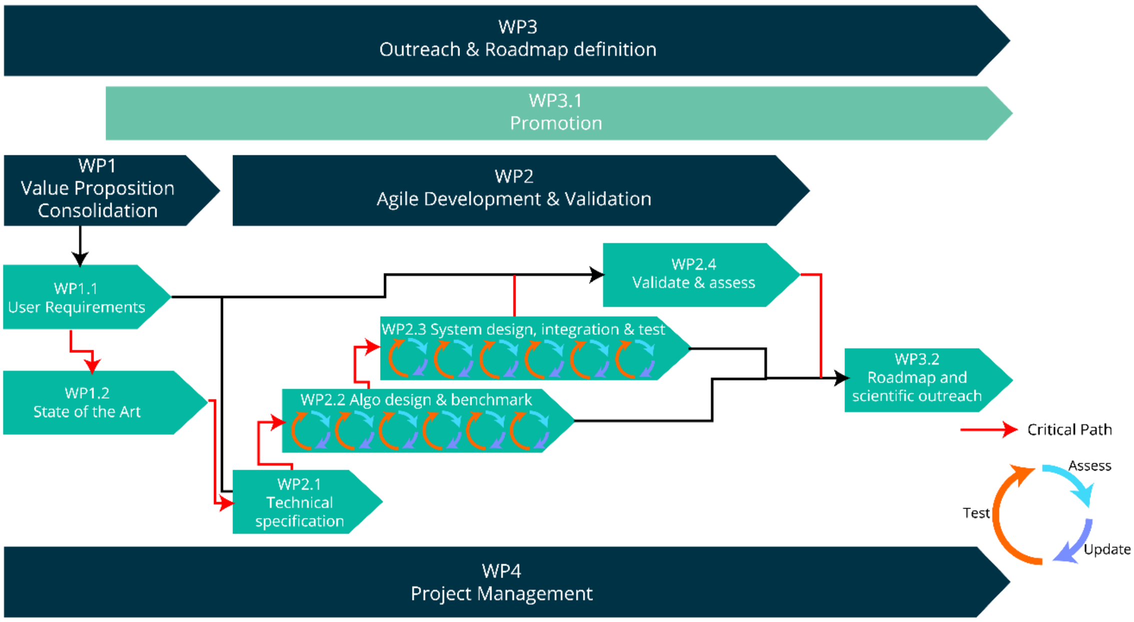


*Figure 1: Overview of WP2 agile iterative co-design development cycle*

## 1.2 Scope of work

Table 1 shows the selected pilot demonstrators, and the Early Adopters (countries) where a test-site will be selected to perform the round-robin benchmarking as a co-design activity.

*Table 1: Overview of ecosystem account pilot demonstrators*

| Account | Country | Details / Indicator | Year | Round-robin |
|---|---|---|---|---|
| **Recreation infrastructure** | Greece | Tourism infrastructure, especially in the coastal zone, to support the constantly increasing demand for recreation and other, nature related cultural ecosystem services | 2018 - 2022 | X |
| | Norway | Mapping recreation infrastructure in the different ecosystems in Norway | 2021 | |

Note that the workflow developed is still experimental and not operational, since it is considered to have reach TRL[1] Level-4. This level declares the technology is validated in the lab (in this context the demonstrations) and requires further R&D work as well as being made compliant to the European Statistics Code of Practice (CoP) before being used for official statistical reporting.

The proposed solution is based on the work done by the Joint Research Centre as described in the report[2]: European Commission, Joint Research Centre, Zulian, G., La Notte, A., Grammatikopoulou, I. and Zurbaran Nucci, M., *Nature-Based Tourism Accounting*, Publications Office of the European Union, Luxembourg, 2024, https://data.europa.eu/doi/10.2760/762803, JRC138538.

## 1.3 About ecosystem service accounts

Within the UN System of Environmental Economic Accounting (UN-SEEA), **ecosystem services** flow **accounts** record the supply of ecosystem services by ecosystem assets and the use of those services by economic units, including households. They can be expressed in physical or monetary terms. Monetary service accounts are however out of the scope of the project.

[1] TRL defines the Technology Readiness Level ranging from 1 (basic principles observed) up to 9 (actual system proven in operational environment).
[2] https://op.europa.eu/en/publication-detail/-/publication/c9f47ec5-86b9-11ef-a67d-01aa75ed71a1/language-en.

# 2. Nature-based recreation service

**Nature-based recreation services** are defined as the ecosystem contributions, through the biophysical characteristics and qualities of ecosystems, that enable people to use and enjoy the environment through direct, in-situ, physical and experiential interactions with the environment.

As they shall be reported in number of **overnight stays** in hotels, hostels, camping grounds, etc., that can be attributed to visits to ecosystems.

The nature-based recreation includes service to both local and non-local visitors, which includes **tourists**.

## 2.1 Key terms and definitions

Several key terms of this nature-based recreation service are defined by the United Nations World Tourism Organization (UN Tourism) in its International Recommendations for Tourism Statistics (IRTS 2008) and standards for measuring tourism[3], summarized below.

*Table 2: Overview of key terms and definitions (source: UN Tourism)*

**Travel** refers to the activity of travellers. A traveller is someone who moves between different geographic locations for any purpose and any duration.

A (non-local) **visitor** is a traveller taking a **tourism trip**. A tourism trip is a trip to a main destination outside his/her **usual environment**, for less than a year, for any main purpose (business, leisure or other personal purpose) other than to be employed by a resident entity in the country or place visited. Tourism refers to the activity of visitors.

A visitor is classified as a **tourist** (or **overnight visitor**) if his/her trip includes an overnight stay, or as a **same-day visitor** (or **excursionist**) otherwise.

Trips to a destination inside the usual environment are considered as daily recreation or trips made by locals.

The **usual environment** of an individual, a key concept in tourism, is defined as the geographical area (though not necessarily a contiguous one) within which an individual conducts his/her regular life routines.

A **domestic** trip refers to trips that have a main destination in the country of residence of the traveller. An **outbound** tourism trip has a main destination outside this country.

Tourism is considered **nature-based** if people travel with a primary purpose of direct, in-situ, physical and experiential interactions with the natural environment.

**Interactions with the natural environment** include visiting (walking, cycling, motorized transport) parks, gardens, the countryside, nature areas, the beach, rivers and lakes or performing activities such as horse riding, boating, adventure sports (e.g., skiing).

Activities which are not considered interactions with the natural environment include visiting theme parks, zoos and aquariums, historical buildings or monuments, shopping and eating in human developments, business trips, competitive sports.

## 2.2 Nature-based recreation service and the Recreation Potential Map (RPM)

The demonstrations for the nature-based recreation service follow the implementation in the model from the QGIS plugin tool developed for the EUROSTAT in the Integrated Natural Capital Accounting (INCA) project.

In turn, the INCA tool and model is, wherever possible, compliant to the Guidance notes for ecosystem accounting established by European Task Force on ecosystem accounting (see figure below).

[3] https://www.unwto.org/glossary-tourism-terms

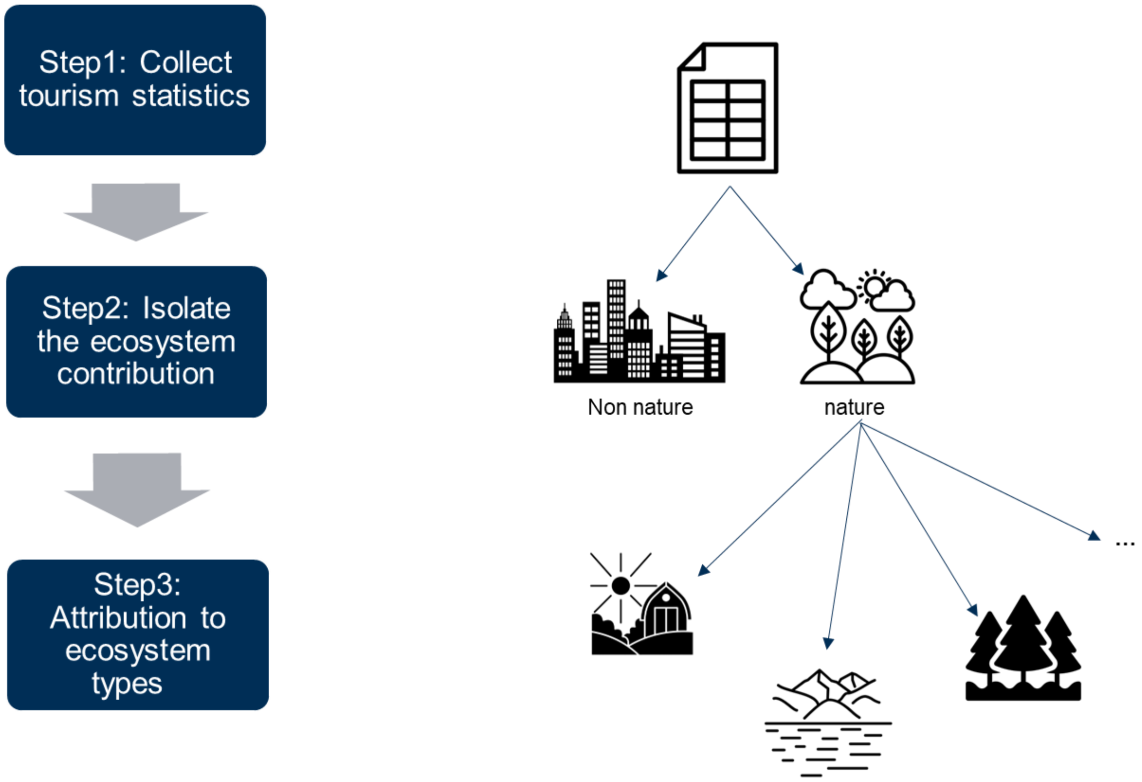


*Figure 2: Three main steps in the nature-based recreation service workflow (source: Task Force Guidance Note)*

In the default method, that is intended to be applied for this demonstration, the Guidance Note proposes to use the Recreation Potential Map (RPM), developed by the European Commission Joint Research Centre (JRC - Zulian et al. 2022). This RPM maps areas according to their recreation potential with raster cell values ranging from 1 (low potential) through 9 (high potential). The RPM is computed from a cross-tabulation of metrics related to landscape attractiveness (e.g., presence of protected areas, beaches or forests) with metrics on accessibility (e.g., proximity to roads and residences).

| Accessibility \ Attractiveness | very low 1 | low 2 | high 3 | very high 4 |
|---|---|---|---|---|
| 5 | 1 | 1 | 4 | 7 |
| 4 | 1 | 4 | 4 | 7 |
| 3 | 2 | 2 | 8 | 8 |
| 2 | 3 | 5 | 5 | 9 |
| 1 | 3 | 6 | 6 | 9 |

*Figure 3: Cross-tabulation of RPM categories (colour-coded values 1 through 9) based accessibility (proximity to roads and settlements: 1 = near to 5 = far) and ecosystem-based attractiveness*

The default method from the Guidance Note foresees the use of the RPM in the Step 2 - the isolation of the nature-based contribution in the collected statistics on overnight stays. In Step 2, the ratio of the areas with medium to high potential for recreation near to roads and settlements (RPM categories 5,6,8,9) to the total administrative (NUTS2) area is used to isolate the nature-based contribution from the tourism statistic.

Optionally, the RPM or other datasets can be used in Step 3 to assign weights for the distribution between the ecosystem types.

The JRC's methodology (ESTIMAP model) for calculating the RPM is summarized in the diagram below. It is in essence a cross-tabulation between the attractiveness (EBP) and accessibility (Human Inputs), whereby the EBP itself is a weighted sum of land suitability, natural elements (protected areas) and water elements.

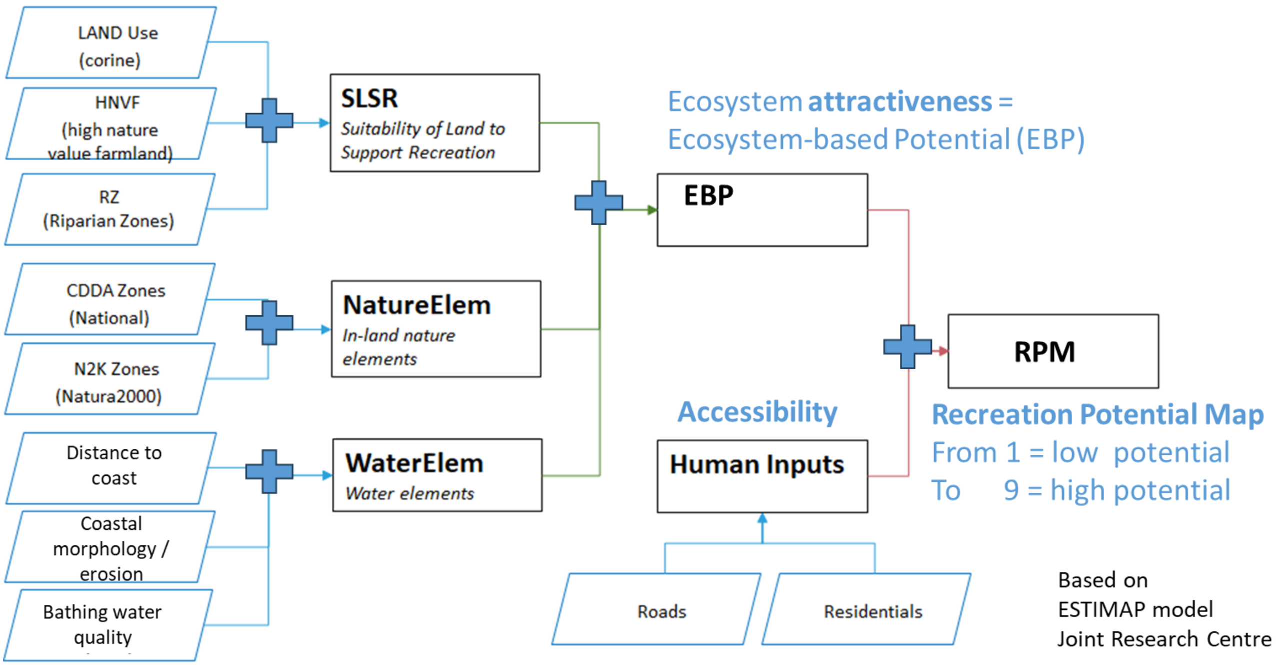


*Figure 4: Diagram of the JRC ESTIMAP model used to produce the Recreation Potential Map (RPM)*

## 2.3 Using EO to enhance the RPM

In PEOPLE-EA, the nature-based recreation demonstration accounts for the Early Adopters Greece and Norway will be computed with an RPM that is enhanced with EO data. This can then be compared with the account using the reference RPM from JRC to evaluate the impact of the EO data on the final accounts.

The EO data sources are expected to bring added value in terms of (i) wider geographic coverage with a consistent retrieval method, (ii) more frequent updates (e.g., to move closer to annually updated accounts) and/or (iii) increased level of geographic detail.

## 2.4 Forest loss in Greece

### 2.4.1 Study scope

In agreement with the Early Adopter in Greece, the study area of the **Peloponnesus peninsula** was selected. In terms of NUTS areas, this involves EL632, EL633, EL651, EL652, EL653 at NUTS Level 3. While the workflows and accounts will be calculated for the whole country, these areas are specifically focused on (also for the validation).

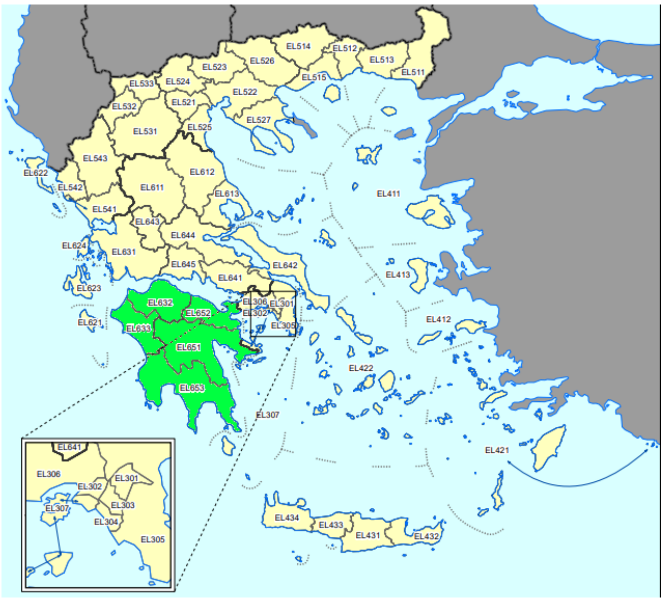


*Figure 5: Map of NUTS Level 3 areas in Greece (source: Eurostat) with study areas highlighted in green*

From the annual statistics on forest fires reported by the Copernicus Emergency Management Service (CEMS – see figure below), it was clear that the year 2021 saw the third highest number of hectares burned in the period 2006-2023 and the highest number among the targeted period (2018-2022). A higher number of burned areas is expected to result in a more substantial impact on the account.

As fires and loss of forest in one year are expected to reduce the recreation potential and activities in the subsequent year, it was decided to compute the accounts for the **year 2022**.

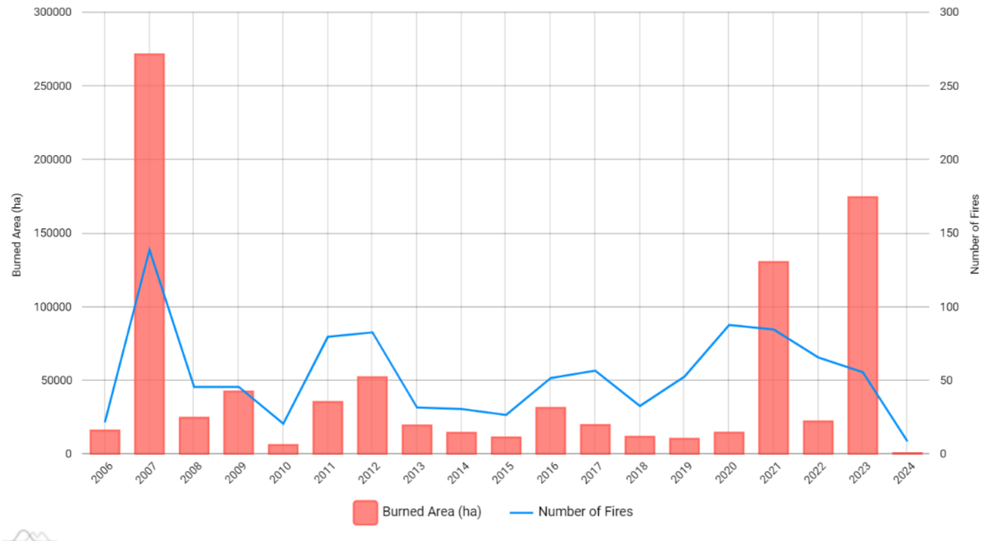


*Figure 6: Annual amount of burned area in hectare and number of fires (source: Copernicus Emergency Management Service (CEMS) - European Forest Fires Information Service (EFFIS))*

The input data availability was found to be sufficient and did not require a change in the selection of the account year nor in the selection of the geographic area.

### 2.4.2 EO data selection and availability

*Table 3: Overview of EO data sources explored for forest loss and/or gain*

| Provider | Dataset | Period / frequency | Grid |
|---|---|---|---|
| University of Maryland | Global Forest Change 2000-2023 version 1.11 | Annual loss 2000-2023<br>Annual gain 2000-2012 | 25-30m |
| Copernicus Land Monitoring Service | Tree Cover Density (%) | 3-yearly, 2012 to 2018 | 10/20 or 100m |
| | High Resolution vegetation productivity<br>(PPI integral over season) | Annual, 2017 onwards | 10 or 100m |
| | CORINE land cover change | 6-yearly, 2000 onwards | 100m |
| | Global Land cover collection 3 | Annual, 2015-2019 | 100m |
| ESA | WorldCover | Annual, 2020-2021 | 10m |

The Global Forest Change (GFC) dataset provides a long time series on the years of forest loss, with annual updates. The author points out that the series includes two levels of quality (before/after 2011). The forest gain data is unfortunately not available for recent years.

The Copernicus Tree Cover Density dataset includes all trees, not only those in forests and would thus need to be classified carefully to cover only forests. Moreover, differences (increases/decreases) in tree cover density (%) would need to be translated into a level of decrease of recreation potential. Moreover, the TCD dataset is 3-yearly, with no information on the year of tree loss/gain, which is a limitation for the production of annually updated accounts.

From the Copernicus High Resolution Vegetation Phenology and Productivity (HR-VPP) dataset, the annual productivity parameters are the most relevant. As these parameters cover all types of vegetation, it would require an effort to identify (classify) the forests and to score the loss of productivity (integral of PPI index) in terms of loss of recreation potential. This dataset offers a potential benefit in the mapping of vegetation regrowth (e.g., grasses, bushes) after the forest loss due to fire. It may thus help to establish the timeline (year) of recovery of the recreation potential. For this first demonstrator on the use of EO to enhance recreation accounts, the focus is on forest loss. The concepts of vegetation regrowth and forest gain in subsequent year(s) and accounts is left out of the scope of the first demonstrators, as further study is required.

The CORINE land cover change dataset shows the land cover class in a more recent CORINE map (e.g., 2018) for those raster cells that changed class since the preceding CORINE map (e.g., 2012). As such, the loss of forest would need to be computed for all raster cells with change where the preceding map had a forest class.

While the Copernicus global dynamic land cover dataset is focused on forest classes and change detection, the dataset is based on only a single satellite mission (PROBA-V) that ended its lifetime in mid-2020. Therefore, no updated maps before 2015 or after 2019, with the same methodology, are to be expected.
ESA/Copernicus are expected to produce land cover maps, spanning more years, that benefit from the experiences of the WorldCover maps (Sentinel-2, 10m) and the Copernicus global dynamic land cover datasets (e.g., annual change detection).

The activity to produce those maps - the Copernicus Global Land Cover and Tropical Forest Mapping (LCFM[4]) – was started up recently and its first maps will not be available in time for the PEOPLE-EA demonstrators.

For these reasons, the **Global Forest Change dataset** was selected for the PEOPLE-EA demonstrator on **annual forest loss** in Greece.

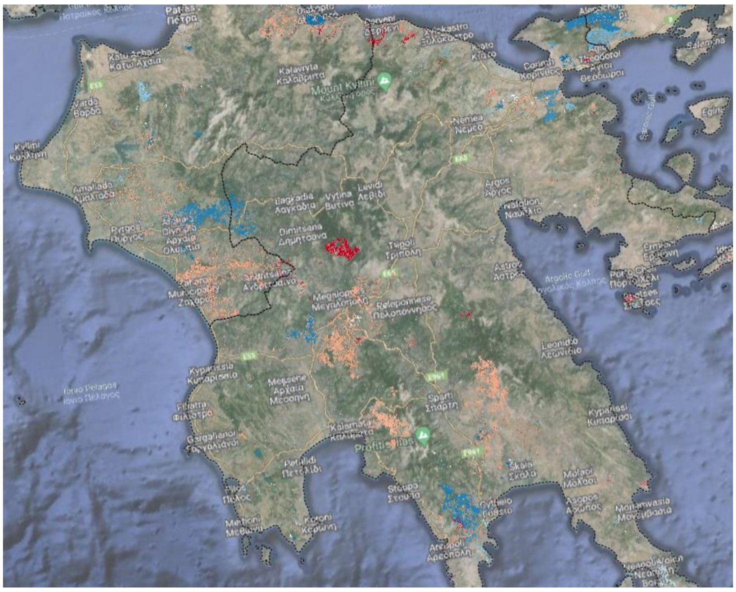

*Figure 7: Map of the Global Forest Change dataset over the Peloponnesus peninsula, with loss year 2007 in orange, 2021-2023 in blue tones and 2001 in red and Google satellite background*

## 2.4.3 Proposed concept

Conceptually, the reference RPM focuses on *summing up* all the available elements that contribute to the recreation potential. In the demonstrator, the loss of forest is introduced as *decrease* of potential from a natural disturbance, as depicted in the diagram below.

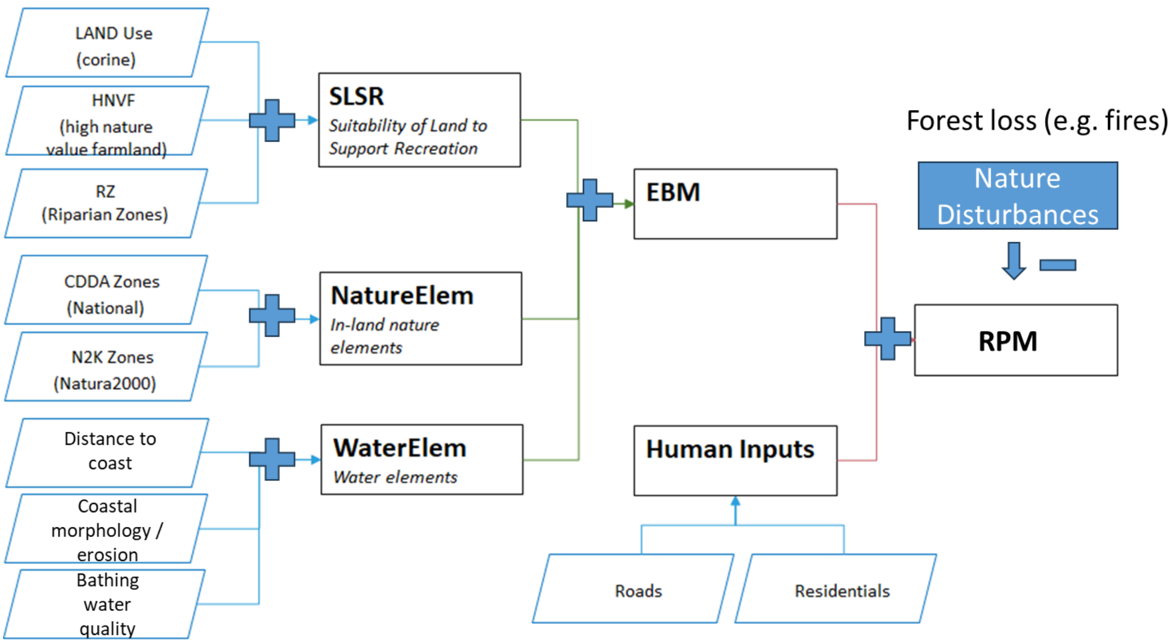


*Figure 8: Proposed concept for reducing RPM values for nature disturbances such as loss of forest*

[4] https://remotesensing.vito.be/news/copernicus-global-land-cover-and-tropical-forest-mapping-and-monitoring-service-lcfm-awarded

Whereas the loss of forest implies a loss of landscape attractiveness, it can be noted that forest fires can also affect the accessibility (loss of residences), which is not mapped separately in this demonstrator. For simplicity, the natural disturbances are considered a complete loss of recreation potential, bringing the RPM down to its minimal value (1) for the affected areas.

### 2.4.4 Proposed workflow(s)

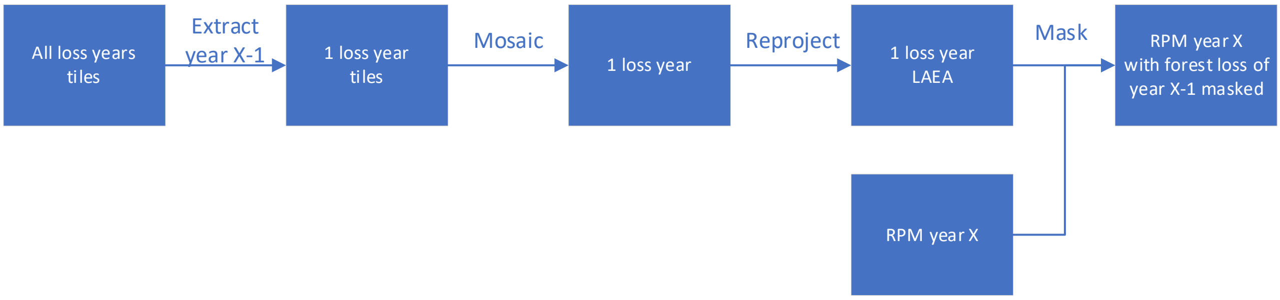


*Figure 9: Diagram of the workflow for the RPM masking based on Global Forest Change EO input data*

Global Forest Change data is downloaded in the form of 10x10 degree raster tiles in GeoTIFF format, with EPSG 4326 coordinate reference system and 0.00025 degree pixel size.

All pixels except those with the intended loss year (2021) are then masked out using Python rasterio code.

Using GDAL's *gdalbuildvrt* and *gdal_translate* utilities, the tiles are then mosaicked to cover Europe in a single image.

The resulting loss year mosaic is reprojected to the same grid and coordinate reference system as the reference RPM (EPSG 3035). By this reprojection from 10m to 100m grid, small patches of forest loss (e.g., 1 ha) are filtered out, which is intentional. An additional Sieve filter was tested to further reduce the small forest loss patches but proved to be unnecessary.

Lastly, the reference RPM is masked by setting all raster cells to the minimal value (1) where the forest year is found.

## 2.5 Water quality in Norway

### 2.5.1 Study scope

In the reference RPM, countries that are not full EU members show less recreation potential than EU members. This is the case for EFTA countries like Switzerland and Norway, but also candidate EU members (Balkan countries, Turkey). These lower RPM values are likely caused by gaps in the input data.

One example of missing areas with high potential are the inland protected areas. These are clearly visible in the RPM for Sweden, close to the Norwegian border, but not showing within Norway. As the boundaries of such areas are already carefully defined by Norwegian authorities, adding them to the RPM would improve the recreation potential. However, there is no real need to use Earth Observation to map or delineate the areas. The addition of protected areas to the Norway RPM is thus out of scope of the PEOPLE-EA demonstrator.

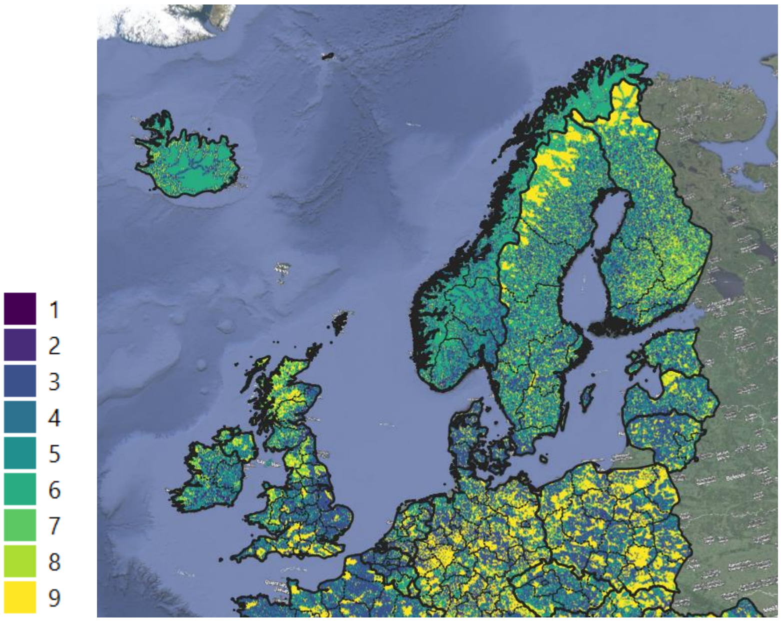


*Figure 10: Reference RPM showing lower values for EFTA countries like Norway when compared to its EU neighbours Sweden and Finland*

As another example, all the data sources for the Water Element in the RPM were found to be missing, resulting in lower recreation potential values for sea and inland coastal areas for Norway when comparing to its neighbours (see image below).

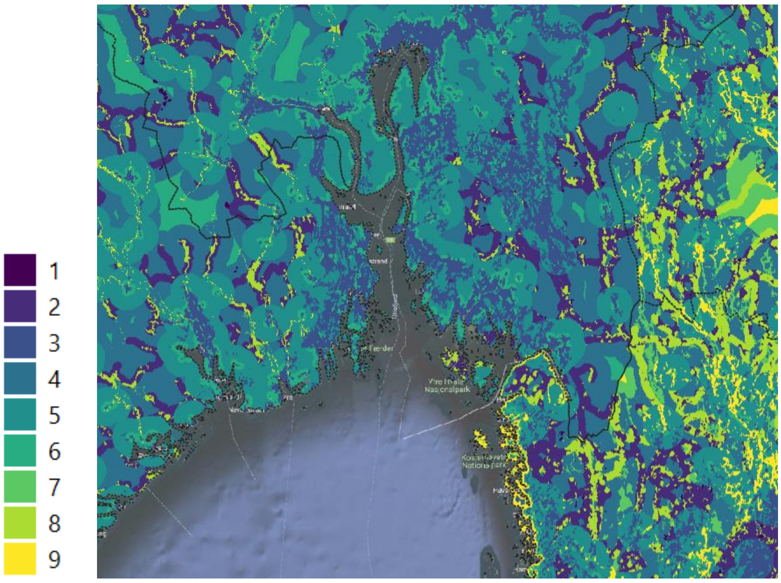


*Figure 11: Visualization of the reference RPM around Oslofjord. While some water elements are visible on the Norwegian side, the Swedish water and coastal areas score consistently higher.*

In the RPM, the water element is computed as a weighted sum of the following data sources:

- the presence of marine protected areas (score 0 to 1),
- the distance to lake and seacoasts (each scored between 0 and 1),
- the coastal morphology and coastal evolutionary trends like erosion (scoring between 0 and 1.2)
- and the Bathing Water Quality (BWQ) data (scoring up to 2.4)

Conceptually, even more water characteristics may influence the potential for water recreation, such water temperature, wind speed & wave heights, pollutants like oil spills, suspended matter (water clarity), turbidity & currents. Many of those could be estimated with EO, are inter-related and offer more dynamism.

Based on (i) the relatively higher weight of BWQ in the water element of the reference RPM implementation, (ii) VITO's previous experience with the production of EO-based water quality data, (iii) the EO data availability and (iv) the added value that EO could bring, it was decided to focus on the **water quality** part for the demonstrator.

Through a framework of water-related directives, the EU is systematically monitoring and managing water quality. The BWQ directive data for instance comprises of in situ measurements of bacterial water content that can pose health risks to people in the water. The BWQ is measured at many locations during the bathing season and the measurements are classified as 'excellent', 'good', 'sufficient' or 'poor', depending on the levels of faecal bacteria detected. Depending on those values, the member states are prompted to take actions such as banning or advising against bathing, improving urban wastewater treatment and so on. These classified values are scored in the implementation of the reference RPM.

In the agreement with the Early Adopter in Norway, accounts for the NUTS areas of Oslo og Viken (NO08 – NUTS level 2), Møre og Romsdal (NO0A3) and Nordland (NO071) (both level 3 areas) and the year **2021** were requested.

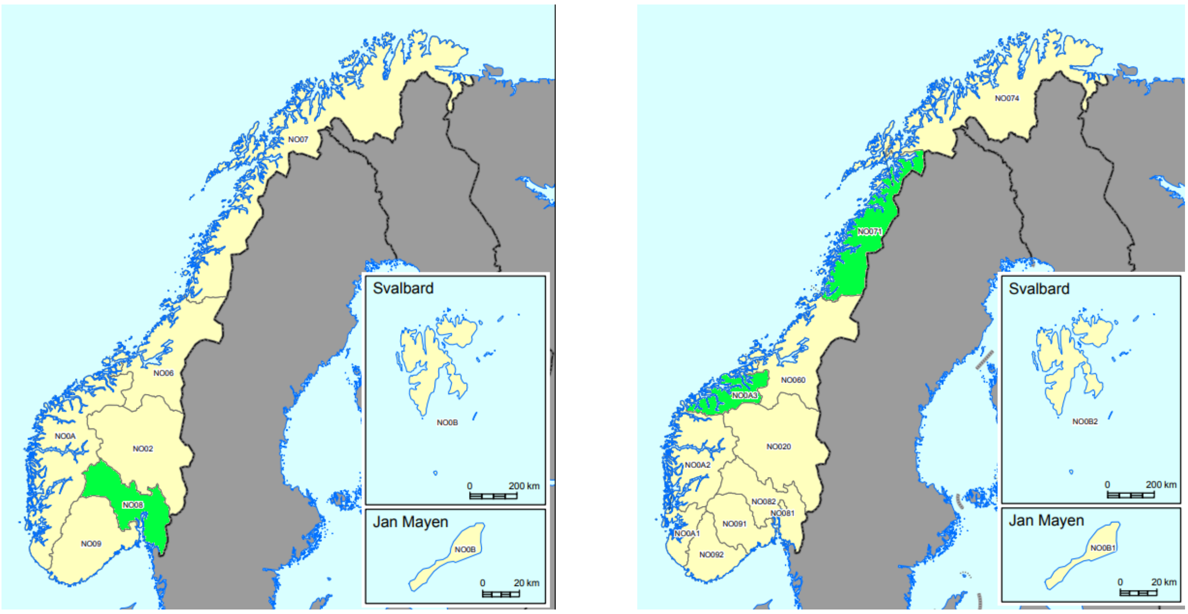


*Figure 12: NUTS level 2 (left) and 3 (right) areas in Norway (source: Eurostat) with study areas highlighted in green*

In view of the EO data availability and coverage, the **focus** of the demonstrator lies on the **area around Oslo** (Oslo og Viken), with partial coverage of Møre og Romsdal area. Nordland was not covered by the EO data sources, hence very small to no impact on the account was expected there. Oslo og Viken is an area with many lakes and marine coast (fjord).

### 2.5.2 EO data selection and availability

To establish if the EO-based water quality can be used as a replacement of or a supplement to the Bathing Water Quality (BWQ) data (where both are available), it is important to compare the characteristics of both.

*Table 4: Characteristics of EO-based water quality and Bathing Water Quality directive datasets*

| | Bathing Water Quality | EO-based water quality |
|---|---|---|
| **Measures** | Bacterial content | Nutrient content and eutrophication |
| **Water sampling** | Measured near the coast, at water access points for bathing | Retrieved over the whole water body, with limitations from cloud cover (optical EO sensor), which can be relevant for water recreation types other than bathing (e.g., boating) |
| **Geographic coverage** | Large number of in situ monitoring locations | Depending on the source, it can be small scale (high detail) to large scale (EU, global) |
| **Updates** | Most sites are monitored continuously during bathing months and reported in the dataset as a single value per year | Frequent updates (daily, 10-daily) |

When looking for EO-based water quality datasets, three readily available products from Copernicus services were found with the following characteristics.

*Table 5: Comparison of two Copernicus service datasets on sea and lake water quality*

| | High Resolution Ocean Colour (HROC) | Lake Water Quality |
|---|---|---|
| **Source** | Copernicus Marine Environment Monitoring Service (CMEMS) | Copernicus Land Monitoring Service |
| **Pixel size** | 100m | 100m and 300m |
| **Area coverage** | North West Shelf (other areas are available separately) | 100m: processed over selected Sentinel-2 tiles<br>300m: processed over selected lakes |
| **Data for summer (May-Sept) 2021** | Yes<br>Period Jan 2020 – June 2024 is available | Yes<br>100m is available from July 2021 onwards<br>300m is available from 2016 to present |
| **Update frequency** | Daily observations or monthly aggregates | 10-daily averages |
| **Parameter** | Chlorophyll-a concentrations | Trophic State Index<br>(derived from chlorophyll-a) |
| **Link(s)** | CMEMS HROC for North West Shelf | CLMS Lake Water Quality 100m<br>CLMS Lake Water Quality 300m |

*Figure 13: Example of data coverages of the CMEMS HROC data (left), CLMS 100m Lake Water Quality over specific Sentinel-2 tiles (middle) and CLMS 300m Lake Water Quality over selected lakes (right)*

The above examples of the data coverage illustrate why the focus of the demonstrator was on the Oslo og Viken study area. For a more complete coverage of the country, the use of lower resolution ocean colour could be envisaged, or the use of on-demand processing of Sentinel-2 tiles (with cloud computing cost).

Moreover, it can be noted that the 100m and 300m Lake Water Quality products can be used in conjunction, with the 100m adding spatial detail and smaller lakes and the 300m adding lakes outside the Sentinel-2 tiles.

### 2.5.3 Proposed concept

Conceptually, the reference RPM focuses on *summing up* all the available elements that contribute to the recreation potential. In the demonstrator, the EO-based water quality is added into the Water Element as a supplement to the bathing water quality and other Water Element inputs.

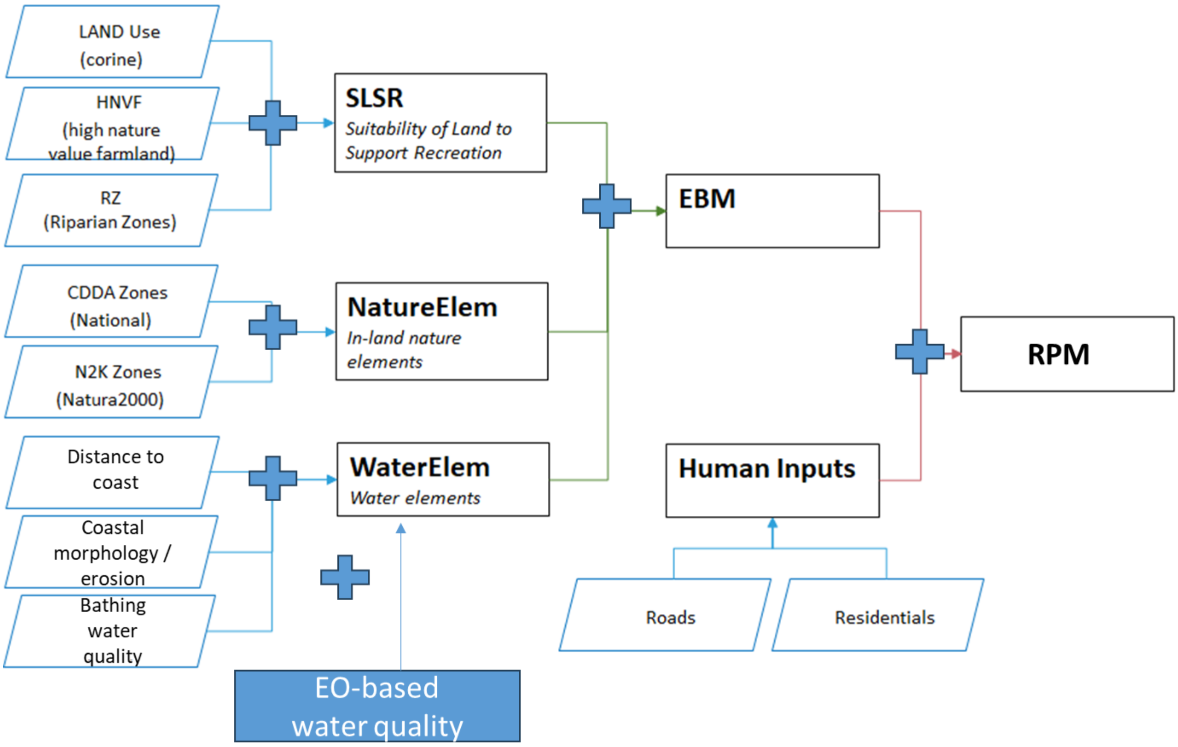


*Figure 14: Proposed concept for increasing RPM values using EO-based water quality input data*

Whenever possible, the integration of the EO-based water quality data into the Water Element of the RPM (e.g., scoring and distance impedance buffer over the coast) should follow an approach equal or similar to that of the Bathing Water Quality.

### 2.5.4 Proposed workflow(s)

The workflows aim to provide a per-pixel average values of water quality, averaged over the months of May through September. Here, Trophic State Index (TSI, Carlson et al., 1977) values are used, because they can be stratified into trophic classes (oligotrophic, mesotrophic etc.) that can be scored. For each water quality data source, TSI is retrieved from underlying chlorophyll-a concentrations.

**Workflow for the retrieval of Sea TSI from CMEMS High Resolution Ocean Colour input data**

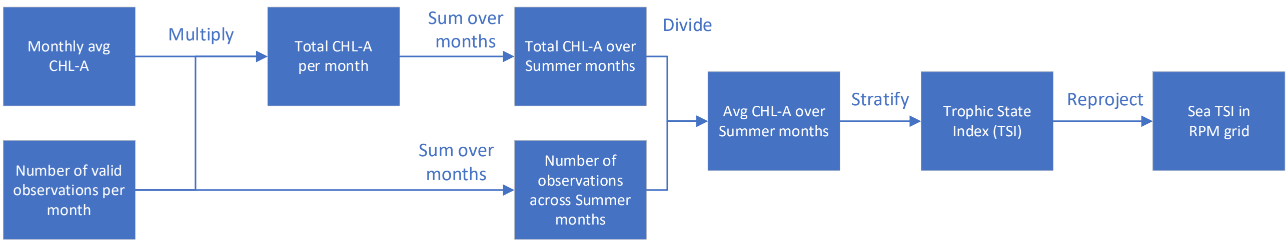


*Figure 15: Diagram of the workflow for the retrieval of Sea TSI from CMEMS High Resolution Ocean Colour input data*

The CMEMS HROC input data is provided as either daily observations or aggregated monthly average values, in tiles with 10m grid with EPSG 4326 coordinate reference system and North West Shelf coverage. The designed workflow starts with the monthly aggregate files, that provide average chlorophyll-a values and the number of valid observations, per month. A single tile (32V) is used.

By multiplying the average chlorophyll-a with the number of valid observations, the total sum of chlorophyll-a concentrations for each month is calculated.

Subsequently, these monthly total concentrations are summed up over the months of May through September.

Likewise, the number of valid observations of each month are summed up over the same months.

By dividing those two values, the summer average chlorophyll-a concentration is computed for each pixel.

These chlorophyll-a concentrations are then stratified into 11 TSI classes (0, 10, 20…100).

The resulting summer average Sea TSI file is then reprojected to match the 100m grid, extent and EPSG 3035 coordinate reference system of the RPM.

**Workflow for the retrieval of Lake TSI from CLMS Lake Water Quality input data**

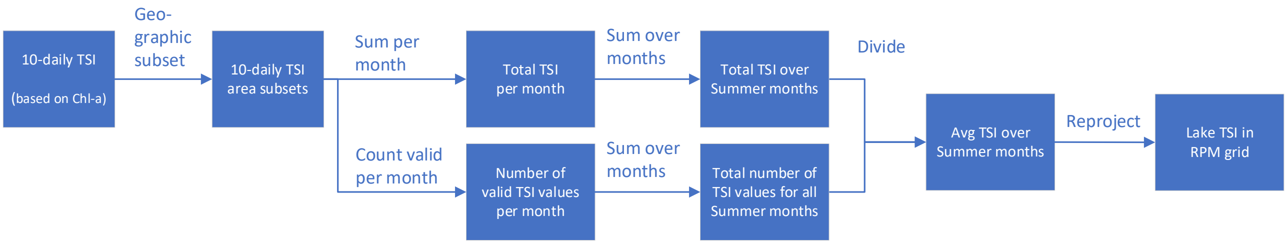


*Figure 16: Diagram of the workflow for the retrieval of Lake TSI from CLMS Lake Water Quality input data*

The CLMS Lake Water Quality input data is provided as global netCDF4 files with 10-daily average TSI values and number of observations, with 100m and 300m grids and EPSG 4326 coordinate reference system. The designed workflow is run separately on the 100m and 300m inputs.

In the first step, the global files are geographically subset over Norway, covering the same area as the HROC data (longitude 3° to 13°E, latitude 57.8° to 64°N).

Then, the 10-daily TSI values and number of valid observations are summed up, first per month and then across the available summer months (July through September for 100m, May through September for 300m).

From those total TSI value and total number of observations over the summer months, the summer average TSI is calculated. Note that this TSI value is still a continuous number, it is not stratified into 11 classes.

The resulting summer average Lake TSI file is then reprojected to match the 100m grid, extent and EPSG 3035 coordinate reference system of the RPM.

**Workflow for bringing the Sea TSI and Lake TSI together into the Water Element**

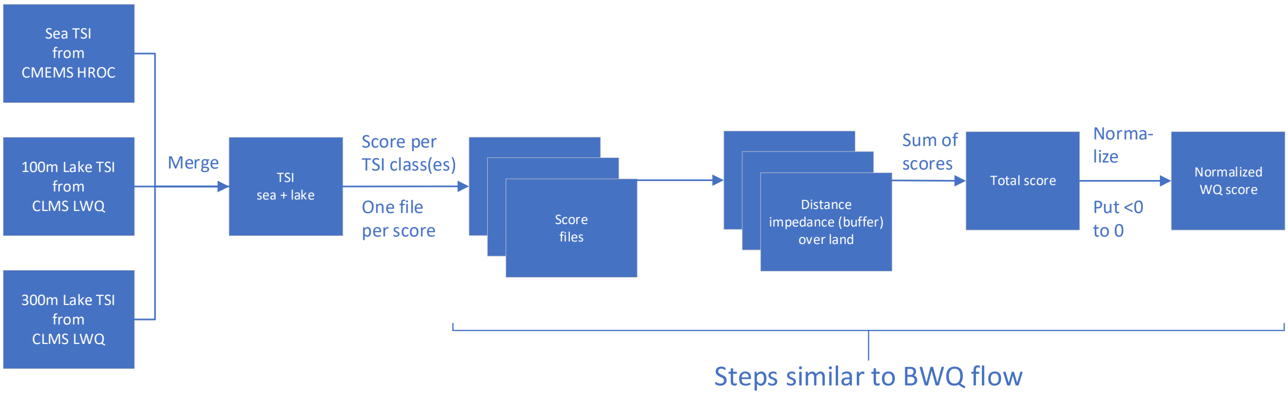


*Figure 17: Diagram of the workflow for integrating Sea and Lake TSI into the Water Element*

This workflow starts with the outcomes of the Sea TSI (strata) and Lake TSI (continuous values), for the 100m and 300m grids, that are the outcome of the previously described workflows.

As the inputs already share a common geographic extent, grid and coordinate reference system, they can be merged into a single raster image. Where 100m and 300m Lake TSI overlap, the minimum value is selected.

The summary TSI raster image is then split up into several files, one per TSI class, and for each TSI class, the pixel values are scored in accordance with the following table:

*Table 6: Scoring based on trophic classification*

| Trophic classification | Trophic State Index | Chlorophyll-a (upper limit) | Assigned score (0 = poor, 1 = excellent) | |
|---|---|---|---|---|
| Oligotrophic | 0 | 0.04 | 1.0 | Very clear water<br>Low amounts of aquatic vegetation<br>Suitable for drinking<br>Lots of fish |
| | 10 | 0.12 | | |
| | 20 | 0.34 | 0.8 | |
| | 30 | 0.94 | | |
| Mesotrophic | 40 | 2.6 | 0.5 | Common/medium level |
| | 50 | 6.4 | | |
| Eutrophic | 60 | 20 | 0.3 | Abundant plants<br>Abundant algae |
| | 70 | 56 | 0.0 | |
| Hyper-eutrophic | 80 | 154 | -0.5 | Algae can be unhealthy Oxygen depletion |
| | 90 | 427 | | |
| | 100 | 1183 | | |

Note that this scoring is like the scoring of the Bathing Water Quality dataset that is applied where BWQ data is used and classified as excellent quality (score 1), good quality (0.8), sufficient quality (0.5), sufficient (0.4), poor quality (-0.5).

Then, the same distance impedance buffer is applied as for the BWQ dataset. This effectively extends the score values from the water to the coastal area.

Then, the files for each trophic class score are summed up into one total score.

The total score undergoes the Water Element normalization with a factor of 5.4, in line with the JRC's reference implementation.

The value is then added into the EBP.

**Workflow for updating the EBP and RPM**

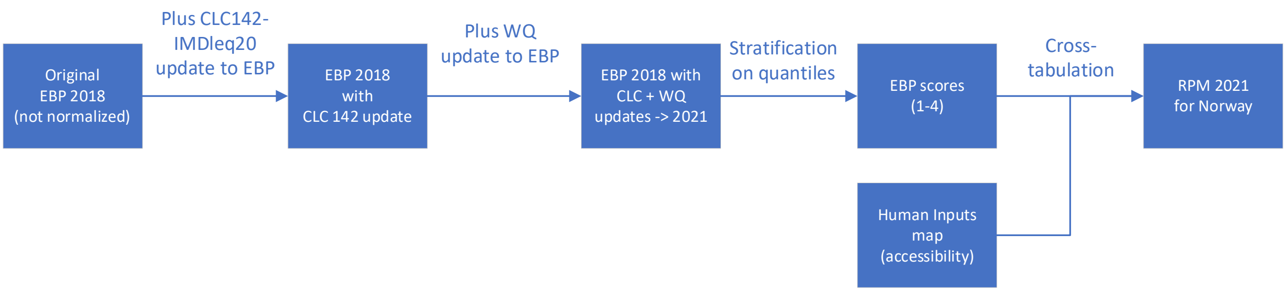


*Figure 18: Diagram of the workflow for updating the EBP and RPM from the water quality updates and the land cover score fine-tuning from section 2.6*

This workflow starts from the EBP map, without normalization, that served as input to the reference RPM.

Firstly, the EBP updates from the Sports and Leisure Facilities class score fine-tuning (see section 2.6) is added.

Then, the outcome of the previous workflow that integrates and scores the Lake and Sea TSI is added to the EBP.

Lastly, the normal steps for the production of the RPM are followed: the EBP is stratified (1-4) according to the quantile statistics and then cross-tabulated with the Human Inputs element to produce the RPM.

## 2.6 Fine-tuning of the Sports and Leisure Facilities class score

### 2.6.1 Study scope

In the CORINE Land Cover, the class 142 on Sports and Leisure Facilities (class 142) is defined to include:

- buildings: such as sport compounds (e.g., stadiums, sports halls), museums, related parking lots
- lodging like caravan parks, camping sites
- outdoor sports areas like racetracks, golf courses, bike paths
- holiday parks, formal parks

Hence, this class includes a mix of both indoor and outdoor recreation and only the outdoor part is relevant for the nature-based recreation service, insofar that they cover interactions with the natural environment.

Below is an example of the CORINE map for downtown Athens. In the east, the Nea Filadelfeia Forest and park area is identified as green urban area (class 141).

More to the west is the larger metropolitan park, Antonis Tritsis. This park is known as one of the last wildlife refuges in the Athens urban environment, that is used among others for hiking, cycling and ornithology and is classified as Sports and Leisure Facilities (class 142). Upon closer inspection, some buildings such a swimming pool and a sports stadium can be identified along the outskirts of the park.

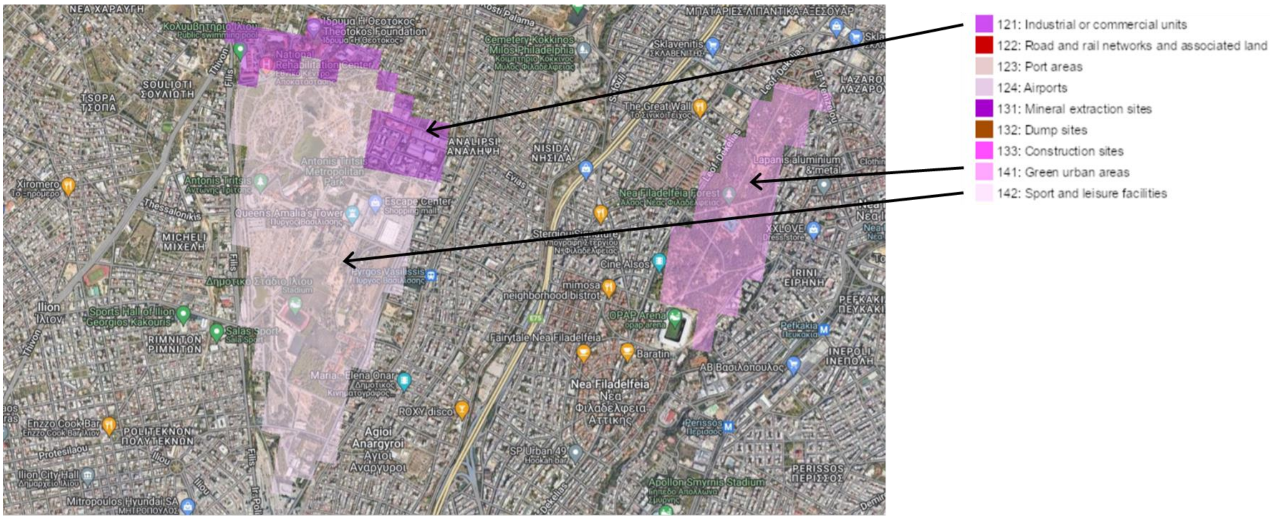


*Figure 19: Example of CORINE Land Cover for two nearby green areas in downtown Athens*

Therefore, it is concluded that the classification in class 142 is correct. However, the outdoor parts (void of buildings and other built-up areas like parking lots) are relevant to the nature-based recreation service account.

In the reference implementation, the CORINE Land Cover (CLC) is used as one of the inputs to the land suitability (SLSR) element, with classes scored between 0 (unsuitable land) and 1 (suitable land). The class on urban green scores the maximum (1). The Sports and Leisure facilities class is however scoring very low (0.1).

Among other factors, this can lead to a significantly lower RPM value, as shown in the below image for the Nea Filadelfeia Forest and Antonis Tritsis parks in Athens.

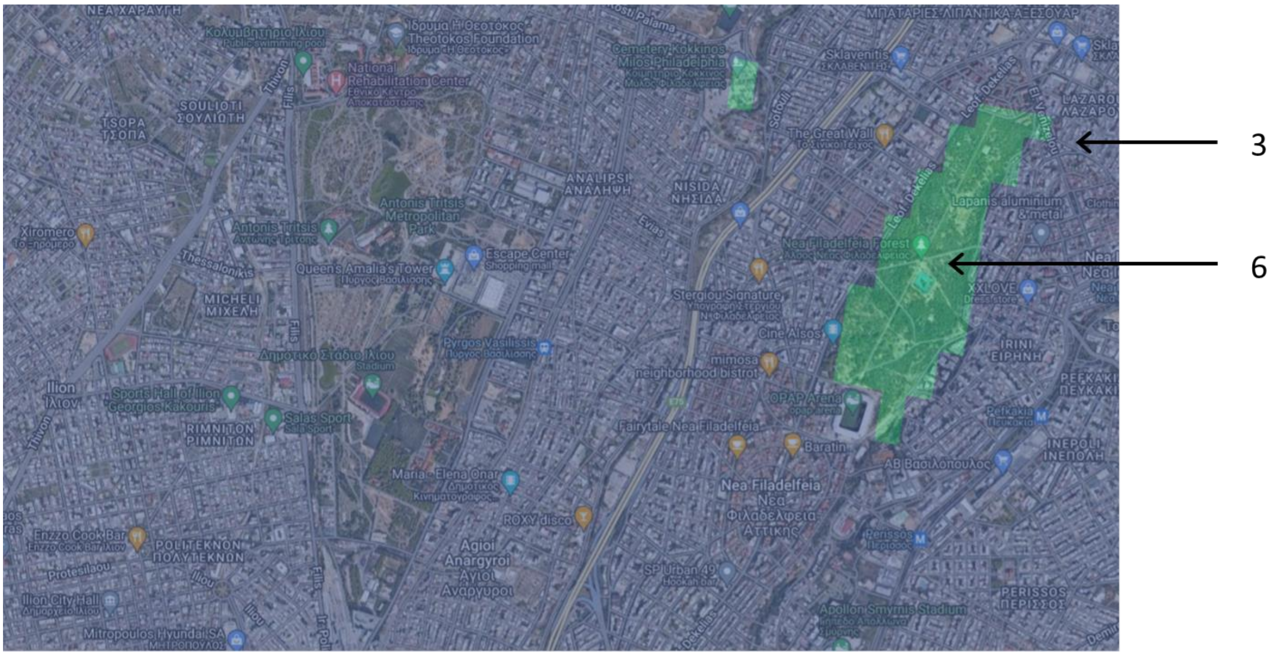


*Figure 20: Example of the same two green areas in Athens, showing significantly lower value (3 instead of 6) for the Antonis Tritsis Park (west) in the reference RPM*

Similar areas can also be found outside of the urban environment. A few examples:

- areas of beaches and beach resorts surrounded or interlaced with green elements such as trees, forests
- sports areas (tennis and basket courts) where people can walk or ride their bikes on the surrounding paths amidst trees and park or picnic areas

The issue occurs in all areas in Europe, hence affecting both the Greece and Norway demonstrations. The below image illustrates this for a forest area (suited for recreation) around a camping site and several marinas on Føynland island (in Oslofjord).

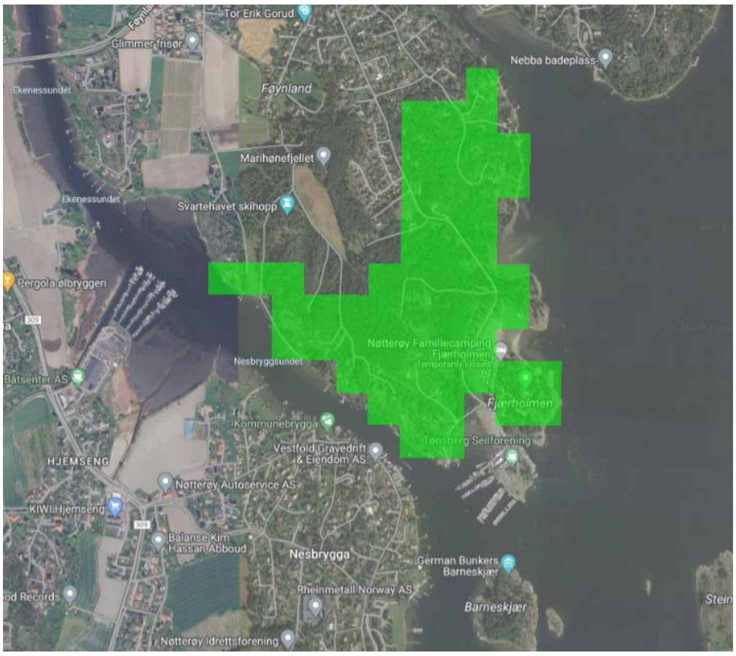


*Figure 21: Example of a forest area (green highlight), suited for outdoor recreation, that is classified as leisure area in CORINE, with nearby camping site and marinas*

## 2.6.2 EO data selection and availability

For the land cover, the CORINE map is retained that is already used for the Suitability for Land to Support Recreation (SLSR) element of the reference RPM methodology.

For areas with class 142 Sports and Leisure Facilities, EO data can be used to distinguish between the outdoor and indoor parts.

In this concept, the imperviousness density dataset from the Copernicus Land Monitoring Service is used. It is available in grids with 20m and 100m (10 and 100m for 2018) pixel size, with 3-yearly updates, starting in 2006.

An alternative could be to use an EO dataset that indicates the presence of green vegetation (green cover, vegetation productivity, vegetation condition). A small test was done using the High Resolution Vegetation Phenology and Productivity dataset on total annual vegetation productivity from the Copernicus Land Monitoring Service. This dataset is available in 10m and 100m grids, in UTM and EPSG 3035 coordinate reference systems, but only from 2017 onwards. The test with the maximum productivity of the two available seasons, yielded similar results as with the impervious density.

### 2.6.3 Proposed concept

Conceptually, the idea is to identify areas with CORINE class 142 and low imperviousness and increase the scoring for those areas so that it matches to the scoring for the urban green area class, which take a value of 1 in the weighted sum of the SLSR elements.

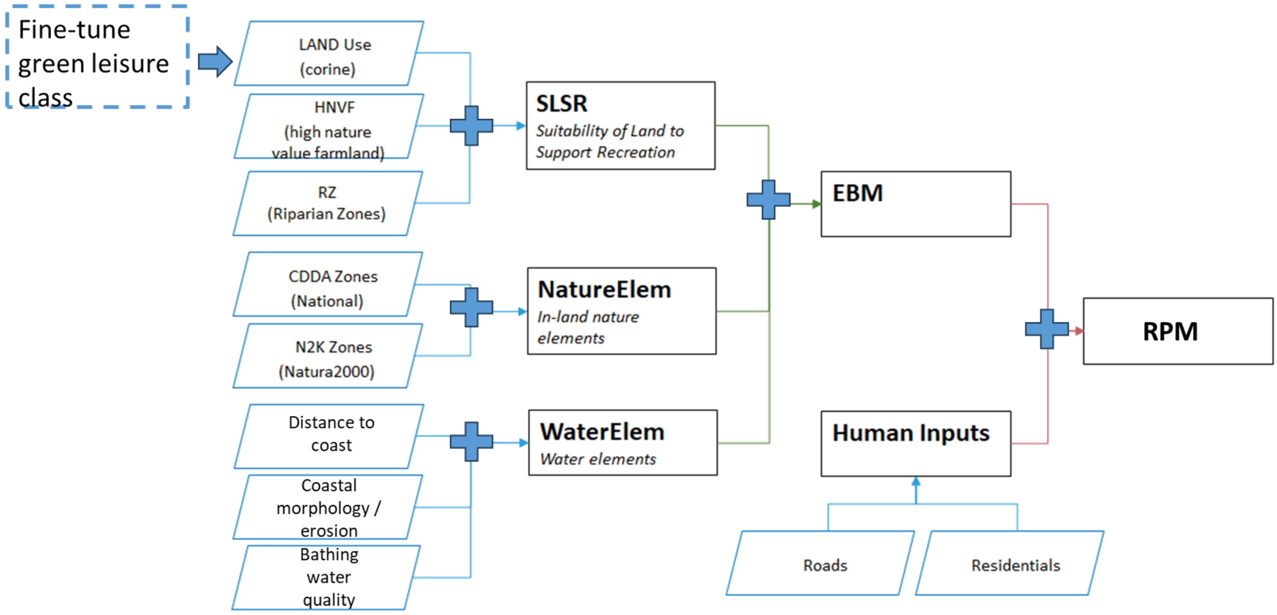


*Figure 22: Proposed concept for increasing RPM value by fine-tuning the scoring for the Land cover/use part of the SLSR*

### 2.6.4 Proposed workflow(s)

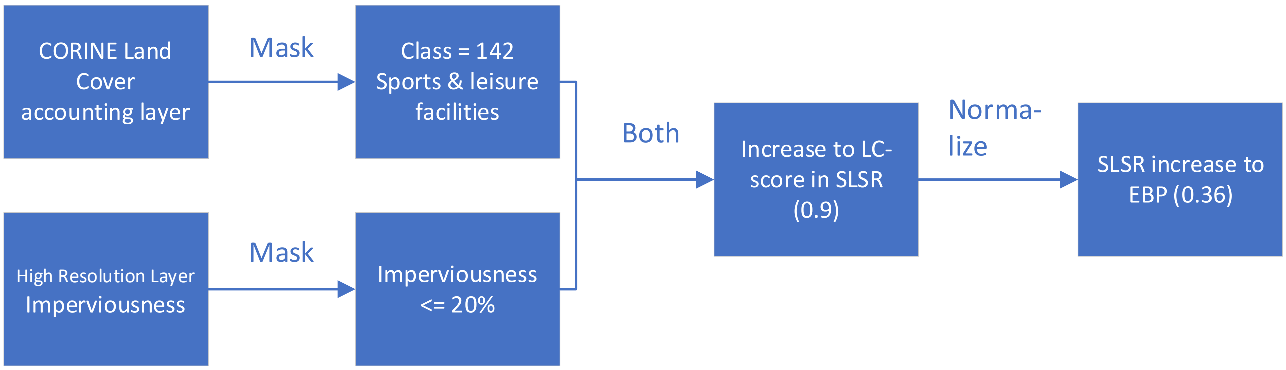


*Figure 23: Diagram of the workflow for fine-tuning of the land cover/use scoring for CLC class 142 areas with imperviousness of 20% or less*

Firstly, CORINE land cover is masked to retain only the areas of class 142 – Sports and Leisure Facilities.

Then, the Imperviousness Density data is masked to retain only those areas with 20% density or less.

Next, the two resulting files are combined to identify the areas that meet both conditions.

The CLC class 142 normally receives a score of 0.1 in the SLSR element and this scoring is increased to 1 for the identified areas. This SLSR delta of 0.9, after normalization for the weighted sum of the EBP, leads to an EBP increase of 0.36 for the identified areas.

This 0.36 is added to the EBP map, that is then put through the normal steps for producing the RPM – the stratification on quantiles and cross-tabulation with the Human Inputs part, as shown in Figure 18 (omitting the water quality update for the Greece demo).

## 2.7 Outcome

### 2.7.1 For Greece

For the demonstration over Greece, the RPM was updated for the forest loss and for the fine-tuning of the CLC 142 class scoring. The water quality update was not applied.

**Forest loss**

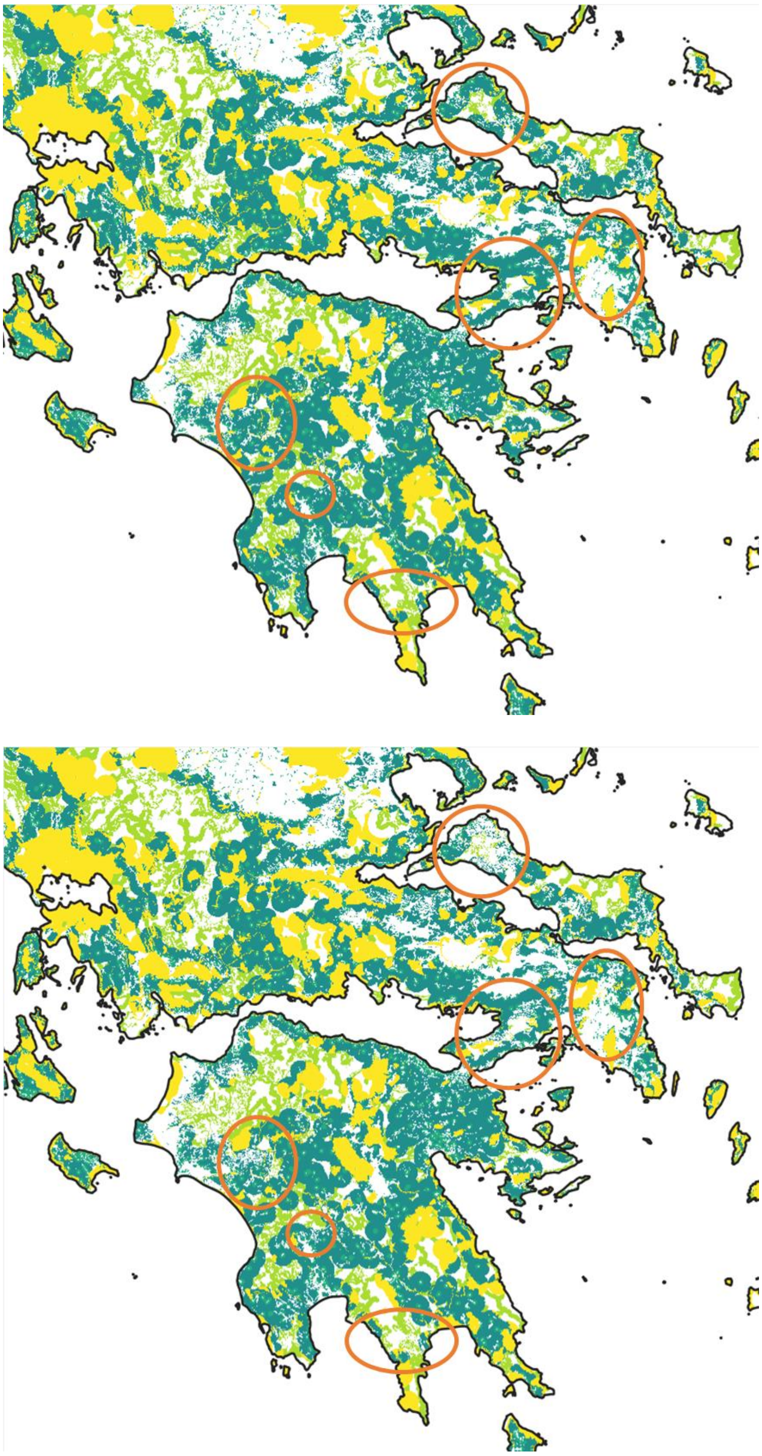

*Figure 24: The reference RPM (left) and updated RPM (right), both colour-coded to show the values 5-6-8-9, with the forest loss areas marked by orange circles and ovals. For reference, see the blue areas of Figure 7.*

**Fine-tuning of CLC Sports and Leisure Facilities class scoring**

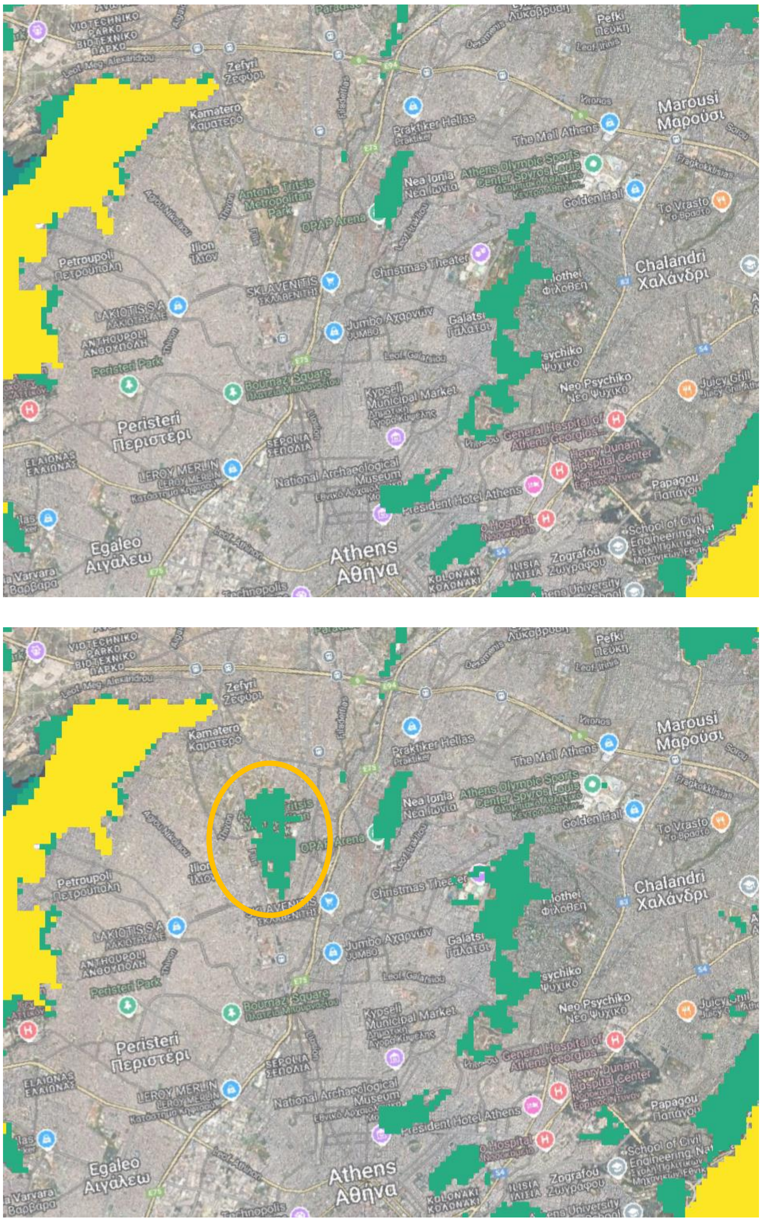


*Figure 25: RPM update for the CLC class 142 score fine-tuning. Downtown Athens area is overlaid with the reference RPM scores (top) and the updated RPM (bottom), with increased RPM value for the Antonis Tritsis Park (orange circle). The RPMs are colour-coded to only show values 5, 6, 8 and 9.*

The nature-based recreation accounts were calculated, using both the reference RPM and the updated RPM, for the year 2022 at NUTS2 and 3 levels, using the INCA tool. The relative difference between the Supply, per NUTS2 area is shown in the figure below. The areas of relevance to the Early Adopter are marked in green for convenience. The relative difference values are colour-coded from white (no different) to dark orange (highest difference).

The relative differences represent well the geographic distribution of the forest loss areas. For example, the second smallest area of Attica shows the largest difference (4.2%) and sees significant forest loss (e.g., north of Athens). The much larger area of Sterea Ellada shows a 2% difference, that can be attributed to the large area of forest loss on Evia (Euboea) island. Study areas EL63 and EL65 are affected from the forest loss areas on the Peloponnesus peninsula.

| NUTS cod | NUTS name | total |
|---|---|---|
| EL30 | Αττική | -4.20% |
| EL41 | Βόρειο Αιγαίο | -0.11% |
| EL42 | Νότιο Αιγαίο | -0.10% |
| EL43 | Κρήτη | -0.07% |
| EL51 | Ανατολική Μακεδονία, Θράκη | -0.09% |
| EL52 | Κεντρική Μακεδονία | -0.01% |
| EL53 | Δυτική Μακεδονία | -0.06% |
| EL54 | Ήπειρος | -0.07% |
| EL61 | Θεσσαλία | -0.11% |
| EL62 | Ιόνια Νησιά | -0.01% |
| EL63 | Δυτική Ελλάδα | -0.68% |
| EL64 | Στερεά Ελλάδα | -2.05% |
| EL65 | Πελοπόννησος | -0.63% |
| all regions | | -0.42% |

*Figure 26: Relative differences in the nature-based accounts comparing the accounts computed with the updated and reference RPMs, per Greek NUTS level 2 area, with a reasonable geographic distribution and a loss of recreation potential*

The negative impact on the forest loss outweighs the positive effect of the score update for Sports and Leisure Facilities class, as can be expected from the size of the affected areas.

### 2.7.2 For Norway

For the demonstration over Norway, the RPM was updated for the water quality and for the fine-tuning of the CLC 142 class scoring. The forest loss update was not applied.

The increased recreation potential values for the coastal areas around the water bodies are clearly visible in the revised RPM, as shown in the maps below.

When examining the relative difference of the accounts, created with the updated RPM and the reference one, the increased potential is clearly visible, in particular for the NO08 Oslo og Viken area given high RPM values around the lakes there. The difference is significant but relatively small (1%), likely due to the aggregation to the extensive NUTS level 2 areas and due to fact that water quality only constitutes only one part of the water element in the RPM.

| NUTS code | NUTS name | total |
|---|---|---|
| NO02 | Innlandet | 0.60% |
| NO06 | Trøndelag | 0.00% |
| NO07 | Nord-Norge | -0.02% |
| NO08 | Oslo og Viken | 1.09% |
| NO09 | Agder og Sør-Østlandet | 0.46% |
| NO0A | Vestlandet | 0.25% |
| all regions | | 0.46% |

*Figure 27: Relative differences in the nature-based accounts comparing the accounts computed with the updated and reference RPMs per Norwegian NUTS level 2 area, with a reasonable geographic distribution and an increase in recreation potential due to the water quality update*

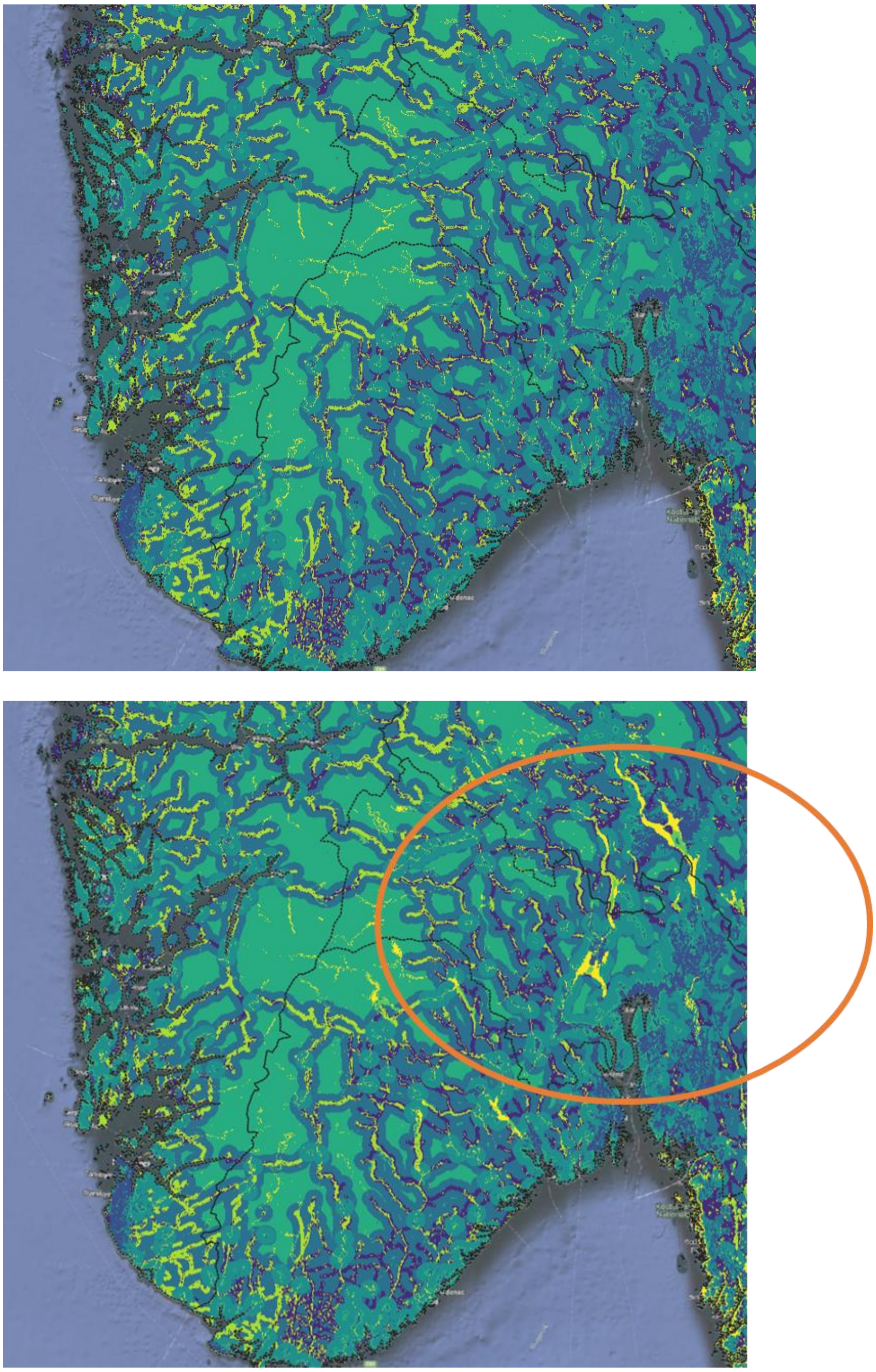

*Figure 28: RPM update for the water quality and CORINE land cover score fine-tuning, where the lakes in the area around Oslo are particularly more prominently visible.*

## 2.8 Conclusions

For the demonstrators in Greece and Norway, different contributions from EO to the nature-based recreation account were put into practice:

- For Greece, a loss of recreation potential by natural disturbances - forest loss – was introduced with the processing of Global Forest Change data from Landsat.
- For Norway, the missing water element input data was supplemented with three different EO datasets on water quality from Copernicus services, that cover the seas, larger and smaller lakes in the developed workflows.
- For both countries, a smaller-scale fine-tuning of the recreation potential scoring was carried out for the CORINE land cover class 142 – Sports and Leisure Facilities, by distinguishing outdoor from indoor areas through the Copernicus Imperviousness Density dataset.

The updated RPM show the expected updates in recreation potential value.

The service accounts were calculated per NUTS level 2 and 3 areas and compared between the runs with the reference and EO-updated RPMs. They showed a significant impact on the accounts, in the expected (positive/negative) direction and for the expected geographic areas.

## 2.9 Outlook and next steps

### 2.9.1 For Greece

If the data is available and accessible, it would be good to validate the results on smaller (local) scales. Looking for instance to the areas of forest loss and checking if recreation and accommodations for overnight stays in those areas are impacted.

As noted in the Early Adopter's validation results, it would be good to look at areas where the methodology is not performing too well. An example would be the over-estimated potential around shallow rivers with little to no water flow. Perhaps by use of the Copernicus Digital Elevation Model data (slopes, altitude above sea level) or EO-based water or soil moisture indicators.

In Greece, developers are required to compensate for ecosystem value that is lost by their developments, either by monetary compensation or by adding nature value elsewhere. The amount of compensation is thereby determined by a set of equations for different nature aspects (biodiversity, recreation value etc). While these equations have their own limitations - they are e.g. using the affected surface area (ha) as main parameter - it can be interesting to use these equations to put a monetary value to the loss of recreation value due to loss of natural forest (instead of local development).

### 2.9.2 For Norway

The impact of the revised RPM on the nature-based recreation account is mainly observed for the area around Oslo. This is mainly explained by limitations in the spatial coverage of the EO input data: the 100m lake water quality data only covers specific Sentinel-2 tiles, the 300m lake water quality only covers pre-selected (e.g., larger or environmentally important) lakes, the high-resolution ocean colour dataset only covers the North West Shelf area, effectively around the south/southwestern coastline of the country.

Therefore, a next step could be to recommend to the two Copernicus services that provide those datasets, to extend the spatial coverage of their datasets. Alternatively, EO-based water quality could be calculated for the whole country using a cloud-based or on-demand processing approach (e.g., similar to https://portal.terrascope.be/catalogue app market place), however at cost.

In terms of addressing the input data gaps of the reference RPM, EO datasets can help to address the distance to lake shore and seacoast, another part of the RPM's water element. Non-EO or reference datasets, for instance on the shoreline (for reference/validation) or delineation of protected areas (harder to estimate from EO alone) could be sourced from the Norwegian Mapping Authority or the Norwegian Environment Agency.

Nature-based recreation is especially attracted to open mountainous areas above the treeline for hiking, skiing, off-road cycling, viewpoints and so on. Altitude depends on the regional climate zones; from 200m in the south-west to around 1000m in the central southern parts of Norway and even lower in the regions north of the Arctic circle. The combined use of the Copernicus Digital Elevation Model and an EO dataset on vegetation or tree cover (e.g. Tree Cover Density) could be used to map more recreation potential.

# 3. References

Carlson, R. E. (1977). A trophic state index for lakes, *Limnology and oceanography,* volume 22, issue 2, pp. 361-369, DOI 10.4319/lo.1977.22.2.0361

Zulian, G. La Notte, A. (2022). How to account for nature-based tourism in Europe. An operational proposal. *One Ecology*, *7*, e89312, DOI 10.3897/oneeco.7.e89312

# Annex 1. National reference datasets

| Country | Validation of: | Dataset | Source |
| --- | --- | --- | --- |
| Greece | Near Shore tourism recreation service | Blue flag beaches database for Greece / Photointerpretation of ortho-photo imagery | https://www.blueflag.global/ Hellenic Cadastre ortho imagery: https://gis.ktimanet.gr/wms/ktbasemap/default.aspx |