

# **ARIES for SEEA**

## **Global runs**

### **Nature-Based Tourism**

#### **Deliverable 3: Global Results**

under the SEEA-Related Indicators for the GBF Project  
between UN-DESA and BC3

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**Release date: 1 Apr 2026**



**Funded by  
the European Union**



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Preliminary



# On computing global results for nature-based tourism (NBT)

## Overview of NBT ecosystem services

Nature-based tourism (NBT) ecosystem services are a subset of recreation-related services, which are a crucial component of cultural ecosystem services. These collectively represent "The ecosystem contributions, through the biophysical characteristics and qualities of ecosystems, which enable people to use and enjoy the environment through direct, in-situ, physical and experiential interactions with the environment." (United Nations 2024). These include services both to locals and to non-locals (i.e. visitors, including tourists) (SEEA EA, Table 6.3).

This module focuses on nature-based tourism services. These are recreation-related ecosystem services used by non-locals and visitors. Tourism contributions are reported in number of overnight stays (or when not available in overnight visitors, i.e. tourist arrivals)<sup>1</sup> in hotels, hostels, camping grounds, etc. that can be attributed to visits to ecosystems. This approach excludes day-to-day recreational activity by locals, whose visits are often shorter but more regular in duration and may often be important to their physical, cultural and mental well-being. This approach is also aligned with current regulations in the European Union (2024).

Large-scale nature-based recreation modelling approaches have limitations for consistent national or global accounting due to missing visitation data and over-reliance on assumptions, such as important limitations in the representativeness and spatiotemporal consistency of sources such as geotagged photos and mobility data (Zulian *et al.* 2013; Baró *et al.* 2021; Wilkins *et al.* 2024). Because of these limitations, there is a pressing need to improve the attribution, scaling, and valuation of nature-based tourism services in line with SEEA-EA guidelines and policy needs (PEOPLE-EA D19; UN SEEA-EA 2024).

While models for nature-based attractiveness in nature-based recreation and tourism are conceptually similar, and based on the ESTIMAP recreation model (Zulian *et al.* 2013, Paracchini *et al.* 2014), the key difference lies in the measurement metrics (see also Zulian and La Notte (2022)). However, at present tourism statistics are considered more robust,

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<sup>1</sup>In this document, "tourist arrivals" refers to overnight visitors, while "overnight stays" refers to the total number of nights spent in accommodation (i.e., arrivals multiplied by nights spent). See also the UN Tourism Glossary of tourism terms: "A visitor (domestic, inbound or outbound) 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".



which is why they are proposed as a starting point for estimating nature-based tourism services in Europe (EUROSTAT 2024).

In the context of SEEA EA, nature-based tourism should be measured in physical units, e.g., the number of overnight stays in accommodation facilities (e.g., hotels, camping grounds, hostels) that can be attributed to visits to natural areas. These stays can be further classified by:

- Type of visitor (domestic vs international, or inbound)
- Ecosystem types associated with the destination
- Use category (household consumption or exports, which in turn depends on the first bullet point)

This classification supports integration into both physical and monetary supply-use tables under SEEA EA.

## Methodological documentation of NBT module

The objective of this documentation is to explain the globally applicable and SEEA EA-compliant modelling strategy implemented in ARIES to estimate and map the supply and use of nature-based tourism services in physical terms, at the country level.

This modelling strategy is largely inspired by the INCA methods (EUROSTAT 2024, European Commission 2025) developed for the EU by the European Commission, but is generalised to allow for global applicability.

The model consists of 4 main components:

1. Tourism statistics at a certain administrative level (here we use National Statistics at the country level provided by UN Tourism).
2. Ecosystem contribution to separate nature-based tourism from total tourism.
3. Ecosystem attribution to spatially allocate tourists within the context.
4. Tabular reporting by ecosystem type (and or land cover type).

The modelling framework can integrate different *tourist visitation statistics*, which can be observed in terms of overnight stay data or arrivals, both domestic and inbound. Here we used the UN Tourism statistics (available at <https://www.untourism.int/tourism-statistics/tourism-statistics-database>) as the primary reference. The most comprehensive data set within this resource is **inbound tourist arrivals (code 1.15)**, which represents international overnight visitors rather than overnight stays.

The *ecosystem contribution* of visits establishes the proportion of tourism attributed to nature-based tourism. To identify this proportion we used the extent of the land classified as attractive and accessible<sup>2</sup>, at the country level. We first model NBT theoretical value following the ESTIMAP inspired recreation model approach of Martínez-López et al. (2019). Under this approach, the entire territory of a country is assigned a recreation value based on human influence (i.e., non-naturalness), attractive landscape features (i.e., waterbodies, coastlines, mountains and protected areas) and positive environmental management features (i.e., biodiversity and campsites). This recreation value and the accessibility in each gridcell are then reclassified to produce the Recreational Opportunity Spectrum (ROS) country map. The NBT ratio of the total tourism statistics is then derived as the portion of country territory with accessible and medium and high opportunities for recreation. This function always derives a ratio  $\leq 1$ , which is then applied to the number of international overnight visitors (tourists) for a country. This approach is broadly aligned with the approach of Eurostat (2024), based on Parracchini et al. (2014) and Zulian and La Notte (2022) to estimate nature-based tourism from European level tourist statistics. **Annex 1** provides more details and the associated source code for the ecosystem contribution and attribution steps.

The *Ecosystem attribution* step attributes the (nature-based) visitation metrics to specific ecosystem types (or habitats or land use/cover classes). This is done by considering factors influencing supply and use, later applied as weights to reclassify land in terms of suitability for nature-based tourism, and produce spatially explicit outputs. These factors are here summarized in 3 dimensions: attractiveness, ecosystem management and accessibility.

- Attractiveness (of landscape features and environmental features): the quality of the landscape influenced by its extent and condition, landscape diversity, presence of iconic landmarks, uniqueness, viewsheds. This includes: (A) The degree of human influence on natural environments, as a reclassification of land cover classes with higher levels indicating more significant alterations due to human activities, thus making the land less attractive for nature-based tourism. (B) Distance to geomorphological features of interest such as mountain peaks, coastline, protected areas and water bodies. This step primarily utilizes global datasets for elevation and land cover, in addition to the World Database on Protected Areas (WDPA). (C) To better capture the role of biodiversity we included "Vertebrate Species Richness" dataset, an indicator of global biodiversity sourced from the World Bank (using IUCN and BirdLife International data), scores biodiversity at a 1-km resolution. It is based on the total count of mammals, birds, amphibians, and reptiles, utilizing over 25,000 species range maps.

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<sup>2</sup> Corresponding to the classes 5,6,8,9 in the official Recreation Opportunity Spectrum (ROS) map for EU (EUROSTAT 2024, originally in Parracchini et al. (2014), used also in Zulian and La Notte (2022)).



- *Ecosystem management*: includes facilities to support access and facilitate enjoyment, the availability of equipment or infrastructure to perform specific activities such as walking and biking paths, an information or visitor centre, benches and picnic areas, cultural heritage sites, etc. This implementation also incorporated distance to campsites, serving as a proxy for this dimension, in addition to the distance to protected areas; this accommodation category was included after initial calibration in pilot countries, which was deemed appropriate given its strong association with nature-based tourism. This metric has been incorporated into the overall attractiveness score (i.e. the below described recreation metric semantically defined as NBT theoretical value) .

- *Accessibility*: the ability to access an ecosystem and reach the ecosystem by public or private transportation. Accessibility can consider distance to roads and settlements. In this implementation have used global products on travel time to major cities considering cost-distance models (i.e. <https://forobs.jrc.ec.europa.eu/gam>).

These factors are used as weights to reclassify land, generating spatially explicit outputs that indicate the suitability of different areas for nature-based tourism.

The final spatial results are aggregated by landcover type, to create a biophysical supply and use tables (Figure 1). Overnight stays performed by international visitors who are not residents of the reporting country (also called inbound tourism) are to be reported as 'Exports' in the use tab.

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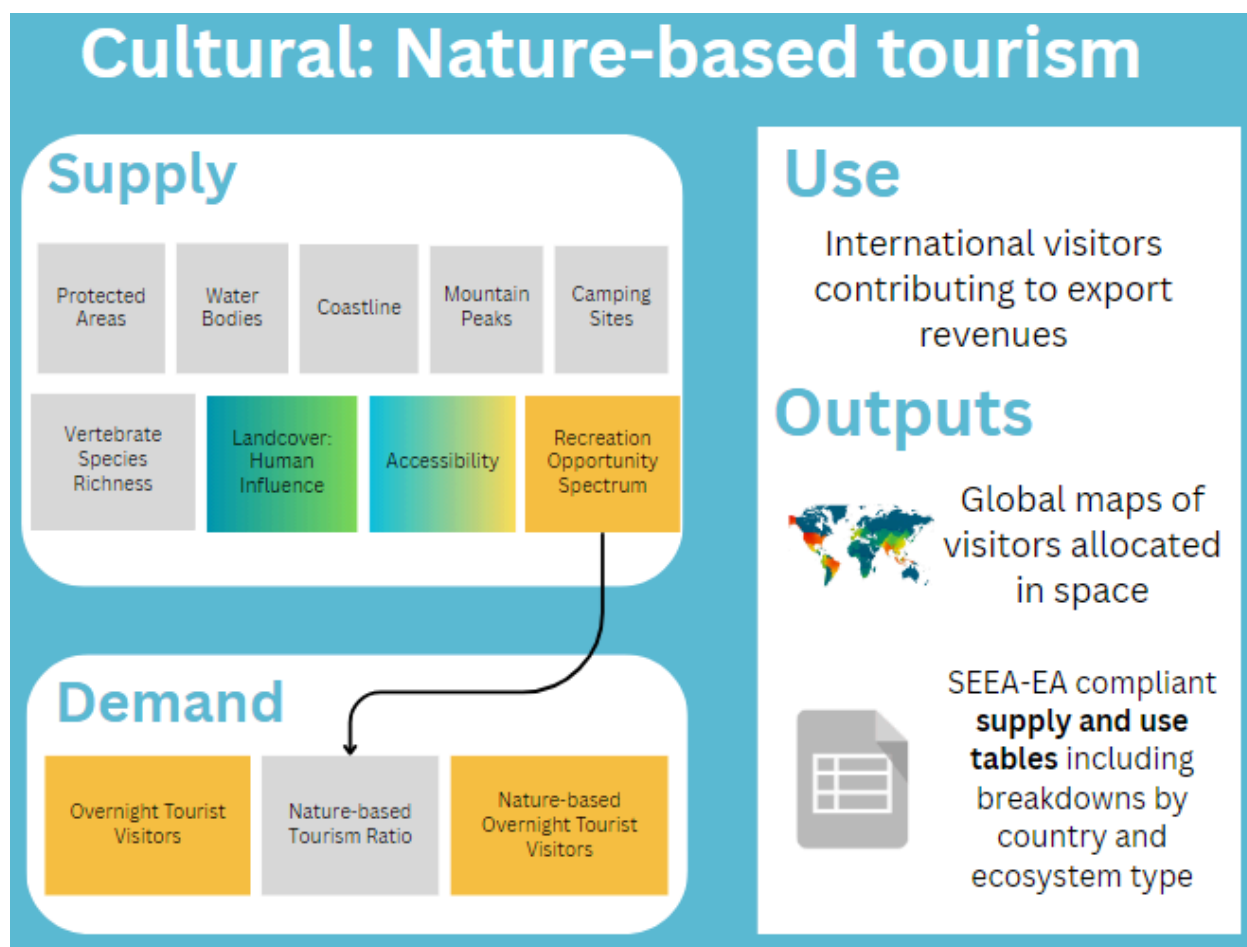


Figure 1. Broad workflow for defining ecosystem contribution and attribution of visitors statistics

### Data Inputs

Table 1 contains the list of input resources used in the current implementation of the modelling framework. Improved and additional inputs will be sought during the revision and feedback period.

Table 1. List of data input in the Nature-based tourism model.

Resource	Producer	Purpose	Spatial and Temporal coverage
Tourism Statistics	UN Tourism	Entry statistics on inbound overnight visitors to be spatialized	By country, from 1995 to 2022.
Vertebrate Species Richness dataset	The World Bank (using IUCN and BirdLife International data). Dasgupta et al. 2024.	An indicator of global biodiversity	Global, 1 km, 2024



Digital Elevation Model (DEM)	NASA/METI/AIST/Japan Spacesystems, and U.S./Japan ASTER Science Team, 2019	Provides high-resolution elevation information suitable for global terrain and relief analyses. Used to identify mountain peaks.	Global 30 m
GLC_FCS30 land cover layer	Zhang <i>et al.</i> 2023	To classify human influence, identify coastline and water bodies, and aggregate results by class.	30 m, Annual (1985–2022).
The World Database on Protected Areas (WDPA)	A joint project between UN Environment Programme and the International Union for Conservation of Nature (IUCN), and is managed by UN Environment Programme World Conservation Monitoring Centre (UNEP-WCMC)	To locate protected areas	Updated annually
Global accessibility	Nelson <i>et al.</i> 2019	Estimated travel time to reach a destination.	Global, 1 km, for 2015
Campsites	OpenStreetMap (OSM)	Direct query to OSM API	Global, points

To preserve consistency across the different modules estimating ES and their results, whenever feasible, the data used for common core input in the analysis is the same (e.g. the product used to represent the terrestrial land cover). The current choice is the GLC\_FCS30 land cover dataset (Zhang *et al.* 2023) because of its highly disaggregated land cover classification, and a larger time series, spanning back to 1985. The more detailed disaggregation is particularly important in some models (e.g., the tourism module benefits significantly from this level of detail). While we are aware that landcover accuracy for global product ranges between 74% and 80% (Xu *et al.* 2024), some inconsistencies and inaccuracies noted made us less confident in the overall accuracy of the products. Moreover, and more important from a medium-long term perspective, it is unclear whether the datasets will be generated for future years (beyond 2022).

### Notes on limitations and uncertainties of the global runs

The analysis covered both 2020 and 2022. While official UN Tourism statistics were available for 182 countries in 2020, a number of small islands and micro states were excluded from the results due to a lack of necessary input data. While the number of countries with available statistics for 2022 is currently lower (i.e. 142), we are actively collaborating with UN Tourism to integrate all available information in the future. National

Statistical Offices are encouraged to share their official and publicly available statistics by contacting [aries@integratedmodelling.org](mailto:aries@integratedmodelling.org).

The module's execution scale is set at the country level, aligning with the available statistical data, at 1 km resolution. Country borders are based on the UN administrative level 0. While the final resolution for all results is 1 km, meaning the output represents the number of tourists per km<sup>2</sup>, some larger countries (e.g., USA, China, Brazil) were initially processed at 2 km, and Canada at 3 km, due to the high computational requirements. These intermediate results were subsequently downscaled to 1 km.

The country-level results were integrated using state-of-the-art spatial data processing tools. Tabular outputs were then generated by aggregating these spatial results according to the land cover categories defined in the Zhang *et al.* 2023 dataset. These are considered preliminary results, and to this end, we plan to use more refined data on ecosystem types during 2026.

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## ANNEX 1. Source code and algorithms.

The complete source code is accessible at <https://github.com/integratedmodelling/un.gbf.aries>.

The NBT-related modules are organized into 4 dedicated namespaces.

1. `gbf.aries.nbtourism.recreation` implements the ESTIMAP inspired recreation model (published in Martínez-López *et al.* 2019) updated and restructured into four main components, plus an accessibility component:
  - A. Human influence: represents the inverse of hemeroby or naturalness.
  - B. Landscape features: includes (distance to) waterbodies, coastline, mountain peaks, and protected areas (which also accounts for management).
  - C. An additional set of environmental and management features including biodiversity (vertebrate species richness) and facilities (distance to campsites). The combination of B and C is achieved through weighted averages.
  - D. NBT theoretical value, i.e. the overall recreation metric : calculated using components A, B, and C. This combined value is then integrated with A using a Cobb–Douglas type production function, similar to the approach in Martínez-López *et al.* (2019). The function, calibrated for country-level application, is non-symmetric and is expressed as  $A^{1.25} * (B+C)^{0.5}$ .



This formulation suggests a "disamenity," where a deficiency in naturalness (A) has an impact 2.5 times greater than a deficiency in features (B+C).

- E. Accessibility as measured by travel time. This component is later combined with the NBT theoretical value (D) to compute the Recreation Opportunity Spectrum (ROS).
2. `gbf.aries.nbtourism.tables` implements the algorithms in a lookup table fashion to compute the ROS and human influence values according to globally calibrated parameters and thresholds for country level assessments.
  3. `gbf.aries.nbtourism` This process utilizes the ROS output of namespace 2 (`gbf.aries.nbtourism.tables`), i.e. , alongside national statistics. It then spatializes the visits based on the previously described attribution and contribution principles. The spatial distribution is determined by a weighted allocation within the country. This weighting is based on the recreation metric values, which have been rescaled (using a power of 3 and ranging from 1 to 10) across the subset region. This region is specifically where nature-based recreation is available and offers medium to high opportunities, thereby defining the spatial extent and proportion of nature-based tourism. Within the defined spatial area for nature-based tourism, the number of visits assigned to a specific grid cell is determined by the proportion of its rescaled recreation metric relative to the total sum of all recreation metrics across that entire area.
  4. `gbf.aries.nbtourism.features` implements the algorithms to identify the features mentioned at point 1B.