ARIES for SEEA
Global runs

Nature-Based Tourism

Deliverable 3: Global Results

under the KM-GBF Project between UN-DESA and BC3

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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). Recreation-related services are contributions of ecosystems, in particular their biophysical characteristics and qualities, that enable people to use and enjoy the environment through direct, in situ, physical and experiential interactions. These include services both to locals and to non-locals (i.e. visitors, including tourists) (SEEA EA, Table 6.3).

In line with the **October 2024 EU regulation** on environmental economic accounts modules (see https://data.consilium.europa.eu/doc/document/PE-31-2024-INIT/en/pdf), 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)[1] 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.

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).

[1]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".

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, which is why they are proposed as a starting point for estimating nature-based tourism services in the EuroStat ecosystem accounting guidelines.

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 modellling 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. We used extent statistics of the land classified as attractive and accessible over the entire country using the categories with accessible and medium and high opportunities for recreation (i.e., classes 5,6,8,9) of 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))[2].

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 in line with the INCA methodology, 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 in (mountain peaks and coastline), protected areas and water bodies. The datasets used here are global elevation and land cover dataset, 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.

• *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.In this implementation, the number of Campsites is used as a proxy for this dimension, given the strong nature-based association of this accommodation category. This metric has been incorporated into the overall attractiveness score (i.e. the below described recreation metric semantically defined as NBT theoretical value) .

[2] The ROS method has been used extensively in recreation modelling, and classifies land according to recreation potential and accessibility, see annex 1 in EUROSTAT (2024).

• 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 line with the accessibility component of the Recreation Opportunity Spectrum (ROS), used in INCA). 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 visitors who are not residents of the reporting country (also called inbound tourism) are to be reported as 'Exports.'

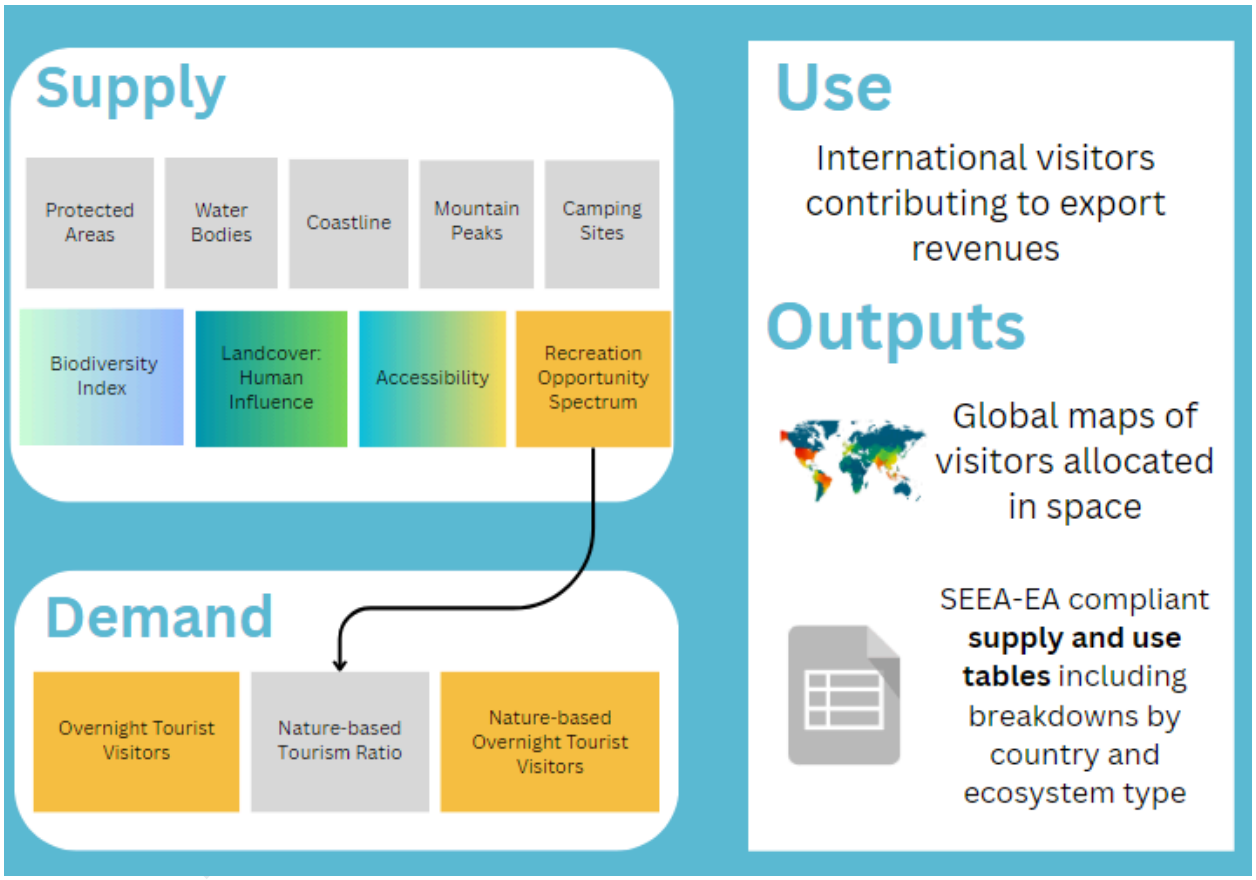

Figure 1. Broad workflow for defining ecosystem contribution and attribution of visitors statistics

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` This process utilizes the ROS output, which is derived from the recreation metric and accessibility inputs, 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.

2. `gbf.aries.nbtourism.recreation` implements the ESTIMAP inspired recreation model (published in Martínez-López *et al.* 2019) updated and restructured into four main components:
    A. Human influence: represents the inverse of hemeroby or naturalness.
    B. Landscape features: includes (distance to) waterbodies, coastline, mountain peaks, and protected areas (which accounts for management).
    C. NBT theoretical value, i.e. the overall recreation metric: calculated using components A, B, and B1., i.e. an additional set of environmental and management features including biodiversity (species richness) and facilities (distance to campsites). The combination of B and B1 is achieved through weighted averages. 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+B1)^{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+B1).
    D. Accessibility as measured by travel time. This component is combined with the NBT theoretical value (from component C) to compute the final ROS.

3. `gbf.aries.nbtourism.tables` implements the algorithms to compute the ROS and human influence values according to globally calibrated parameters and thresholds for country level assessments.

4. `gbf.aries.nbtourism.features` implements the algorithms to identify the features mentioned at point 2B.

Notes on 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.

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 km², 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.

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	The World Bank (using IUCN	An indicator of global	Global, 1 km, 2024

Richness dataset	and BirdLife International data). Dasgupta et al. 2024.	biodiversity	
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 *et al.* 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 et al. 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).

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