GBF Indicators A.2 and B.1: Implementation Tests

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1. Introduction

The Global Biodiversity Framework (GBF) headline indicators A.2 Share of natural ecosystem services and B.1 Ecosystem Services can be calculated by using the ecosystem extent and condition accounts in line with the SEEA EA. While the indicators have already been compiled for the first national reports, the concrete methodology is, to some degree, still in development following countries' first experiences with the indicator framework. We provide tests and experiences from the German implementation on the following issues: A2: Cross-walk from national ecosystem types to IUCN Ecosystem Function Groups: (i) using additional data sources with focus on the natural/semi-natural/anthropogenic split, (ii) sensitivity of the indicator to cross-walk choices. B.1: Overall and disaggregated trends in ecosystem service flows: (i) selection of services, limitations of the methodology, (ii) interpretation issues for regulating services, (iii) disaggregation exercises to strengthen focus on biodiversity and sustainability.

2. Indicator A.2 Extent of natural ecosystems

Indicator A.2 shows the "extent of natural ecosystems as a proportion of total area of the country". Compilers are tasked to report ecosystem areas for ecosystem functional groups according to IUCN GET. Functional groups are assigned to natural/semi-natural categories (see Table 1 taken from the global metadata). From these categories the indicator is derived as a proportion of total area for both terrestrial and marine ecosystems.

Table 1: Anthropogenic biomes/functional groups (Global Metadata Sheet)

Realm	Biome	Ecosystem functional group
Terrestrial (T)	T7 Intensive land-use biome	T7.1 Annual croplands [Short-rotation croplands]
		T7.2 Sown pastures and fields [Sown livestock pastures]
		T7.3 Plantations [and woody croplands]
		T7.4 Urban and industrial ecosystems
		T7.5 Derived semi-natural pastures and old fields
Freshwater (F)	F3 Artificial wetlands biome	F3.1 Large reservoirs
		F3.2 Constructed lacustrine wetlands
		F3.3 Rice paddies [Aquatic and semi-aquatic croplands]
		F3.4 Freshwater aquafarms
		F3.5 Canals, ditches and drains
Marine (M)	M4 Anthropogenic marine biome	M4.1 Submerged artificial structures
		M4.2 Marine aquafarms
Marine-terrestrial (MT)	MT3 Anthropogenic	MT3.1 Artificial shorelines

The indicators are reported for different time steps and interpretation focuses on changes over time rather than absolute values. The indicator should capture changes in area between ecosystem functional groups rather than changes in condition within a given ecosystem type. The compilation guidelines for indicator A.2 go into great depth to explain the term "natural ecosystems". The category includes ecosystems influenced or modified by human interventions.

For compilers who use a national ecosystem classification (or another international typology, e.g. the European Union Ecosystem Typology EUET) the crucial step is to set up a crosswalk from national types to IUCN GET Ecosystem Functional Groups. There are several possible scenarios (IUCN 2025), for which separate guidance is available:

1) The national classification is nested in the IUCN classification
2) The national classification is cross-walked using a best-fit-mapping
3) The national classification is cross-walked using spatial mapping
4) The national classification is cross-walked using expert-based membership scores

Scenario 1 is ideal and newly set-up national ecosystem typologies should consider the nesting option. Realistically, for existing non-nested classifications a combination of approaches 2-4 may be required. Most mappings are likely to be already nested in IUCN types and cross-walking may be required only for a few specific types. The compilation guidelines provide a detailed walk-through of borderline cases that are potentially mapped to more than one ecosystem functional groups. Interestingly, these are often very specific ecosystems particularly relevant for biodiversity, which increases the relevance of the exercise.

3. Compilation challenges for Germany

Most national ecosystem classes for Germany are in fact nested in the IUCN GET Functional Ecosystem Groups. Table 2 summarizes the many-to-one cross-walk from national to IUCN types. There are some national types that could be mapped to more than one EFG.

1) (marked in red): differentiations by "structural" characteristics within natural/semi-natural ecosystems. For low- and upland rivers (F1.1, F1.2), we use a simple bioregions dataset to identify Alpine and pre-Alpine areas and uplands to spatial crosswalk rivers from our national extent account. Shrubland in the national classification is mapped to T3.3 Cool temperate heathlands or MT2.1 Coastal shrublands and grasslands depending on its proximity to the shoreline. We use a 3km buffer to spatially map the data.
2) (marked in blue): differentiations that are particularly relevant for the A.2 indicator, as they regard borderline cases between natural/semi-natural and anthropogenic ecosystems. In addition, these are some of the largest ecosystems (in total areas), making their cross-walk a sensitive matter. The remainder of this section will address the mappings of these forest and grassland ecosystems.

Table 2: Mapping national ecosystem types to IUCN GET EFGs

	Ecosystem functional group	National Types
marine	M1.1 Seagrass meadows	B02.21 Coastal sea with macrophytes
marine	M1.4 Shellfish beds and reefs	B02.22 Coastal sea reefs
marine	M1.6 Subtidal rocky reefs	B02.32 Open sea reefs
marine	M1.7 Subtidal sand beds	B02.23 Coastal sand banks, B02.33 Open sea sandbanks
marine	M1.8 Subtidal mud plains	B02.29, B02.39 Other coastal and open sea
marine	MT1.2 Muddy shores	B02.11, B02.12, B02.19 Tidal flats
terrestrial	F1.1 Permanent upland streams	B01.11, B01.12, B01.19 Natural or heavily modified water courses
terrestrial	F1.2 Permanent lowland rivers	B01.11, B01.12, B01.19 Natural or heavily modified water courses
terrestrial	F2.1 Large permanent freshwater lakes	B01.21, B01.22 Large natural or heavily modified lakes
terrestrial	F2.2 Small permanent freshwater lakes	B01.29 Small lakes
terrestrial	F3.1 Large reservoirs	B01.23 Large artificial lakes
terrestrial	F3.5 Canals, ditches and drains	B01.13 Large artificial water courses
terrestrial	MFT1.3 Coastal saltmarshes	A04.25 Salt marshes
terrestrial	T2.1 Boreal & temperate high montane forests & woodlands	A03.11, A03.21, A03.31, A03.29 Montane and subalpine forests
terrestrial	T2.2 Deciduous temperate forests	A03.19, A03.39, A03.42, A03.49 Broadleaf and mixed forests and woodland
terrestrial	T3.3 Cool temperate heathlands	A04.11, A04.33, A04.39 Heath- and shrubland
terrestrial	T6.1 Ice sheets, glaciers and perennial snowfields	A04.36 Glaciers and perpetual snow

terrestrial	T6.2 Polar alpine rocky outcrops	A04.34, A04.35 Screes and natural bare rock
terrestrial	T6.4 Temperate alpine grasslands and shrublands	A04.12, A04.37 Alpine meadows and montane sub-alpine shrubland
terrestrial	T7.1 Annual croplands	A02.11 Arable land
terrestrial	T7.2 Sown livestock pastures	A02.30 Pastures
terrestrial	T7.3 Plantations	A02.21, A02.22, A02.24, A02.40, A03.41 Permanent cropland and hedgerows A03.19, A03.29, A03.39 Forests
terrestrial	T7.4 Urban and industrial ecosystems	A01.11 - A01.59 Settlements and transport infrastructure
terrestrial	T7.5 Derived semi-natural pastures and old fields	A02.23, A04.19 Orchard meadows and (semi-)natural grassland
terrestrial	TF1.2 Subtropical-temperate forested wetlands	A03.13 Riparian forests
terrestrial	TF1.6 Boreal, temperate and montane peat bogs	A03.12, A03.22, A03.32, A04.22, A04.23 Bog forests and bogs
terrestrial	TF1.7 Boreal and temperate fens	A04.21, A04.24 Fens
terrestrial	MT1.3 Sandy shores	04.31, A04.32 Beaches and dunes
terrestrial	MT2.1 Coastal shrublands and grasslands	A04.39 Shrubland

Both borderline cases are explicitly discussed by the compilation guidelines for indicator A.2 and we follow the mapping suggestions as closely as possible.

a. Forest ecosystems

The national ecosystem classification does not necessarily lend itself to distinguish between natural/semi-natural and anthropogenic types for these ecosystems. For forests, the compilation guidelines for indicator A.2 highlight that they may occur as natural ecosystem types in a modified condition state:

> *Temperate forests in Europe (T2.1): Centuries of logging, agriculture, and settlement have fragmented many forest ecosystems in countries such as Germany, France and the UK. Many are secondary growth forests rather than pristine old-growth. However, they retain native species, natural regeneration processes, and ecological functions such as carbon storage and hydrological regulation.*

The guidelines provide further useful guidance on planted forests:

> *Planted forests,* which can take the form of intensively managed timber plantations (EFG T7.3, anthropogenic) but in other cases may be considered modified natural forest ecosystems in the T1 or T2 biome. When planted forests are composed of native species, allowed to regenerate naturally, and managed with low intensity, they are modified natural ecosystems. For example, in parts of Europe (e.g. UK, Germany) and East Asia (e.g. Japan), large areas of forest have been re-established through deliberate planting of native tree species after historical deforestation. These planted forests often include oak, beech, or pine, and over time develop structural complexity, understorey vegetation, and wildlife communities associated with natural forests. Natural regeneration processes (succession, seed dispersal, nutrient cycling) gradually reassert themselves. When planted forests are monocultures, harvested on short rotations, or reliant on ongoing silvicultural inputs (fertiliser, pest control, replanting), they are anthropogenic ecosystems. The classification depends on whether the forest's ecological identity (species diversity, structural heterogeneity, natural regeneration) is recognisable as a forest ecosystem, or whether it functions essentially as a managed crop of trees.

In the national classification, we distinguish between different types of coniferous, broadleaf and mixed forests. Montane and subalpine, bog and riparian forests are classified to natural/semi-natural types regardless of the management regime, leaving "other" or "common" forests, which constitute about 26% of the total terrestrial area of the country.

To follow the focus on species composition and management intensity, we broadly test three referencing approaches described in IUCN (2025).

i. Best fit referencing (default)

Best fit referencing was done by manually comparing ecosystem type profiles of the national classification with the IUCN GET EFGs.

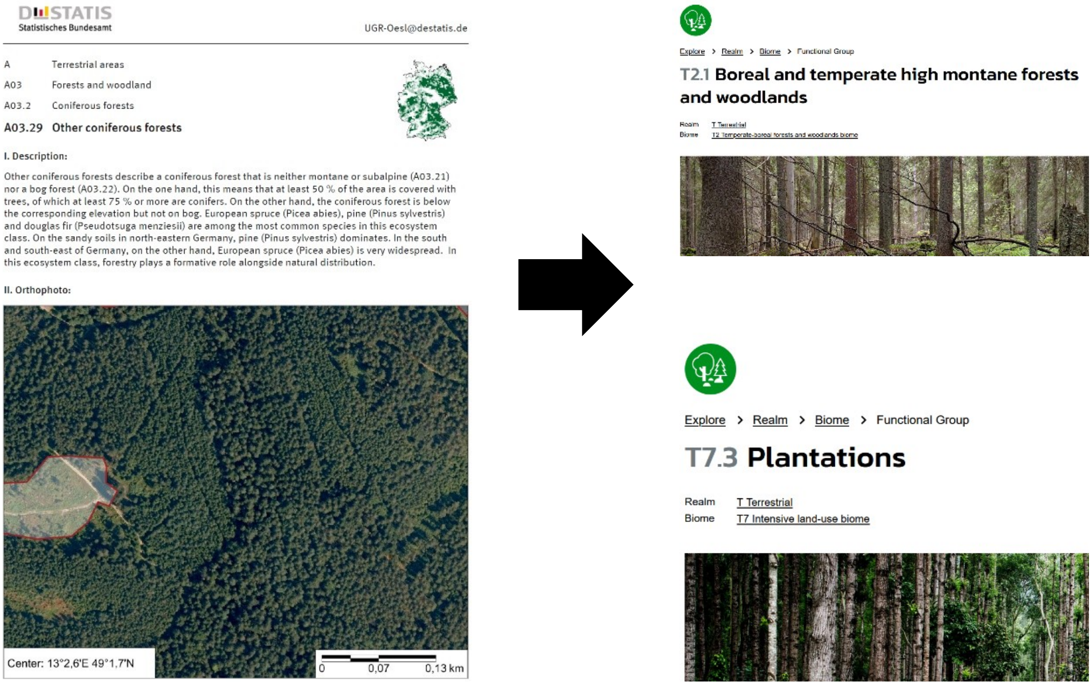

Figure 1: Comparison of Ecosystem Type profiles: German National Ecosystem Classification and IUCN GET EFGs

It was concluded that most coniferous forests in Germany are likely to be within the broad scope of T2.1. There are other EFGs that may be dominated by conifers, but they are unlikely in Germany: T2.3, occurring in wetter climates where mountains/hills intercept rain-bearing oceanic winds or T4.4, occurring in drier climates than Germany. The best fit referencing was cross-checked by the national GBF focal point. It was agreed, that a more differentiated view on forests should be further explored.

ii. Spatial cross-referencing

Next, spatial cross-referencing was used as an experimental approach to differentiate forests. Additional spatial data sources can support this approach. In fact, the data used in this exercise are all established condition indicators in the German ecosystem condition accounts. This highlights the importance of the spatial ecosystem accounting system and its various accounts and reduces the effort necessary to derive GBF indicators.

Tree type diversity: To capture the diversity of main tree species, the Shannon-Evenness Index is calculated using the Dominant Tree Species Map for Germany (Blickensdörfer et al. 2022) that covers 11 tree species group. A low diversity index suggests the presence of monocultures. We use a threshold of 0.2 to identify monocultures at a 1km resolution to identify candidate areas for forests that belong to T7.3 Plantations.

Forest management layer: The distribution map of plantations (T7.3) in the IUCN GET EFG profile was mapped using the Forest Management Layer "Major occurrences of plantations were taken from the map of Habitat type 14.3 by Jung *et al.* (2020) based on the IUCN Habitats Classification Scheme v3.1 (IUCN 2012)" (Keith et al. 2022) using data from Lesiv et al. (2020). Mimicking this approach, we selected type 31 (planted forest) in the IIASA management layer to identify areas of planted forests that belong to T7.3 Plantations.

Protected areas: Lastly, we use protected areas to identify forests, that are certainly not belonging to class T7.3. The protected area map includes nature reserves, national parks, core zones of biosphere reserves, bird sanctuaries and FFH areas. The input data for this analysis was taken from https://www.protectedplanet.net/country/DEU. For our exercise, this constitutes the lower bound of natural/semi-natural forests, as these areas are certainly not plantations, but other non-protected areas may also not be.

iii. Membership score referencing

There are several possibilities to estimate membership scores, according to IUCN (2025). Since for this exercise we could not use a structured expert elicitation, we use a data-driven alternative approach:

Data-driven membership scores: The German National Forest Inventory survey a sample of trees on roughly 80000 sample points every 10 years. Among other information, this inventory reports an indicator on naturalness of tree species composition. This indicator “describes the extent to which a forest's tree species composition corresponds to today's potential natural vegetation” (Federal Ministry of Food and Agriculture 2025). The trends from 2012 to 2022 and the comparison between main and young stocks shows that the naturalness of German forests has increased slightly following structural changes in forests after droughts and damages of the past decade. We use the three “natural” classes to proxy for natural/semi-natural ecosystems, leading to a score of 79%.

Table 3: Conditions for categorization of Forest Naturalness in the German National Forest Inventory

Degree of Naturalness	Share of tree species of natural	Share of main tree species of natural	Completeness of main tree species	Share of non-European tree species	Value for 2022
Very near-natural	≥ 0,9	≥ 0,5	= 1,0	≤ 0,1	**16 %**
Near-natural	≥ 0,75 and < 0,9	≥ 0,1 and ≤ 0,1	< 1,0	> 0,1 and ≤ 0,3	**22%**
Semi-natural	≥ 0,5 and <0,75	< 0,1		> 0,3	**41%**
Heavily managed	≥ 0,25 and < 0,5				**7%**
Plantation-type	< 0,25				**14%**

b. Grassland ecosystems

For grassland ecosystems (not intensively used pastures), we attempt to filter out areas with a use intensity of more than two mowing events per year and only record the remainder as semi-natural ecosystems. Due to the relatively small area of these ecosystems, the overall effect on the indicator is negligible. Additionally, in line with forest ecosystems we calculate a lower bound of semi-natural grasslands by only considering protected areas.

i. Spatial cross-referencing

Mowing/grassland use intensity: Grassland use intensity describes how often meadows and pastures are mowed or grazed per year. Mowing frequency on grassland is directly related to vegetation dynamics and plant community composition. The frequency and timing of mowing can influence species composition and plant growth and thus the availability and quality of food for grazing livestock. The data is based on remote sensing and provided by the Thünen Institute: https://eodata.thuenen.de/collections/grassland-use

Protected areas: Lastly, we use protected areas to identify grasslands, that are certainly not belonging to class T7.2. The protected area map includes nature reserves, national parks, core zones of biosphere reserves, bird sanctuaries and FFH areas. The input data for this analysis was taken from https://www.protectedplanet.net/country/DEU.

c. Results

When calculating the indicator using different approaches of classifying national ecosystem classes to anthropogenic and natural/semi-natural IUCN Ecosystem Functional Groups, the comparison starts with the default specification.

Default: Best fit referencing → no forests and grasslands are mapped to anthropogenic EFGs

The low bound is provided by the relatively strict assumption that natural/semi-natural ecosystems in Germany exist only in protected areas.

Protected [prot]: Spatial referencing

In-between we have cases of different proxies for the naturalness of forest and grassland ecosystems:

Diversity [div]: Spatial referencing

Management [man]: Spatial referencing

Naturalness [bwi]: Membership scores

Naturalness [bwi]: Membership scores **+ Use intensity [mow]**: Spatial referencing

Figure 2 shows the indicator under different specifications. Interestingly, while there is little movement in the indicator over time, it does show slightly different trends depending on the proxy. This is due to the fact that the spatially referencing allows for different trends across different types of forest ecosystems. Note that all dynamics here stem from changes in the extent of these ecosystems rather than changes in the proxies (currently held constant). Using year-specific proxies may uncover further trends in the indicator. Different trends depending on the crosswalk choices will affect the indicator, which is supposed to report the change in share of semi-natural/natural ecosystems. If the proxy choice would only represent a level effect, it would still lead to potential differences between countries in the disaggregated metrics, but not in the headline indicator.

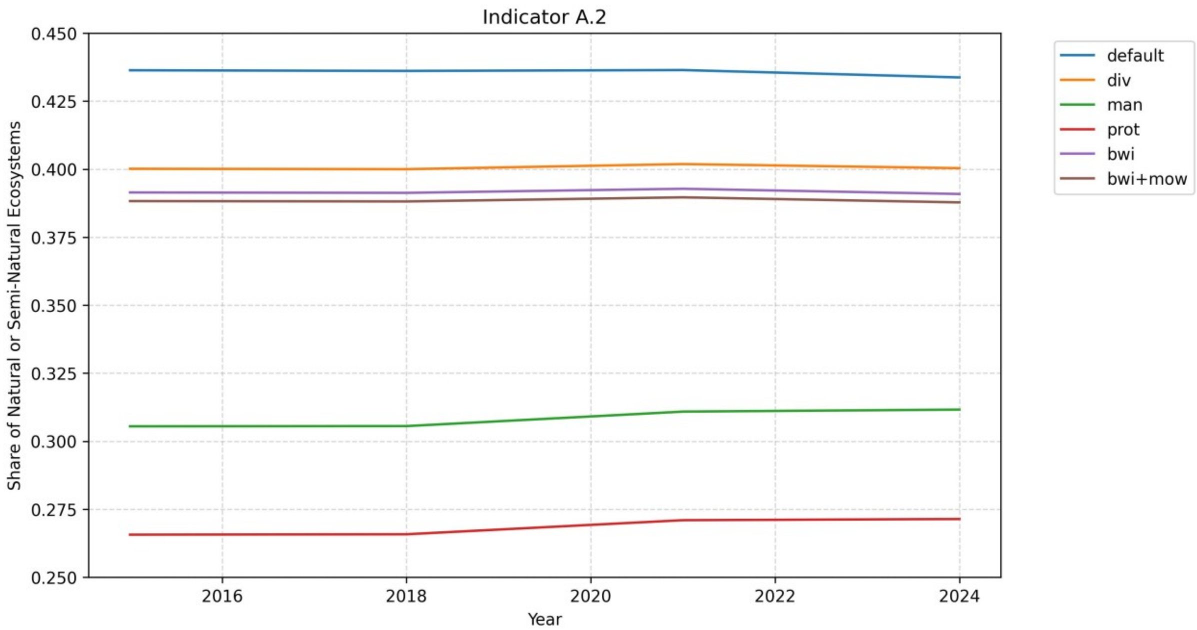

Figure 2: Indicator A.2 for different proxies of naturalness of forests and grasslands

Caveats and conclusions:

The forest management (man) layer is currently not regularly available, the used version represents the forest distribution of 2015 and therefore may miss important structural changes to the ecosystem following the big drought around 2018. The global availability would be a strong argument in favor of this crosswalk option, but regular updates would be necessary.

The national naturalness score (bwi) and diversity (div) options perform very similarly and represent a national and regular crosswalk solution. However, the naturalness score is only updated roughly every 10 years with the national forest inventory as a national average, while the diversity measure can pick up local and yearly differences.

3) Indicator B.1: Services provided by ecosystems

Indicator B.1 reports “services provided by ecosystems” as a geometric mean for all services or differentiated by provisioning, regulating and cultural services. It ought to show whether the contributions of nature to the well-being of people are overall stable, increasing or decreasing.

The indicator should ideally be interpreted in close connection with biodiversity and sustainability, meaning that i) it could highlight services provided by semi-natural/natural ecosystems, ii) flag unsustainable use of services, iii) avoid misinterpretations.

Exercise 1: Differentiating ecosystem services by type and whether it is supplied by a natural/semi-natural ecosystem.

Figure 3 shows the trends in ecosystem service flows from the German Ecosystem Accounts for the following services: Wood provision, crop provision, air filtration and local climate regulation. The only cultural service (nature-based tourism) is excluded from this exercise, because we currently do not attribute the service to specific supplying ecosystems (supply is instead collective by all natural ecosystems). Global climate (carbon sequestration) is currently excluded because negative values (net emissions) cannot be incorporated in the geometric mean (it will be introduced using carbon stock data). The remaining 4 services are included in the exercise. Provisioning and regulating services move jointly for most years. However, after the drought in 2018 that damaged forests across the country, timber provision recovered swiftly, while regulating service required more time to stabilize at a lower level.

When differentiating indicator B.1 by indicator A.2 categories (using the default crosswalk approach) we observe fairly similar dynamics, although seemingly more pronounced for natural ecosystems. While the disaggregation exercise is feasible and relevant to reflect trends connected to biodiversity, it should be noted that it is most likely picking up correlations between the location of natural ecosystems and external factors such as weather or emissions. It should furthermore be noted that not all biophysical models can necessarily differentiate between natural and anthropogenic ecosystems when services flows are attributed to supplying ecosystems (e.g. nature-based tourism).

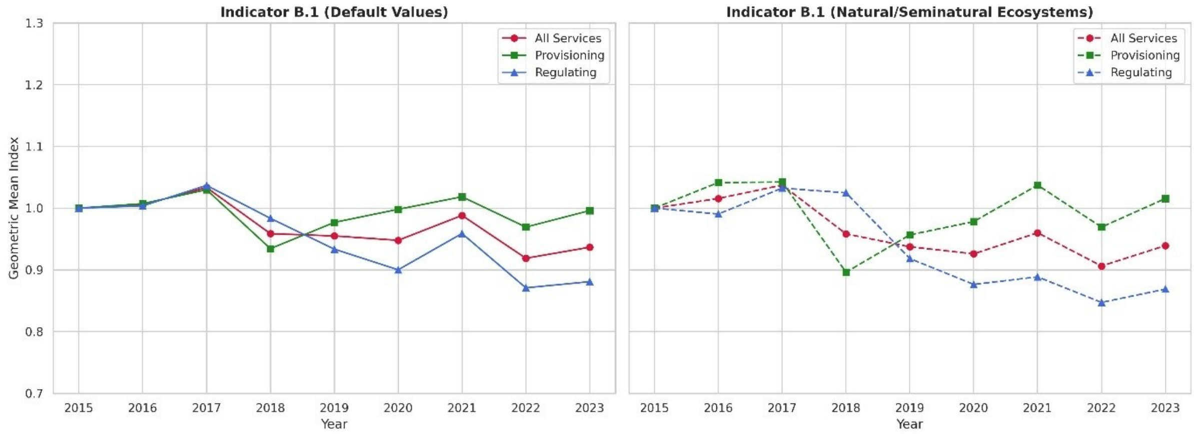

Figure 3: Overall and disaggregated trends in ecosystem services (Indicator B.1) differentiated by type and naturalness of supplying ecosystems

Exercise 2: Interpretation issues for regulating services: Linking potential, demand and flow.

Another relevant question revolves around the selection of services that are linked to biodiversity and sustainable use and how indicator B.1 can be interpreted. Figure 3 shows that disaggregation by service type and by type of supplying ecosystem is useful to uncover different trends and patterns that provide a nuanced view to the supply and use of nature's services to society. As a subsequent exercise we look closer at regulating services that may be interpreted wrongly even if the service is provided entirely by natural ecosystems.

Figures 4 and 5 shows that the trend in the ecosystem service flow for air filtration (regulating service) over time. The orange and blue lines depict the service flow resulting from using a national deposition model and the proposed EU-wide default model. The service flow is mainly driven by the reduction of PM concentration (due to lower emissions) rather than by a declining capacity (leaf area is stable) of the ecosystem to provide the service. Here the indicator may mask a healthy ecosystem as providing low service. Were emissions increasing and leaf area index declining, it could mask ecosystem degradation, if no additional information is provided.

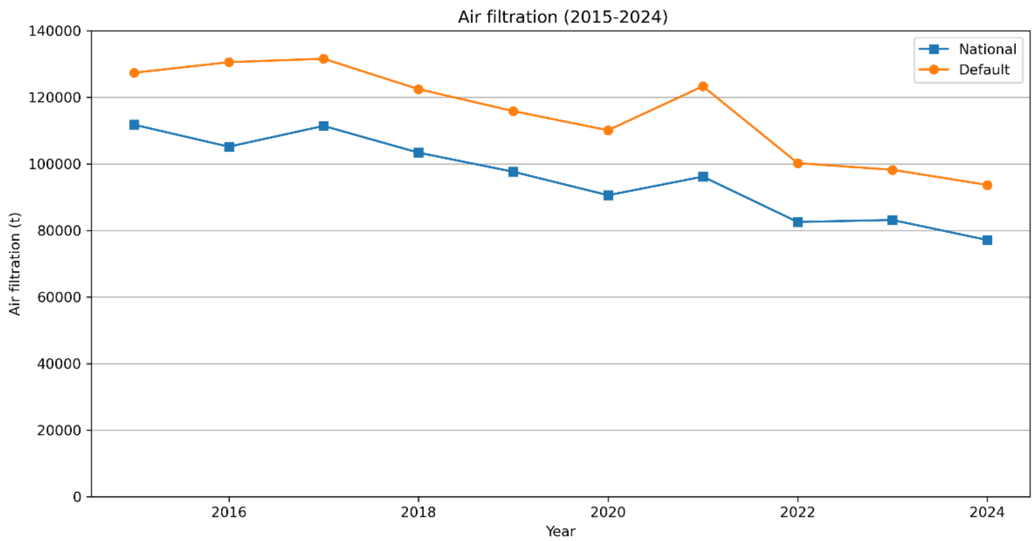

Figure 4: Trends in the air filtration ecosystem service using the default and national approaches

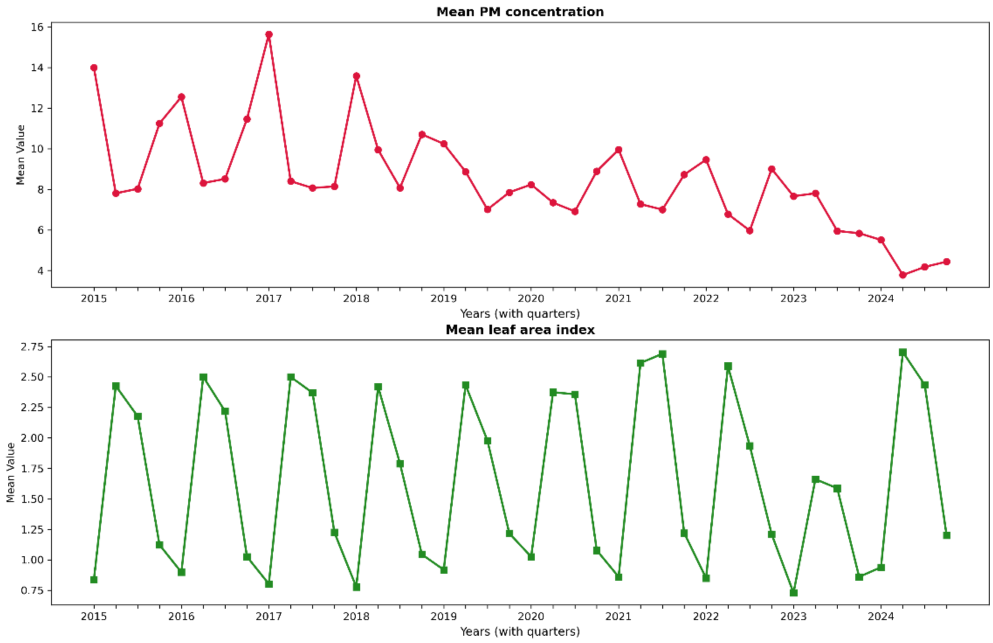

Figure 5: Quarterly data on PM concentration and leaf area index

4) Conclusions:

Regarding Indicator A.2 we regard the crosswalk from national and international classifications to the IUCN EFGs as feasible. The existing guidance is useful to conduct the cross-walking exercise. We believe that a mix of best fit, membership score and spatial referencing may be needed to adequately map ecosystems, because of type-specific criteria and data availability. For membership scores and spatial referencing it could be **useful to provide type-specific lists of qualitative characteristics that form the basis of the referencing**. Otherwise, as we show in this paper, there is a risk of introducing large differences in the level of the share of natural/semi-natural ecosystems and, more importantly, **even divergent trends**. Given that crosswalk choice may have large level-effects, we believe the indicator should focus on trends in the share of natural/semi-natural ecosystems (as originally intended) rather than disaggregated values of extent and shares.

Regarding Indicator B.1 we show that a **disaggregation to natural/semi-natural and anthropogenic supplying ecosystems is mostly feasible**. Although trends overall and for natural/semi-natural ecosystems are comparable, we believe both approaches should be reported. We also show, that the **trends in service flows do not necessarily link back to ecosystem capacity or biodiversity**, when they are driven by changes in demand. Providing additional information on demand and capacity (through condition indicators) can help to avoid misinterpretations. These data are ideally available in the ecosystem condition accounts. We believe that disaggregations and additional information are more suited to connect ecosystem services to biodiversity than selecting only specific services for this indicator.

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