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Discussion paper 2.3: Proposed typology of condition variables for ecosystem accounting and criteria for selection of condition variables

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Research area #2: Ecosystem condition

Discussion paper 2.3: Proposed typology of condition variables for ecosystem accounting and criteria for selection of condition variables

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The SEEA EEA revision process

Ecosystem condition is defined in the SEEA EEA as the overall quality of an ecosystem asset in terms of its characteristics (United Nations, 2012).

How do we measure and report on the condition of ecosystems in an ecosystem accounting framework? Addressing this question means establishing a common definition of ecosystem condition, selecting suitable indicators of condition, evaluating the actual condition of an ecosystem against a reference, and providing an overall, comparable condition score for reporting or accounting. It also requires a further understanding of the relationship between the ecosystem condition, biodiversity and the delivery of ecosystem services as well as knowledge about the pressures (or in a broader sense the drivers of change) that continue to impact ecosystems.

The SEEA EEA Technical Recommendations (United Nations 2017) do not yet provide definitive advice on how to address these several challenges when reporting ecosystem condition in condition accounts. These challenges have been addressed in a Revision Issues Note for the Ecosystem Accounting Revision 2020 (United Nations, 2018) which recommends providing further guidance on ecosystem condition.

This paper is part of a series of discussion papers on ecosystem condition. It aims to provide **a conceptual basis for the selection of variables and indicators that can be used to describe the most relevant ecosystem characteristics with a view to assess ecosystem condition.** Two other papers are part of this series: a paper on the purpose and structure of ecosystem condition accounts (Discussion Paper 2.1) and a paper reviewing existing approaches for ecosystem condition accounting (Discussion Paper 2.2).

These discussion papers have been developed by a working group established as part of the revision process. The working group on ecosystem condition is one of five working groups for the four research areas (RAs) identified in the Revision Issues Note: RA1 focuses on spatial units, RA2 on ecosystem condition, RA3 on ecosystem services and RA4 on valuation.

1. Introduction

The SEEA EEA defines ecosystem condition as the overall quality of an ecosystem asset in terms of its characteristics (United Nations et al., 2012). The origins and purposes and of the ecosystem condition concept, its role in the SEEA EEA framework, and the basic structure of ecosystem condition accounts is discussed in detail in DP 2.1. This paper builds on the fundamentals laid down in DP 2.1, and adds further details to several key elements necessary for any practical implementations:

- the *characteristics* of the ecosystems (which ones are relevant for describing ecosystem condition); and
- the concrete quantitative metrics (*variables*, *indicators*, and *indices*) which can be used to describe these characteristics

In the context of this discussion paper, variables, indicators, and indices are all considered as quantitative metrics (numbers) that characterize the studied system (i.e. specific ecosystem units) from a certain perspective. The broader term is *variable*: any quantitative metric reflecting a phenomenon of interest can be seen as a variable. *Indicators* are variables with a strong direct **normative interpretation** (i.e. distinguishing "good" from "bad") with a view to informing policy and decisions. An *index* is an aggregated indicator constructed from other indicators, which thus represents relatively broad aspects of the studied system in a single number. Finally, the term *metric* is used to refer to any of the previous three categories.

Ecosystems have many quantifiable characteristics but not everything can be measured. A first step in exploring the inherent multidimensionality of ecosystems is to understand how many relevant characteristics of ecosystem condition can be determined and what should be the criteria to decide on the relevance of characteristics. Then for the most relevant characteristics, variables and indicators can be selected. This selection procedure needs to be supported by an appropriate typology for ecosystem condition metrics, which can both guide the selection process, and create a structure for the condition accounts compiled. The main objective of this discussion paper is to provide (1) a detailed and consistent set of criteria for selecting relevant ecosystem characteristics and condition metrics, and (2) a proposal for a SEEA EEA ecosystem condition typology (SECT).

2. Criteria for ecosystem condition characteristics, variables and indicators

The identification of an adequate set of condition metrics can be a complex and challenging process. Good indicators need to be scientifically credible, responsive to user needs (salience), and be perceived as such by their end users (legitimacy, Cash et al., 2003). From a policy perspective, the success of a metric resides in its utility for policy actors, influence on policy processes, and impact on policy outcomes (Bauler, 2012). There are many papers in the scientific literature that provide criteria and recommendations for identifying the right metrics (indicators) in various policy contexts (e.g. Dale and Beyeler, 2001; Niemeijer & de Groot, 2008; Giannetti, 2009; Kandziora et al., 2013).

There are several criteria that potential metrics must meet in order to characterize the condition of ecosystems in a way that complies with accounting principles, is policy-relevant, and is also meaningful from a biophysical perspective. This chapter gives a comprehensive overview on all potential selection criteria that need to be observed in order to create an adequate set of ecosystem condition variables and indicators in a SEEA EEA context (Table 1). Following Niemeijer & de Groot (2008) we distinguish two types of selection criteria: *individual criteria*, which can be used to appraise the relevance or usefulness of each ecosystem characteristic or indicator proposed; and *ensemble criteria*, which need to be applied to the whole set of candidate indicators (e.g. to ensure that there are no gaps or double counting).

SEEA EEA 2012 (e.g. §4.60, 4.66) clearly distinguishes (1) ecosystem characteristics (i.e. major groups of system properties or components based on ecological understanding), and (2) the metrics (variables and indicators) which are used to quantify them. Characteristics can be broad and abstract (for example, SEEA EEA lists water, timber, carbon and biodiversity as characteristics relevant for "basic resource accounts"), whereas metrics should be concrete and specific as much as possible. Characteristics and metrics can be seen as two hierarchical levels of structuring and organizing condition information. The selection procedure should address both stages. Adapting the recommendations of Niemeijer and de Groot (2008), the general procedure for the selection of ecosystem condition variables and indicators should include the following three steps:

- Identifying key characteristics (ecosystem components and processes),
- Selecting (identify and /or create) the best metrics for the selected characteristics,
- Verify the balance and comprehensiveness of the whole set of metrics, and adjust if necessary.

Table 1. Selection criteria for ecosystem characteristics and their metrics (variables and indicators)

Criterion	**Short description**
Individual criteria for characteristics, variables and indicators	
Relevance	ecosystem characteristics (and their metrics) should be relevant in terms of the fundamental purpose (intrinsic or instrumental) that can be linked to ecosystem condition accounts (see DP 2.1)
State orientation	ecosystem characteristics and their metrics should describe the state of the studied (ecological or socio-ecological) system
Framework conformity	ecosystem characteristics and their metrics should be differentiated from other components of the SEEA EEA framework
Individual criteria for variables and indicators	
Spatial consistency	ecosystem condition metrics should be linked to a specific location (mapped) or spatially referenced
Temporal consistency	ecosystem condition metrics should be linked to a specific time period and be sensitive to change
Feasibility	ecosystem condition metrics should (potentially) be covered by data sources over large areas
Quantitativeness	ecosystem condition metrics should be measured at a well-defined quantitative scale that allows comparisons in space and time
Reliability	primary (measured) data should be preferred over derived data which, in turn, should be preferred over modelled data.
Normativity	ecosystem condition indicators should have a strong inherent 'normative' interpretation (‘good’ vs ‘bad’)
Simplicity	ecosystem condition metrics should be as simple as possible
Ensemble criteria (for the whole set of variables and indicators)	
Parsimony (or complementarity)	the final set of ecosystem condition metrics should cover as much information on the studied ecosystem as possible with as few variables/indicators as possible
Data gaps	ecosystem characteristics which seem to be relevant, but which are not covered adequately by available data sources should be highlighted as data gaps

The selection of characteristics and their metrics (variables, indicators) cannot be sharply separated in real life contexts, so several of the criteria proposed in Table 1 operate both at the conceptual (characteristics) and the practical (variables, indicators) level of decisions. The identification of a consistent and comprehensive set of indicators and variables is followed by the creation of aggregated indices and sub-indices. The aggregation procedure should follow the structure of the SECT typology, and is discussed in detail in DP 2.1.

2.1. Criteria for characteristics and metrics

The criterion of **relevance** implies that the selection process should reflect the *fundamental purpose* (value choices) underlying the condition accounts, let it be intrinsic, instrumental, or anything in between (see DP 2.1 for more detail). From an *instrumental* perspective those characteristics need to be selected, which exert the most influence on the capacity of the ecosystems for providing multiple ES. Accordingly, the instrumental approach could be guided by well-designed systematic reviews exploring the relationships between ecosystem characteristics and ecosystem services (‘EC~ES’ relationships, e.g. Verhagen et al., 2016; Czúcz et al., 2017; Schwartz et al., 2017; Smith et al., 2017). There is a high amount of primary research studies that test the relationship between a particular ES and a particular ecosystem characteristic in a specific context (ecosystem type), however, this knowledge is still very fragmented, and a general synthesis is still largely missing. On the other hand, the *intrinsic* approach does not seek to analyse the individual EC~ES relationships, but starts out from long standing ecological knowledge on the key characteristics for ‘healthy’ ecosystems. To ensure that these characteristics be represented in the accounts, the typology has to be used much more prescriptively (i.e. as a shortlist of ‘relevant’ characteristics). As long as this ‘big picture’ is still missing the intrinsic approach may also be more operative. The SECT typology discussed in Chapter 3 was designed from this intrinsic perspective, so that it could facilitate an intrinsic selection process. Nevertheless, in case an appropriate synthesis of EC~ES relationships, and the relevance of variables is measured in terms of their instrumental influence, the SECT typology can still be useful as an aggregation structure.

The relatively abstract criterion of ‘**state orientation**’ requires that ecosystem characteristics and their metrics should describe the state of the studied ecosystem as much as possible. In system science, state is considered to be the set of variables which at any time (a ‘snapshot’) describe enough about the system to determine its future behaviour in the absence of any external forces (Palm et al., 2005). As in the context of ecosystem accounting the key output (“future behaviour”) of the studied system is the portfolio of ES generated, it is important that the ‘state variables’ describing the system would capture everything that can influence this portfolio.

Most ecosystem characteristics do not have a single ‘default’ formulation (definition/quantification approach), but can be measured/quantified in several potential ways. There can be many potential reasons for this: e.g. the characteristic can be abstract & ambiguous (e.g. biodiversity, use intensity), or difficult to measure (e.g. NPP, grazing intensity) or just too highly fluctuating (water availability, vegetation cover) which needs to be ‘averaged’ somehow (and there are always multiple options for this). The arising options can lead to different quantitative metrics, which just describe the same ecosystem characteristic. If there is a choice between two alternative ways (metrics) for quantifying a relevant system characteristic, the one which conforms more to the idea of ‘state’ is the one which should be preferred.

The criterion of **framework conformity** is of key importance for the integrity of the whole assessment. According to this criterion, each aspect of the studied system should only be described under a single component of the SEEA EEA conceptual framework. Characteristics that can be better considered under *ecosystem extent* (e.g. forested area or deforestation) or *ecosystem service* (e.g. carbon sequestration) should be handled there and only there. If such characteristics are considered in multiple accounts then this can lead to confusing ambiguities.

2.2. Criteria for metrics

The criterion of **spatial consistency** means that the variables and indicators need to be linked to a specific location (mapped). More specifically, all candidate variables have to be interpretable over *any area* that is (1) larger than a predefined minimum area (‘*spatial grain*’), and (2) is covered by one of the ecosystem types (ET) for which the variable makes sense (‘*thematic domain*’). The grain and the thematic domain of each variable should be included in their definition. Ideally, the whole accounting should have a harmonized spatial grain and the definition of the metrics should respect this grain. For example, a large grassland is handled as an ecosystem type, whereas a small (‘sub-grain’) grassland is considered as a part of the embedding ecosystem type (e.g. cropland) with the ‘density’ of such embedded fragments considered as a condition attribute of the embedding ecosystem type).

Temporal consistency implies that variables and indicators are sensitive to change and linked to a specific time period (*temporal grain*), which should be regularly in SNA / SEEA EEA, e.g. every year or every 5 years. Biophysical considerations also suggest that the grain should cover at least one full annual cycle, which is the key periodical cycle for the studied system. **Sensitivity to change** should also be considered (with respect to this temporal grain), so that condition would be reasonably variable across a few time steps (i.e. *quasi-constant* or *extremely variable* candidate variables should be excluded or adjusted). This means that for data streams with relatively fine temporal resolution (e.g. remote sensing data) the precise definition of the condition metric should involve some sort of ‘temporal aggregation’, e.g. in the form of appropriate statistical aggregation functions (central tendencies or extremities, e.g. mean annual values, annual maxima, etc.). Defining the timeframe and time resolution is important for selecting indicators: for instance, to estimate change over 50 years with data every 5 years, the most useful variable may be different than a variable which measures intra-seasonal variations of an ecosystem characteristic.

Feasibility means that variables and indicators should be covered by (potentially) available data sources over large areas. This implies that those characteristics that are difficult to measure or are in any way unfeasible to be covered by data in the foreseeable future should be avoided.

According to the criterion of **quantitativeness** metrics should be measured at a well-defined quantitative scale, which allows for meaningful comparisons and change detection. Condition metrics should ideally be measured at a ratio/interval scale or at least at an ordinal scale (sensu Stevens, 1946). Attributes measured at a categorical/nominal scale should preferably not be used as condition metrics, unless they can be adjusted to an ordinal/interval/ratio scale (e.g. by using scores/weights, or by being quantified as the ‘share’ of a relevant subtype over a larger area).

The concept of **reliability** is linked to the uncertainties concerning the variables and indicators. Suitable metrics should rely on data that are measured in a transparent, objective and standardized way. Data manipulations should be kept to minimal, i.e. to necessary data cleaning / harmonization / transformation operations, such as spatial / temporal interpolation, aggregation, noise reduction, or the rescaling transformation for creating indicators from variables (see also at normativity). Primary (measured) data should be preferred to modelled / derived data, which always rely on a number of assumptions, contain inherent errors, and are thus more prone to being criticized or disputed. Modelled data can change even retrospectively if the modelling technique is updated. In the formulation of variables and indicators, subjective elements should be avoided as much as possible, and if unavoidable (e.g. scores used for weighting 'components' of a composite indicator) they should rely on a broad consensus of 'experts' in a clearly documented way. Data streams should ideally be resistant to malicious tampering/manipulation.

Condition metrics should have a '**normative**' message, i.e. they should be able to distinguish what is 'good' or desirable from what is 'bad' or undesirable -- preferably with societal consensus. For variables, this normative message can be context-dependent, thus allowing for some 'neutrality' in the accounts. Nevertheless, even the most neutral variables need to have a clear and relevant message to expert policy users -- in the absence of such a message there is no point in including the variable into the condition accounts.

In line with DP 2.1 we suggest that SEEA should provide on the role of variables and indicators in the condition accounts, and also on the when, why and how variables should be transformed into indicators. Relatively neutral variables and fully normative indicators can both be excellent ways of describing the state of a system, but while variables demand an expertise for a correct interpretation, indicators can also be interpreted by inexpert users, especially if they are rescaled to a common scale (e.g. ranging from 0='bad' to 1='good'). Thematic aggregation into indices also demands rescaled indicators. The simplest and most straightforward way to transform a variable into an indicator is through appropriate reference levels (typically defined through a carefully selected reference condition, see DP 2.1). In some cases (e.g. when the variable in question has no meaningful zero value) two reference levels may be necessary (defining the 'good' and the 'bad' endpoints of the scale). Ideally, there should be a monotonous 'quasi-linear' relationship between the values of the indicator and the underlying human 'value judgement' (i.e. an increase in the indicator value should always mean a better condition, and the same increase in the indicator value should always mean approximately the same degree of 'improvement' in the condition -- at all parts of the scale). The transformation should be selected / constructed in a way that the resulting indicator would approximate this ideal situation as much as possible, as this can allow easier policy interpretations and more straightforward aggregation procedures.

To illustrate the differences between variables and indicators we can take the human body temperature as a well-known example. Core temperature is an important **variable** describing a key health characteristic of the human body, which does not have a single linear normative interpretation (i.e. an increase in the temperatures is bad above 36 °C, but it is good at lower parts of the scale: fever vs. hypothermia). To transform it into a 'fever indicator' we can make use of the widely accepted fever threshold (T1, 37°C / 98.6 F) as a reference value. As the human body temperature scale has no meaningful zero value nor any well-defined ‘pessimal’ limit, a second (‘bad’) reference value (T0) is also needed. Then the fever indicator could take a value of 0 for all temperatures T>T0 (pessimal state), a value of 1 (optimal state) for all temperatures T < T1, and should change linearly in between. This example can also be used to illustrate the added value of including both variables and indicators into the accounts. While most of the expert users would prefer the original variable as information, the rescaled and standardized values of the indicator can be more informative for an inexpert user and they are also more useful for thematic aggregation.

Finally, good metrics should be as **simple** as possible (but not any simpler). If every other criterion is ensured, simpler variables and indicators (allowing easier policy interpretation and messages that are more powerful) should be preferred over more complex/abstract metrics.

2.3. Ensemble criteria

The remaining two criteria do not focus so much on the characteristics of the individual metrics, but on the whole set. **Parsimony** or complementarity means that there should be as few metrics as possible so that they would cover as much information as possible (without any unnecessary redundancies). To this end the selected variables / indicators should be independent / non-correlated as much as possible, but the set should still represent all major ‘aspects’ of the studied system (so that they could be rightfully considered as 'key indicators' of system state). Many times there can be correlations between seemingly unrelated variables describing different system aspects (and listed under different SECT headings, see Chapter 3), which are generated by the internal mechanisms of the studied system. Correlations can also be introduced by technical artefacts (e.g. by inconsistent reuse/re-labelling of data streams). In case of ‘correlation conflicts’, the most appropriate (relevant, simple, reliable, framework conform...) candidate should be chosen following all the other criteria. Correlations in the final indicator set can create confusion and technical artefacts, which can lead to a loss of credibility.

Finally, the set of metrics should be checked for comprehensivity, and all system characteristics which are known to be relevant, but are not covered adequately by available data sources should be highlighted as **data gaps**. The identification of such information gaps can help in guiding future research activities.

2.4. Implications of the selection criteria for pressures, protection and land management

The conceptual criteria of state orientation and framework conformity are also of key importance for SEEA EEA, which can offer valuable guidance in open questions related to particular types of variables.

Pressures are often considered as an “indirect approach” for measuring ecosystem condition (e.g. Erhard et al., 2016, p.31). If there are little data available on state, then pressures can be considered a useful surrogate, as long as the relationship between the two is well understood and justified (Bland et al. 2018). This is clearly a compromise, as conflating pressures with state variables can compromise the credibility and salience of the resulting accounting tables. Nevertheless, this does not necessarily mean that accounting tables should be blind to the policy issues highlighted by the most relevant pressures. In the case of most pressures (*erosion*, *pollution*, *invasion…*) there is an underlying 'hidden' variable that reflects the 'degradation' of the ecosystem with respect to that specific pressure. This underlying variable is an environmental 'stock' (e.g. the thickness of soil layer, the concentration(s) of pollutants, or the abundance of invasive species) that is gradually degraded (depleted, accumulated...) by the pressure. Typically, such stocks can meet all the criteria, so they can be more appropriate for condition accounting than their change or the connected flows (degradation / depletion rates, fluxes, flows, or other metrics of flow intensity). Using these 'degradable stocks' as condition variables comes with multiple further advantages: they can be used to formulate very clear and pertinent policy messages on ecosystem degradation (as a change in these environmental stocks); and the degree of policy attention highlights those 'degradable stocks' that are perceived as the most valuable or most endangered.

Focussing at 'degradable stocks' in the condition accounts will allow significant progress in reporting on changes in the quality of ecosystem assets that is not available currently when change in area of an ecosystem asset is reported under ecosystem extent. An example of the benefit of quantifying and reporting condition as well as extent is the carbon accounting under the UNFCCC, where change in carbon stocks are reported if land use change occurs, that is change in ecosystem extent, but are not reported if degradation of stocks occur within a land use type, that is a change in ecosystem condition (IPCC, 2014). Treating degradable stocks in a condition account is particularly relevant when ecosystem extent is often measured by remote sensing, which will detect a stock loss due to change in ecosystem type, e.g. clearing vegetation, but may not detect a stock loss due to degradation e.g. loss of understorey or weed invasion.

A further important type of pressures worth considering is *overexploitation*, which can frequently, but not necessarily, also be linked to degradable stocks (e.g. timber or fish stocks for forest management and marine fishing). If overexploitation cannot be characterised with stock sizes, **management** intensity metrics can be used as a controversial alternative. Most of the ecosystem types have a specific target ecosystem service (typically a provisioning service), and 'traditional' ecosystem management aims at the maximization of that service (de Groot et al., 2010). The intensity of these management activities has shown to exert very strong influences the supply of a broad range of services, well beyond the original 'target ES' of the management activities (Santos-Martin et al., 2019). No wonder that some of the case studies reviewed in DP 2.2 also apply metrics of management intensity (case studies 20, 21). Nevertheless, the inclusion of management intensity into condition accounts is a controversial option for SEEA EEA, which assumes that we consider humans and their primary management activities as an internal part of the ecosystems (e.g. as a sort of 'anthropogenic' disturbance regime).

Some pressures should probably *not* be considered in the ecosystem condition accounts, even if underlying environmental stocks can be identified. This includes pressures (or drivers) with rather indirect influence on ecosystems (e.g. *climate change*, *human population changes*), which should probably been considered external to the studied ecosystems. *Habitat loss*, which is a direct pressure with a clearly identifiable degradable stock (the area of the ecosystem/habitat type in question), should probably be omitted from condition accounts for framework conformity reasons (it should be addressed as ecosystem extent rather than ecosystem condition). For 'habitats' that are distinguished as ecosystem types this type of stock and its 'degradation' should be discussed under the 'ecosystem extent' accounts. On the other hand, if a habitat change is ‘internal’ to a specific ecosystem type (e.g. soil sealing in the case of urban ecosystems), then it can be added to the condition account (preferably with a variable describing the underlying degradable stock; e.g. the share of impervious surfaces). This variable will then be specific to the given ecosystem type.

Similarly to pressures, **protection status** (e.g. the location, area, or representativeness of protected areas) is also frequently proposed as a proxy for condition if no other information is available (e.g. Maes et al., 2018; see further examples in DP2.2 case studies 10, 20, 21, 22). Protection could also be thought of as a rough proxy for reduced pressures, especially for reduced overexploitation (lower management intensities). Nevertheless, policy interventions performed in response to degradation processes do not make good condition variables. There is no inherent relationship between protection status and other metrics of ecosystem condition, for example, an ecosystem could fall within a protected area and nevertheless be in poor condition / intensively modified (for example if it is the site of a dam or lodge, or if the management of the protected area is ineffective). In order to avoid confusion and double counting, metrics describing policy response categories should be avoided. Including such metrics into the SEEA EEA ecosystem condition accounts would, among other issues, compromise their applicability in measuring the impact / efficiency of policy changes (e.g. the efficiency of a newly designated protected area).

The problems discussed in this chapter are related to a broader question: how much should SEEA EEA rely on the DPSIR framework? Should SEEA EEA make recommendations for the DPSIR categories? Or could the DPSIR framework perhaps even be used as the starting point to the classification of ecosystem condition metrics? To answer these questions, it is important to notice that the popularity of the DPSIR framework stems from its flexibility: this framework can be used to describe a very broad variety of problems in a simple way. To adapt the framework to a new context, the first step is to identify the most important drivers, pressures, etc. This means that these categories are not absolute, they are context-dependent. For example, while droughts and wildfires can be seen as an impact in a climate modelling context, they should be considered as a driver/pressure in an ecological study. Similarly, habitat loss can also be considered as a driver or an impact, or conservation status can also be considered as a state or a response depending on the exact question being addressed. While there is a general tendency that condition should describe the ‘state’ of the ecosystems (as also highlighted by the criterion of ‘state orientation’), this is not exactly the same ‘state’ as the letter S in DPSIR. Accordingly, we think that SEEA EEA should not base their recommendations upon the DPSIR categories, as this might create more problems than it could resolve.

3. A typology for ecosystem condition

A *typology* or *classification* is the operation of distributing objects into classes or groups that are less numerous than the original objects. This operation is very broadly and frequently used in science, as it can create an order among the “chaotic and muddled multiplicities” of life and thus can reduce the complexity of the problems (Parrochia, 2019). Classifications are therefore the essence of accounting systems. Classifications need to be ***exhaustive*** and ***mutually exclusive***: classes should not overlap, and their union should restore the divided concept. As each division (class) can be further subdivided, classifications can also be hierarchical.

An *ecosystem condition typology* is a hierarchical classification for the metrics (variables and indicators) used to describe the condition of the ecosystems. Nevertheless, as these metrics are supposed to reflect the underlying reality of the ecosystem, the condition typology can also be applied for ecosystem characteristics, thus defining the relevant "information structure" of the ecosystem itself. This way the typology for ecosystem condition can create a meaningful order for the accounting tables, which can have multiple advantages:

- it can help to establish a common language and a shared understanding;
- it can make different studies (assessments, countries, etc.) more comparable;
- it can be used as a structure for aggregation; and
- it can be used as a template for the selection of variables and indicators.

As also emphasized by SEEA EEA, different ecosystem types have different relevant characteristics, which should be described by different indicators (see e.g. SEEA EEA 2012: §A.5). Nevertheless, in order to facilitate communication, as well as comparisons and aggregation across ecosystem types, an ecosystem condition typology should be ***universal*** at least at the top levels (i.e. it is expected to be relevant for all major ecosystem types). On the other hand, the typology also needs to be able to host ecosystem type specific metrics at the lower levels.

3.1. Classification systems for ecosystem condition

Related to the concept of ecosystem condition, there are already several classifications in the scientific literature. Many of the ecological concepts discussed in DP 2.1 (e.g. ecosystem integrity, ecosystem health, naturalness…) also come with a typology, created either on a theoretical or a practical basis (e.g. for use with real life data). Such typologies include:

- the classification of essential biodiversity variables (EBV), as outlined by Pereira et al. (2013);
- the ecosystem integrity typology proposed by Müller et al. (2005);
- the BESAFE/OpenNESS typology the characteristics of 'natural capital' (Smith et al., 2017);
- the MAES typology for the mapping and assessment of ecosystem condition in the EU (Maes et al., 2018).

These proposals have a lot in common, but there are also differences (see Annex 1). The following section aims to deliver a common denominator of these classification systems by placing them through the filter of the abovementioned criteria.

3.2. Proposal for a SEEA EEA ecosystem condition typology

We propose the hierarchical classification shown in Table 2 to be used as the SEEA EEA ecosystem condition typology (SECT). The structure of the proposed classes reflects a combination of long-standing ecological tradition (composition, structure and function, cf. Noss, 1990), theoretical considerations as discussed in the previous chapters, and practical considerations from DP2.2. Nevertheless, composition, structure, and particularly function are extremely broad concepts, interpreted in different ways by the different researcher communities. For example, while most ecologists consider the 'relative abundance of a species in a community' as a compositional characteristic, some would consider it as a structural attribute of the community, while others would consider it as a functional attribute (linked to the function of the species). To avoid ambiguities, and to ensure the *mutual exclusivity* of the classes, we also propose a detailed interpretation for each class, with a detailed discussion on boundary cases (what should be included and what should not) based on the criteria discussed in the previous chapter. The proposed SECT classes are also linked to EBVs and the case studies (from DP 2.2) in Table 2, and in more detail in Annexes 1 and 2.

Table 2. Proposal for a SEEA EEA ecosystem condition typology (SECT) for ecosystem accounting

SECT superclass	**SECT class**	**link to EBV classes**	**Link to case studies in DP2.2***
Abiotic ecosystem characteristics	Physical state characteristics (e.g. soil structure, water availability)	--	8, 9, 21
	Chemical state characteristics (e.g. soil nutrient levels, water quality, air pollutant concentrations)	--	1, 2, 5, 8, 11, 12, 14, 16, 20, 22
Biotic ecosystem characteristics	Compositional state characteristics (including species-based indicators)	B1-2, D1 (E3)	2, 5, 6, 8, 10-14, 16, 17, 19, 20-22
	Structural state characteristics (including vegetation, biomass, food chains)	E1 (partly)	3, 4, 10, 12-14, 16
	Functional state characteristics (including ecosystem processes, disturbance regimes)	F4, (F1-3, D2)	2, 10, 12, 16, 20
Landscape and seascape characteristics	Overall landscape characteristics (including landscape diversity)	--	--
	Ecosystem type specific landscape characteristics (e.g. forest connectivity / fragmentation, embedded semi-natural elements in farmland)	--	2-5, 7-10, 13, 16, 21

* case study numbers as listed in Annex 1 of DP 2.2

The class **physical state characteristics** hosts the physical descriptors of the abiotic components of the ecosystem (soil, water, air…). Physical stocks that are typically being degraded (depleted) due to human pressures (e.g. soil organic carbon, water table level, impervious surfaces, as discussed in Chapter 2.4) are very good choices, as they are both sensitive to changes, and relevant for policy interpretation.

The class **chemical state characteristics** contains metrics related to the chemical composition of the abiotic ecosystem compartments. This typically involves the accumulated stocks of various pollutants in soil, water, or air, but only if the selection criteria are met (e.g. global atmospheric CO_2 concentration probably should not be seen as a condition metric). Similarly to *physical state characteristics*, variables should describe the state ("stocks" of pollutants) rather than the flows (emission of pollutants). This way both abiotic SECT classes accommodate major pressures in a way that is compatible with accounting (the pressures are related to the changes in these variables).

The SECT class **compositional state characteristics** comprises a broad range of 'typical' biodiversity variables, describing the composition of ecological communities from a biodiversity perspective. This includes the presence / abundance of a species or species group, or the diversity of specific species groups at a given location and time. From a location-based perspective (required by spatial consistency) the distribution of a species also boils down-to species composition (local presence). Compositional metrics can characterize the presence / absence or abundance individual species, taxonomic groups (birds, butterflies), or non-taxonomic guilds (e.g. soil invertebrates, macrozoobenthos). However, variables based on highly specialist functional groups, where even data collection was performed from a functional perspective (e.g. pollinators, N-fixers, etc.) should be considered either as *functional state characteristics*, or as *ecosystem service indicators* (if they are tightly connected to a single specific ES). Abundance metrics of very large guilds (e.g. trees, phytoplankton) comprising entire ecosystem compartments should be considered as *structural state characteristics* (biomass, vegetation).

The class **structural state characteristics** primarily focuses at the vegetation and biomass of the sites, comprising metrics describing the local amount of living and dead plant matter (vegetation, biomass) in an ecosystem. This class includes all metrics of vegetation density and cover, related either to the whole ecosystem, or to just specific compartments (canopy layer, belowground biomass, litter...). For marine and freshwater ecosystems this class can include chlorophyll concentrations, phytoplankton abundance, or plant biomass (e.g., seagrasses). There is some overlap between *compositional* and structural state metrics, particularly for foundation-species-based ecosystems such as mangrove, or where species groups and vegetation compartments coincide (trees on savannah, lichens on mountain rocks). Such cases should be registered in this class.

The class **functional state characteristics** should host simple summary statistics (e.g. frequency, intensity) of relevant ecosystem processes / functions which meet the selection criteria discussed in the previous chapter, and which are not already covered by other classes. Ecosystem functions is a hugely diverse umbrella concept, which is used in highly different ways by the various research communities. Many of the characteristics that can be seen as 'ecosystem functions' can also be seen as a *compositional* (e.g. species abundances), *structural* (e.g. plant biomass), or *abiotic state descriptors* (e.g. surface albedo), or even as *ecosystem service indicators* (ES accounts). It is a good practice to avoid placing functional characteristics into this class whenever they can find a better home in another class.

Overall landscape characteristics comprise the integrative (non ecosystem type specific) characteristic of ecosystem type mosaics, typically quantifiable at large (landscape, seascape) spatial scales. The diversity of ecosystem types in a landscape ('landscape diversity'), for example, can describe the integrity of landscapes at broader spatial scales, and also exerts influence on several ecosystem services (Verhagen et al., 2016). The proposed structure of condition accounts suggests that the metrics should be linked to specific ecosystem types. This can be achieved by linking the local landscape diversity (e.g. calculated with a moving window) to the local ecosystem type, which means that we define the 'landscape diversity' of a forest with the diversity of the landscape in which the forest is situated.

Ecosystem type specific landscape characteristics include metrics of landscape connectivity / fragmentation from the perspective of a specific ecosystem type (or group of ecosystem types). Landscape connectivity can be interpreted and measured very differently in terrestrial, freshwater, and marine biomes. Furthermore, in the case of ecosystem types, which themselves are 'mosaics' of relevant subtypes (e.g. a cropland with nested seminatural vegetation fragments), the abundance or the spatial pattern (connectivity) of these subtypes can also be hosted under this SECT class.

3.3. Ancillary data

The SECT typology, as introduced in the previous chapter, does not cover all policy-relevant environmental metrics. Both the EBVs and the case studies reviewed in DP 2.2 contain some variables that cannot be hosted in the classes presented above. In general, these variables violate some of the selection criteria to some degree, so this does not necessarily mean that the SECT classification would not be *exhaustive*. In the following we discuss the most important types of such variables in the context of the selection criteria. We propose that these groups of variables should be seen as 'ancillary data', which should in general not be included into the condition accounts. The extent to which exceptions can be made from this rule should be discussed by SEEA EEA -- e.g. if in well-defined cases when there are relevant data gaps in some SECT classes, such ancillary data could still be used as proxies for missing metrics in a transparent and well-documented way (see later). Here we list the main types of ancillary data recognized, with a short description and justification (criteria being violated), as well as examples from DP 2.2.

- **Ecosystem extent** (EBV E2): The extent of the main ecosystem types should definitely go under the ecosystem extent component of the SEEA EEA framework (*framework conformity*). The extent of a 'minor' ecosystem types can be registered in SECT class *ecosystem type specific landscape characteristics,* if necessary. The change of extent is also often seen as a pressure (habitat loss, urban sprawl…), but even this way it should not be added to the condition accounts (it should rather be handled in the context of the extent accounts, if necessary).
- **Accessibility** (case studies 11, 12, 14, 20-22): Distance from roads or human population centres appears in a high number of condition accounts, yet they do not necessarily meet some of the selection criteria. Such 'accessibility' indicators can be seen as a factor behind ES demand, and may be considered as something external to the studied ecosystem (violating *framework conformity*, *state orientation*, or even *system scope*). *Normativity* can also be an issue: if an ecosystem becomes more accessible (e.g. there is a new highway), would we like to see this as a condition improvement or degradation? The density of human populations or road networks (e.g. forest roads, or mountain trails) can also considered as a pressure/management indicator

(characterizing the ‘infrastructure’ for ES extraction), but such indicators violate some of the criteria anyway.

- **Protected areas** (case studies 10, 20-22): Administrative land designations (including the status and degree of nature protection) do not reflect the state of an area, but rather a human response to degradation or perceived land value. Using such indicators in condition accounts violates state-orientation (see also Chapter 2.4).
- **Pressures** (case studies 1, 2, 5, 7): As discussed in Chapter 2.4, ‘raw’ pressure indicators (e.g. pollutant loads) should be avoided and preferably the underlying ‘degradable stocks’ (e.g. pollutant concentrations) should be used instead as condition indicator. (If this is not possible, and pressures are still used as a proxy, then they should be assigned to the same SECT class that the underlying degradable stock would belong to.)
- **Natural resource management** (case studies 20, 21): Ecosystem management (e.g. grazing, felling, fishing, agriculture...) is not necessarily considered as an internal part of the studied ecosystems (*system scope*, *state orientation*), so such metrics should not be considered in condition accounts (see also Chapter 2.4). If there is an underlying stock that is being extracted (timber, fish) this stock can be considered under the SECT class where it best fits (as a *compositional*, *structural*, or *functional characteristic*). (In the case of heavily transformed ecosystems management can potentially be considered as an 'anthropogenic’ disturbance regime, which can then be characterized with its intensity as a *functional state characteristic*)..
- **Species population phenology** (EBV C1): The phenological phase of species populations can be challenging to be integrated across *temporal* grain units, and lacks *normativity*. The timing (of the events) is not necessarily considered as ‘state’, and a ‘phase shift’ by itself does not influence functioning. In the cases when asynchronous timing shifts create a relevant net impact on functioning (e.g. an earlier greening and a later leaf-fall creates a longer vegetation period) than the latter should probably be captured by a state variable (e.g. more biomass, different species).
- **Stable environmental characteristics** (case study 8): Environmental variables that are virtually constant (e.g. climate, local topography (slope, aspect), or geology) do not meet the criterion of *temporal consistency*, and in many cases they also lack *normativity*. Some of these variables may not be constant on longer timescales, and climatic variables, in particular have started to change due to anthropogenic climate change. Nevertheless, climate itself is rather external to the ecosystems (*scope*, *state-orientation*), and the ecological impacts of climate change are already covered by the classes listed above. In addition, climatic variables are very well monitored by a number of international conventions and data exchange processes, so it might be reasonable to keep the ecosystem condition accounts for ‘more ecological’ variables.

- **Pre-aggregated indices** (case studies 3, 6, 7, 9, 11, 12, 14-16, 18, 22, 23): Data collected and processed for various policies are often available in a highly aggregated format. This aggregation may combine data from several SECT classes, but other data types that are irrelevant or problematic for ecosystem condition accounting may also be involved. Driven by the necessity to reuse what is already available, such pre-aggregated indices are often considered in practical ecosystem condition accounts. Such data might violate high numbers of criteria (e.g. *reliability*, *spatial & temporal consistency*, *state orientation*, and *framework conformity*). If these violations are minor, then the pre-aggregated index should be considered in the SECT class where it most logically belongs. Pre-aggregated indices covering multiple SECT classes should be avoided, if possible. The ideal practice would be to add all relevant characteristics individually, and perform the appropriate aggregations within the condition account itself. One of the main functions of the SECT typology is to provide a standardized aggregation scheme that can be meaningfully used across countries, continents and ecosystem types. Such 'overarching' pre-aggregated indices might violate this function.

- **Certificates, audits** (case studies 14, 22): Evaluation by companies or organizations (e.g. the 'blue flag' certificate for EU beaches, or the 'green flag' certificate for UK urban parks) cannot be seen as 'original' measurements (*reliability*), and such audits need to rely on primary (socio-) ecological data. Certificates come with costs and they need to be applied for, thus the absence of a certificate does not mean that the location in question would not meet the necessary qualifications (*reliability*, *state orientation*). If such data are still considered as necessary, they should be classified under the SECT class where they best fit. Similarly to pre-aggregated indices, in the case of certificates the ideal practice would also be to encode all relevant characteristics individually in the condition account, and create appropriate aggregated indices there (as a substitute of the audit process).

Even if they are not added to the condition accounts, ancillary data can still be important for SEEA EEA. For example, they can be key input data for ES models (especially: climate, geology, topography, accessibility, management intensity, and protection status), so they might need to be collected and handled anyway in the context of SEEA EEA. Nevertheless, to ensure the consistency of the condition accounts, such ancillary data should preferably not be included into the tables there.

3.4. Selection and subtypes

In line with the principles discussed in DP2.1 and the previous chapters of this discussion paper, the selection of the EC metrics should be an iterative process, reflecting a good ecological understanding, as well as practical considerations of data availability. Individual (datasets on) characteristics should be matched against the criteria (to see if they can be considered condition metrics or ancillary data), and the main SECT classes (see Fig. 3 in DP 2.1). The proposed SECT classification plays a key role by highlighting major data gaps (e.g. no metrics for a specific class).

To operationalize the selection process, we propose the following simple recommendations ("thumb rules") to set the number of variables per SECT class:

- for biotic ecosystem characteristics (*compositional*, *structural*, and *functional* state characteristics) the number of variables should be 1-10;
- for abiotic and landscape characteristics the number of variables should be between 1 and 4.

This proposal lays more emphasis on the biotic components of the ecosystems, for which more variables are recommended. These variables can then be condensed into the same (or slightly fewer) number of indicators. In case there are no (or too few) potential ‘candidate’ variables available for a SECT class, then there are two main options:

- if there is a conceptual reason for not having variables (e.g. seascape metrics in an open sea ecosystem, compositional metrics in deserts) then it may be reasonable to omit the SECT class; while
- if the lack of variables is due to data gaps then variables that do not meet some of the criteria may also be considered (as proxies or ‘second best options’). Nevertheless, it is important that the ‘compromises’ made, and their justification would be documented in detail in the accounting reports.

These simple ‘thumb rules’ should be a topic for discussion in the SEEA EEA consultation process. We think that such simple rules can be particularly useful to start the accounts in the lack of a good functional understanding (which characteristics are important for which services).

In terms of creating a consistent structure across accounts, the SECT classes, as proposed in chapter 3.2 (Table 2), provide only a rough thematic structure. To make the SECT classification more responsive to user needs, further subtypes (SECT subclasses) can be defined. Nevertheless, notwithstanding the broad SECT classes which can be considered universal across all biomes and ETs, the lower hierarchical levels of the SECT classification will necessarily be ecosystem type specific. This is even true if there are many ‘cross-cutting’ characteristics (e.g. soil characteristics or vegetation biomass) that are shared between several ETs (e.g. all terrestrial ecosystems, see some examples in Table 3). To bring the best out of them, one more recommendation can be made:

- Cross-cutting characteristics should be represented by cross-cutting metrics, i.e. the same variable(s) and indicator(s) should be used to describe the characteristic for all of the affected ETs. For example, soil quality should be characterized by the same variable (e.g. soil organic carbon content, SOC) in all terrestrial ecosystem types (and it can be seen as a ‘poor solution’ if it is characterized e.g. with SOC in grasslands, but with soil depth in forests).

Cross-cutting metrics create an important opportunity for meaningful comparisons and ‘horizontal’ aggregations. Defining and testing SECT subclasses can be the key for further standardization of the condition accounts. In principle, they can be specified concretely enough (what characteristic to measure, how to measure it) so that the variables and indicators implemented for them would be comparable across countries, continents, and -- for crosscutting characteristics -- also ecosystem types. Nevertheless, this would also mean that at the level of subclasses the SECT classification will not be *exhaustive* any more: the list of SECT subclasses should rather be seen as the SEEA EEA recommendation on the concrete metrics to measure, than as a comprehensive classification for all possible metrics.

To make condition accounts consistent across countries and world regions SEEA EEA should provide some guidance on subclasses too, but the nature of this guidance is not very clear. Here again there are several options:

- SEEA EEA could directly propose subclasses for all ecosystem types (ET) recognized by the final typology of ecosystem types (the expected outcome of the RA#1 discussions). This would need considerable efforts from a broad range of SEEA EEA experts (most importantly RA#1 experts, but not only). Furthermore, the long-term maintenance of such a classification would also be a highly challenging (supporting organization / maintenance process).
- SEEA EEA could stop at the level of SECT classes, and leave the question of subclasses open for the countries / NSOs implementing SEEA EEA. In this case the criteria proposed in Chapter 3.1 can be seen as guidelines for finding metrics for the SECT classes, and the classes would be free to apply groupings (or not) at the lower levels.
- As a third "intermediate" option, SEEA EEA could provide examples ("case studies") for some (most widespread, the most problematic) ecosystem types, but leave the final decision open to the countries.

In line with the third option, we conclude with presenting a partial and incomplete example for SECT subclasses and metrics. These lists are based on a recent systematic review of European studies testing functional relationships between ecosystem characteristics and a number of ES (Czúcz et al., 2017, 2018), which means that only temperate terrestrial ecosystems are covered, and even for them there might be a 'European bias'. Annex 3 lists a few potential SECT subclasses for all non-urban terrestrial ETs based on the direct outcomes of this systematic review.

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Annex 1: Crosswalks linking SECT classes to other relevant indicator typologies

Table A1.1: Crosswalk to SECT classes (overlaps can be partial, strong matches are highlighted in bold)

	SECT classes	**EBV (Pereira et al., 2013)***	**OpenNESS (Smith et al., 2017)**	**Ecosystem integrity (Müller, 2005)**	**EU ecosystem condition assessment (Maes et al., 2018)**
Abiotic ecosystem characteristics					
	Physical state characteristics		**E Abiotic factors**	**Water balance** Matter balance	Structural soil attributes, Habitat conversion and degradation
	Chemical state characteristics		**E Abiotic factors**	**Matter balance**	Pollution and nutrient enrichment,
Biotic ecosystem characteristics					
	Compositional state characteristics	A1 Allelic diversity A2 Co-ancestry A3 Population genetic differentiation A4 Breed and variety diversity **B1 Species distribution** **B2 Population abundance** **D1 Taxonomic diversity** E3 Ecosystem composition by functional type	**C Presence of a particular species, functional group or trait** **D Biological and physical diversity**	**Biotic structures**	**Structural ecosystem attributes based on species diversity** Structural ecosystem attributes monitored under the EU nature directives Structural soil attributes
	Structural state characteristics	**E1 Habitat structure**	**A Amount of vegetation** B Provision of supporting habitat D Biological and physical diversity	**Energy balance**	Structural ecosystem attributes (general)
	Functional state characteristics	B3 Population structure by age/size class C2 Morphology C3 Reproduction C4 Physiology C5 Movement D2 Species interactions F1 Net primary productivity F2 Secondary productivity F3 Nutrient retention **F4 Disturbance regime**	A Amount of vegetation C Presence of a particular species, functional group or trait E Abiotic factors	Energy balance Water balance Matter balance Biotic structures	**Functional ecosystem attributes (general)** Structural ecosystem attributes (general)
Landscape and seascape characteristics					
	Overall landscape characteristics		D Biological and physical diversity	Abiotic structures	Structural ecosystem attributes (general)
	Ecosystem type specific landscape characteristics		B Provision of supporting habitat D Biological and physical diversity	Abiotic structures	Structural ecosystem attributes (general)

* EBVs for species traits listed after Kissling et al. (2018)

Table A1.2: Crosswalk to the further types of indicators discussed in this paper

	SECT classes	**EBV (Pereira et al., 2013)***	**OpenNESS (Smith et al., 2017)**	**Ecosystem integrity (Müller, 2005)**	**EU ecosystem condition assessment (Maes et al., 2018)**
Ancillary data					
	Ecosystem extent	E2 Ecosystem extent and fragmentation	B Provision of supporting habitat		Habitat conversion and degradation (Land conversion), Structural ecosystem attributes monitored under the EU nature directives
	Accessibility				
	Protected areas				
	Pressures				Habitat conversion and degradation (Land conversion) Climate change Pollution and nutrient enrichment Over-exploitation Over-harvesting Introduction of invasive alien species Other pressures
	Natural resource management				Over-exploitation Over-harvesting
	Species population phenology	C1 Phenology			Functional ecosystem attributes (general)
	Stable environmental characteristics		E Abiotic factors		Climate Structural soil attributes
	Pre-aggregated indices				Structural ecosystem attributes based on species diversity, Structural ecosystem attributes monitored under the EU nature directives
	Certificates, audits				

* EBVs for species traits listed after Kissling et al. (2018)

Annex 2: The condition metrics reviewed in discussion paper 2.2 grouped according to the SECT classes

Table A2.1: Condition metrics from the case studies grouped according to SECT classes (in italics) and broad ecosystem types GEN: any terrestrial ecosystem, urb: urban, cro: croplands, for: forests, shr: shrublands (incl. heathland), gra: grasslands, wet: wetlands, frw: freshwater (rivers, lakes, reservoirs); coa: coastal ecosystems (mangroves, estuaries, lagoons, transitional waters, beaches, sea cliffs), mar: marine (open sea) ecosystems. The numbers listed in each cell correspond to the ID number of each case study used in DP 2.2.

	Broad ecosystem types									
Main groups of metrics (with examples)	**GEN**	**urb**	**cro**	**for**	**shr**	**gra**	**wet**	**frw**	**coa**	**mar**
Physical state characteristics										
water quantity (e.g. hydrological flow, reservoir stock, groundwater table...)	8					21		9		
Chemical state characteristics										
air quality (pollutants concentrations)	8	14?			20	20, 21				
water quality (e.g. pollutant concentrations, dissolved oxygen, Chlorophyll-a, turbidity)	8						20	9, 11, 12, 16	1, 5, 22	2
soil quality (e.g. nitrogen content, heavy metal content, soil carbon stock)	8, 12, 22			10, 13	20	20	11, 20			
Compositional state characteristics										
corals										2
(macro)invertebrates						12, 20, 21		16	5	
fish							12	12	5	2
birds	17		12	12, 13	12		10, 11, 12	11	12	
species and habitats-based indices (red-list indices, conservation status of species or habitats)	6, 8?, 12, 17, 19	14?						10	5, 22	
Structural state characteristics										
vegetation cover (e.g. LAI, urban green cover...)	3, 16	14?		10						
biomass / carbon / timber stock	12			10, 13						
litter	3									
forest age (age classes)				4, 10						
Functional state characteristics										
flood risk	16			10						
fire risk	20				20	20				
NPP, biomass growth, carbon uptake	2, 16			12						

	Broad ecosystem types									
Main groups of metrics (with examples)	**GEN**	**urb**	**cro**	**for**	**shr**	**gra**	**wet**	**frw**	**coa**	**mar**
Overall landscape characteristics										
(none)										
Ecosystem type specific landscape characteristics										
connectivity/fragmentation (barrier density, patch size, shape...)	3, 7, 8			13?		21	??			
the presence/abundance of specific habitat (sub)types (e.g. riparian habitats, seagrass fields, forest types)				4, 10				9,16	5	2
Miscellaneous (ancillary data)										
accessibility (distance to ecosystems from population centres, length of trails)	12	14			20	20, 21	20	11	22	
protected areas (or other similar administrative designations -- e.g. Natura2000 (EU), SSSI (UK)...)				10	20	20, 21	20		22	
raw pressures (e.g. pollutant loads, habitat loss)	7								1,5	2
management intensity (e.g. grazing)					20	20, 21				
abiotic / climatic characteristics (e.g. annual rainfall, annual number of growing days)	8									
pre-aggregated indices (e.g. ecosystem integrity, naturalness)	3, 6, 7, 15, 18	14					23	9, 11, 12, 16	22	
certificates (e.g. blue flag (EU beaches), green flag (UK urban parks))		14							22	

Annex 3: A tentative list of ecosystem condition subclasses for European terrestrial ecosystem types

Table A3.1. A demo proposal for SECT subclasses for European non-urban terrestrial ecosystem types. The rows of the table list SECT ecosystem subclasses (grouped following the hierarchy of classes & superclasses, *in italics*), whereas the columns list those ecosystem types in which the subclasses can be meaningfully measured with appropriate variables and indicators (cro: croplands, gra: grasslands, for: forests, shr: shrublands (incl. heathland), svl: sparsely vegetated land, wet: wetlands). For those subtypes which have check marks in multiple columns it is possible to define cross-cutting metrics. The proposed list of subclasses and metrics is loosely based on the systematic review exercise described by Czúcz et al. (2017, 2018). The scope of this exercise was limited to European non-urban terrestrial ecosystem types, and the subclasses / metrics proposed are loosely based on the indicators proposed in the context of the EU-wide mapping and assessment of ecosystem services (EU MAES process, Maes et al., 2018).

SECT subclasses	**cro**	**gra**	**for**	**shr**	**svl**	**wet**	**Comments**
Abiotic ecosystem characteristics							
Physical state characteristics							
Soil thickness	X	X	X	X	X	X	a simple stock variable the change of which can represent the process of erosion ("underlying degradable stock ")
Water and wetness probability index (WWPI)	?	X	X	X	X	X	from remote sensing, the most relevant summary statistic has to be carefully selected, can be seen as the stock underlying drainage/desiccation
Normalized difference water index (NDWI)	X	X	X	X	X	X	from remote sensing, the most relevant summary statistic has to be carefully selected
Chemical state characteristics							
Soil organic carbon (SOC)	X	X	X	X	?	X	another key degradable stock for soils, issues with data coverage and resolution
Soil pollution (e.g. heavy metal content)	?	?	?	?	?	?	more relevant in urban contexts than in the ETs shown here
Chemical status of surface water					X	X	the EU WFD indicator is highly aggregated, and it would probably make sense to consider its components individually, only relevant for wetlands (among the ETs considered), the underlying stock of pollution
Chemical status of ground water	X	X	X	X			the EU WFD indicator is highly aggregated, and it would probably make sense to consider its components individually, the underlying stock of pollution
Biotic ecosystem characteristics							
Compositional state characteristics							
Plant species diversity (e.g. forest tree species richness)	X	X	X	X	X	X	readily available only for forests and (some) shrublands
Bird species diversity (farmland birds, forest birds...)	X	X	X	X	X	X	a different index for each ET
Insect species diversity (e.g. grassland butterfly indicator)	X	X		?	?	?	issues with data coverage and resolution, not relevant for some ETs

SECT subclasses	cro	gra	for	shr	svl	wet	Comments
Structural state characteristics							
Aboveground vegetation: normalized difference vegetation index (NDVI)	X	X	X	X	X	X	from remote sensing, the most relevant summary statistic has to be carefully selected
Aboveground vegetation: tree cover density	X	X	X	X	?	X	from remote sensing
Tree growing stock	X	X	X	X	X	X	only for forests (and some shrublands), based on national forest inventories
Deadwood amount / density	X	X	X	?	X	X	only for forests, issues withb data coverage and resolution
Functional state characteristics							
Age of site / community (time since last major intervention/ disturbance: felling, fire, abandonment, etc)	X	X	X	X	X	X	very tentative and theoretical, feasibility on a remote sensing basis should be tested
Fire regime (fire frequency)	?	X	X	X	X	X	from remote sensing, the most relevant summary statistic has to be carefully selected
Landscape and seascape characteristics							
Overall landscape characteristics							
Landscape diversity (e.g. Shannon diversity of ETs in a mowing window)	X	X	X	X	X	X	can be relatively easily developed based on an ET map
Ecosystem type specific landscape characteristics							
Fragmentation patterns of natural/seminatural landscapes	X	X	X	X	?	X	can be relatively easily developed based on an ET map
Density of embedded seminatural elements (hedgerows, lines of trees, etc.)	X	X	X	X	X		only small fragments should be considered here, relevant for croplands (and perhaps grasslands), based on remote sensing