DEPARTMENT OF ECONOMIC AND SOCIAL AFFAIRS
STATISTICS DIVISION
UNITED NATIONS

System of Environmental Economic Accounting

SEEA EEA Revision

Expert Consultation

Working group 1: Spatial units

Background paper 2:
A review of existing classifications

Version date: 29 April 2019

Research area #1: Spatial units

Background paper 2: A review of existing classifications

Authors: Edwin Horlings (Statistics Netherlands), Roger Sayre (USGS), David Keith (IUCN), Sjoerd Schenau (Statistics Netherlands), Patrick Bogaart (Statistics Netherlands), François Soulard (Statistics Canada), Silvia Cerilli (FAO)

Table of contents

Summary

The main purpose of SEEA EEA Working Group 1 on spatial units is to establish a statistically and accounting relevant international reference classification for ecosystem types for SEEA EEA. The classification will enable international comparison of ecosystem accounts at different levels of aggregation, and support the development of indicators of ecosystem extent and ecosystem condition as well as the description and classification of ecosystem services.

The international ecosystem type classification will delineate ecosystem types down to a certain level of detail. National classifications can divide international ecosystem types into more detailed classes, depending on national and local user needs.

Any ecosystem type classification should be credible (scientifically sound), salient (with respect to policy needs) and legitimate (reflecting different values and beliefs). It should also be consistent with principles for statistical classifications, and it should be possible to build on and connect to the range of existing classification of land, freshwater and marine areas.

The international ecosystem type classification will have to meet five design criteria:

1. The classification units represent ecosystems that are distinguished based on a set of properties that must be grounded in theory.
2. The classification units are spatially delineable.
3. The classification units are comprehensive across all environmental domains (terrestrial, freshwater, and marine).
4. The classification units are mutually exclusive, both geographically and conceptually.
5. The classification units are exhaustive, geographically and conceptually.

We reviewed existing relevant and potentially useful classifications. This review serves to inform the development of a statistical classification of ecosystem types. We need to align the classification of ecosystem types to other relevant classifications with respect to definitions, scope, hierarchical structure, guidelines, coordination mechanisms, etcetera.

We reviewed the existing classifications using a list of questions based on the five design criteria. The list of questions concerns the classification type, scope (comprehensiveness), hierarchical structure, conceptual basis, and (documentation on) definitions and similarity criteria.

The review of existing relevant classifications shows that IUCN RLE and USGS meet all design criteria. Their starting positions are very different: IUCN RLE takes a theoretical approach, while USGS applies a map-based approach. Of all the existing classifications we have reviewed, these provide the best foundation for a new international classification of ecosystem types.

Other classifications meet some but not all design criteria. However, most do possess a number of desirable properties. The new classification can, for example, align with some of the most prominent of these classifications to capture specific aspects (e.g. land use).

1. Introduction

This discussion paper has two aims. First, we identify the general properties of an international classification systems and apply these to ecosystem types. Second, we review existing classifications and assess their relevance and quality in light of the general properties.

The general properties of an international statistical classification are drawn from the basic principles and best practices developed under UN auspices (Hoffmann & Chamie 1999; Hancock 2013). The specific properties of an international classification of ecosystem types relate to the needs of users, to the way in which the classification is embedded in the SEEA framework, to its relationships with other relevant classifications, and to the theoretical foundations of the classification (which will be developed in another discussion paper).

The review of existing classifications serves to inform the development of a statistical classification of ecosystem types; to align this classification to other relevant classifications with respect to definitions, scope, hierarchical structure, guidelines, coordination mechanisms, etcetera; and to avoid reinventing the wheel.

This discussion paper is the second paper prepared by the working group on spatial units for the SEEA EEA revision process (SEEA EEA 2018). The main conclusions will serve as an input for the paper on the Conceptual base for classification of ecosystem types for ecosystem accounting (Discussion paper 1.3).

From the SEEA EEA Revision Issues Note: "The key focus in this research area is establishing statistically and accounting relevant classifications for land use, land cover and ecosystem types with careful review and application where possible of existing classifications of this type . The land use and land cover classifications of the SEEA Central Framework retain a status of "interim" and given the importance of ecosystem types in underpinning ecosystem accounting, it is essential that substantial, and integrated, progress is made in this area. Work for the revision must establish clear principles for defining ecosystem type classes , in particular concerning links to land use, management and ownership, as well as determining an appropriate set of classes for use at international level. Work should also ensure alignment in the advancement of the SEEA Central Framework land use and land cover classifications as well as ecosystem services and related ecosystem indicators."

2. General properties of an international statistical classification

This section describes the general properties of a statistical classification as described by the UN's basic principles and best practices for developing international classifications.

A statistical classification is "a classification having a set of discrete categories, which may be assigned to a specific variable registered in a statistical survey or in an administrative file, and used in the production and presentation of statistics." (Hoffmann & Chamie 1999, p. 2)

The work involved in making a classification can be divided into four main activities:

1. Developing the substance of the classification
2. Collection of information necessary to develop the classification
3. Identifying user needs and keeping users involved
4. Setting up mechanisms for coordination and revision

Activity 1: Developing the substance of the classification

Developing the substance involves five distinct stepts, namely (1) determining the type of classification; (2) defining the purpose of the classification; (3) developing the conceptual foundations and providing definitions for concepts; (4) defining the scope of the classification; and (5) developing the structure of the classification.

Determine the type of classification: UNSD distinguishes between reference, derived, and related international statistical classifications. In addition, there may be national classifications that refer to the international classifications.

Define the purpose: The objectives and statistical priorities to be served must be clearly stated in the preamble or the introduction.

Develop the conceptual foundations and provide definitions for concepts: Three concepts are defined in the guidelines, i.e. main variables, main statistical units, and building blocks. The main variables are determined based on theory. Main variables are those "for which the set of categories in the classification should be valid". The main statistical unit is the observable unit "which can be assigned to one unique category of the classification without reference to any other observable unit". Hoffmann & Chamie 1999, p. 16) A building block is the most elementary unit of a statistical classification, "i.e. the characteristics that are identified with most detailed codes which may be assigned for a variable, and may be used alone or in combination to describe a category in a classification, or to compare classifications." (Hoffmann & Chamie 1999, p. 9)

Define the scope of the classification: The scope concerns the boundaries of the classification. It defines what will be included and what will be excluded. Examples are national boundaries and the production boundary in the SNA.

Develop the structure of the classification: The classification structure refers to the arrangement of the content of a classification. "The classification structure should make it possible to *identify relevant individual categories uniquely and separately*, yet still be able to present statistics for meaningful broader groupings. The preparation of *explicit statements of similarity criteria used for aggregation*, and *explanations of the basis for drawing distinctions between groups*" (Hoffmann & Chamie 1999, pp. 17-18; emphasis is ours). There are six requirements:

1. Classes must be *mutually exclusive*. They must be unique and clearly defined with unambiguous boundaries between them.
2. The classification should be *exhaustive*: its classes must capture all variation and it must be possible to classify all statistical units. If the classification is hierarchical, it is recommended to have no more than 5 to 9 levels.
3. *Aggregation*: Depending on descriptive and analytical needs, aggregated categories of statistical classifications may be organized in a hierarchy representing different levels of detail for measurement of the variable.
4. *Rules*: "Rules are required for identifying when the statistical units can be classified to the same category of a classification, and when they should be classified to different categories" (Hoffmann & Chamie 1999, p. 18)
5. *Similarity criteria*: "Similarity criteria are required to define higher level categories (aggregated groups of categories) in hierarchical classifications" (Hoffmann & Chamie 1999, p. 18)
6. *Explanatory notes* "explain the boundaries of each of the categories of the classification through definitional descriptions and/or listing of what they include and exclude." (Hoffmann & Chamie 1999, pp. 18-19) Descriptive definitions or exhaustive listings of the contents of the defined categories are needed.

Activity 2: Collection of information necessary to develop the classification

The description of each class should contain the information that is necessary to determine whether a particular unit is similar to one particular type or class in the classification.

Activity 3: Identifying user needs and keeping users involved

The classification should be sensitive to user needs. it must meet the needs of a variety of users. It should be neither single-project oriented nor take a sectoral approach. It should be possible for users to take a sub-set of the classification and from there develop a more detailed classification according to their own specific needs.

Activity 4: Setting up mechanisms for coordination and revision

"Coordination of national and international work on classifications is conducted through the formation and action of committees and joint meetings, as well as through the implementation of well-publicized timetables and hearings to facilitate the participation by a wide range of producers and users of statistics in the preparation, design, implementation and monitoring of statistical classifications." (Hoffmann & Chamie 1999, p. 11) The organization responsible for the preparation and maintenance of a classification (the custodian) should be clearly identified and responsibilities stated. A time table for the work must be well publicised and allow substantive experts who are users and producers of statistics, to contribute to the process at appropriate moments. Instructions are needed on effective use of classifications for data collection and analysis. Guidance and training materials are a necessary part of the development process for a new or revised classification.

3. Application of the general properties to an ecosystem type classification

At the Expert Forum in Glen Cove in June 2018, it was concluded that any ecosystem type classification should be credible (scientifically sound), salient (with respect to policy needs) and legitimate (reflecting different values and beliefs). It should also be consistent with principles for statistical classifications, and it should be possible to build on and connect to the range of existing classification of land, freshwater and marine areas.

In this section, we briefly discuss the specific properties of an international classification of ecosystem types, using the general properties presented in section 2. The work involved in making a classification can be divided into the same four activities.

3.1 Developing the substance of the classification

3.1.1 Determine the type of classification

The main goal of SEEA EEA Working Group 1 on spatial units is to establish a statistically and accounting relevant classification for ecosystem types for SEEA EEA. In that sense, the goal is to come up, after broad consultation and agreement, with a new *reference classification* for ecosystem types.

On the other hand, the classification type (reference, derived, or related) depends in part on the strategy used to construct a classification of ecosystem types. Various classifications already exist and some – such as the Corine Land Cover classification – are highly developed. There is no point in reinventing the wheel. Accordingly, parts of existing reference classifications may be used for the ecosystem type classification, depending on the conceptual base and structure that will be chosen.

Current thinking is that the international ecosystem type classification delineates ecosystem types down to a certain level of detail, that is, the level that is relevant for internationally comparable ecosystem accounting. National classifications can divide international ecosystem types into more detailed classes, depending on national and local user needs. The ecosystem type classification will be an international reference classification. It needs to be accompanied by guidelines that explain how national classifications should link to the international classification.

3.1.2 Define the purpose

The main purpose of a classification of ecosystem types is to support ecosystem accounting. The classification ***enables international comparison of ecosystem accounts at different levels of aggregation, and supports the development of indicators of ecosystem extent, ecosystem condition as well as the description and classification of ecosystem services***.[1]

This statement of purpose gives guidance on several key features of a classification that will enable the classification to support ecosystem accounting. The purpose of the classification proscribes the presence of certain characteristics:

- The scope needs to be global to support international comparisons.
- The classification needs a hierarchical structure to enable different levels of aggregation.

The reference to ecosystem condition and ecosystem services relates to aspects of use and usability rather than design properties.

We are looking to establish a set of classes that can be used by all countries and that supports comparison across scales. This implies a limited level of detail for the upper levels of the classification hierarchy. The international set of classes should provide a basis for developing or linking to more detailed classifications that are applied at a national or lower level as needed. While we may not need to establish agreement on the full set of classes, we need to acknowledge that higher detail will often be useful if not necessary for ecosystem accounting and many countries will have more detailed related classifications, for example of vegetation. The link between the international and national classifications is very relevant.

3.1.3 Develop the conceptual foundations and provide definitions for concepts

The conceptual foundations, which includes definitions of concepts, are at the core of the classification. The variable that is classified – "ecosystem type" – is the set of properties of an ecosystem within a geographic unit. These properties will be grounded in theory, which includes "a range of ecological and non-ecological criteria, including vegetation type, soil type, hydrology, and land management and use." (SEEA EEA TR, 1.65) The building blocks of a statistical classification of ecosystem types are highly detailed and unique combinations of relevant properties. The classification of ecosystem types will be linked to other relevant classifications through these building blocks as well as through the use of common concepts and terminology.

For SEEA EEA, the geographic unit is the main statistical unit (i.e. the observable unit "which can be assigned to one unique category of the classification without reference to any other observable unit", Hoffmann & Chamie 1999, p. 16). "Ecosystems occupy space and can be spatially delineated in a number of mapping approaches ranging from top-down GIS modeling and satellite image interpretation (deductive modeling) to bottom-up, field survey-based prediction of ecosystem distributions (inductive modeling)." (Sayre 2018)

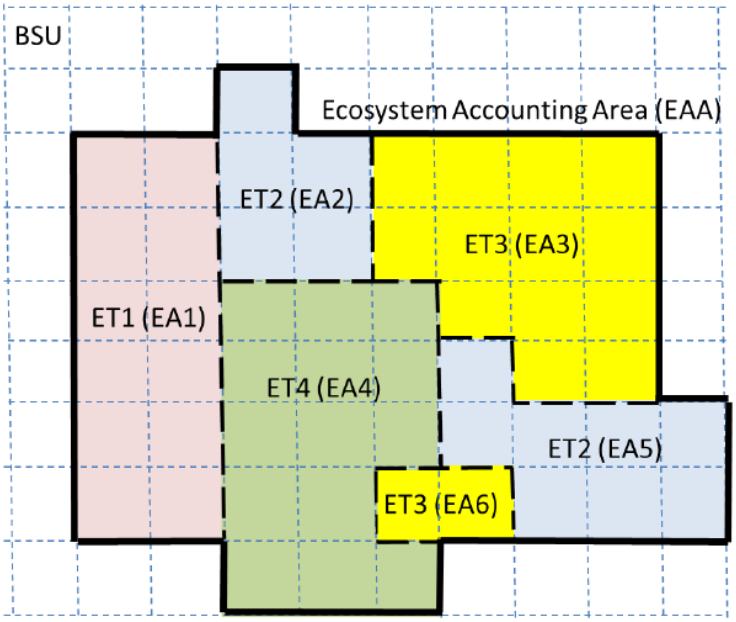
In the SEEA framework the relevant geographic units are Basic Spatial Units (BSUs) and Ecosystem Assets (EAs). Basic spatial units are small spatial areas. Ideally, the BSU should be formed by delineating small areas known as tessellations (e.g., of one square kilometre), typically by overlaying a grid on a map of the relevant territory. However, BSUs may also be land parcels delineated by a cadastre or pixels in remote-sensing images (SEEA EEA, 2.53). EAs are "contiguous areas representing individual ecosystems". "In accounting terminology, ***ecosystem assets*** are defined as individual ecosystem occurrences, or spatial footprints, on the ground or in water. There are often multiple, repeating, patch occurrences of an ***ecosystem type*** throughout its collective distribution on the landscape or in the seascape. The ecosystem type therefore represents the name of an ecosystem, and most ecosystem types have many ecosystem occurrences." (Sayre 2018) Ecosystem types are

[1] "Fully spatial approaches will generally commence from a more ecological perspective where there is a desire to reflect, as a starting point, distinctions between ecosystem assets at a fine spatial level. Using *ecosystem type classifications*, the aim is to delineate a relatively large number of mutually exclusive ecosystem assets (for example using more than 100 ecosystem types) with a particular focus on their configuration in the landscape." (SEEA EEA TR, 1.34; emphasis is ours)

"a specific class of ecosystem assets of comparable ecology and ecosystem use." (SEEA EEA TR, 3.20, 3.22) Figure 1 shows that an EA is a contiguous area covered by one specific ecosystem type (SEEA EEA TR, 3.15). In ecosystem accounting, an Ecosystem type (ET) is an aggregation of individual EAs of a specific type of ecosystem (e.g. deciduous forests).

Figure 1. Relationships between Basic Spatial Units (BSUs), Ecosystem Assets (EAs), Ecosystem Types (ETs) and Ecosystem Accounting Areas (EAAs)

Source: United Nations (2017).



3.1.4 Define the scope of the classification

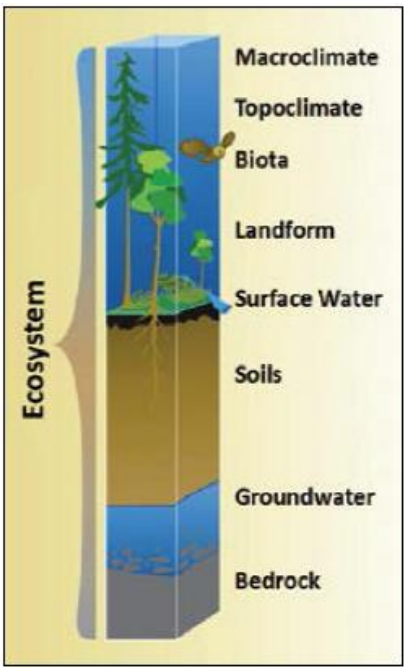
The scope of the classification refers to its boundaries. Some boundaries are defined in the SEEA and SNA frameworks (e.g. national boundaries; the production boundary). SEEA EEA (2012) refers to the Convention on Biological Diversity for a definition of an ecosystem as "a dynamic complex of plant, animal and micro-organism communities and their nonliving environment interacting as a functional unit" (SEEA EEA 2012, 2.1).

A key question concerns the boundaries of the classification system in a three-dimensional sense. Figure 2 shows the elements within the vertical structure of an ecosystem. Key questions are to what extent the atmosphere should be part of the classification, how the classification scheme should be applied to the different layers of the (deep) ocean, and how far down into the (sub)soil the classification should be extended. For some of these elements classifications already exist. These issues will be addressed in separate issue papers.

In the SEEA EEA (2014), no specific guidance is provided on the precise geographical scope that should be determined as regards marine areas. However, SEEA ecosystem accounting should provide comprehensive information on all ecosystems. It should be possible to also account for areas outside the country's exclusive economic zone (EEZ). It is therefore recommended that the classification for ecosystem types should be exhaustive and include all terrestrial, inland water, and marine ecosystems. Basically, it should be able to describe all the ecosystems of the earth.

Figure 2. The vertical structure of an ecosystem, showing the spatial integration of biological and non-living components.

Source: Sayre et al. (2014), p. 8, after Bailey (1996).



3.1.5 Develop the structure of the classification

Developing the structure of the classification refers to the work involved in actually making the classification of ecosystem types. Classification structure refers to the arrangement of the content of a classification.

Based on the theoretical foundations (discussion paper #1) and fully utilising the knowledge that has been accumulated in developing existing classifications, we will develop the rules, similarity criteria, and explanatory notes that a statistical classification requires.

There are different approaches to develop the structure of an ecosystem type classification. It is possible to use a systematic approach in which within each ecosystem class, the classification is further built out using sequential deterministic factors in order of importance. On land, for example, the next levels would be split out by the temperature domains (polar, boreal, cool temperate, warm temperate, subtropical, and tropical), then the moisture domains (humid, dry, desertic), and then by the terrain morphotypes (plains, hills, mountains). Freshwater drivers would include the climate regime parameters, but subsequent determinants would be related to hydrological characteristics, and so on.

This systematic approach might be perceived as potentially rigid and prone to producing artifactual units. For example, terrain morphotypes may be important in warm, moist and seasonal climates, but have less influence on ecosystem structure and function in desertic or polar environments. An alternative approach would be to ask how resource availability and other environmental drivers influence ecosystem structure and function (hence land use, ecosystem services, etc.) and to recognise systems with unique combinations of traits and drivers.

Another question for the options paper concerns the number of levels that will be needed for the international classification. There is a clear need for simplification, fewer classes, and smart-lumping. For aggregate reporting on ecosystems a more limited number of higher level classes would be appropriate, while recognizing the need to establish a hierarchy to allow for connection to more detailed classes that would be needed to support analysis, policy and local /landscape scale applications.

3.2 Collection of information necessary to develop the classification

Two questions are relevant for the collection of information:

- What information is already available and can be used to develop the classification of ecosystem types? Key elements are the body of ecological theory, as it relates to the specified purpose (ecosystem accounting, see 3.1.2), and global spatial data sets on biota & physical environment
- Which methods are available for producers of statistics to measure the criteria and apply the classification to their area of interest?

It is important to keep in mind that

- the classification will be used for ecosystem accounting on a global scale as well as on national, regional, and local scales;
- the classification should link to or integrate other relevant classification schemes; and
- allow derivation of key indicators on key ecosystem types for policy.

3.3 Identifying user needs and keeping users involved

The primary use of the classification should be to enable some level of aggregate reporting on ecosystems.

3.4 Setting up mechanisms for coordination and revision

Mechanisms for coordination and revision will be developed at a later stage, after the substance has been developed. This work involves:

- Determining who will be the classification's custodian. If the classification of ecosystem types is to be an international reference classification – to which other derived (e.g. national) and related classifications will be related – UNSD is the logical custodian.
- Setting a time table for the work, which allows experts, users and producers of statistics to contribute to the process.
- Writing instructions for an effective use of the classification for data collection and analysis.
- Providing guidance and training materials.

4. Assessment of existing classifications

This section examines existing relevant and potentially useful classifications. The review of existing classifications serves to inform the development of a statistical classification of ecosystem types. Some of the problems that have to be solved may have already been tackled by other classifications (e.g. definitions). This will help us to avoid reinventing the wheel. The review helps in aligning the classification of ecosystem types to other relevant classifications with respect to definitions, scope, hierarchical structure, guidelines, coordination mechanisms, etcetera. These other classifications may have to be linked to the new classification of ecosystem types (through correspondence tables); and they may contain conceptual and supporting information that needs to be aligned (e.g. definitions; coordination processes).

4.1 Selection of relevant classifications

First, we made a selection of classification systems for spatial units that are relevant and potentially useful. Table 1 provides a list of relevant classifications for land cover, land use, ecosystem services, and ecosystem types. In addition, we have used some ecological land classifications, biome classifications, and other ecological classifications not mentioned in this table. We note that this list is not comprehensive (there are

many more international and international classification schemes around), but represents a meaningful selection for our review purposes.

Table 1. An inventory of international and national classifications of land use, land cover, ecosystem types and ecosystem services

Land cover	Land cover classification SEEA EEA CF AFF (Annex C, p. 299), which includes possible ecosystem types per land cover class FAO, Land Cover Classification System (LCCS), and the corresponding Land Cover Meta Language: http://www.fao.org/geospatial/resources/standards/en/ http://www.fao.org/docrep/003/x0596e/X0596e00.htm FAOSTAT Land Cover domain: http://www.fao.org/faostat/en/#data/LC CORINE Land Cover (CLC), https://land.copernicus.eu/pan-european/corine-land-cover/view https://land.copernicus.eu/eagle/files/eagle-related-projects/pt_clc-conversion-to-fao-lccs3_dec2010
Land use	Land use classification (interim) SEEA EEA CF AFF (Annex C, p. 289-299) distinguished land, inland waters, coastal waters, and the exclusive economic zone FAOSTAT Land Use Classification for annual statistical reporting by member countries http://www.fao.org/economic/ess/ess-home/questionnaires/en/; http://www.fao.org/faostat/en/#data/RL and SEEA AFF http://www.fao.org/economic/ess/environment/methodology/en/ FAO, World Programme for the Census of Agriculture 2020, Classification of land use (LU) for the agricultural census, http://www.fao.org/3/a-i4913e.pdf FAO, Indicative Crop Classification, http://www.fao.org/fileadmin/templates/ess/documents/world_census_of_agriculture/appendix3_r7.pdf, refers to crops that are grown rather than the product(s) generated from that crop.
Habitats	EUNIS habitats classification, https://www.eea.europa.eu/data-and-maps/data/eunis-habitat-classification, is hierarchical and covers all types of habitat from natural to artificial, from terrestrial to freshwater and marine IUCN Habitats Classification Scheme v3.1, http://www.iucnredlist.org/technical-documents/classification-schemes/habitats-classification-scheme-ver3 WWF ecoregion classification Statistics Canada Ecological Land Classification (ELC), https://www.statcan.gc.ca/eng/subjects/standard/environment/elc/2017-1
Ecosystem types	EEA, Ecosystem types of Europe, https://www.eea.europa.eu/data-and-maps/data/ecosystem-types-of-europe, which combines the Corine based MAES ecosystem classes with the non-spatial EUNIS habitat classification for a better biological characterization of ecosystems across Europe. MAES, Mapping and Assessment of Ecosystems and their Services (MAES), https://biodiversity.europa.eu/maes USGS/Esri/GEO Global Ecosystems Mapping Products (Sayre et al. 2014) IUCN RLE Ecosystem Typology (Keith, in prep.) Ecosystem type map for Italy (Blasi et al. 2017)

Note: FAOSTAT Land Use and Land Cover classes are in line with the System of Environmental-Economic Accounting for Agriculture, Forestry and Fisheries (SEEA AFF).

It was suggested to take a closer look at the CMECS (https://iocm.noaa.gov/cmecs/) Coastal and Marine Ecological Classification Standards. CMECS has become a standard in the US for agency reporting. It allows one

to pick any point in the ocean and classify it according to its biogeography, aquatic setting, geoform, hydroform, substrate, and biota. However, CMECS is not a set of hierarchical and geographically explicit marine ecoregions and finer level ecosystems. Units are not inherently mappable in a standardized fashion.

4.2 Review of existing classifications

In this section we review existing classifications to identify those classifications that can serve as a starting point for a new ecosystem type classification or that provide a solution for specific parts of the classifications (e.g. marine ecosystems). The review is not meant to resolve conceptual differences between classifications or between approaches to the classification ecosystem types (e.g. the difference between conceptual classifications and map-based classifications).

4.2.1 Design criteria

The international ecosystem type classification will have to meet five design criteria:

1. The classification units represent ecosystems that are distinguished based on a set of properties that must be grounded in theory.
2. The classification units are spatially delineable.
3. The classification units are comprehensive across all environmental domains (terrestrial, freshwater, and marine).
4. The classification units are mutually exclusive, both geographically and conceptually.
5. The classification units are exhaustive, geographically and conceptually.

4.2.2 Questions

We reviewed the existing classifications by means of the following list of questions, which include the design criteria.

1. Classification type

- Is it a national or an international classification?
- Has the classification been produced for a specific (national, regional, global) purpose?
- Is there a bias towards a specific environment or specific properties?

2. Scope (comprehensiveness)

- What is the degree of variety at the most detailed level of the classification?
- How does the classification deal with transitional types or ecotones?
- Does the classification distinguish between artificial or managed versus natural or unmanaged ecosystem types? If so, at what level?
- How does the classification deal with urban versus rural areas?
- Does the classification include oceanic layers and the seabed, the (sub)soil, and the atmosphere?

3. Hierarchy

- Does the classification have a hierarchical structure?
- What is the number of levels in the hierarchy?
- What is the rank order of properties in the hierarchy?
- Which properties that might represent a layer in a hierarchy are implicit?

4. Conceptual basis

- Does the classification have a clear conceptual basis? If so, what is that basis?

- Does the classification incorporate information on geo-ecology, land cover, land use, bio-ecology, land ownership, land management, etcetera?
- Is there supporting documentation that explains the conceptual basis?

5. Definitions and similarity criteria

- Is there detailed documentation on the delineation of types and classes?
- Are types and classes defined in terms of observable data (e.g. how to recognise a deciduous forest in a satellite photograph)?
- Are classes unambiguous, discrete, and easy to interpret?
- Is there supporting documentation that explains definitions and similarity criteria?

4.3 Results

The summary results of the comparison of classifications are presented in the Annex. Below we highlight the main outcomes.

Classification type

Which classifications best match with the five design criteria? That is, units must represent ecosystems (derived from and characterized by ecological properties); be spatially delineable; be comprehensive across environmental domains (terrestrial, freshwater, and marine); be mutually exclusive; and be exhaustive.

- Only IUCN RLE Ecosystem Typology and USGS meet all criteria. The difference is that IUCN RLE ET develops the classification from conceptual foundations, whereas the USGS classification emerges from the combination of multiple layers of observations of ecological properties.
- As for the other classifications: IUCN Habitats and EUNIS focus on habitats, not on ecosystems; FAO classifications focus on land use and crops; SEEA CF, CLC, and Italy are biased towards terrestrial and freshwater; StatCan ELC classifies ecoregions rather than ecosystems.

Scope (coverage of specific variants)

- Most classifications do not cover transitional types or ecotones. IUCN RLE does to some extent.
- IUCN RLE, IUCN Habitats, EUNIS, CLC, USGS make a distinction between artificial or managed versus natural or unmanaged ecosystem types.
- IUCN RLE, IUCN Habitats, USGS, and CLC distinguish between urban versus rural areas (mostly at level 2).
- Oceanic layers and the seabed are included in IUCN RLE, IUCN Habitats, EUNIS, and USGS. IUCN RLE and IUCN Habitats are the only classification that include caves. The atmosphere is not covered in any classification.

Hierarchy and rank order of properties

- All classifications have a hierarchical structure.
- Only IUCN RLE and StatCan ELC have a clear rank order of properties. USGS allows users to determine rank order.

Conceptual basis

- StatCan ELC, Italy, IUCN RLE, and USGS have a clear conceptual basis as well as supporting documentation that explains the conceptual basis.
- IUCN Habitats, MAES, and CLC do not have a clear conceptual basis or supporting documentation.

- Most classifications incorporate information on land use, land cover, geo-ecology. Some (StatCan ELC, Italy, IUCN RLE) also cover climate, and biotic and abiotic processes. Land management and ownership are generally excluded or only included implicitly.

Definitions and similarity criteria

- IUCN RLE, EUNIS, FAO, SEEA, CLC, and USGS have detailed documentation on the delineation of types and classes, have defined types and classes in terms of observable data, have classes that are unambiguous, discrete, and easy to interpret, and explain definitions as well as similarity criteria.
- Where definitions and similarity criteria are concerned IUCN Habitats and MAES are the least useful classifications.

5. Conclusions

We have established the purpose and design criteria of an international reference classification of ecosystem types to be used in ecosystem accounting. The classification will enable international comparison of ecosystem accounts at different levels of aggregation, and support the development of indicators of ecosystem extent and ecosystem condition as well as the description and classification of ecosystem services. The classification's units must represent ecosystems (derived from and characterized by ecological properties); be spatially delineable; be comprehensive across environmental domains (terrestrial, freshwater, and marine); be mutually exclusive; and be exhaustive.

The review of existing relevant classifications shows that IUCN RLE and USGS meet all design criteria. Their starting positions are very different: IUCN RLE takes a theoretical approach, while USGS applies a map-based approach. Of all the existing classifications we have reviewed, these provide the best foundation for a new international classification of ecosystem types.

Other classifications meet some but not all design criteria. However, most do possess a number of desirable properties. The new classification can, for example, align with some of the most prominent of these classifications to capture specific aspects (e.g. land use).

References

Bailey, R. (1996). Ecosystem Geography. Springer Verlag: New York, NY.

Balsi et al (2017). Ecosystem mapping for the implementation of the European Biodiversity Strategy at the national level: The case of Italy. Environmental Science & Policy, 78, 173-184.

Hancock, A. (2013). Best Practice Guidelines for Developing International Statistical Classifications. November, 2013.

Hoffmann, E., and Chamie, M. (1999). Standard statistical classifications: basic principles. Statistical Commission, 30th session, New York, 1-5 March 1999.

Keith DA et al. (in prep) Earth's diverse ecosystems: a new synthesis, assembly model and typology for risk assessment and management. For general discussion about the development of the typology and its requirements (see Keith et al. (2015) The IUCN Red List of Ecosystems: motivations, challenges and applications. Conservation Letters 8, 214-226).

Sayre, R., et al. (2014). A new map of global ecological land units—an ecophysiographic stratification approach. Washington, DC: Association of American Geographers.

Sayre, R. (2018). "Environmental Domains and Biomes as Standardized Reporting Units for Ecosystem Accounting." U.S. Geological Survey.

SEEA Experimental Ecosystem Accounting (2018). Revision 2020 Revision Issues Note.

United Nations (2017). Technical Recommendations in support of the System of Environmental-Economic Accounting 2012–Experimental Ecosystem Accounting.

Annex: Summary results of the comparison of classifications

Classification type	Look for a match with fundamental design criteria: units must represent ecosystems (derived from and characterized by ecological properties); spatially delineable; comprehensive across environmental domains (terrestrial, freshwater, and marine); units are mutually exclusive; units are exhaustive
Is it a national or an international classification?	2 national; 8 international/global
Has the classification been produced for a specific (national, regional, global) purpose? Is there a bias towards a specific environment or specific properties?	IUCN Habitats and EUNIS focus on habitats; FAO focus on crops; focus on terrestrial and freshwater (SEEA land cover, CLC land use; Italy; StatCan ELC ecoregions not ET; two classifications appear to meet all criteria: IUCN RLE and USGS; difference is that IUCN RLE develops classification from conceptual foundations up, whereas USGS classification emerges from combination of multiple layers of observations of properties
Scope (comprehensiveness)	
What is the degree of variety at the most detailed level of the classification?	
How does the classification deal with transitional types or ecotones?	Mostly not IUCN RLE does to some extent
Does the classification distinguish between artificial or managed versus natural or unmanaged ecosystem types? If so, at what level?	Some do: IUCN RLE, IUCN Habitats, EUNIS, CLC, USGS
How does the classification deal with urban versus rural areas?	Not all classifications deal with urban areas. Mostly at level 2. IUCN RLE, IUCN Habitats, USGS, CLC
Does the classification include oceanic layers and the seabed, the (sub)soil, and the atmosphere?	Some do: IUCN RLE, IUCN Habitats, EUNIS, USGS
Hierarchy	
Does the classification have a hierarchical structure?	All classifications have a hierarchical structure.
What is the number of levels in the hierarchy?	Mostly 2, 3 or 4 IUCN RLE has 6
What is the rank order of properties in the hierarchy?	Only IUCN RLE and StatCan ELC have a clear rank order of properties. USGS allows users to determine rank order.
Which properties that might represent a layer in a hierarchy are implicit?	Most classifications explicitly capture all relevant properties (exception is IUCN Habitats where climate and hydrology are implicit); as IUCN RLE states: "Properties that explicitly define lower-level units may sometimes be implicit in higher-level units even though they are not used to define the latter."
Conceptual basis	
Does the classification have a clear conceptual basis? If so, what is that basis?	7 yes; 3 no or unclear (IUCN Habitats; MAES; CLC)

Does the classification incorporate information on geo-ecology, land cover, land use, bio-ecology, land ownership, land management, etcetera?	most classifications incorporate information on land use, land cover, geo-ecology; some (StatCan ELC, Italy, IUCN RLE) also climate and biotic and abiotic processes; land management and ownership are generally excluded or included implicitly
Is there supporting documentation that explains the conceptual basis?	4 yes (StatCan ELC; Italy; IUCN RLE; USGS); 6 no or summary
Definitions and similarity criteria	
Is there detailed documentation on the delineation of types and classes?	8 yes; 2 no (IUCN Habitats; MAES)
Are types and classes defined in terms of observable data (e.g. how to recognise a deciduous forest in a satellite photograph)?	6 yes (IUCN RLE, EUNIS, FAO, SEEA, CLC, USGS)
Are classes unambiguous, discrete, and easy to interpret?	Mostly yes; no or limited IUCN Habitats and MAES
Is there supporting documentation that explains definitions and similarity criteria?	8 yes; 2 no (Italy; IUCN Habitats)