Guidelines for developing national ecosystem maps

October 2025

Version 0.2 FOR COMMENT

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Preface

These guidelines were developed for the Global Ecosystems Atlas, an initiative convened by the Group on Earth Observations with a range of partners, including the Secretariat of Convention on Biodiversity (CBD).

The Global Ecosystems Atlas provides an open, harmonised data source on all the world's ecosystems, covering all realms. It takes a dual approach to building a synthesis map of the distribution of ecosystems, by compiling existing high-quality ecosystem maps and using advanced data and technology to fill data gaps. Many of the existing high-quality ecosystem maps come from countries that have invested considerable effort and resources in mapping and classifying their ecosystem types. These national ecosystem maps provide a rich source of data that incorporates local knowledge and is authoritative at the national level for use in policy and decision making. The Atlas is committed to supporting countries that do not yet have such maps to develop them, recognising their value both at the national level and for the Atlas.

The guidelines presented here form part of a suite of support to countries provided by the Atlas. They were developed under the guidance of the Ad Hoc Science and Technical Committee that oversaw the proof-of-concept phase of the Atlas during 2024. The process of developing national ecosystem maps, especially non-technical aspects, has in general not been well documented, so this first version of the guidelines has drawn strongly on the knowledge of the authors, which in turn reflects the experience of ecosystem mapping practitioners across a range of countries and regions. The intention is to build on this as experience in developing national ecosystem maps widens and is, hopefully, captured and shared.

Acknowledgements

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A short factsheet on developing a national ecosystem map is available as an accompanying resource to these guidelines, providing a summary of the core content.

Acronyms and abbreviations

Atlas	Global Ecosystems Atlas
CBD	Convention on Biological Diversity
EBSA	Ecologically or Biologically Significant Marine Area
EIA	Environmental impact assessment
FAO	Food and Agriculture Organisation
FERM	Framework for Ecosystem Restoration Monitoring
GBF	Kunming-Montreal Global Biodiversity Framework
GEO	Group on Earth Observations
ISO	International Organisation for Standardisation
IUCN	International Union for the Conservation of Nature
KBA	Key Biodiversity Area
NBSAP	National Biodiversity Strategy and Action Plan
NGO	Non-government organisation
SANBI	South African National Biodiversity Institute
SEEA	System of Environmental-Economic Accounting
TSCC	Regional or Subregional Technical and Scientific Cooperation Support Centre (established through the CBD)
UN	United Nations
UNEP	United Nations Environment Programme
UNEP-WCMC	UNEP World Conservation Monitoring Centre

1 Introduction

Ecosystems are the foundation for all life on our planet. They host the world's biodiversity and provide the essential services that sustain life on Earth, including services related to food production, carbon storage and climate regulation, water regulation, cultural and recreational value, and others. In 1992, the Earth Summit recognised the critical role of ecosystems and biodiversity as a foundation for sustainable development and established the Convention on Biological Diversity (CBD). Since that time, recognition of the importance of biodiversity and of coordinated action for its conservation and sustainable use has increased, at global, national, and local levels.

The importance of conserving and managing ecosystems is recognised in the goals and targets of the Kunming-Montreal Global Biodiversity Framework (GBF), adopted by Parties to the CBD in 2022, as well as in its monitoring framework, which includes several headline indicators related to ecosystems. In their National Biodiversity Strategies and Action Plans (NBSAPs), Parties to the CBD must address policy, planning and action for ecosystems. Making this a reality requires knowledge of ecosystems, including the variety of ecosystems that exist, where they are located, their condition, how they change over time, and pressures and threats to specific ecosystems.

While all countries have recognised the importance of conserving, managing, and monitoring ecosystems, many countries do not yet have a national map and classification system for ecosystems to provide foundational information for those efforts. These guidelines advise on how to develop such a map and classification, providing a pragmatic approach that can be adapted as required. Below we set out the purpose and scope of the guidelines, a brief discussion on different country contexts and needs, and the intended audience and structure of the guidelines.

Purpose and scope of the guidelines

While some countries have advanced national ecosystem maps, which have been developed over many years or even decades, others are newer to the process. The main purpose of these guidelines is to support countries developing a new national ecosystem map, but they may also be useful for countries wishing to improve an existing one.

The guidelines apply across realms, including terrestrial, freshwater and marine,[1] and cover natural and anthropogenic ecosystems. In many cases, countries develop maps for different realms at different times, or as part of parallel processes led by different institutions. This means that progress often varies between realms. In many countries, mapping and classification of terrestrial ecosystems is more developed than freshwater and marine ecosystems.

The focus of these guidelines is on country-wide ecosystem maps, which have important applications in national-level planning, policy, decision making and monitoring as well as informing

[1] The IUCN Global Ecosystem Typology (see Section 3) recognises four core realms: terrestrial, freshwater, marine and subterranean, as well as transitional realms. In practice, subterranean ecosystems are not often included in national ecosystem maps and are thus not explicitly addressed in these guidelines. However, in principle they would be treated in broadly the same manner as terrestrial, freshwater and marine ecosystems should a country wish to include this realm.

sub-national and local action. Ecosystem maps at sub-national scales may in some cases exist or be developed independently of national maps. These sub-national maps are not the focus of these guidelines, but many of the same principles will apply, and co-ordination between national and sub-national processes is ideal to ensure alignment. Sub-national maps may also provide a data source that can be incorporated in the development or improvement of national maps (see Section 6.3).

There is no single recipe for developing a national ecosystem map, whether from a technical perspective or an institutional perspective. These guidelines are not prescriptive, but aim to identify key considerations and provide a framework that can be adapted, as needed, depending on country contexts. For those embarking on this journey, the guidelines provide a starting point for thinking through the range of aspects involved.

A further purpose of these guidelines is to support the development of high-quality ecosystem maps that are consistent with criteria and standards for inclusion in the Global Ecosystems Atlas synthesis map, including alignment with the International Union for the Conservation of Nature (IUCN) Global Ecosystem Typology (see Section 3). Alignment with the Global Ecosystem Typology will have the added benefit of facilitating alignment of maps along country borders to reflect the continuity of ecosystems across jurisdictional boundaries. Criteria and standards that are relevant for the Global Ecosystems Atlas are flagged in relevant sections, and an overview is provided as an Appendix.

These guidelines do not aim to provide detailed technical guidance on mapping and classifying ecosystems, but rather to point to some high-level principles and approaches. From a technical perspective there are many possible approaches, and this field is advancing rapidly, with increasing data and technological resources available. The technical methods used in developing a particular ecosystem map are typically written up as a technical report and in some cases in the peer-reviewed literature. As far as we are aware, technical guidance on the range of possible methods for ecosystem mapping and classification is not currently readily available as a single consolidated resource.

Also outside the scope of these guidelines are methods for mapping change in the spatial distribution of ecosystems and spatial assessment of ecosystem condition. The focus is on developing a baseline map of the distribution of all ecosystem types in a country, which is an essential starting point for assessing changes in distribution over time as well as ecosystem condition. The need for further guidance on mapping changes in distribution and ecosystem condition is recognised.

Different countries have different needs

These guidelines have been developed with full recognition that countries differ widely in terms of ecological context, socio-economic context, institutional context, and geographical extent; all of which have bearing on the process of developing a national ecosystem map.

Further, we recognise there is a continuum of countries from those that have well developed national ecosystem maps to those that have yet to begin developing such maps. We have characterized four broad groups of countries based on progress towards developing a national ecosystem map (***Error! Reference source not found.***). These groups are stylised, and not all countries will fit neatly into one group. Nevertheless, they provide a useful framework for thinking about the needs of different countries in relation to ecosystem mapping and classification.

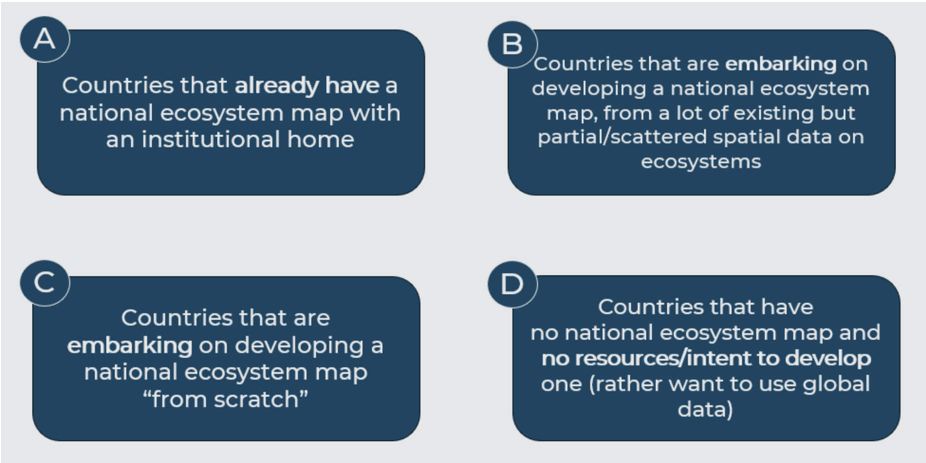


Figure 1. Different countries are at different stages in relation to developing national ecosystem maps, falling into four broad groups.

Countries in Group A already have a national ecosystem map with a clear institutional home, and a process in place to maintain, refine and update the map.[2] The institutional home would ideally be in the public sector, to facilitate maintaining and updating of the map as well as its credibility for use in policy and regulation. In many cases, research institutions or NGOs play an important partnership role, which could include initiating the process to develop the map and providing technical expertise. Systems for ingesting new data to improve the map and classification over time may be in place to varying degrees in these countries – this is not achieved overnight.

Countries in Group B are embarking on developing a national ecosystem map, in a context where there is a large amount of existing data but the data are typically not consolidated in one place, not necessarily in suitable formats, and not necessarily openly available for use.[3] This could include a combination of national, subnational and ecosystem-specific datasets, belonging to a range of institutions and individuals. The initiative to develop the map could come from government, or from a research institution or NGO, in which case this would preferably be working in partnership with government. Although there may not yet be arrangements in place to provide a permanent institutional home for the map with systems for maintaining, updating, and serving it, countries in this group would typically have a relatively well-resourced public sector with many of the skillsets required for the endeavour. Putting medium to longer term arrangements in place may follow the development of the first version of the map.

[2] Examples of countries in Group A include Brazil, Germany, Malawi, Mexico, Mozambique, The Netherlands, South Africa, and the United Arab Emirates. They span a range of different development and institutional contexts.
[3] At the time of writing, examples of countries in Group B included Australia, Canada, and New Zealand.

Countries in Group C, like those in Group B, are embarking on developing a national ecosystem map, but with less existing data to draw on and typically fewer resources to bring to bear on the process.[4] However, even in the least resourced countries there are usually some existing datasets that are relevant, and nationally- or locally-based experts who have first-hand ecological knowledge. The specialist technical skillsets needed to develop the map may not exist, and the country may need to draw on support of external ecosystem mapping practitioners. Countries in this group especially can benefit from utilising advanced modelling techniques and global efforts to make Earth observation data readily available in forms that support national application, combined with existing datasets and local ecological knowledge. The process of developing the map should be designed to build in-country capacity for all aspects of maintaining and updating it over time, ideally embedding this in the public sector.

Countries in Group D have no national ecosystem map and no intent to develop one in the short to medium term, for a range of possible reasons. For these countries, efforts by the Global Ecosystems Atlas to develop a synthesis map of all ecosystems in the world, filling data gaps where necessary drawing on advanced modelling techniques and Earth observation data, are especially important.[5] The Atlas synthesis map will provide a stopgap measure for these countries, aligned with the Global Ecosystem Typology and delivering spatial data on the distribution of ecosystems at a relatively broad scale but with sufficient reliability for a range of national applications. The Atlas synthesis map could also provide a starting point for more detailed national classification and mapping of ecosystems if the country decides to embark on that process.

As noted, a country may be at different stages for different realms, and ecosystem maps for different realms are often led by different institutions (see Section 8). For example, a country could fall within Group A in relation to its terrestrial ecosystem map but Group C for its marine ecosystem map. In the freshwater realm, maps of rivers and wetlands are often developed separately and may be at different stages of development. An ultimate objective may be to develop a single integrated national ecosystem map by “stitching together” information from all realms. These guidelines also help lay the basis by ensuring a conceptually consistent approach across realms. In practice, it is often pragmatic to start with one or two realms, based on, for example, which realms are spatially most extensive, of highest policy , and/or have data and expertise available.

These guidelines are aimed mainly at countries in Groups B and C. They may also be useful for countries in Group A that are working to improve their existing ecosystem maps, and for countries in Group D that are scoping the resources and other considerations that would be needed to develop a national ecosystem map.

Who should use these guidelines?

The guidelines are likely to be most useful for people directly involved in the process of setting up and undertaking national ecosystem mapping work. This could include officials in government ministries, departments or agencies with a mandate related to ecosystem mapping and

[4] At the time of writing, examples of countries in Group D included the Maldives, The Philippines, and Indonesia.
[5] The Atlas synthesis map is intended to be completed during Phase 1 of the initiative, ending December 2026.

classification, as well as staff in research institutions, NGOs or other organisations at the national, regional or global level who are involved in the process. For technical specialists with expertise related to ecosystem mapping and classification, these guidelines will help to place the technical work in a broader context.

The guidelines may also be useful for those aiming to catalyse or fund projects or programmes related to ecosystem mapping-related work, to better understand the requirements and needs. This could include the Regional and Subregional Technical and Scientific Cooperation Support Centres (TSCCs), a mechanism established through the CBD, which could provide support for ecosystem mapping for countries affiliated with them.[6]

The guidelines are structured as follows:

- Section 2 discusses the importance of a national ecosystem map, gives examples of its many applications, and clarifies some core concepts related to ecosystem mapping and classification,
- Section 3 explains the role that the Global Ecosystem Typology can play in national ecosystem mapping and classification,
- Section 4 provides an organising framework for approaching the development of a national ecosystem map,
- Section 5 describes the suite of products that make up a national ecosystem map,
- Section 6 sets out typical inter-related phases in the development of a national ecosystem map and briefly describes key elements of each phase,
- Section 7 explores the different roles within an ecosystem mapping team, including a short skills profile for each role,
- Section 8 discusses the importance of institutional and social processes for the successful development of a national ecosystem map that will be taken up in policy, planning, action and monitoring.

[6] There are 18 TSCCs, selected in 2024. Parties to the CBD choose which TSCC they wish to be affiliated with. The focus of the TSCCs is intended to be demand driven, based on the needs and requests of affiliated countries.

2 What is a national ecosystem map and why is it useful?

This section describes what is meant by the term "national ecosystem map", gives some examples of the applications of a national ecosystem map, and introduces some concepts related to ecosystem mapping and classification.

2.1 What is a national ecosystem map?

In these guidelines, we use the term "national ecosystem map" as shorthand for a national classification and map of the spatial distribution *of ecosystem types* in a country. A national ecosystem map may be known by another name – see Box 1. The *map* shows the spatial distribution (geographical locations) of the ecosystem types that occur in the landscape or seascape, and the *classification* distinguishes between different ecosystem types, each with a name and description. The classification should preferably be hierarchical, with ecosystem types at lower levels of the hierarchy nested within broader classes that share similar characteristics at higher levels (see Section 3 for more on the hierarchical classification of ecosystems). The map and the classification are in almost all cases developed iteratively, alongside each other, and refined and improved over time.

In practice, many national ecosystem maps are realm specific. For example, a country may have a separate national terrestrial ecosystem map, national freshwater and wetland map, and national marine ecosystem map. For a particular realm, a national ecosystem map should cover all ecosystems in that realm that occur within the country rather than just focusing on a subset of ecosystems. No part of the landscape, or seascape for marine ecosystems, should be excluded from the classification and mapping effort, as this can result in unintended biases towards certain ecosystem types in many applications of the ecosystem map (see Section 2.2) and limits meaningful comparison between ecosystem types.

As discussed further in Section 6, the level of detail in mapping and classifying ecosystems need not be uniform across the country, between realms or even within a realm, especially in earlier versions of the map(s). Some parts of the classification could have finer levels of detail than others, depending partly on the available data and expertise. For example, it may be possible to classify and map natural ecosystems in more detail than anthropogenic ecosystems, or terrestrial ecosystems in more detail than freshwater. Ideally, ecosystem types should be mapped and classified with enough detail to be useful for national through to local applications, although the detail required for local applications may not be possible in early versions of the map. As noted in Section 1, realm-specific national ecosystem maps can eventually be combined into a single integrated national ecosystem map, but this need not be an immediate aim.

Throughout these guidelines, when we refer to a country's national ecosystem map in the singular, it is with the recognition that a country could have two or three realm-specific national ecosystem maps and/or an integrated multi-realm map. For simplicity we do not spell this out every time as the principles and approaches we discuss are relevant irrespectively.

Developing a national ecosystem map requires the integration of various types of geospatial data from a range of sources, including historical maps, earth observation data, environmental variables and field data, together with expert and local knowledge. An interdisciplinary approach is important, drawing on expertise from ecologists, biologists, spatial analysts, environmental scientists and remote sensing experts, among others. This is discussed further in Section 6.

A national ecosystem map should consist of a suite of products, as discussed further in Section 5. These include a well-organised geospatial dataset with well-annotated attribute data and metadata; a technical report that describes the data, methods and a description of the process used to develop the map; and names and descriptions of each ecosystem type and the nested hierarchy within which they occur. Some of the input datasets that were collated to produce the map may also be useful products in their own right, and should preferably be organised and made available.

Box 1. A note on alternative names for a national ecosystem map

Various terms can be used to refer for a national ecosystem map. In some countries there may be existing maps and classifications of ecosystem types (or very closely related concepts) that are called by a different name, so it is important to be aware of this.

Examples include:

- *Vegetation map* (vegetation types are not always equivalent to ecosystem types but may be; they may be maps of potential vegetation, showing the likely historical distribution of vegetation types),
- *Habitat map* (habitat types strictly defined are different to ecosystem types, but the term habitat types is sometimes used to describe what are effectively ecosystem types),
- *Geobotanical map* (geobotanical types are not always equivalent to ecosystem types but may be),
- National wetland maps can form part of *National Wetland Inventories* developed by countries that are signatories to the Ramsar Convention on Wetlands of International Importance.

Land cover or land use maps and their associated classifications should not be conflated with maps and classifications of ecosystem types, although there may be correspondences for some classes, especially those representing anthropogenic ecosystems. In most contexts, a land cover or land use map is not a good proxy for an ecosystem map. See Section 2.3 for more on this.

A baseline map of ecosystem types

An important distinction ought to be made between developing a *baseline map* of ecosystem types and *mapping changes* in the distribution or extent of ecosystem types over time, which typically require different methods. A reliable baseline map is an essential starting point for measuring and assessing change as well as for meaningful assessment of ecosystem condition. Baseline maps can also be used as a starting point for estimating the expected future distribution of ecosystems, for example under different scenarios of climate change. The focus of these guidelines is on developing the baseline map, not on mapping change in the distribution of ecosystems or on assessing ecosystem condition. Nevertheless, the discussion below on updating the baseline map takes us into the arena of mapping change.

A baseline map represents the distribution of ecosystems at a certain time. Different countries have typically taken one of two contrasting approaches in this regard, depending on their context, aims and available information:

- One approach is to begin by mapping the *contemporary distribution* of ecosystems, with the baseline map representing the *present-day or relatively recent* distribution of ecosystem types. The baseline date selected could relate to, for example, the starting year of long-term datasets that provide consistent data at suitable resolution over multiple years, a policy-determined date (such as the baseline year of 2020 for reporting on headline indicators of the Global Biodiversity Framework), or the date of development of the map. “Relatively recent” could be a few decades ago, in other words “relative” is intended to mean relative to the distant past. Although typically expressed as a particular year, the baseline date may in practice represent a period of, say, a few years rather than strictly one year, as the multiple datasets required for an ecosystem map (see Section 6.3) may not all neatly represent one particular year. An example of this approach is The Netherlands’ national ecosystem map, shown in Figure 2.
- Another approach is to begin by mapping the *historical distribution* of ecosystems, with the baseline map representing the distribution of ecosystem types *prior to major human modification of the landscape*, or as close as possible an estimate of the historical distribution. Historical distribution is often pegged to circa 1750, the start of industrial development, when human impacts on ecosystems intensified. Such maps are sometimes called “potential ecosystem maps”. An example of this approach is Malawi’s national ecosystem map, shown in Figure 3.

Of course, mapping the historical and contemporary distribution of ecosystems are not mutually exclusive. It is also possible to develop maps of the distribution of ecosystems at intermediary dates, between historical and recent, based on best available data for different time periods. Nevertheless, a country will typically choose either the approach of mapping historical distribution or the approach of mapping contemporary distribution for the initial baseline ecosystem map. A third approach is to select an intermediary date as the baseline, for example linked to the first availability of certain key datasets. Regardless of the baseline date or period, investing in a good baseline map will enhance the reliability of measurements of change over time.

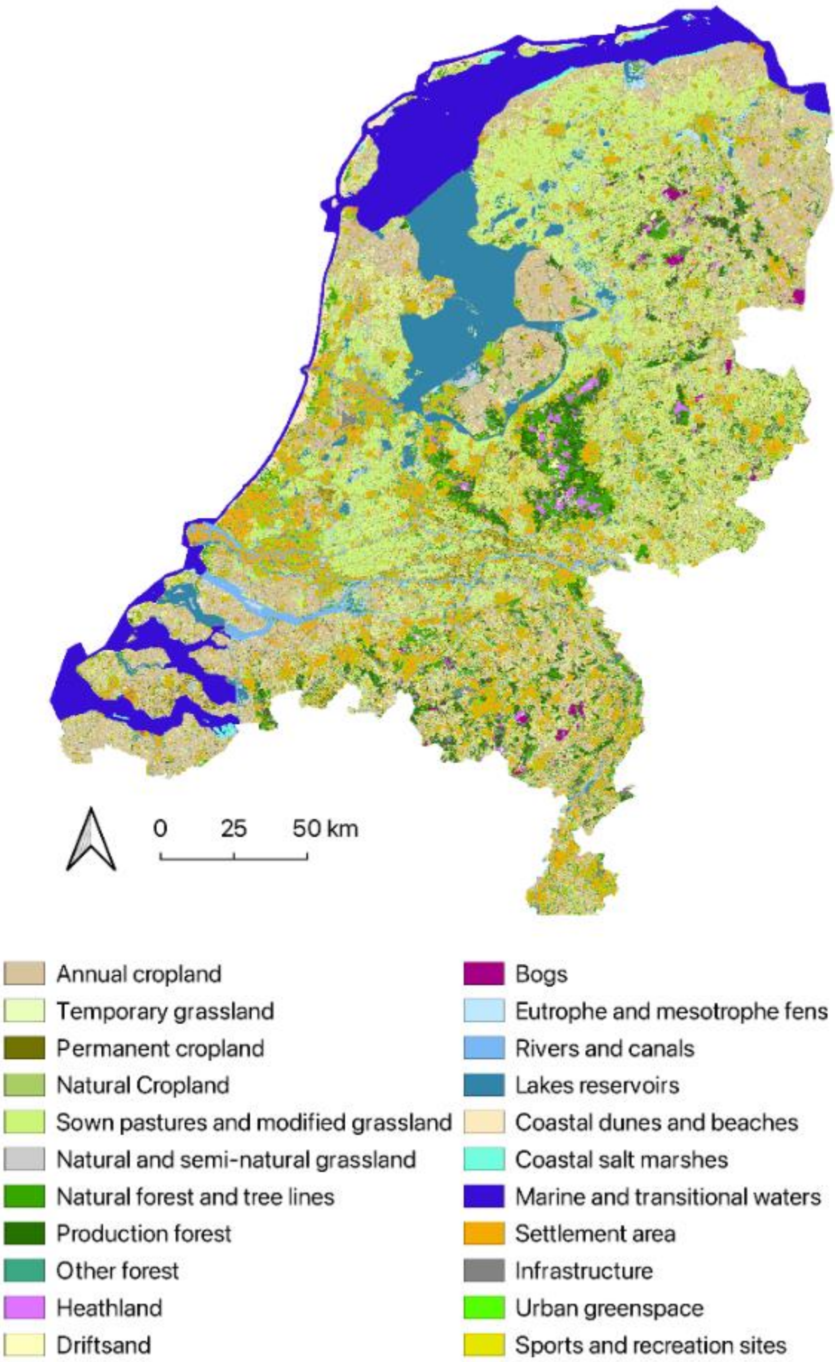


Figure 2. The Netherlands' national ecosystem map reflects the contemporary distribution of ecosystems.

(Source: Central Bureau of Statistics (CBS) Netherlands; Wageningen University; Ministry of Agriculture, Nature and Food Quality (LNV), 2022)

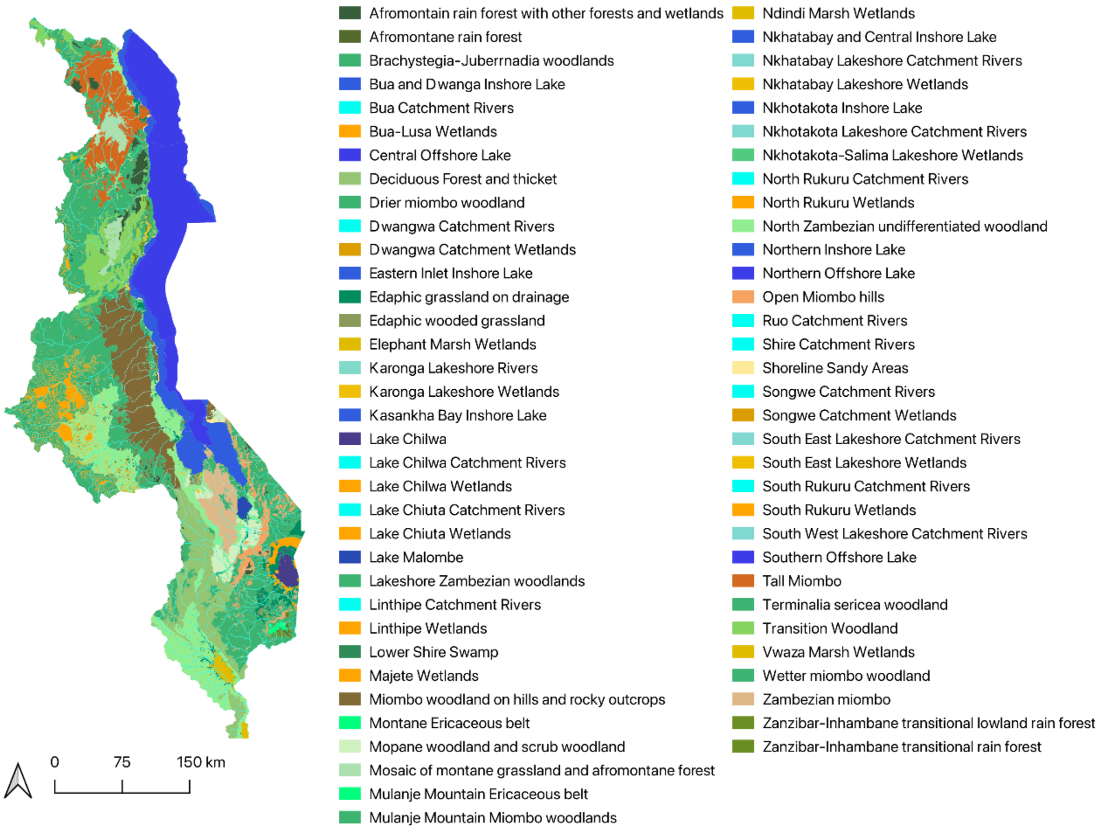


Figure 3. Malawi's national ecosystem map reflects the historical distribution of ecosystems, prior to major human modification of the landscape.

(Source: Environmental Affairs Department, Malawi (EAD) & Malawi University of Science and Technology (MUST), 2022)

Distinguishing between improvements and updates of ecosystem maps

Typically, maps and classifications of ecosystem types are periodically improved and/or updated. It can be useful to make a distinction between *improvement* in the quality of a national ecosystem map representing a particular date or period, and *updates* of the map to reflect changes that have taken place in the distribution of ecosystem types.

Improvements to the quality of a national ecosystem map could take the form of changes to the ecosystem classification to better reflect the different ecosystem types that exist and/or refining the delineation of ecosystem types to better represent their spatial distribution on the ground. If the classification is changed, the map would usually be revised alongside the classification. On the other hand, the classification could remain stable while the map is refined as data improves to better represent the spatial distribution of ecosystem types in the classification.

In practice, a national ecosystem map may be improved and updated at the same time, and it is ideal to be able to tease apart the improvements and updates. In cases where a timeseries of the ecosystem map is developed, changes in the classification and refinements in the delineation of ecosystem types should preferably be replicated retrospectively throughout the timeseries, so that it is possible to distinguish between real change and improvement in data and methods.

2.2 Applications of a national ecosystem map

A national ecosystem map provides an essential foundation for a range of applications, often together with other foundational spatial information on ecosystems and in some cases species. Some important applications are summarised in Figure 4 and described briefly below, without aiming to be comprehensive. Many of the applications link directly to Goals A and B of the Global Biodiversity Framework and to the implementation and monitoring of National Biodiversity Strategies and Action Plans (NBSAPs). Table 1 summarises how national ecosystem maps provide an enabling resource for multiple targets and headline indicators of the Global Biodiversity Framework. All of these applications are supported when the national ecosystem map is credible and legitimate to national- and local-stakeholders as well as knowledge holders. Broad acceptance of the ecosystem amp increases the confidence in its use for policy, planning, regulation and decision making with real-world impacts.

A national ecosystem map should be a multi-purpose product. While the need for a national ecosystem map might initially be prompted by a specific application, it should ideally be suited to other applications too. For example, a national ecosystem map developed initially for the purpose of ecosystem accounting can be suitable for a Red List of Ecosystems assessment, or vice versa (Xiao et al., 2024). Ecosystem map developers should consider the immediate purpose of the map as well as other possible applications, cognisant that improvements in the map over time are likely to support a growing number of applications. The nested hierarchical classification of ecosystem types allows for uptake of the map in macro, meso- and local-scale applications. Local and site-level applications generally increase for maps at lower classification levels and higher spatial resolutions. Considering multiple uses of the map will help to guide who should be involved in its development (see Sections 6.1 and 8).

The multi-purpose nature of a national ecosystem map is not only possible in principle but also pragmatic. Having more than one national ecosystem map is likely to cause confusion among users and stakeholders and can undermine the effectiveness of any of the maps. It is also an unnecessary duplication of effort and investment. If different ecosystem maps have already been produced independently for different purposes, effort should ideally be made to harmonise all or parts of them into a single product, as appropriate.

Figure 4. National ecosystem maps provide foundational data for a wide range of applications that support the implementation and monitoring of the Global Biodiversity Framework.

The Red List of Ecosystems

The IUCN Red List of Ecosystems is a global standard that uses criteria and thresholds to assess the risk of collapse of an ecosystem, allocating ecosystems to risk categories such as Critically Endangered, Endangered, Vulnerable or Least Concern (Figure 5). Maps of ecosystem types provide the spatial units that are assessed. The Red List of Ecosystems has a wide range of applications in biodiversity policy and practice. See Red List of Ecosystems | Home for more.

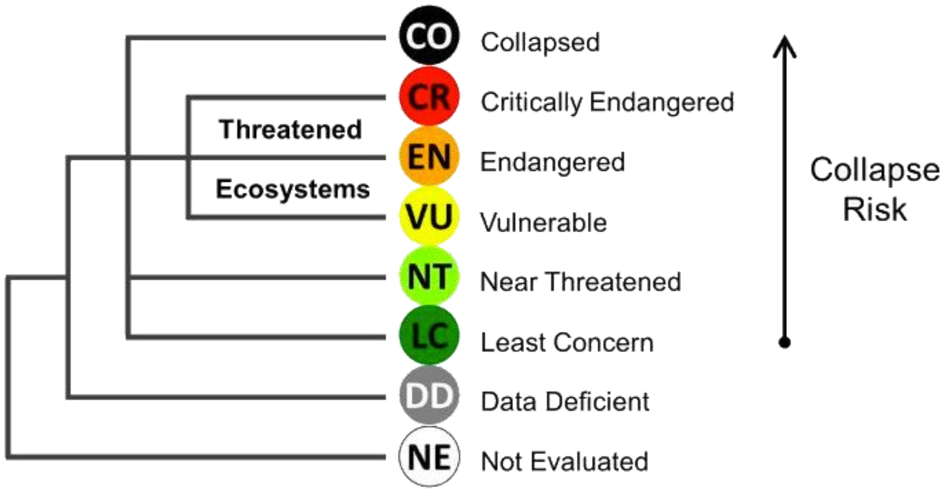


Figure 5. Categories in the IUCN Red List of Ecosystems

(Source: https://iucnrle.org/rle-categ-and-criteria)

The System of Environmental-Economic Accounting (SEEA) Ecosystem Accounting

SEEA Ecosystem Accounting (UN et al., 2024) is a statistical framework for measuring ecosystems and their contributions to people and the economy. Classifications and maps of ecosystem types provide the foundation for the core ecosystem accounts, which deal with the extent and condition of ecosystem assets (classified according to ecosystem type) and the flow of ecosystems services from these assets in biophysical and monetary terms (Figure 6). Ecosystem accounts have a wide range of applications. See [Ecosystem Accounting | System of Environmental Economic Accounting] for more.

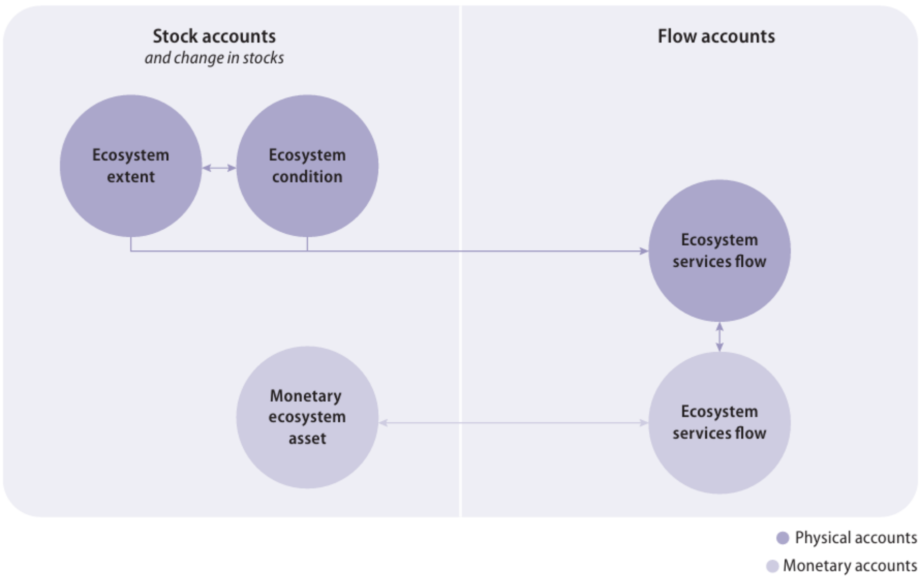


Figure 6. Core ecosystem accounts in SEEA Ecosystem Accounting

(Source: UN et al., 2024, Figure 2.2)

Measuring and assessing ecosystem condition

Ecosystem condition refers to the overall state or quality of an ecosystem, which influences the biodiversity of that ecosystem as well as the ecosystem services it provides. For the measurement of ecosystem condition to be meaningful, variables and indicators of condition should relate to the characteristics and properties of the ecosystem type being assessed. Generic spatial assessments of ecosystem condition, using variables and indicators that are agnostic to the ecosystem types present in the landscape or seascape, are much less useful than those that are informed by key properties that distinguish different ecosystem types. Knowledge of which ecosystem types occur where, allows condition metrics to be correctly chosen and interpreted with reference to their ecological context. Assessments of ecosystem condition in turn feed into several of the other applications discussed here.

Ecosystem restoration

The UN Decade on Restoration (2021 – 2030) is a global initiative to prevent, halt and reverse the degradation of ecosystems worldwide as a key strategy to combat climate change, enhance biodiversity and improve livelihoods. In line with this, Target 2 of the Global Biodiversity Framework addresses restoration of degraded ecosystems across all realms. A map and classification of ecosystems is vital for assessing which ecosystem types have been degraded, designing appropriate restoration interventions based on their essential characteristics, and monitoring outcomes. This information also supports the Framework for Ecosystem Restoration Monitoring (FERM), a geospatial registry of restoration initiatives for tracking global progress (FERM Registry).

Key Biodiversity Areas

Key Biodiversity Areas (KBAs) are sites contributing significantly to the global persistence of biodiversity, based on criteria set out in a global standard developed by the IUCN. The criteria address biodiversity at the genetic, species and ecosystem levels, and include criteria related to threatened ecosystem types and geographically restricted ecosystem types. Maps of ecosystem types are an essential input for evaluating these criteria. See keybiodiversityareas.org for more.

Ecologically or Biologically Significant Marine Areas

Ecologically or Biologically Significant Marine Areas (EBSAs) are areas of the ocean that have special importance in terms of their ecological or biological characteristics, for example, as essential habitats, food sources or breeding grounds for particular species, identified based on a set of criteria. Spatial data on ecosystem types provides a useful input for assessing ecosystem-related criteria. See Ecologically or Biologically Significant Marine Areas (EBSAs) for more.

National Wetland Inventories

The Ramsar Convention on Wetlands of International Importance requires Parties to develop National Wetland Inventories, which should include information on the extent and condition of wetlands. A national map of wetland ecosystem types can provide a foundation for such an inventory. See Home page | The Convention on Wetlands, The Convention on Wetlands for more.

Systematic conservation planning

Systematic conservation planning aims to identify a portfolio of sites that represent a viable sample of all ecosystem types and species and allow for the persistence of key ecological processes in the landscape or seascape. A map of ecosystem types, with quantitative targets for the proportion of each ecosystem type that should be conserved, is an essential input. The resulting maps of biodiversity priority areas can in turn feed into several of the other applications discussed here.

Expanding the network of protected and conserved areas

Target 3 of the Global Biodiversity Framework aims to conserve 30% of the Earth's land, water and seas by 2030, and is reflected in similar targets at the national level. Classifications and maps of ecosystem types are essential for ensuring that the network of protected and conserved areas is ecologically representative (i.e. includes all ecosystem types), which is one important aspect of Target 3.

Biodiversity-inclusive integrated spatial planning

Target 1 of the Global Biodiversity Framework emphasises the importance of integrating biodiversity considerations in multi-sectoral spatial planning processes such as land-use planning, marine spatial planning and catchment-level planning. A map and classification that provides information about which ecosystem types occur where and their essential characteristics is a vital starting point, and identifying areas of high biodiversity importance such as threatened ecosystems, KBAs and EBSAs can further strengthen spatial planning.

Environmental impact assessments

Environmental impact assessments (EIAs) are an essential step in implementing the mitigation hierarchy, which aims sequentially to avoid, minimise, restore, or offset negative impacts of development, including on biodiversity and ecosystems. A map and classification of ecosystems provides information that enables better assessment of the potential impacts of development on ecosystems, supporting better decision-making.

Integrated water resources management

Integrated water resources management is a cross-sectoral process that promotes co-ordinated development and management of water, land and related resources to meet economic and social needs without compromising the sustainability of vital ecosystems. A map and classification of freshwater ecosystems provides essential information for this, and identifying areas of high importance for freshwater biodiversity can further strengthen the process. See Global Water Partnership - GWP for more.

Private sector assessment and disclosure frameworks

According to Target 15 of the Global Biodiversity Framework, Parties should take legal, administrative or policy actions to encourage businesses to assess, disclose and reduce biodiversity-related risks and negative impacts. Frameworks for assessing and reporting on nature-related dependencies, impacts, risks, and opportunities, such as that developed by the Task Force for

Nature-Related Financial Disclosures, require reliable data on ecosystems, with maps and classifications of ecosystem types providing an essential input.

Monitoring and reporting on headline indicators of the Global Biodiversity Framework

The Global Biodiversity Framework includes a monitoring framework with headline indicators on which all Parties to the CBD are required to report at regular intervals. Several of the headline indicators are ecosystem-related, including A.1 Red List of Ecosystems, A.2 Extent of natural ecosystems, B.1 Services provided by ecosystems, 2.1 Area under restoration, and 3.1 Coverage of protected areas and other effective area-based conservation measures.

A map and classification of ecosystem types supports the compilation of all these indicators, and more broadly supports an effective national biodiversity monitoring framework. See Indicators for the Kunming – Montreal Global Biodiversity Framework | Indicator Repository for more.

Reporting on indicators for the Sustainable Development Goals

Several of the indicators for the Sustainable Development Goals of the UN 2030 Agenda for Sustainable Development are ecosystem related, including 6.6.1 Change in the extent of water-related ecosystems over time; 14.5.1 Coverage of protected areas in relation to marine areas; 15.1.1 Forest area as a proportion of total land area; 15.1.2 Proportion of important sites for terrestrial, and freshwater biodiversity that are covered by protected areas, by ecosystem type; and 15.4.1 Coverage by protected areas of important sites for mountain biodiversity. Compiling these indicators may be assisted by a map and classification of ecosystem types. See Home — SDG Indicators for more.

Given this wide range of applications, the time and resources spent on developing and maintaining a good quality national ecosystem map that has the confidence of key users can be viewed as an investment that delivers substantial returns.

Table 1.National ecosystem maps provide a vital or enabling resource for multiple Global Biodiversity Framework targets and headline indicators.

Global Biodiversity Framework targets supported by national ecosystem maps	
T1 Plan and manage all areas to reduce biodiversity loss	A national ecosystem map is a vital starting point for biodiversity-inclusive spatial planning, providing information about which ecosystem types occur where and their essential characteristics, so that this can be taken into account in multi-sectoral land-use planning and marine spatial planning. It is also essential for identifying areas of high biodiversity importance, such as threatened ecosystems (based on the Red List of Ecosystems), Key Biodiversity Areas (KBAs) and Ecologically or Biologically Significant Marine Areas (EBSAs), which can further strengthen spatial planning.

T2 Restore 30% of all degraded ecosystems	A national ecosystem map is vital for assessing which ecosystem types have been degraded and designing appropriate restoration interventions based on their essential characteristics. For assessments of ecosystem condition to be meaningful, indicators of condition should relate to the characteristics and properties of the ecosystem type being assessed and should be interpreted with reference to their ecological context. Characteristics of the ecosystem type should also inform restoration objectives and monitoring of restoration outcomes, which should be ecosystem-specific rather than generic.
T3 Conserve 30% of land, waters and seas	A national ecosystem map is vital for ensuring that a country's network of protected and conserved areas is ecologically representative (i.e. includes a representative sample of all ecosystem types), which is one important aspect of Target 3. Knowing which ecosystem types occur where is essential for assessing current protection levels of different ecosystem types and identifying under-protected ecosystem types that should be a focus for consolidation and expansion of the network of protected are conserved areas.
T4 Halt species extinction, protect genetic diversity, and manage human-wildlife conflicts	A national ecosystem map can support conservation of species. Because many species are associated with certain ecosystem types, a map of the distribution of ecosystem types can help in identifying suitable habitat for particular species. This is especially important for species at risk of extinction, many of which are threatened by habitat loss.
T8 Minimize the impacts of climate change on biodiversity and build resilience	A national ecosystem map is an important starting point for understanding which ecosystems are likely to be most vulnerable to the impacts of climate change, for example through spatially explicit projections of the impact of climate change on the distribution of different ecosystem types. A national ecosystem map can support identifying ecosystems that could contribute to ecosystem-based approaches, such as Nature-based Solutions and Ecosystem-based Adaptation, based on ecosystem-specific characteristics and properties. Taking the location and characteristics of ecosystem types into consideration when designing, implementing and monitoring climate change adaptation and mitigation activities can also contribute to avoiding negative impacts of the activities on biodiversity and ecosystems.
T10 Enhance biodiversity and sustainability in agriculture, aquaculture, fisheries, and forestry	A national ecosystem map can support ecologically sustainable and biodiversity-friendly approaches to agriculture, forestry and fisheries in a landscape or seascape context. Conversion of natural ecosystems to intensive agricultural and forestry-related uses, such as croplands and plantations, is a major driver of biodiversity loss. At the same time, the productivity and sustainability of agricultural and forestry depends on ecosystem services, and agricultural ecosystems contain or support important biodiversity that requires management and conservation. Knowledge of which ecosystem types exist, their characteristics and location can support implementation of a range of approaches to sustainable agriculture, such as agroforestry, agroecology and regenerative agriculture. Understanding the characteristics of different types of forest ecosystems is essential for assessing forest ecosystem condition, developing criteria and standards for sustainable forest management and identifying priority areas for forest restoration. In fisheries, implementing the ecosystem approach to fisheries management, which aims to minimise the habitat impacts associated with key fisheries (among other objectives), requires an understanding of which ecosystem types occur where and their essential characteristics.

T11 Restore, maintain and enhance nature's contributions to people	A national ecosystem map can support the identification of ecosystem types that provide particular functions and services and the associated contributions to people, supporting management of those ecosystems to maintain or restore their benefits. As noted for Target 9, a national ecosystem map can also support identifying ecosystems that could contribute to ecosystem-based approaches, such as Nature-based Solutions and Ecosystem-based Adaptation, based on ecosystem-specific characteristics and properties.
T12 Enhance green spaces and urban planning for human well-being and biodiversity	Depending on its spatial resolution, a national ecosystem map may provide a valuable input into urban planning, helping to identify ecosystem types that provide green and blue spaces, supporting assessments of their ecological connectivity and integrity, and aiding an understanding of the ecosystem functions and services they provide.
T14 Integrate biodiversity in decision-making at every level	A national ecosystem map can support mainstreaming biodiversity in a range of policy, regulatory, planning and decision-making processes. It can provide a credible science-based tool for integrating information about ecosystems into, for example, national development plans, strategic environmental assessments, EIAs, and even budgeting, especially if linked to identification of areas of high biodiversity importance, such as threatened ecosystems and KBAs. A national ecosystem map can also be an awareness raising tool, helping to make people across a range of sectors aware of the importance of biodiversity at the ecosystem level.
T15 Businesses assess, disclose and reduce biodiversity-related risks and negative impacts	A national ecosystem map can support companies and financial institutions wishing to assess and report on their nature-related dependencies, impacts, risks and opportunities. Global frameworks that support these efforts, such as that developed by the Task Force for Nature-Related Financial Disclosures (TNFD), require reliable data on ecosystems, with maps and classifications of ecosystem types providing an essential input.
T21 Ensure that knowledge is available and accessible to guide biodiversity action	A national ecosystem map is an excellent tool for synthesising information about biodiversity at the ecosystem level, and making it accessible in a readily understandable form to a wide range of users, including policy makers, practitioners and the public.
Global Biodiversity Framework headline indicators supported by national ecosystem maps	
A.1 Red List of Ecosystems	Ecosystem types in a national ecosystem map provide the spatial units for Red List of Ecosystem Assessments, which form the basis for Indicator A.1. While a Red List of Ecosystem assessment can be done for an individual ecosystem, the assessments are most effective when done comprehensively, covering all the ecosystem types that occur in a country. This enables comparison of the ecosystem risk status across ecosystem types, helping to focus interventions strategically. In addition, national ecosystem maps that have been cross-referenced to the Global Ecosystem Typology enable disaggregation of Indicator A.1 by ecosystem functional group, which is one of the suggested disaggregations for this indicator.

A.2 Extent of natural ecosystems	National ecosystem maps are the basis for SEEA ecosystem extent accounts, which provide a structured way of recording the area and changes in area of different ecosystem types (natural and anthropogenic). This in turn provides the basis for Indicator A.2, which tracks the extent of natural ecosystems as a proportion of the total area of a country. In addition, national ecosystem maps that have been cross-referenced to the Global Ecosystem Typology enable disaggregation of Indicator B.1 by ecosystem functional group, which is one of the suggested disaggregations for this indicator.
B.1 Services provided by ecosystems	National ecosystem maps are an input into the development of SEEA ecosystem services accounts, which provide the basis for Indicator B.1. While is it possible to measure some ecosystem services without reference to specific ecosystem types, understanding which ecosystem services are linked to which ecosystem types can strengthen measurement. In addition, national ecosystem maps that have been cross-referenced to the Global Ecosystem Typology enable disaggregation of Indicator B.1 by ecosystem functional group, which is one of the suggested disaggregations for this indicator.
2.1 Area under restoration	National ecosystem maps that have been cross-referenced to the Global Ecosystem Typology enable disaggregation of Indicator 2.1 by ecosystem functional group, which is one of the suggested disaggregations for this indicator.
3.1 Coverage of protected areas and OECMs	National ecosystem maps that have been cross-referenced to the Global Ecosystem Typology enable disaggregation of Indicator 2.1 by ecosystem functional group, which is one of the suggested disaggregations for this indicator.
10.1 Proportion of agricultural area under productive and sustainable agriculture	National ecosystem maps may provide information about agricultural ecosystem types relevant to Indicator 10.1.
10.2 Progress towards sustainable forest management	National ecosystem maps may provide information about forest ecosystem types relevant to Indicator 10.2.
12.1 Average share of the built-up area of cities that is green/blue space for public use for all	National ecosystem maps, if their spatial resolution is sufficiently high, may provide information about green and blue space within cities for Indicator 12.1

2.3 Some core concepts for mapping and classifying ecosystems

In this section we look at some concepts that are central to mapping and classifying ecosystems, including ecosystems, ecosystem types, and natural, semi-natural and anthropogenic ecosystems. We also briefly discuss the relationship between land cover, land use and ecosystem types, and the distinction between spatial distribution and extent of ecosystems.

This section draws on *Guidelines for Classifying Agricultural Ecosystems in the Global Ecosystem Typology* (Driver & Botts (eds)., 2025), a resource intended for country teams involved in national ecosystem mapping, with a specific focus on agricultural ecosystem types. These *Guidelines for Developing National Ecosystem Maps* were developed alongside the guidelines for classifying agricultural ecosystems. The two documents share similar content related the concepts that underpin national ecosystem mapping and classification.

Ecosystem

An *ecosystem* is defined by the CBD as a dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit (CBD Article 2). Important elements of this definition are the biotic (living) component, the abiotic (non-living) component and the interactions among the biota and between the biotic and abiotic components. Alongside this definition, three attributes of ecosystems are often identified: composition, structure and function. Simply put, composition relates to species that occur within or are associated with the ecosystem, structure relates to the physical structure and patterns of the ecosystem, and function relates to ecological processes.[7]

Ecosystem type

For many real-world applications, it is useful to divide the ecosystems that occur in a continuous landscape or seascape into different *ecosystem types*, which provide units that can be used for planning, decision making, management and monitoring (Keith et al., 2015). Although there is always uncertainty in applying discrete categories and spatial boundaries in the context of a natural continuum (Keith et al., 2022), ecosystem types are widely used in practice and have stood up legally and in policy and implementation in many parts of the world (Nicholson et al., 2021). Synonyms sometimes used for ecosystem types include habitat types, vegetation types and ecological communities (see Box 1).

An ecosystem type is distinguished from other types by its characteristic functional, structural and compositional properties (IUCN, 2025). Each ecosystem type has characteristic biota (species) and abiotic features that can be described and recognised in the landscape or seascape. An ecosystem type need not be contiguous in the landscape; it could consist of several or many occurrences interspersed with other ecosystem types.

An ecosystem type is typically identified as part of a hierarchical classification system. The Global Ecosystem Typology, discussed in Section 3, is one such hierarchical classification, in which ecosystem types are reflected at levels 5 and 6 of the classification. Ecosystem types that share similar characteristics can be grouped together at successively higher levels in a hierarchical classification. Higher levels, such as biomes and ecosystem functional groups, represent *groups of ecosystem types* and should not be confused with the ecosystem types themselves.

In classifying and mapping ecosystem types, it is important that compositional, structural and functional attributes are *all* considered in identifying and distinguishing between ecosystem types, in order for the types identified to be ecologically meaningful units that are consistent with the concept of an ecosystem. If any of these three attributes (composition, structure or function) is absent from a classification system, then it is not consistent with the ecosystem concept and will not provide an effective framework for identifying ecosystem types.

[7] For a more detailed explanation, see Noss (1990).

Some ecosystem types are characterised by more temporal variability than others, whether seasonal, interannual, multi-year or over decadal cycles. Natural variation in dynamic ecosystems, within defined ranges of variability, should not be confused with changes in ecosystem type. For example, a seasonal wetland ecosystem does not become a different ecosystem type depending on whether it is dry or wet, and a savanna ecosystem remains the same ecosystem type notwithstanding transitions between grass-dominated and tree-dominated states.

Within the geographic distribution of a given ecosystem type, there can be a spectrum of ecosystem condition. Indeed, in many circumstances ecosystem condition will not be uniform across the whole distribution of an ecosystem type. This should not preclude the identification and classification of the ecosystem type and delineation of its distribution.

Natural, semi-natural and anthropogenic ecosystems

It is useful to distinguish between natural and anthropogenic ecosystems as two broad categories, while recognising that almost all ecosystems have some level of human influence and that the degree and form of this influence vary on continuous scales. The term 'natural' in this broad sense does not imply pristine or unimpacted by humans, and the composition, structure and functioning of most natural ecosystems have been modified to varying degrees through human activity or its direct consequences. Nevertheless, if the *characteristic functional and structural properties* of the ecosystem type are still recognisable and at least *some of the key native biota* are still present, the ecosystem can be considered part of the broad category of *natural ecosystems*.

In contrast, *anthropogenic ecosystems* are those *created and maintained* through human activity, where human activities are the *primary determinant* of the ecosystem's composition, structure and function and are essential for its ongoing existence. Examples include urban and industrial areas, croplands and plantations. Anthropogenic ecosystems typically replace an antecedent natural ecosystem, and conversions from natural to anthropogenic ecosystems are generally abrupt, with some exceptions. Once converted to an anthropogenic ecosystem, the *antecedent natural ecosystem type is no longer recognisably present*. If the human activities that create and maintain anthropogenic ecosystems cease,[8] these ecosystems may revert to the antecedent natural ecosystem type they replaced, or they could develop into a novel ecosystem type. The length of time this takes could extend from a few years to more than a century, depending on many factors.

Key criteria for identifying anthropogenic ecosystem types are thus:

- The ecosystem type was created and is maintained through human activity, which is the primary determinant of the ecosystem's composition, structure, and function,
- The antecedent natural ecosystem type is no longer recognisably present.

In the context of the broad understanding of natural ecosystems described above, the term *semi-natural* is widely used to describe a *condition state* of a natural ecosystem in which composition and

[8] This could be for a range of reasons, for example if the human activity is no longer economically viable or an area is abandoned because of war.

structure have been modified (by human activity or its direct consequences) but the characteristic functional and structural properties of the natural ecosystem type are still recognisable and at least some of the key native biota are still present. This semi-natural condition would generally apply to portions of the distribution of a natural ecosystem type, not to its whole area. If the human activity were to be removed, the condition of the ecosystem could improve, but its ecosystem type would not change. The delineation of ecosystem types in a national ecosystem map should *not* be based on their condition; the whole area of a natural ecosystem type, including portions in semi-natural condition, should be delineated. This helps to ensure the map's usefulness as a foundation for measuring and assessing ecosystem condition, which in turn supports a range of applications of the map (as discussed in Section 2.2).

The term semi-natural is also sometimes used in a different sense, especially in the European context, to describe anthropogenic ecosystem types that have been transformed through human management into pastures or meadows that retain local indigenous species but from which woody components have been largely removed. Although these ecosystem types are comprised of indigenous species, only species that can adapt to regular biomass extraction (grazing or mowing) persist, and the structure and functioning of the ecosystem are substantially different from the antecedent ecosystem, meaning that the antecedent ecosystem type is no longer recognisably present. Without ongoing human management these ecosystems would generally revert to tree-dominated ecosystem types. In this second sense, "semi-natural" is a descriptor of an ecosystem type rather than ecosystem condition, and semi-natural ecosystem types would be classified and mapped as distinct types. It is important to be aware of these two quite different uses of the term semi-natural and to be clear about the intended meaning in a particular context.

Distinguishing between land cover, land use and ecosystem types

Land cover and land use are related to some ecosystem types but they are conceptually distinct from ecosystem types, and care should be taken not to conflate land cover or land use classes with ecosystem types. However, for anthropogenic ecosystem types the link is stronger, as discussed below.

Land cover is the observed physical cover on the Earth's surface, including vegetation (natural or planted) and human constructions (FAO, 2025). Land cover classes are often organised in a hierarchical classification. Land cover datasets, generally derived from satellite imagery, tend to reflect structural aspects of ecosystems, less so functional and compositional aspects.[9] Because functional and compositional attributes are not central to distinguishing between different land cover classes, these classes are not, in general, consistent with the concept of an ecosystem and in most cases do not represent ecosystem types. Exceptions are discussed below.

Land use is characterized by the arrangements, activities and inputs people undertake in a certain land cover type to produce, change, or maintain it (FAO, 2025). Land uses can be organised into land use classes in a hierarchical classification. From the definition of land use, there is a link between land cover and land use. However, several land use classes may be associated with multiple land

[9] Although hyperspectral imagery offers the potential to identify and distinguish between species in some cases.

cover classes, so the relationship is not direct or nested. Land use classes are defined based on human activities and inputs, not based on the compositional, structural and functional attributes of the ecosystems in which they take place. This means that land use classes, like land cover classes, are in general not consistent with the concept of an ecosystem and in most cases do not represent ecosystem types.

The exception is anthropogenic ecosystem types, which are created and maintained by human activities that are typically directly related to land use.[10] For these ecosystem types, land use is the primary determinant of ecosystem composition, structure and function, and there is often a closer correspondence with land cover and land use classes, which may be useful in useful in mapping these ecosystem types.

Some spatial datasets combine spatial information on both land cover and land use. The Food and Agricultural Organisation (FAO) leads the Land Cover Land Use International Standard development process along with the International Standard Organization (ISO) through ISO TC211 AG13 on land cover land use.

To summarise, land cover or land use maps and their associated classifications should not be conflated with maps and classifications of ecosystem types, as their conceptual basis differs. Land cover and land use classes do not, in general, sufficiently reflect the compositional and functional attributes that are essential for meaningfully identifying ecosystem types.

The common misperception that land cover classes can be used as a proxy for ecosystem types is complicated by the fact that some land cover classes may have similar names to ecosystem types. Examples are grasslands, shrublands and in some cases forests. Grass cover in a land cover map is not necessarily associated with grassland ecosystems – it could represent, for example, a grassy area in a savanna ecosystem, a shrubland in poor condition that has been overrun by grass species, a planted pasture or a golf course. All these grass-covered areas belong to different ecosystem types, some natural and some anthropogenic. Tree cover in a land cover map could represent, for example, a forest ecosystem, a treed area in a savanna ecosystem, a plantation or orchard, or woody invasive vegetation in a grassland ecosystem in poor condition, all of which belong to different ecosystem types. Caution should thus be applied in linking land cover classes to ecosystem types based on names of classes. Where terms such as grassland, shrubland or forest are used for land cover classes, these may be more appropriately called grass cover, shrub cover or tree cover respectively, to reduce the possibility of confusion between land cover classes and ecosystem types.

Waterbodies deserve specific mention. Open waterbodies are often observable from land cover data, and in many cases are associated with freshwater ecosystems, whether natural or artificial. However, many freshwater ecosystems do not always contain open water, in which case their spatial distribution is not readily discernible from land cover data. Examples include seasonal or ephemeral rivers and wetlands, which are all or partly dry for some parts of the year or over longer cycles, while nevertheless retaining characteristic wetland soils and vegetation. Land cover data also cannot

[10] Or sea use in the marine context, but the discussion here is focused on land.

provide information about the chemical composition of water, for example whether it is saline or fresh, which is an important distinguishing characteristic of ecosystem types in the freshwater realm.

Distinguishing between spatial distribution and extent of ecosystems

It is useful to distinguish between the spatial distribution of ecosystems and their extent. A map of ecosystem types shows the *spatial distribution* of those ecosystem types, in other words their geographic location in the landscape or seascape. The *extent* of an ecosystem type is a *metric* that can be derived from the map of its spatial distribution. Usually, extent refers to the total area[11] of all occurrences of an ecosystem type, measured, for example, in hectares or square kilometres.

The extent of ecosystem types is an important metric for several applications of ecosystem maps, including SEEA Ecosystem Accounting and the Red List of Ecosystems. The ecosystem extent account in SEEA forms the basis for all the other accounts and for GBF headline indicator A.2 Extent of natural ecosystems. Criteria A and B in the Red List of Ecosystems require data on the extent or area of the ecosystem type being assessed.

It is preferable to *avoid the terms "extent map" or "ecosystem extent mapping*", which conflate the map showing the spatial distribution of ecosystems and the metric derived from the map. Also, "mapping extent" does not distinguish between mapping the baseline distribution and mapping changes in distribution, which, as noted above, typically require different methods. It is clearer to refer to mapping the distribution of ecosystems and mapping changes in their distribution, from which extent-related metrics can be derived. This is especially important for ecosystem accounting.

[11] For rivers, which are often mapped as lines, extent may be expressed as length. For three dimensional ecosystems such as caves it could be expressed as volume.

3 The role of the IUCN Global Ecosystem Typology

The Global Ecosystem Typology (Keith et al., 2020; Keith et al., 2022) is a global framework for ecosystem classification, developed in collaboration with scientists around the world and endorsed by the UN Statistical Commission as an international statistical classification. It provides a hierarchical framework for identifying and classifying different ecosystem types across all realms, enabling global consistency at the upper levels of the Typology while encouraging detailed national ecosystem classifications at the lower levels. Here we provide a short introduction, focusing on aspects that are especially relevant for national ecosystem classification and mapping.

The Global Ecosystem Typology has six levels (**Error! Reference source not found.**). The upper three levels are *realms*, *biomes* and *ecosystem functional groups*. Realms (level 1) are major components of the biosphere that differ fundamentally in ecosystem organisation and function: terrestrial, freshwater, marine, subterranean, as well as transitional realms. Biomes (level 2) are components of realms, united by one or a few common major ecological drivers that regulate major ecosystem functions and ecological processes. The 25 biomes of the Global Ecosystem Typology are derived through top-down subdivision of realms. Ecosystem functional groups (level 3) are groups of related ecosystem types within a biome that share common ecological drivers and ecosystem properties. There are 110 ecosystem functional groups in v2.1 of the Global Ecosystem Typology, derived through top-down subdivision of biomes. Ecosystem functional groups are nested within biomes, which are nested within realms. These upper levels of the Global Ecosystem Typology classify ecosystems based on their functional characteristics (such as roles of foundation species, water regime, climatic regime or food web structure), rather than based on which species live in them.

Ecosystem functional groups are an important level for comparing information across countries and synthesising ecosystem-related data and information for the entire globe, as they provide sufficient detail to be meaningful from a biodiversity perspective while still providing a manageable summary. For further global synthesis, the 110 ecosystem functional groups can be aggregated to the 25 biomes; however, at the biome level much valuable information about biodiversity is obscured. Ecosystem functional groups have been recommended as the level to which detailed national ecosystem information should be aggregated for global reporting, in SEEA Ecosystem Accounting, the Red List of Ecosystems, and across the ecosystem-related headline indicators for the Global Biodiversity Framework.[12]

At the time of writing, the Global Ecosystems Atlas is working to develop a high-quality synthesis map of all ecosystem functional groups in the world, suitable for many applications, drawing from a range of high-quality national, regional and global datasets. In the meantime, the Global Ecosystem Typology website provides indicative maps of ecosystem functional groups, indicating where each ecosystem functional group is likely to occur. These are broadscale maps, not intended to confirm or exclude the presence of an ecosystem functional group at the national or local level, but to be used

[12] See CBD/COP/16/INF/3/Rev.1 (Section 2) for detailed discussion on the rationale for the use of the Global Ecosystem Typology in the monitoring framework of the Global Biodiversity Framework. https://www.cbd.int/doc/c/ea34/8414/8c5e6797d291af15f33d6e40/cop-16-inf-03-rev1-en.pdf

as a starting point for identifying which ecosystem functional groups may be present in a country (see Section 6.2).

Ecosystem types are identified at levels 5 and 6[13] of the Global Ecosystem Typology, where distinctions between ecosystem types within an ecosystem functional group are based on compositional characteristics, in other words related to the suite of species that are present. Ecosystems that share similar functional characteristics may be composed of substantially different species and would be considered different ecosystem types at levels 5 or 6. Compositionally different ecosystem types recognised at levels 5 or 6 of the Global Ecosystem Typology within the same ecosystem functional group may differ in some structural characteristics and functional properties, within the broad range of variation described for the group.

Ecosystem types, shown in red in **Error! Reference source not found.**, are derived bottom-up though a range of possible methods, as discussed in Section 6. A national ecosystem map should ideally classify and map ecosystems at level 5 or 6, to provide the necessary detail for informing planning, decision-making and action related to ecosystems from national through to local level. Ecosystem types at level 5 or 6 should ideally be cross-referenced to the ecosystem functional groups at level 3, so that data and information on ecosystem types at levels 5 and 6 can be aggregated to ecosystem functional groups when needed.

The Global Ecosystem Typology provides names, a numbering system and descriptions for realms, biomes and ecosystem functional groups. It is not prescriptive about the ecosystem types that should be identified at levels 5 and 6 – this is up to country-level and local experts to determine from the best available data and evidence. For all ecosystem types, there is flexibility at levels 5 and 6 for countries to classify ecosystems in a way that is appropriate to the national context and to develop names, a numbering system and descriptions of these ecosystem types, as discussed further in Section 6.5. In many countries, ecosystem types at level 5 or 6 would be seen as 'national ecosystem types', with recognition that some national ecosystem types may well be shared across national borders (i.e. a national ecosystem type need not be endemic to the country).

In between levels 3 and 5 of the Global Ecosystem Typology are *regional ecosystem subgroups* at level 4, derived through top-down subdivision of ecosystem functional groups by the ecoregion[14] in which they occur. Regional ecosystem subgroups provide proxies for compositionally distinctive variants of an ecosystem functional group that occupy different geographic areas within the global distribution of that ecosystem functional group. They are regional expressions of an ecosystem functional group.

[13] The Global Ecosystem Typology distinguishes between global ecosystem types at level 5 and sub-global ecosystem types at level 6. These ecosystem types are global in the sense that they are globally unique – they do not occur anywhere else on Earth. National ecosystem types can correspond with either level 5 or level 6, and parts of the national ecosystem classification could be more detailed than others.

[14] Ecoregions are broad biogeographic regions, each of which contains multiple ecosystem types. They are intended to represent the broad distribution of biodiversity rather than both compositional and functional attributes of ecosystem types (Keith et al., 2022). Global terrestrial ecoregions have been developed by Dinerstein et al. (2017). In addition, many countries have their own ecoregionalisations, which are often more elaborate and more grounded than the global ones and will generally be more suitable for subdivisions at level 4.

If it is not initially possible to classify and map ecosystem types at level 5 or 6 for a national ecosystem map (for example because of insufficient data related to species composition), ecosystem functional groups (level 3) or regional ecosystem subgroups (level 4) provide good provisional alternatives. Early versions of the national map at level 3 or 4 can be improved on over time, as discussed in Section 2.1, working towards more detailed classifying and mapping ecosystems at levels 5 or 6. If resources allow and sufficient data are available, especially related to species composition, a country may wish to map and classify ecosystems at an even finer level, below level 6.

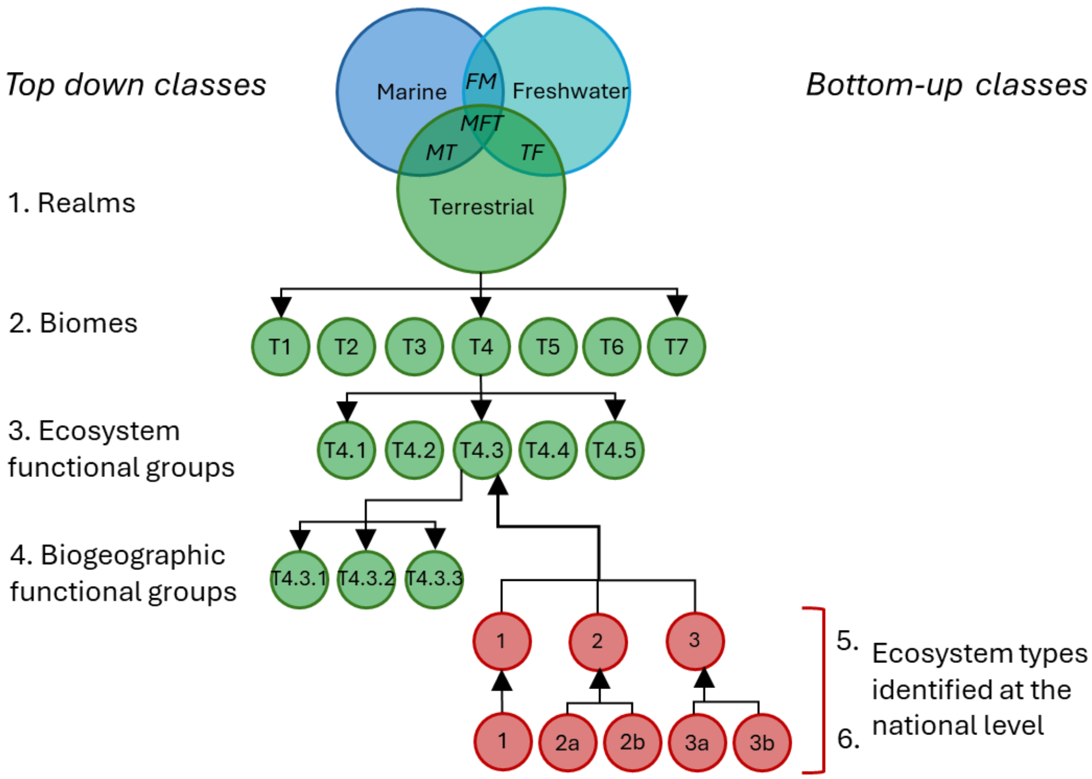


Figure 7. The Global Ecosystem Typology provides a hierarchical framework of six levels for classifying ecosystems, enabling global consistency at the upper levels of the Typology (shown in blue and green) while encouraging detailed national ecosystem classifications at the lower levels (shown in red).

(Source: Based on Xiao et al., 2024)

To emphasise, the Global Ecosystem Typology does *not* replace national ecosystem classifications or national ecosystem types. Rather, it provides a way of linking national ecosystem classifications to a consistent global system that allows ecosystem information to be compared across countries and regions and synthesised at the global level. There is no intention that the Global Ecosystem Typology will provide a pre-determined classification of ecosystems at levels 5 and 6; countries should develop their own classifications at this level.

Countries can align with the Global Ecosystem Typology by cross-referencing their national ecosystem types to the ecosystem functional groups. As noted, this allows for national ecosystem data and information to be aggregated to ecosystem functional groups when needed. For countries developing a national ecosystem classification for the first time, this cross-referencing can be done from the outset, with each national ecosystem type at level 5 or 6 ideally nested within one ecosystem functional group. For countries that have an existing national ecosystem classification, a process of cross-referencing national ecosystem types to ecosystem functional groups will need to be undertaken. Some national ecosystem types may not fit clearly into an ecosystem functional group, for example if an ecosystem type shares properties of two or more ecosystem functional groups. In such cases, the principles and methods set out in guidelines for cross-referencing, developed by the IUCN (IUCN, 2025), will help to identify the ecosystem functional group that is the best fit, the level of uncertainty involved, as well as other plausible candidate groups. Countries can thus develop or retain as much detail as is useful in their national maps and classifications while also aligning with the Global Ecosystem Typology.

4 A framework for approaching the development of a national ecosystem map

There are several aspects involved in developing and maintaining a national ecosystem map, relating to the suite of products, phases of the process, the people and skills involved, and the institutional and social processes involved. Each of these aspects is equally important and deserves close attention. Figure 8 gives an overview, and each aspect is unpacked in the sections that follow.

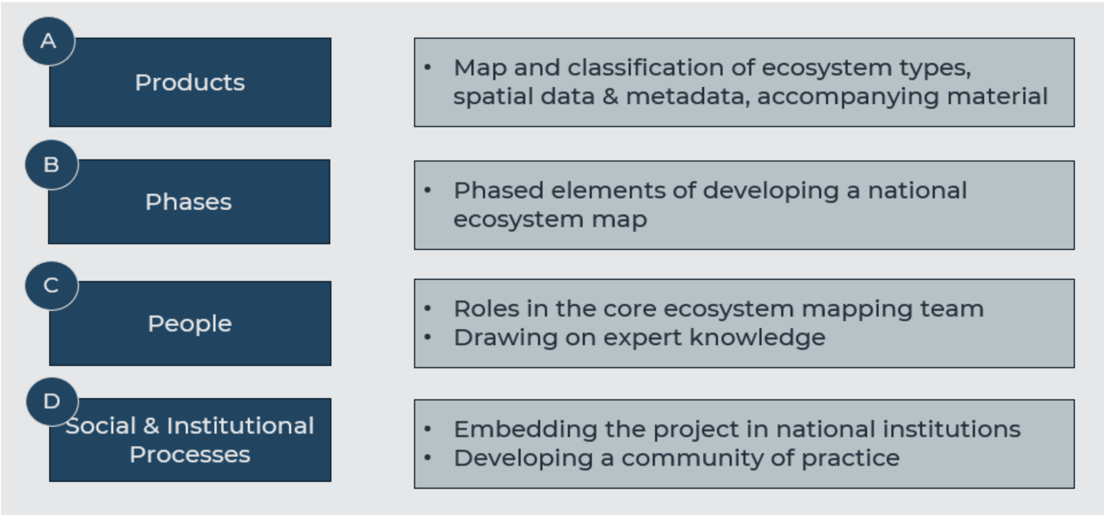


Figure 8. A framework for approaching the development of a national ecosystem map.

Products

Products are the "tangible" outputs associated with a national ecosystem map. They are the most visible aspect, with which a wide range of users will interact directly. It's important that the products are clear and presented in a way that facilitates uptake in the range of applications discussed in Section 2.2. The suite of products is discussed in Section 5.

Phases

Developing a national ecosystem map is not a simple task, and it helps to think about the process as a series of phases, including: scoping and preparation; identifying and classifying ecosystem types likely to be present in the country; data discovery, collection, organisation and evaluation; mapping and validating the distribution of ecosystem types; and finalising the suite of products. These phases are interlinked and sometimes iterative, and, as the map and classification are refined over time, they can be seen as a cycle. Notwithstanding this complexity, the simplified representation of phases can be helpful when figuring out where to start and conceptualising a programme of work for developing a national ecosystem map. The time required to complete the process varies greatly and depends partly on the resources available – more about this in Section 6.

People

Developing a national ecosystem map requires a team of people, with some essential roles that need to be filled and some core skillsets required in almost any national context. Section 7 discussed these roles, as well as the need to involve national and local knowledge holders closely to ensure the quality and credibility of the products.

Social and institutional processes

Last but not least, careful attention to social and institutional processes is essential for developing a map that has credibility and legitimacy for use in policy, planning, decision making and monitoring. Social and institutional processes are in some ways the least visible aspects of developing a national ecosystem map, often taking place “behind the scenes”, but provide the foundation for success, as discussed in Section 8.

5 A national ecosystem map consists of a suite of products

A national ecosystem map should consist of a suite of products, all of which are essential for its usefulness and application. It's important to build time and budget into the work programme for developing these products, and to ensure that they are widely and easily available to users. Figure 9 gives an overview of the suite of products and they are discussed briefly below, along with guidance on ensuring open access to the products and licencing.

**** Criteria and standards flag:** This section includes important information about criteria and standards that are relevant for inclusion of national ecosystem maps in the Global Ecosystems Atlas synthesis map. An overview of the criteria and standards is provided in the Appendix.

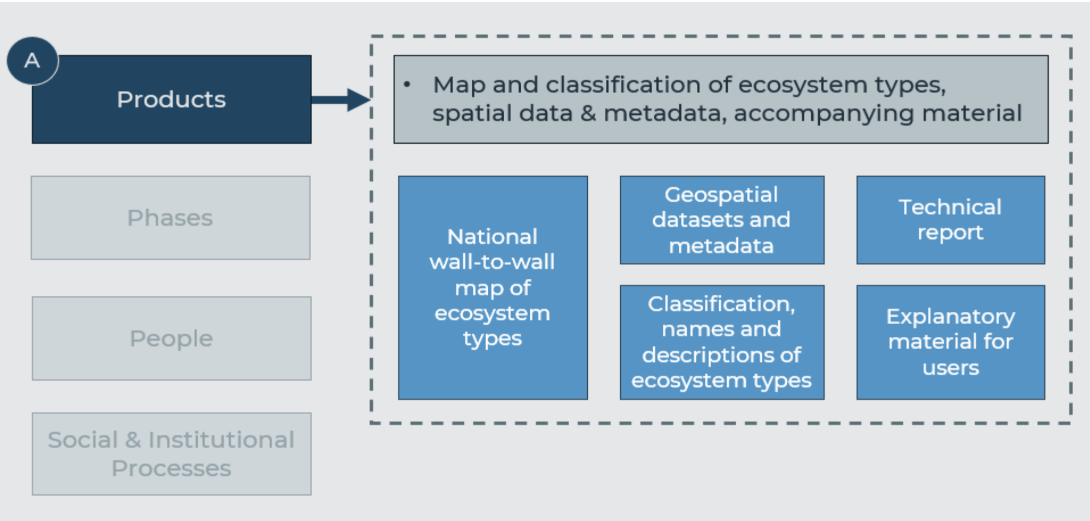


Figure 9. Products typically associated with a national ecosystem map.

Map of ecosystem types

A map representing the spatial distribution of all ecosystem types in a country is at the heart of a national ecosystem map. In addition to being available as a geospatial dataset (see below), the map can also be made available in forms such as interactive applications and downloadable pictures at high and low resolution. It could also be presented as a poster that can be printed.

Colour schemes for map classes are important for conveying information as well as for visual appeal, and require careful thought. For example, ecosystem types within each ecosystem functional group or biome could have a specific colour theme.

As a national ecosystem map is likely to be improved and updated over time, it is important to think about a system for keeping track of different versions of the map products from the outset, with clear naming and numbering of successive versions so that users can be sure which is the appropriate version to use for a certain purpose.

Classification of ecosystem types, including names and descriptions

The mapping and classification of ecosystem types are intimately connected, but it is nevertheless worth thinking of the map and the classification as two distinct products. As discussed, the classification should be hierarchical, with ecosystem types typically representing the lowest level of the classification (equivalent to Level 5 or 6 of the Global Ecosystem Typology – see Section 3).

Each level of the classification requires a name (which could draw on the level names in the Global Ecosystem Typology), and each class within each level requires a name and a code. It is useful to develop a naming convention for ecosystem types, with names that are meaningful for identifying and locating the ecosystem type. For example, names of terrestrial ecosystem types could include the name of the geographic region, a geological of physiographic property, and the structural character of the dominant vegetation. Names of ecosystem types can incorporate local place names and terms that are familiar to people who live in areas where the ecosystem type occurs. Mapping practitioners should be mindful to choose names that are uncontentious and socially accepted (e.g. avoid old names for geographic regions, or find a neutral alternative if the name of an area is under dispute). The name helps to give the ecosystem type a clear identity, but should never be interpreted as the only information required to identify it or understand its properties, for which the name is necessary but not sufficient.

Each ecosystem type should have a description of its key characteristics and features, focusing on those that distinguish it from other ecosystem types, especially from ecosystem types that are adjacent or similar. Photographic examples of the ecosystem type are a useful complement to the written description and quantitative estimates of certain characteristics (e.g. altitudinal range). The description of an ecosystem type should include:

- *Characteristic species*, focusing on dominant native species (an exhaustive species inventory is not necessary) and dominant communities or assemblages of species within the ecosystem type, especially those that distinguish the composition of an ecosystem type from others and/or are centrally relevant to ecosystem dynamics and function.
- *Abiotic characteristics*, focusing on those that influence the distribution or function of an ecosystem type, define its natural range of variability, sustain its characteristic native biota, and differentiate it from other systems,
- *Ecological processes and interactions* that define the behaviour of the ecosystem type.

Box 2 and Box 3 give examples of descriptions of ecosystem types from national terrestrial ecosystem maps in Myanmar and Mozambique, respectively.

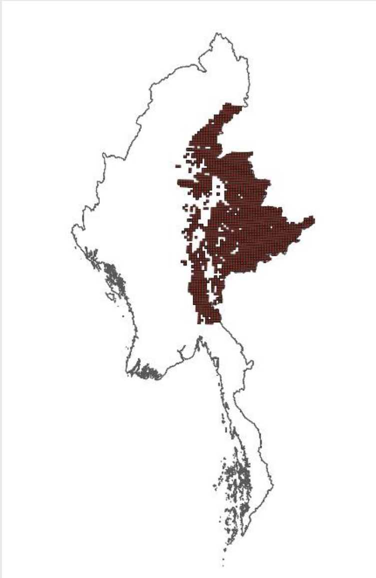
Initial descriptions, for the first version of the national ecosystem map, could be brief outlines of the main characteristics. These descriptions can be expanded over time as more information is gathered, to include additional aspects of the characteristic species and ecological processes of the ecosystem, and eventually to describe a conceptual model of the ecosystem. Developing the description can help to think through the distinctiveness of the ecosystem type in the landscape or seascape and is a useful way to test whether an ecosystem type is valid in the map and classification.

Descriptions of ecosystem types are an essential starting point for cross-referencing a national ecosystem classification to the Global Ecosystem Typology, as noted in Section 3. They are also valuable for guiding conservation actions that are aligned with the distinctive characteristics of ecosystems.

The Guidelines for the Red List of Ecosystems (IUCN, 2024) provide additional detailed guidance on descriptions of ecosystem types, which are a requirement for submitting threatened ecosystem types to the global Red List of Ecosystems database.

**** Criteria and standards flag:** To be included in the Global Ecosystems Atlas synthesis map, a national ecosystem map should have a classification system with names and descriptions of each map class.

Box 2. Example of a description of an ecosystem type from Myanmar's national terrestrial ecosystem map



Ecosystem type: Western Shan Plateau subtropical evergreen rainforest
Biome: Tropical and subtropical forests (T1)
Ecosystem functional group: Tropical/subtropical lowland forest (T1.1)
IUCN Red List of Ecosystems status: Vulnerable
URL: https://www.myanmar-ecosystems.org/myanmar-ecosystems/t1-1-7-western-shan-plateau-subtropical-evergreen-rainforest

Description
This is a complex evergreen rainforest that occurs on rich limestone and shale soils on the western Shan plateau. The closed tree canopy is up to 25 - 40 m tall, with a diversity of notophyll to microphyll leaf sizes. The trees represent a diverse array of plant families, and some have buttress roots and cauliflory. Epiphytic orchids and ferns, and lianas are abundant in the tree canopy. The understorey includes ferns and forbs. Subtropical rainforest on the western Shan plateau typically forms distinct mosaics with Shan Hills pine savanna with fine scale distributions probably mediated by water availability and occurrence of fire. However, the rainforest matrix has been severely fragmented by intensive agricultural land use. A particularly good remnant example of this ecosystem can be found at Ye Aye reservoir, Kalaw.

Distribution
Distributed in small fragments between about 900 m and 1,400 m elevation along the western Shan plateau.

Characteristic native biota

The biota is likely to share some affinities with distant subtropical rainforests of upper Myanmar and Yunnan plateau in China including Scimitar babblers and their allies (Timaliidae) as well as the recently described Skywalker Hoolock Gibbon *Hoolock tianxing* (EN).

Abiotic environment

Western Shan Plateau subtropical evergreen rainforest occurs in areas with reliable year-round rainfall of between about 1,400 and 2,000 mm, with the majority falling during June-November. Forms on rich limestone and shale soils at elevations of 900-1,400 m.
Most fragments remain on slopes and hills, although some small remnant patches occur on flatter areas of the Shan plateau.

Key processes and interactions

Reliable water availability from regular rainfall, warm temperatures and the occurrence of rich soils support a highly diverse ecosystem. These conditions support continuous growth and gap phase recruitment of trees and a complex trophic web. Dense-canopies and abundant rainfall maintain a humid micro-climate, with thick leaf litter that is not fire-prone unless fragmented by human activity.

Major threats

The ecosystem has been widely cleared and fragmented for agriculture, primarily rice and crops. Cutting for hardwood. Anthropogenic fires after clearing limit regeneration.

Ecosystem collapse definition

Western Shan Plateau subtropical evergreen rainforest is regarded as collapsed when its area has declined to zero, or when primary forest accounts for 0% of total forest cover, or when all patches of primary forest are smaller than 1-10 km^2.

Source: Murray, N.J. et al. 2020. Threatened Ecosystems of Myanmar. An IUCN Red List of Ecosystems Assessment. Version 1.0. Wildlife Conservation Society. ISBN: 978-0-9903852-5-7

Box 3. Example of a description of an ecosystem type from Mozambique's national terrestrial ecosystem map

Ecosystem type: Lugenda Lowland Dry Miombo
Portuguese name: Miombo seco das terras baixas de Lugenda
Biome: Savannas and grasslands (T4)
Ecosystem functional group: Pyric tussock savannas (T4.2)
Regional ecosystem: Zambezian Dry Miombo

Description: Deciduous miombo woodland mainly occurring on granite derived sandy soils.

Distribution: In northern Mozambique, from Negamano on the Rovuma River, southwards and westwards up the Rovuma and Lugenda River catchments, into Niassa Special Reserve and far south as Naneuma (north of Marrupa). Occurring in Cabo Delgado and Niassa Provinces.

Characteristic native biota: A drier form of miombo woodland, dominated by *Julbernardia globiflora* and *Brachystegia spiciformis*, with *B. boehmii* locally common. In somewhat drier areas the woodland is shorter and more open. *Combretum* species (*C. adenogonium, C. apiculatum, C. kirkii, C. molle, C. mossambicense, C. psidioides, C. zeyheri*) are common, with fewer *Brachystegia* or *Julbernardia* trees. Other species include *Albizia amara* subsp. *amara, Annona senegalensis, Azania garckeana, Balanites aegyptiaca, Baphia massaiensis* subsp. *gomesii, Boscia angustifolia, B. mossambicensis, Brackenridgea zanguebarica, Carpodiptera africana, Commiphora pteleifolia, Cordia goetzei, Diplorhynchus condylocarpon, Diospyros squarrosa, D. kirkii, Dombeya acutangula, Entada chrysostachya, Flacourtia indica, Grewia inaequilaterale, Holarrhena pubescens, Homalium abdessammadii, Hymenocardia acida, Markhamia zanzibarica, Monanthotaxis obovata, Olax dissitiflora, Ozoroa insignis subsp. reticulata, Pavetta schumanniana, P. refractifolia, Philenoptera bussei, Piliostigma thonningii, Pteleopsis myrtifolia, Pterocarpus angolensis, Rauvolfia mombasiana, Steganotaenia araliacea, Sterculia quinqueloba, Stereospermum kunthianum, Swartzia madagascariensis, Syzygium guineense, Tamarindus indica, Terminalia trichopoda, Vitex buchananii, V. mombassae, Xylotheca tettensis, and Ziziphus abyssinica*.

Herbaceous species include *Barleria spinulosa*, *Blepharis affinis*, and *Dioscorea schimperiana*.

Closer to the Lugenda River a drier woodland type, dominated by *Millettia stuhlmannii* becomes common, interspersed with drier vegetation of *Acacia*-dominated wooded grassland in and around pans and small patches of *Euphorbia cooperi* thicket on cemented soils. *Hyphaene coriacea* palms are locally common.

The transition of woodland types across the landscape is from deeper sandy soils on broad ridges through drier woodland on the slopes, to the *Millettia* and *Acacia* woodland types on soils with lower moisture storage capacity.

Abiotic environment and climate: Altitude range of 170 to 530 m asl with a mean of 347 m. Sand content, expressed as % between 1 – 30 cm deep, is an estimated 64.3% while the similarly measured clay content is 22.9 Soil pH is 6.1. Precipitation during driest quarter is 5.4 mm.

Species of Conservation Importance:
Endemic Plant Species: *Habenaria hirsutissima* [endemic], *Hugonia grandiflora* [near-endemic].
Threatened Plant Species: *Hugonia grandiflora* [Endangered].

Source: Lötter et al. 2023. Historical vegetation map and Red List of Ecosystems assessment for Mozambique – Version 2.0 – Final report. USAID / SPEED+, AFD/FFEM. Maputo. Available at Mozambique's Ecosystems | GEF-Mozambique (click on "Related documents").

Geospatial datasets and metadata

The spatial dataset representing ecosystem types could be in vector or raster format and should be accompanied by the necessary metadata, based on established conventions and standards such as those of the International Organisation for Standardisation (ISO). As with the map product, a clear system of numbering and naming for different versions produced over time is important.

**** Criteria and standards flag:** To be included in the Global Ecosystems Atlas synthesis map, a national ecosystem map should have appropriate metadata.

In addition to the geospatial dataset for the ecosystem map itself, there may be other spatial datasets developed or better organised in the process of developing the ecosystem map, for example as input data. Where appropriate, these datasets could be seen as products in their own right to be made available alongside the spatial dataset for the map.

The ISO has developed a suite of geospatial metadata standards. The base fundamental standard is ISO 19115-1, which provides information about the identification, the extent, the quality, the spatial and temporal schema, spatial reference, and distribution of digital geographic data. Other ISO standards include ISO 19110, which is used for feature attribute table, and ISO 19157, which establishes the principles for describing the quality of geographic data. The AGI's BS 7666 Guidelines and INSPIRE are other standards and good practice guidance for geographic information.

Technical report

A thorough technical report that details the data and methods used to develop the national ecosystem map and describes the classification and ecosystem types is vital for several reasons:

- It supports the *credibility* of the map, in the science community and among users more broadly;
- It supports *reproducibility*, providing sufficient detail on data and methods to enable an independent team to reproduce the work. This helps to ensure that when those directly involved in developing the map move on or retire, a new generation of mapping practitioners can access the work, either reapplying the methods with better data or refining the methods;
- It indicates the *resources* needed to develop the map (e.g. dependencies on certain data, experts, etc.);
- It provides essential information on the ecosystem classification and map classes (ecosystem types) to enable *cross-referencing* to the Global Ecosystem Typology;

- It serves as a form of *institutional memory*, especially if the report documents some of the institutional processes involved in developing the map;
- It provides information that can be valuable for ecosystem mapping practitioners and teams in *other countries*.

Recommended content for a technical report includes:

- Acknowledgements,
- How to cite the document,
- Input data sources,
- Mapping approach and methods,
- Validation approach and methods used to ensure the map is a reasonable representation of ecosystems on the ground,
- Description and rationale of the ecosystem classification,
- Names and descriptions of all ecosystem types, preferably including photographic examples,
- A description of gaps and further work required to improve the map and classification, ideally with some prioritisation,
- A high-quality image of the final map and legend,
- A summary of the process by which the map was developed, for example, institutions involved, and workshops held,
- In appendices: List of workshops and participants.

**** Criteria and standards flag:** To be included in the Global Ecosystems Atlas synthesis map, a national ecosystem map should ideally have a technical report that sets out the data and methods used to develop the map and describes the classification and ecosystem types.

In addition to a technical report, it is ideal to publish relevant aspects of the map development in the formal literature. This helps in documenting the development of the map thoroughly and making it more readily discoverable by other ecosystem mapping practitioners. However, this is not essential, and there is no need to hold up finalising the map and making it available ahead of publishing it in the formal literature

Explanatory material for users

In addition to the technical report, it can be useful to have a short document that explains what the national ecosystem map is, aimed especially at non-technical users. This could include brief information on what a national ecosystem map is with examples of how it has been or could be used for national policy, planning and decision making and to support conservation action, with clear information on how to access the map and associated products.

Providing access to the products

For national ecosystem maps to fulfil their potential uses, they should be consistent with the principles of open science (see Box 4) and the FAIR principles (Findable, Accessible, Interoperable, Re-useable). Ecosystem map developers should familiarise themselves with established and emerging guidelines and standards that aim to enhance the accessibility and usability of science and research outputs.

The suite of national ecosystem map products should be made available from a central and easily accessible source, ideally curated by a credible national entity that is seen as a source of biodiversity information. Access should preferably be through an open-access online platform that allows downloads of reports, high-resolution pictures of maps, and spatial data in a range of appropriate formats to allow wide usage. Having a single reference point helps users to know where to access final, legitimate products and helps to avoid confusion that can arise about multiple versions or revisions of maps and spatial datasets. Sharing products over more accessible platforms such as online citizen science portals and mobile maps accompanied by video tutorials can also build capacity and encourage data sharing back to map curators. Once the map has been published, there should be a clear mechanism for users to provide feedback on the map (for example, if they are aware of inaccuracies), and it is ideal if users are able to contact a person if they have queries on how to use the map. It can be useful to track web traffic and numbers of downloads, to give an indication of which products are being accessed and to enable monitoring of this over time (Drawn from SANBI & UNEP-WCMC, 2024).

Box 4. The principles of open science applied to national ecosystem maps

National ecosystem maps should preferably be consistent with the principles of open science, which aims to promote transparency, sharing, inclusivity, and collaboration. The six principles of open science are:

- **Open methodology** (The methodology for developing the national ecosystem map should be clearly set out in a technical report)
- **Open source** (Any source code used in creating the map should be made freely available for possible modification and redistribution)
- **Open data** (The spatial data products for the map should be made freely available – see notes on licencing below) (Note: This need not mean that all input data used to create the map should be open – in some cases such data may legitimately be considered sensitive, such as data on locations of threatened species)
- **Open access** (All products associated with the national ecosystem map should be available free of charge or other barriers to access)
- **Open peer review** (Relevant if the work is published in a peer reviewed paper)
- **Open educational resources** (Relevant if teaching, learning or research materials are produced based on the national ecosystem map – these should be available free of charge or other barriers to access)

The importance of licencing

The spatial dataset for the national ecosystem map should preferably have an open licence. Typically this would be a Creative Commons licence that requires attribution of the source of the data but does not restrict its use, including for commercial purposes. A Creative Commons Attribution 4.0 International (CC BY 4.0) licence is suitable. Including licence conditions such as ShareAlike (SA) or Noncommercial (NC) can unnecessarily restrict use of the spatial dataset without having a clear benefit. For more information, see Creative Commons Licenses - Creative Commons.

**** Criteria and standards flag:** To be included in the Global Ecosystems Atlas synthesis map, a national ecosystem map should have an open licence.

6 Typical phases in developing a national ecosystem map

Developing a national ecosystem map is a substantial process that usually involves several organisations, many people with a wide range of different expertise, multiple data sources and a range of technological resources. It can be thought of in phases, as shown in Figure 10, with key tasks and outputs for each phase. The phases are not neatly delineated and in practice several of them may run concurrently for good reason.

Timeframes for each phase and the process as a whole can vary greatly depending on the context, the mapping approach taken and the financial and other resources available for the work (with greater resourcing allowing for more intensive work over a shorter period). However, it would be difficult to produce a credible national ecosystem map in less than two years, even working at an accelerated pace. For a more comfortable pace, it makes sense to plan on approximately three years assuming steady progress with no big interruptions.

It is likely that at least one national workshop with key stakeholders and knowledge holders would be held for each phase, with smaller work sessions and meetings as needed. These workshops require careful planning, preparation and facilitation to get the most out of them and ensure good use of participants' time – it is important not to underestimate the time needed for this.

As discussed in Section 2.3, the first version of a national ecosystem map is likely to be exactly that – a first version, with room for improvement over time, in both the classification and the map of ecosystem types. A map with room for improvement is better than no map, so pragmatism is appropriate – aim for a good-enough product and plan for subsequent versions. How does one determine what is "good enough"? *A good-enough national ecosystem map is one that is consistent with the ecosystem concept (see Section 2.3), that is credible to ecologists who have context-specific ecosystem knowledge, and that has legitimacy with key national stakeholders*. Even for the first version, these are important and achievable objectives.

In tackling improvements of the national ecosystem map over successive versions, it can be useful to develop a plan that identifies key uncertainties or areas that are known to need improvement, and prioritise these based on materiality, for example based on where errors or uncertainties may have substantial consequences for people or biodiversity.

Box 5 at the end of this section provides a case study of South Africa's national marine ecosystem map, which illustrates aspects of all phases of developing a national ecosystem map, as well as the process of improvement through successive versions over time.

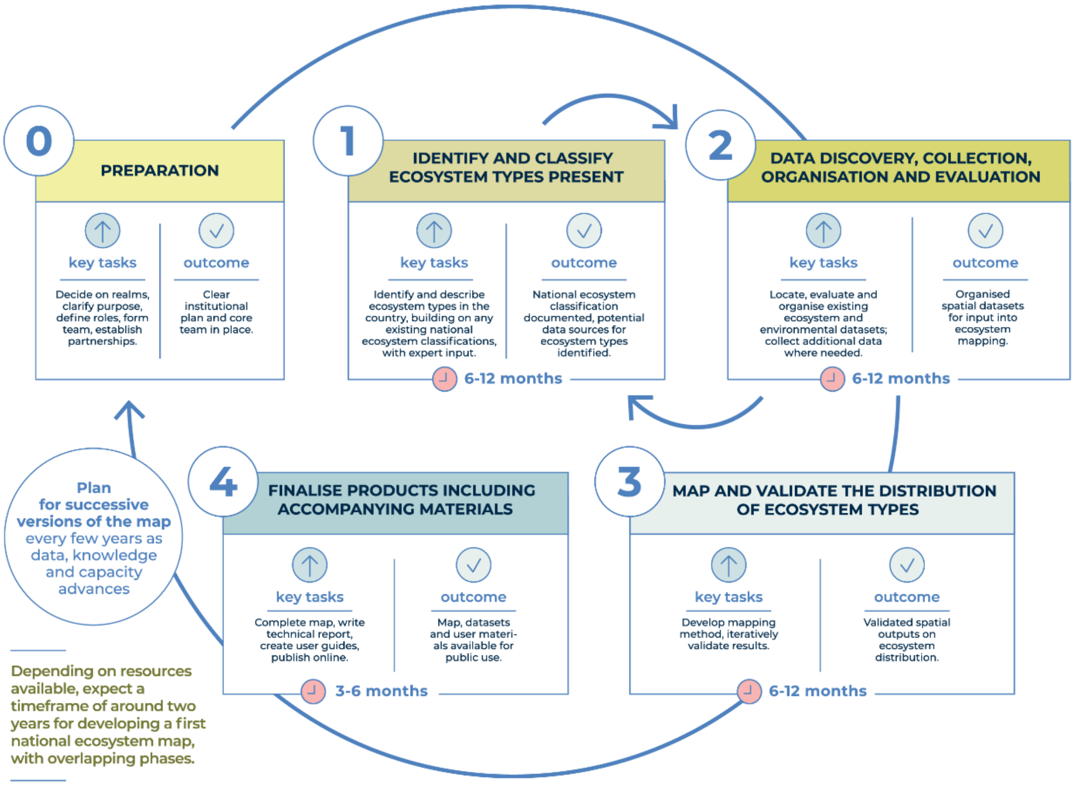


Figure 10. Phases typically involved in developing a national ecosystem map

6.1 Phase 0: Preparation

Key tasks: Decide which realms to focus on; Determine institutional mandates; Determine budget requirements and secure resources; Set up a core team; Put partnership agreements in place if needed. **Main results:** Clear institutional home and arrangements for the work; core team in place.

As an initial starting point, it is important to decide on the scope of the mapping effort in terms of which realms it will cover. As discussed in earlier sections, many national ecosystem maps are realm specific, and for countries new to ecosystem mapping it can be more manageable to start with one or two realms rather than tackling all realms at the same time. Realm-specific national ecosystem maps can eventually be combined into a single integrated national ecosystem map, but there need not be an immediate rush to accomplish this. Priority realms will depend partly on policy needs and may relate to which realms make up the largest proportion of the country's territory. Availability of data and expertise may also be a factor. Clarity early on about which realms are in scope is important for exploring institutional mandates and for ensuring that people with appropriate expertise are included in the process.

In many countries there are likely to be formal mandates in place related to mapping and classifying ecosystems, as discussed further in Section 8. These may be implicit in mandates related to, for example, monitoring and reporting on the state of biodiversity, natural resource management, or related language, rather than explicitly stated as "mapping and classifying ecosystems". Whoever is initiating the development of a national ecosystem map, whether from within or outside government, should clarify which line ministries or public sector agencies may have responsibility for mapping and classifying ecosystems in the realms being addressed, bearing in mind that it may not be the environment ministry and that in some cases mandates might be shared or overlapping. Ministries and agencies to consider in addition to the environment ministry include:

- Ministries dealing with land, water, oceans, fisheries, forestry, agriculture,
- Specialised government agencies, for example for conservation or biodiversity,
- National statistical office (especially if there is a section dealing with environmental and ecosystem accounting),
- Agencies with mandates related to spatial data and mapping,
- Public sector research councils or institutes.

A further level of complexity may be the existence of a combination of national and sub-national mandates, for example in countries where provinces, states or municipalities have a conservation function. In such cases, the best way to involve sub-national government will need careful attention. If provinces or states already have their own ecosystem maps and classifications, these would need to be considered thoroughly in Phases 1, 2 and 3.

Over and above public sector mandates, it is important to consider whether there are universities that have departments, research units or similar with a focus related to ecosystem classification and mapping and that may have researchers who are able to contribute time and expertise. There may be national NGOs or international NGOs with a country office that would be willing to contribute resources and expertise. Indeed, in some cases the development of the national ecosystem map may be initiated by a research institution or NGO, which may be in a position to take the lead on technical aspects of developing the map. In such cases this should always be with the involvement of the mandated national institutions.

Determining budget requirements, securing resources and putting partnership arrangements or agreements in place can take time and patience. In-kind resources, especially contributions of time and expertise, can make all the difference to the viability of the work, especially if there are departments and agencies that have these activities embedded in their mandates and the core functions of staff, or partner organisations who are willing to allocate staff time to the process. In some cases, it may be possible to proceed with some early work such as gathering existing data sources alongside these arrangements being put in place. Hardware and software requirements should also be identified and put in place.

Section 7 discusses the different roles that need to be filled within the national ecosystem mapping team, including co-ordination, technical leadership, ecological expertise, data management and GIS expertise, and administrative support. Team members need not all be in the same organisation. Especially if multiple partners are involved, the importance of good co-ordination cannot be overstressed, and it is useful to have a national co-ordinator in place as soon as possible in the process of setting up the project. Also consider setting up an advisory or reference group or a formal committee to guide the process (see Section 8 for more on governance arrangements).

A further consideration is neighbouring countries. Do any of them have national ecosystem maps? If so, they may have information and lessons to share and may be willing to work jointly to ensure that there is alignment of maps across country borders. Even if this is not possible in the first version of the national ecosystem map, it can be flagged for future work.

Workshops associated with Phase 0: It could be useful to hold a workshop to introduce the project and bring people on board. However, there not be sufficient substance to present at this stage, and it may be better to use a national workshop in Phase 1 to do this.

6.2 Phase 1: Identify ecosystem types likely to be present in the country

Key tasks: Identify ecosystem types likely to be present in the country; Establish a network of ecologists with on-the-ground knowledge to contribute to the national ecosystem map.
Main outputs: Initial national ecosystem classification, described in a document; list of possible data sources for each ecosystem type or groups of ecosystem types.

Identifying ecosystem types that are likely to be present in the country provides an organising framework within which to tackle data collation, modelling and mapping. It is useful to establish a basic hierarchical framework, in which ecosystem types are nested within broader categories that group similar ecosystem types and are useful for summarising ecosystem-related information. The biomes and ecosystem functional groups of the Global Ecosystem Typology (Section 3) can be a useful starting point for the upper levels of the hierarchy, within which national ecosystem types can be nested and refined over time.

It is advisable to investigate whether there are any existing ecosystem-related classifications in place at the national or sub-national level, for the realms that are in scope. If the classes in an existing classification are consistent with the ecosystem concept, these could provide a useful starting point and may be able to be adopted wholly or partly. If they are not considered suitable, it is useful to document the rationale for that decision. Many countries have an existing land cover and/or land use classification. As discussed in Section 2.3, this is not a substitute for an ecosystem classification, and land cover or land use classes in themselves are not a suitable proxy for most natural ecosystem types (even though land cover data may be a useful input for mapping and modelling some ecosystem types).

An initial aim can be to develop a list of ecosystem functional groups (or an equivalent hierarchical level) that are likely to be present, with some description for each one of its expression in the country and if possible a list of possible data sources for these ecosystems. This can help to structure a more detailed review and search for datasets that can be compiled in Phase 2. The descriptions and indicative maps of the ecosystem functional groups in the Global Ecosystem Typology can provide an initial sense of whether ecosystem types in that group are likely to occur in the country. For an example of the outputs of such a process, see Toor et al. (2022) which reports on the process of identifying 33 ecosystem functional groups in the Maldives and describes each of them, laying the basis for more detailed national ecosystem classification and mapping.

At this stage it can be useful also to start to think about different ecosystem types that could be distinguished within each ecosystem functional group. This level of detail might be possible for some ecosystem functional groups but not others. As noted in Section 2.1, early versions of a national ecosystem map may well have varying levels of detail in different parts of the classification and map. In practice, Phase 1 and Phase 3 are usually iterative. As the mapping proceeds, greater clarity will emerge on which ecosystem functional groups and ecosystem types are present.

For agricultural ecosystem types, the IUCN has led the development of guidelines for applying the agricultural ecosystem functional groups in the Global Ecosystem Typology in national ecosystem classifications, including factors that can be used to distinguish between different agricultural ecosystem types within those ecosystem functional groups (Driver & Botts, 2025).

A substantial amount of expert elicitation is involved in this phase. Establishing a network of ecologists with on-the-ground knowledge of the ecosystems in the country, and drawing them into the process of developing the national ecosystem map, can be seen as part of the tasks of Phase 1. See Section 7.6 for more discussion on this.

Workshops associated with Phase 1: Workshop for contributors and potential contributors to introduce the project and start the process of identifying ecosystem functional groups or similar

- Dual aim:
    - To introduce the project and bring them on board,
    - To begin the process of identifying ecosystem functional groups using expert elicitation, and. where possible, also to identify potential data sources for each ecosystem functional group.
- Include ecologists and other relevant experts, including technical staff from ministries and agencies who are likely to have a role to play (e.g. in contributing data and expertise).
- The focus at this stage not necessarily on users, these can be brought in once there is something more tangible with which to engage.

6.3 Phase 2: Data discovery, collection, organisation and evaluation

Key tasks: Locate, compile and evaluate any relevant existing ecosystem maps; Locate, compile and evaluate other relevant spatial datasets as inputs for ecosystem mapping
Main outputs: Organised spatial datasets, including existing ecosystem maps, satellite imagery, environmental variables, field data, other relevant spatial datasets

Ecosystem mapping requires integrating different types of data from a range of sources. Broad categories of data include:

- **Existing ecosystem maps**, including sub-national (for specific areas and/or specific ecosystem types), national, regional and global maps,
- **Earth observation data**, which is increasing available from a growing range of sensors (including spaceborne, airborne and underwater sensors), and products derived from these data,
- **Environmental variables**, such as geology, soils, climate, rainfall, water cover, topography, bathymetry, depth, water temperature, salinity and oxygen data, ocean currents,

- **Field data**, such as species records, phytosociological plot data, confirmed ecosystem occurrences from site visits, sediment samples, trawl samples, dredges and visual surveys,
- **Local knowledge**, including of ecologists, indigenous and local communities,
- **Historical data** such as topographic maps, aerial photographs, landscape photographs and paintings.

In most cases, Earth observation data, other environmental variables and field data need to be brought together in the ecosystem mapping or modelling process, combined with expert judgement based on on-the-ground knowledge of the ecosystem types being mapped to interpret, sense-check and validate the mapping outputs, as illustrated in Figure 11 and discussed further in Section 6.4.

An important aim is to have confirmed records of the location of each ecosystem type. These are essential for a) training of advanced spatial distribution models if these are used (see Section 6.4), and b) validation of draft map outputs. These diagnostic datasets can be compiled from different data sources.

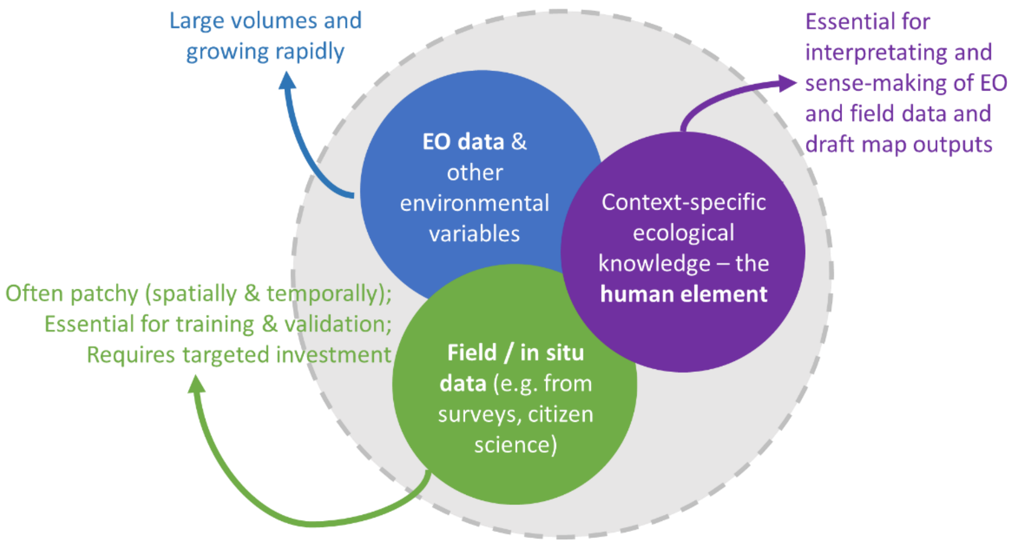


Figure 11. Developing a reliable ecosystem map typically requires data from a range of sources, including Earth observation data and field observations, combined with context-specific ecological knowledge

A search for potential datasets could include a review of available national datasets, literature review, and searches for previously collected field observations that could be collated and organised. Major environmental projects may have datasets behind them that can be accessed. A partnership with a university could be helpful, drawing on students and interns. Wherever possible, it is important to avoid biases towards certain ecosystem types or certain geographic areas, although available data may well be biased towards "charismatic" or "iconic" ecosystem types and places that are more readily accessible. Thorough record keeping of the data search is essential, to demonstrate due diligence and to avoid duplicating effort when further work is done for subsequent versions of the map.

Potential datasets from the categories listed above should be carefully evaluated by ecosystem map developers to understand their genesis, methods of collection and limitations of their use, to determine if they are fit for purpose. This may involve working with dataset owners to better understand the data. Questions for evaluating potential datasets include:

- Do the data represent ecologically meaningful units, consistent with the ecosystem concept?
- Can they be incorporated into the classification approach that has been decided?
- Do the data have sufficient coverage of the area being mapped? If not, are they supplementing or being supplemented by other data?
- Is the mapping scale appropriate?
- Is the source of the data known?
- Does the dataset include estimates of uncertainty?

Field observations may be a limiting factor, as they are often scarce or patchy, with large gaps in coverage and datasets that are out of date. There are various ways to approach the task of gathering field observations, including working with research institutions, NGOs, other partners and citizen scientists, as well as conducting targeted field campaigns. All these approaches require strong co-ordination and data management, as well as guidance in terms of data collection planning and protocols. Citizen science initiatives to gather images and descriptive data for ecosystem types exist in a growing number of countries, for example using the iNaturalist platform.[15] For species records, one approach is to organise a BioBlitz, which is a citizen science effort to gather as many new records as possible for a particular site or set of sites in a short period of time (Bioblitz Guide · iNaturalist). Fine-scale local imagery (e.g. from Google Maps) combined with expert knowledge of the ecosystem types can be used to generate point data, to complement point data from field observations.

It is essential in Phase 2 to document data gaps as well as data that exists, and if possible, to provide some sort of prioritisation of which data gaps are most urgent to address from the point of view of improving the quality of the ecosystem map. This can help to guide investment in data collection to support subsequent versions of the map. Making the data gaps clear can help to stimulate allocation of resources and effort to filling them by a range of partners including research institutions who are keen to contribute to policy relevant products and processes. Identifying data gaps can be done iteratively as draft map outputs are sense-checked and validated, giving information about which areas are least certain. These areas can be targeted for additional fieldwork.

Workshop(s) associated with Phase 2: One of more workshops with ecologists, data owners, government staff, other relevant experts – to review potential data sources. If possible, begin evaluating existing data, identify data gaps per ecosystem type and plan to fill them. With some careful planning, this workshop could include starting to build diagnostic datasets for EFGs. Data gathering and mobilisation efforts should preferably start before these workshops.

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[15] For examples from Africa, see https://www.inaturalist.org/projects/vegmaphoto-s-afr (South Africa), https://www.inaturalist.org/projects/namibian-ecosystems (Namibia) and https://www.inaturalist.org/projects/rwanda-ecosystem-map-photo (Rwanda). For a citizen science example from the United Kingdom see National Biodiversity Network.

6.4 Phase 3: Map and validate the distribution of ecosystem types

Key tasks: Develop and implement a mapping approach; Sense-check and validate draft outputs iteratively involving key knowledge holders. **Main outputs:** Spatial layer representing ecosystem types. (Could be more than one layer, for example if mapping ecosystem types in more than one realm.)

There are various approaches to mapping ecosystem types, and current practice varies across countries and across realms.[16] Nevertheless, different mapping approaches can deliver conceptually equivalent ecosystem maps that can be compared meaningfully and synthesised across different parts of the world. There is no need to promote standardisation of mapping approaches or methods across different contexts as long as there is clarity on the nature of the spatial units that are represented in the map – in this case ecosystem types. These should be conceptually consistent regardless of the mapping approach. Below we discuss two broad mapping approaches and some of the key issues to consider.

We have already noted that a variety of different data sources is typically necessary to map ecosystem types. These data sources can be integrated using different approaches, including modelling the spatial distribution of ecosystems and developing a composite map from multiple input layers. A combination of these approaches is possible, with modelled outputs being one of the input layers into a composite map. Regardless of the mapping approach, key issues include the mapping scale, mutually exclusive delineation of ecosystem types, and the role of expert knowledge.

Ecosystem distribution models

Ecosystem distribution models, as one broad approach to ecosystem mapping, involve selecting and combining a suitable set of spatial proxies to predict the spatial distribution of ecosystems. They utilise the fact that many terrestrial and marine ecosystems have interpretable signatures from different remote sensing platforms. In most cases, it is necessary to apply remote sensing in combination with on-ground observations and environmental data to achieve the most accurate mapping outcomes. New geospatial analysis platforms have made ecosystem distribution modelling more accessible, including by providing access to vast data archives and enabling complex analyses at no cost.

A new generation of ecosystem distribution models that utilise artificial intelligence are developing rapidly. These so-called foundation models use Earth observation data and environmental variables combined with a relatively limited amount of training data to identify and delineate ecosystem types. The quality of the training data is a critical factor in determining the quality of the map outputs. If high quality training data are available or can be generated, using these new generation models can result in significant time savings compared to "traditional" mapping and modelling methods.

[16] This variation in ecosystem mapping approaches has been evident in the process of gathering and cataloguing ecosystem mapping datasets for the Global Ecosystems Atlas proof-of-concept.

Training data consists of confirmed records of the location of an ecosystem type. Possible sources of training data include point localities from existing high-quality ecosystem maps, existing data from field surveys, and annotations from high resolution satellite images. Some open training datasets are available, such as CoasTrain (https://www.coasttrain.org/).

Developing a composite map from multiple input layers

Developing a composite map from multiple input data layers is another broad approach to developing an ecosystem map. The map can be built up from a range of data sources, starting with most reliably mapped and fine-scale features, then filling in broader ones. As noted, the outputs of an ecosystem distribution model could be one of the input layers, to which others are added. For example, detailed national maps of features such as peatlands, rivers and streams, dams, agricultural fields or transport infrastructure may be available from government agencies that have invested substantial resources over many years in their quality. Using such maps can enrich the ecosystem map and also help to generate interest in and support for the mapping effort from other sectors. Especially with this approach, a country with relatively little national data may choose to use existing global maps for specific ecosystem types as input layers, where these maps are considered sufficiently reliable.

In practice, this approach is often used because different ecosystem types require different mapping approaches. Ecosystem distribution models can struggle to differentiate some ecosystem types with any certainty, and other maps can be brought in to resolve this, combined sometimes with verification in the field. It can be useful to have a sense upfront of which ecosystem types are likely to be difficult to map, and to use a combination of qualitative and quantitative methods can be used to tease these apart (see discussion on the role of experts below).

There can be trade-offs between these two broad approaches, with ecosystem distribution models being more easily replicable and repeatable than developing a composite map but having shortcomings especially for ecosystem types that are more difficult to model. These shortcomings can result in substantial uncertainties in the map product, also making it more complicated to map change in ecosystem distribution over time.

Mapping scale

Regardless of the mapping approach taken, it is important to choose an appropriate and practical mapping scale. The scale will help to guide which datasets are suitable for creating the map. Ideally the mapping scale should be sufficiently fine that the map can be used to inform local level planning and decision-making. This may not be possible in early versions of the map, but it something to work towards as the map is improved over time. An appropriate mapping scale depends partly on the characteristics of the ecosystem types being mapped. Some ecosystem types may be driven by ecological processes operating over large landscapes or seascapes while others may be more meaningfully mapped at a finer scale. Hence, ecosystem types can be mapped at different scales in different countries, and even within one country. For example, it may be appropriate to map offshore marine ecosystems at a broader scale than coastal ecosystems, and ecosystem functional groups for which there is more data or a greater need to distinguish between different ecosystem types from a policy or implementation perspective could be mapped more finely.

Mutually exclusive delineation of ecosystem types

Regardless of the mapping approach taken, it is preferable for the delineation of ecosystem types within each realm to be mutually exclusive. This is useful for several applications, and is essential for ecosystem accounting. In the three-dimensional marine realm, benthic (seabed) ecosystems underlie the pelagic ecosystems that make up the water column, so benthic and pelagic ecosystems are typically mapped, assessed and accounted for separately. There may be cases where there are overlaps between ecosystems in different realms (e.g., between wetlands and some terrestrial ecosystem types) – this is not necessarily a problem, as it is fine to have separate maps per realm. If realm maps are stitched together at a later stage, protocols will be needed for dealing with overlaps – deciding which realm trumps others. Bear in mind that the Global Ecosystem Typology includes transitional realms (e.g. Terrestrial-Freshwater) so in many cases transitional ecosystem types are recognised as such. In such cases transitional types can be co-developed and agreed by experts in both realms and represented in both maps using a common name and spatial distribution.

The role of expert knowledge

Regardless of the approach taken, expert knowledge plays a critical role in developing a map product that is credible and legitimate (see Section 7.6). Experts with relevant ecological knowledge can be involved at various stages of the ecosystem classification and mapping process, including in identifying ecosystem types likely to be present (Phase 1), in identifying and evaluation data sources and data gaps (Phase 2), and in ecosystem mapping (Phase 3). Experts should include a mix of generalists with an overview of all or many ecosystem types in the country, or regional experts who focus on particular ecosystem types. Ideally, they should include individuals involved in both research and applied ecology to ensure that the mapping and classification into ecosystem types remains both ecologically sound and practical.

Expert consultation should be iterative until the map is satisfactory. Experts can assist with splitting, combining or revising the spatial units based on their knowledge and judgement, providing additional descriptive data for ecosystem types, and advising on key missing data. In Phase 3, the draft ecosystem mapping outputs should be reviewed by experts. This review is an important part of the iterative refinement of draft map outputs, with sense-checking by experts being an initial form of validation of the ecosystem map. The final draft of the ecosystem map could be reviewed by additional external reviewers.

Validation of map outputs

In addition to expert-based sense-checking, it is preferable for the map to be formally validated. Comparing mapped ecosystem types to independently confirmed observations of the ecosystem types is the most common approach for estimating accuracy (Murray et al., 2018). This can involve ground truthing in the field, and can provide quantitative estimates of map accuracy. Validation methods and results must be documented in the technical report that accompanies the map.

**** Criteria and standards flag:** To be included in the Global Ecosystems Atlas synthesis map, a national ecosystem map should be validated. A range of validation approaches is possible, from expert review through to quantitative statistical approaches. Validation methods and results should be documented in the technical report.

Workshop(s) associated with Phase 3: Workshop to present mapping methods in some detail, review spatial outputs and discuss the process of synthesising/combining these into a single map product. Include ecologists, data owners, government staff, other relevant experts and key users of the map.

6.5 Phase 4: Finalise the map and associated products

Key tasks: Finalise the map product, names and descriptions of ecosystem types, spatial datasets and metadata; Develop technical report and materials to support users; Make products accessible.
Main outputs: Map of ecosystem types with classification, names and descriptions, spatial datasets, metadata, technical report, explanatory material for users, all available for use.

The main task of this phase is to finalise the spatial output from Phase 3 into a beautifully presented map product representing the distribution of ecosystem types. Other tasks include:

- Finalising the spatial datasets and metadata,
- Finalising names and descriptions of ecosystem types,
- Finalising the technical report, which should describe the data and methods used to produce the ecosystem map and include the names and descriptions of the ecosystem types,
- Making the products available on an open platform.

It is ideal to publish the methods in the formal literature, but this may take longer and should not hold up the process of sharing the products.

See Section 5 for more detail on the suite of products that should be finalised and made available in Phase 4.

Workshop associated with Phase 4: Workshop with producers and key users of the map – to advise on presentation of the map and accompanying products to support uptake. May want to walk through key use cases and think about how these could be facilitated.

In addition, consider a launch event of some sort, ideally with high level representation from relevant government departments or agencies.

Box 5. South Africa's national marine ecosystem map illustrates aspects of all phases of developing a national ecosystem map and the process of improving the map through successive versions

South Africa has taken an iterative approach to marine ecosystem mapping over 18 years that has provided a valuable foundation for ecosystem assessment, planning and decision-making, supporting improved ecosystem-based management and protection. Iterative progress has been made in overcoming challenges faced by developing countries, especially in the inaccessible marine realm. Our aim is to report on the approach to produce and improve a national marine ecosystem map to guide other countries facing similar challenges, and to illustrate the impact of even the simplest ecosystem map.

South Africa has produced four map versions, from a rudimentary map of 34 biozones informed by bathymetry data, to the latest version comprising 163 ecosystem types informed by 83 environmental and biodiversity datasets that aligns with the IUCN Global Ecosystem Typology. Data were unlocked through academic and industry collaborations; multi-disciplinary, multi-realm and multi-generational networks of practitioners; and targeted research to address key gaps. To advance toward a more transparent, reproducible and data-driven approach, limitations, barriers and opportunities for improvement were identified. Challenges included limited human and data infrastructure capacity to collate, curate and assimilate many data sources, covering a variety of ecosystem components, methods and scales.

Five key lessons that are of relevance for others working to advance ecosystem classification and mapping, were distilled. These include (1) the benefits of iterative improvement; (2) the value of fostering relationships among a co-ordinated network of practitioners including early-career researchers; (3) strategically prioritizing and leveraging resources to build and curate key foundational biodiversity datasets and understand drivers of biodiversity pattern; (4) the need for developing, transferring and applying capacity and tools that enhance data quality, analytical workflows and outputs; and (5) the application of new technology and emerging statistical tools to improve the classification and prediction of biodiversity pattern.

South Africa’s map of marine ecosystem types has been successfully applied in spatial biodiversity assessment, prioritization to support protected area expansion and marine spatial planning. These successes demonstrate the value of a co-ordinated network of practitioners who continually build an evidence base and iteratively improve ecosystem mapping while simultaneously growing ecological knowledge and informing changing priorities and policy.

Source: Abstract from Sink et al. 2023. Iterative mapping of marine ecosystems for spatial status assessment, prioritization, and decision support. *Front. Ecol. Evol.* 11:1108118. doi: 10.3389/fevo.2023.1108118

7 Developing a national ecosystem map requires a team

There are many ways to configure a team of people to work on developing a national ecosystem map. How to go about doing this will depend on a range of factors including but not limited to the organisation from which the work is being led, whether there are existing staff who will integrate this work into their current roles and whether consultants will be involved (in practice it is often a combination of both), the budget available, and the extent to which it is possible to draw on in-kind expertise from people in other organisations.

This range of factors notwithstanding, it is possible to identify different roles that will need to be fulfilled to successfully develop a national ecosystem map, shown in Figure 12. We have taken the approach here of setting out these roles in a somewhat stylised way, with a series of responsibilities, skills and expertise associated with each role. Regardless of the exact configuration of people, it is important to ensure that all these responsibilities are allocated in some way among the team and that these skillsets and expertise exist within the team. Depending on capacity constraints and skill profiles of those involved, one person may be able to fulfil more than one role.

In addition to the core team, it is essential to involve ecologists who have firsthand knowledge of the ecosystems that are being classified and mapped. Their role is discussed in Section 6 in relation to the phases of developing the map, and in Section 7.6.

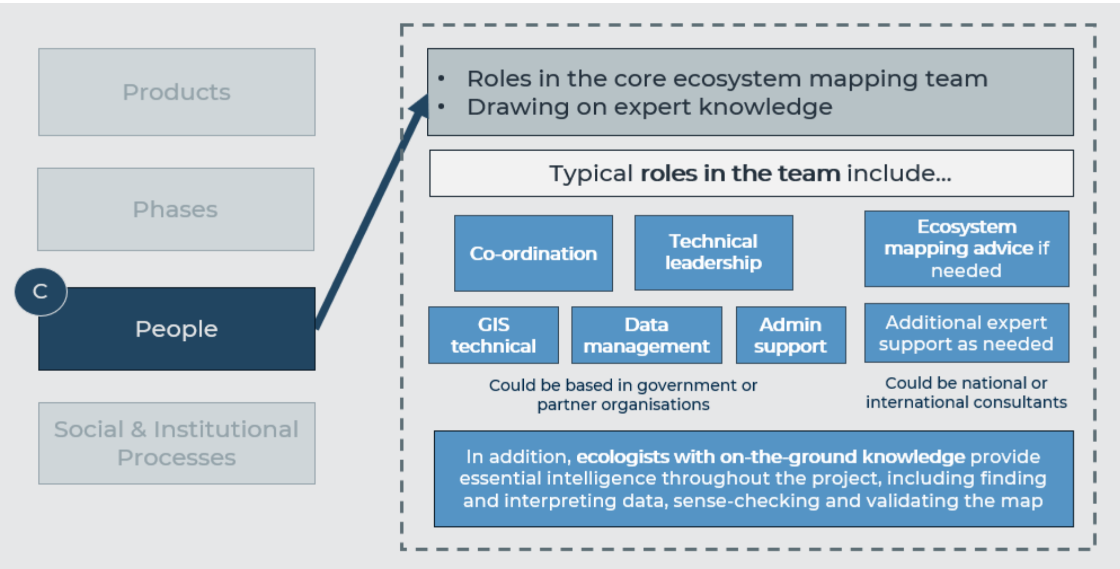

Figure 12. Typical roles in a national ecosystem mapping team

7.1 The role of national co-ordination

Strong co-ordination is vital for the success of a national ecosystem mapping project – it is not possible to overstate the importance of this role, which holds together the many moving parts of the process. Ideally a full-time co-ordinator is required for a national ecosystem mapping project, especially if it is being done for the first time. Depending on the timeframes of the work, this could be at least a two- to three-year role. It is also possible for the role to be part-time, combined with other (preferably related) responsibilities.

The national co-ordinator should be based in an institution in the country, preferably the institution that has the mandate for ecosystem mapping and classification in the realm concerned (see Section 6.1). If this is not possible, the national co-ordinator could be based in a related government department or agency or in a partner organisation such as an NGO or research institution (which may have received funding to develop a national ecosystem map), ideally with a clear memorandum of understanding or collaboration agreement in place. The national co-ordinator could initially be supported by an international expert with relevant country-level experience.

Responsibilities of a national co-ordinator would typically include:

- Managing the project (work planning, budgeting etc),
- Convening regular team meetings,
- Organising workshops and documenting the outcomes (or at least overseeing this),
- Convening additional meetings with contributors to the national ecosystem map as needed,
- Co-ordinating data gathering and mobilisation (this could be of existing or new data, including co-ordinating teams involved in data gathering in the field),
- Ongoing liaison with key stakeholders, including in related national and subnational initiatives and relevant global initiatives,
- Working with the national technical lead and ecosystem mapping advisor to organise the suite of products associated with the national ecosystem map (see Section 5),
- Exploring options for making the products available to users, for example through an existing government online repository (see Section 5), and working with the national technical lead to arrange this,
- Communicating the launch of national ecosystem map on its completion.

Skills and experience required for the national co-ordination role include:

- Project management,
- Stakeholder engagement,
- Workshop design and facilitation,
- Ideally some knowledge of the national ecological context,
- Ideally some familiarity with GIS, remote sensing and related technologies, although in-depth knowledge is not required,
- Knowledge of the national institutional context,
- Writing and presentation skills.

7.2 The role of national technical lead

The development of a national ecosystem map requires a person to lead the science and technical aspects of the process, holding the responsibility for producing the map and the accompanying technical products. In most cases it is not realistic for this person to play the role of co-ordinator at the same time, and the skillsets required for these roles differ. Depending on the timeframes of the work, the technical lead could be at least a two- to three-year role. It is also possible for the role to be part-time, combined with other (preferably related) responsibilities.

Ideally the national technical lead would be based in an institution in the country – either in government or a partner organisation (e.g. NGO, research institution). In a country that is relatively new to ecosystem mapping and classification, there may not be someone who has the full set of skills and expertise needed to play the role of national technical lead. In such a case, it may be possible to identify a person who has some of the technical skills required and who could grow into the full role with support from an ecosystem mapping advisor.

In many countries, different technical leads would be needed for national ecosystem maps dealing with different realms, whether these are developed concurrently or sequentially. It is important for technical leads for different realms to be in regular contact, for example to align approaches used for ecosystem classification and to ensure that transitional realms and neighbouring ecosystem types across different realms are sensibly dealt with from both a classification and mapping perspective.

Responsibilities of the national technical lead include:

- Leading on locating and compiling input data from a range of sources (see Section 6.3),
- Leading on data management,
- Guiding field work and expert elicitations to ensure data collected is suitable for use in the mapping of ecosystems,
- Leading on developing the ecosystem classification, including descriptions of each ecosystem type identified in the map, in collaboration with relevant experts (see Section 6.2),
- Leading the development of the national ecosystem map, which includes developing a mapping pipeline, producing map products, validating any map drafts and overseeing the publication of any project outputs (see Section 6.4),
- Leading on writing the technical report and metadata,
- Co-ordinating and overseeing the work of data manager and GIS technicians if needed,
- Working closely with the national co-ordinator in designing workshops, including presenting and co-facilitating where appropriate,
- Working closely with the national co-ordinator to ensure that the full suite of products associated with the national ecosystem map is readily available to users.

Skills and experience required for the role of national technical lead include:

- Advanced GIS and spatial analysis skills,
- Expert knowledge of ecosystems in the country concerned,
- Experience in environmental mapping, such as remote sensing classifications, in the realms being included in the map,
- Demonstrated experience overseeing the production of spatial data products such as maps of ecosystem types,
- An ability to interact with others in technical analysis pipelines, such as image providers and other collaborators,
- Communication skills, and an ability to work in a collaborative team.

7.3 The role of ecosystem mapping advice

Many countries that are new to ecosystem mapping and classification will require support from external consultants or advisors, who should work closely with the core national team. One or more ecosystem mapping advisors with relevant technical expertise as well as knowledge of the ecological context can be an essential complement to the national team. Their role should include building capacity in the national team and especially the national technical lead, laying the basis for fully embedding the further development of the map in national institutions. The advisory role could be fulfilled by different people with insights into different areas geographic areas within the national map. It does not replace the need to involve a network of ecologists who have firsthand knowledge of the ecosystems that are being classified and mapped.

Responsibilities of an ecosystem mapping advisor include:

- Providing technical direction on development of the national ecosystem map,
- Providing expertise and experience in developing and delivering large-scale ecosystem mapping projects, supporting the national technical lead where needed,
- Building capacity of technical members of the team,
- Supporting the national co-ordinator in convening workshops where needed, for example helping with planning and presenting.

Skills and experience required for the role of ecosystem mapping advisor include:

- Demonstrated experience with developing ecosystem classifications and maps, using approaches appropriate for the context (for example, integrating earth observation-based imagery with other forms of data),
- Knowledge of the ecological context in the country and in the realms being included in the map,
- Expertise in applying the Global Ecosystem Typology at the national level,
- Demonstrated ability to build technical expertise of relatively less experienced colleagues.

7.4 The roles of data management and GIS technician

There will usually be a need for a data manager and one or more GIS technicians to support the national technical lead, including in compiling and managing relevant spatial data. As discussed in Sections 5 and 6.3, it is important to build a well organised set of spatial datasets, including input and output layers, for the ecosystem map to be replicable and updatable. Data management and technical GIS functions could be based in government or in a partner organisation.

Responsibilities related to data management and GIS work include:

- Conducting data processing,
- Developing metadata,
- Coordinating data contributions,
- Conducting any pre- or post-processing,
- Implementing the validation process for the ecosystem map.

Skills should include high-level GIS skills, with an ability to operate common geospatial software such as ArcGIS, QGIS, Google Earth Engine etc.

7.5 The role of administrative support

Good administrative support is vital to the process of developing a national ecosystem map. For example, administrative processes to support partnership agreements, flow of funds and procurement processes can be complex and time consuming. While some meetings can be conducted online, the development of a national ecosystem map will necessarily involve several national workshops, often requiring travel of participants from different parts of the country. One or more able administrators to support the ecosystem mapping team, working closely with the national coordinator, can help to ensure steady progress.

7.6 Involvement of ecologists with on-the-ground experience

In addition to the core national team and expert advisor(s), ecologists with on-the-ground knowledge provide essential intelligence throughout the project, including finding and interpreting data, sense-checking and validating the spatial outputs, as discussed in Section 6. These people could be formally trained ecosystem scientists but need not necessarily be, and could include local and indigenous knowledge holders. What is essential is extensive experience in the field acquiring first-hand knowledge of the ecosystems to be classified and mapped.

These experts and knowledge holders may be based in universities or other research institutions, in government departments or agencies (at national, subnational or local level), in NGOs or community-based organisations. Some of them may be independent consultants. Experts based in universities and in government may be easiest to draw on if they are able to allocate paid work time to being involved in the national ecosystem mapping process. Experts based in NGOs or community-based organisations or working in the private sector may be willing to contribute time, with or without remuneration – this would need to be discussed on a case-by-case basis. The opportunity to contribute to an impactful national process and to collaborate with like-minded colleagues can be a significant motivating factor for experts, who are often eager to contribute their knowledge and expertise, especially if workshops and other engagements are well organised with a clear purpose.

It is not simply the involvement of ecologists with on-the-ground experience that is important, but also building consensus among them about the approach taken to developing the national ecosystem map and the resulting classification and map product. Different experts may have different views, sometimes strongly held, and bringing these together through facilitated conversation and discussion about the details of draft map products and the associated classification is effort well spent. Sufficient time should be allocated for this – rushed workshops or sporadic opportunities for interaction are less likely to be fruitful. Consensus among the ecological community will strengthen the credibility and legitimacy of the national ecosystem map, especially when it comes to legislative and regulatory applications that could be subject to legal challenge. The science community should be able to stand behind the map with confidence. Any disparate views that remain after discussion and consultation should be carefully documented in the technical report, and decisions that are implemented in the map should be supported by evidence.

For national ecosystem mapping teams who are unsure how to access and mobilise a network of contributors with ecological knowledge, it can help to identify an initial handful of people who may in turn be able to recommend others from their networks. Members of the ecosystem mapping team could present the work (even if still at early stages) at relevant conferences or workshops and invite involvement and contributions. A scan of relevant literature on biomes or ecosystem types in the country could yield relevant experts to contact. Much expertise sits within ecology and biology departments at universities, and the research interests of academics are often listed on their profiles along with contact details. Many researchers can be approached in this way. Ecosystem mapping and classification outputs can be published as papers (e.g. the description of an ecosystem type, or a group of types in a region can be a short communication in a local journal), which can provide an incentive for researchers to contribute their time and knowledge.

8 Institutional and social processes are key to success

Institutional and social processes are central to developing a national ecosystem map, as much as the technical processes discussed in earlier sections. They include the formal and informal policies and arrangements that enable or facilitate (or in some cases impede) the work, as well as the softer aspects such as relationships within the team and with the wider community of contributors. In this section we outline some institutional and relationship issues to consider and discuss the potential for developing a community of practice at the national level to support ecosystem mapping and classification and its range of applications.

Institutional and governance considerations

As discussed in Section 6.1, part of setting up the process to develop a national ecosystem map involves exploring and clarifying institutional mandates. It is preferable to identify a mandated public sector institution to lead the development of an ecosystem map for each realm as early as possible in the process. Often this will be the environment ministry or an agency related to ministry. However, especially for the freshwater and marine realms, the primary mandate could lie elsewhere, for example in the water ministry or fisheries ministry. In some cases, making matters more complex, the mandate for developing national ecosystem map may be shared between more than one ministry or agency, without an obvious primary home for the map. For example, the mandate for mapping, assessing and monitoring freshwater ecosystems (rivers and wetlands) may lie with the water ministry, while the environment ministry is responsible for ecosystems in general, in principle including freshwater ecosystems. In such a case, officials and decision makers would need to discuss and decide who will take the lead on a national ecosystem map for the freshwater realm. Even if ecosystem maps for all realms are not tackled at once, it is useful to be aware of which ministries or organisations could take the lead for each realm in future.

In addition to ministries and agencies whose primary purpose is directly related to the environment and ecosystems, others that may have an important link to ecosystem classification and mapping include: national statistical offices, especially if they have or intend to develop a programme of work on ecosystem accounting; ministries of agriculture, with whom collaboration on classifying and mapping agricultural ecosystems is especially important; and agencies mandated to develop and maintain the country's spatial data infrastructure. Integrating a national ecosystem map in the national spatial data infrastructure can facilitate its uptake in various national processes and is something to work towards.

From the start, it is important for the work of developing a national ecosystem map to be seen not just as a once-off project but as a process to be embedded in national institutions. A clear institutional home for the map helps to institutionalise the process of maintaining and updating the map, enabling the allocation of resources to this. It also contributes to the credibility and legitimacy of the map, enhancing uptake in policy, planning and decision-making, both inside government and more widely. Further, a clear lead institution can facilitate the establishment of partnership arrangements that bring in other organisations and strengthen the case for raising funds for the work.

The role of co-ordinating the development of the ecosystem map is key to success and should preferably sit within the mandated institution, as discussed in Section 7.1. However, this role could be located in a partner organisation that works closely with the mandated institution. If national ecosystem mapping for different realms is led from different institutions, strong collaboration and good working relationships between the coordinators for each realm are essential.

Collaboration between institutions, departments and agencies with mandates related to ecosystem mapping can be built as part of the process of developing a national ecosystem map – it need not be a prerequisite for making a start. In fact, a national ecosystem mapping project can be a powerful catalyst for greater institutional collaboration and for building new working relationships and networks that are purpose driven. Building this collaboration can help to lay the basis for periodic improvements and updates of the map, and for eventually stitching together the maps from different realms into an integrated national map that covers the entire national territory.

There is no one-size-fits-all approach to governance arrangements for a national ecosystem mapping process, but some form of advisory or steering structure can play a valuable role in guiding the process, helping to embed it institutionally and to foster partnerships. One option is to start with an informal advisory group or reference group, and to develop more formal governance structures and protocols over time, as the roles and needs from such a structure become clearer. The example from New Zealand in Box 6 provides an example of this approach. In other cases, depending on the institutional and cultural context, more formal arrangements may be appropriate from the start.

Box 6. An example from New Zealand of governance arrangements for national ecosystem classification and mapping

National ecosystem classification and mapping often evolves though time, with different approaches and classifications used in different realms. New Zealand offers a valuable case study on the benefits of investing in establishing national governance structures and inclusive processes for ecosystem classification and mapping across all realms.

Even though some of New Zealand's ecological domains had their own ecosystem classification systems prior to 2024, these lacked consistency and there was no single overarching classification system that could be used for national and sub-national purposes. This led to a national initiative to establish a national ecosystem typology (https://environment.govt.nz/facts-and-science/biodiversity/national-ecosystem-typology/).

The New Zealand Ministry of the Environment ran workshops with stakeholders and end-users to identify the principles of a good typology and commissioned a comprehensive study to review existing ecosystem classifications based on these principles, learning from other countries around the world. The outcome of this effort was the adoption of Levels 1-3 of the Global Ecosystem Typology as the best system for international reporting obligations and a broad range of applications nationally and regionally. Further work is being carried out to populate the lower levels of the Global Ecosystem Typology.

Led by the Ministry for the Environment – one of the government departments contributing to national commitments to the Convention on Biological Diversity (CBD) and the Inter-governmental science-policy Platform for Biodiversity and Ecosystem Services (IPBES) – ecosystem mapping in New Zealand involves central government agencies responsible for environment, conservation, fisheries, agriculture, as well as local government authorities (councils). The technical work and advice has come from multiple independent science agencies (Public Research Organisations) with specific domain expertise on the terrestrial and wetland realms, freshwater and marine realms, and subterranean ground water systems.

These efforts are invaluable for New Zealand to align to international biodiversity commitments, while also building a strong foundation for national conservation, land-use planning, marine spatial planning and research.

For more information, see: Sprague, R.I. & Wiser, S.K. 2024 *Investigating a unifying ecosystem typology for all of New Zealand*. Contract Report: LC4514 to the Ministry for the Environment. Manaaki Whenua – Landcare Research.

Relationships

In addition to suitable advisory and governance arrangements, good working relationships and trust among members of the core team are critical success factors. Especially if team members are distributed across different organisations and different parts of the country, it is important to pay attention to this, with sufficient opportunities for team members to meet regularly, ideally not only virtually but also in-person. If external experts are brought in as consultants to assist the national team, the social process of integrating these external people into the team requires extra care. External experts are likely to have to demonstrate their own knowledge and understanding of the national context as well as respect for the knowledge that exists within the country to gain the trust of in-country colleagues.

More broadly than the core team, working relationships and trust with data providers in a range of organisations and the community of experts involved can be make-or-break for mobilising the data and expertise needed to produce a credible map. These relationships and networks need not pre-exist the development of the national ecosystem map – they can be developed along the way. The co-ordinator and technical lead can greatly [facilitate] the development of a network of committed contributors from diverse sectors.

Communities of practice

The process of developing and maintaining a national ecosystem map can stimulate the formation of a community of practice among those directly involved as well as users involved in various applications of the map, as people interact regularly, build working relationships and share knowledge and experience.

Establishing a strong community of practice promotes communication amongst a group of practitioners within a country, supporting peer-to-peer learning and consensus building. Regular forums, learning exchanges and other opportunities to build working relationships and communication channels can help to improve the technical and scientific methods used for ecosystem mapping, as well as exploring how uptake of the map in various applications can be enabled and strengthened. Communities of practice provide a sounding board for innovation and a peer review mechanism for practitioners, as well as a platform for the development of human capacity and a common place of learning for new practitioners. This contributes to the continuity between projects, adaptive learning, and improvement in the quality of ecosystem maps over time. The institution leading the development of a national ecosystem map can play a key role in convening such a community of practice, for example through an annual forum or other meetings, events or working groups, or this role could be played by a partner organisation. (SANBI & UNEP-WCMC, 2024)

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Glossary

Anthropogenic ecosystems	Ecosystems created and maintained through human activity, where human activities are the primary determinant of the ecosystem's composition, structure and. (Drawn from Typology - Global Ecosystem Typology)
Baseline ecosystem map	A map of the distribution of ecosystem types at a certain time. Depending on the approach taken, the baseline could represent the *contemporary distribution* (present day or relatively recent) or *historical distribution* of ecosystems, or another agreed date (for example, related to the first availability of certain key datasets). A baseline ecosystem map is an essential starting point for mapping ecosystem change. (Section 2.1)
Biodiversity	Biological diversity means the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part; this includes diversity within species, between species and of ecosystems. (Article 2 of the CBD)
Biome	A component of a realm, united by one or a few common major ecological drivers that regulate major ecosystem functions and ecological processes. Level 2 of the Global Ecosystem Typology, derived through top-down subdivision of realms. (Typology - Global Ecosystem Typology)
Contemporary distribution (of ecosystem types)	The present-day or relatively recent spatial distribution of ecosystem types. The date may represent a period of, say, a few years rather than strictly one particular year. Contrast with *Historical distribution*. (Section 2.1)
Ecoregion	A broad biogeographic region containing multiple ecosystem types, intended to represent the broad distribution of biodiversity rather than both compositional and functional attributes of ecosystem types (Keith et al., 2022)
Ecosystem	A dynamic complex of plant, animal and micro-organism communities and their non-living environment interacting as a functional unit. (Article 2 of the CBD)
Ecosystem condition	The quality of an ecosystem measured in terms of its abiotic and biotic characteristics. Condition is assessed with respect to an ecosystem's composition, structure and function which, in turn, underpin the integrity of the ecosystem (SEEA Ecosystem Accounting). May also be referred to as ecological condition.
Ecosystem functional group	A groups of related ecosystem types within a biome that share common ecological drivers and ecosystem properties. Level 3 of the Global Ecosystem Typology, derived through top-down subdivision of biomes. (Typology - Global Ecosystem Typology)

Ecosystem map	In this context, used as shorthand for a classification and map of the spatial distribution of ecosystem types. Also see *national ecosystem map*. (Section 2.1)
Ecosystem type	A type of ecosystem distinguished from other types by its characteristic functional, structural and compositional properties (IUCN, 2025). An ecosystem type is identified and delineated as part of a hierarchical classification system, based on biotic and abiotic factors.
Extent (of an ecosystem type)	The total area of all occurrences of an ecosystem type, for example in hectares or square kilometres. Ecosystem extent is a metric derived from a map of the spatial distribution of ecosystem types. Also see *Spatial distribution*. (Section 2.1) In SEEA Ecosystem Accounting, ecosystem extent is defined as the size of an ecosystem asset, where ecosystem assets are contiguous spaces of a specific ecosystem type. The extent of an ecosystem type is the combined extent of all ecosystem assets of that type. (UN et al., 2024) Ecosystem assets are effectively occurrences of an ecosystem type, so these two definitions are conceptually consistent.
Historical distribution (of ecosystem types)	The spatial distribution of ecosystem types prior to major human modification of the landscape or seascape. Often pegged to circa 1750, the start of industrial development, but not intended to represent a precise date. Sometimes referred to as "potential distribution". Contrast with *Contemporary distribution*. (Section 2.1)
Improvement (of an ecosystem map)	Improvement in the quality of a national ecosystem map, through changes to the classification of ecosystem types and/or refinement of the delineation of ecosystem types. Also see *Update*. (Section 2.1)
Land cover	The observed physical cover on the Earth's surface, including vegetation (natural or planted) and human constructions (FAO). Land cover datasets are often organised into land cover classes in a hierarchical classification. These classes are conceptually distinct from and do not correspond with ecosystem types in general, although they may be a reasonable correspondence with anthropogenic ecosystem types.
Land use	Characterized by the arrangements, activities and inputs people undertake in a certain land cover type to produce, change, or maintain it (FAO). Land uses may be organised into land use classes in a hierarchical classification. These classes are conceptually distinct from and do not correspond to ecosystem types in general, although there may be a reasonable correspondence with anthropogenic ecosystem types.

National ecosystem map	A classification and map of the spatial distribution of ecosystem types in a country. The map shows the spatial distribution (geographic locations) of the ecosystem types that occur in the landscape or seascape, and the classification provides a hierarchy that differentiates ecosystems at different levels, with names and descriptions of distinct ecosystem types. (Section 2.1)
Natural ecosystems	A broad category of ecosystems, contrasted with anthropogenic ecosystems. The term 'natural' does not imply unimpacted by humans, and the composition, structure and functioning of most natural ecosystems have been modified to varying degrees through human activity or its direct consequences. If the characteristic functional and structural properties of the ecosystem type are still recognisable and at least some of the key native biota are still present, the ecosystem is considered part of the broad category of natural ecosystems rather than an anthropogenic ecosystem.
Realm	One of five major components of the biosphere that differ fundamentally in ecosystem organisation and function: terrestrial, freshwater, marine, subterranean, atmospheric, and combinations of these (transitional realms). Level 1 of the Global Ecosystem Typology. (Typology - Global Ecosystem Typology)
Regional ecosystem subgroup	An ecoregional expression of an ecosystem functional group. Level 4 of the Global Ecosystem Typology, derived through top-down subdivision of ecosystem functional groups. (Typology - Global Ecosystem Typology)
Semi-natural ecosystems	The term semi-natural can be used in two ways in relation to ecosystems. It is widely used to describe a condition state of a natural ecosystem, in which composition and structure have been modified but ecosystem function is still largely intact, and the natural ecosystem is still recognisably present. Semi-natural condition would often be found in portions of the distribution of a natural ecosystem type rather than across its entire area. The term semi-natural is also sometimes used, especially in the European context, to describe anthropogenic ecosystem types that have been transformed through human management into pastures or meadows that retain local indigenous species but from which woody components have been largely removed. Without ongoing human management these ecosystems would generally revert to tree-dominated ecosystem types. In this second sense, semi-natural is a descriptor of an ecosystem type rather than an ecosystem condition state. (Section 2.1)
Spatial distribution (of an ecosystem type)	The geographic location(s) where an ecosystem type occurs in the landscape or seascape. Also see *Extent*, a metric derived from a map of the spatial distribution of ecosystem types. (Section 2.1)

Update (of an ecosystem map)	An update to reflect changes in the distribution of ecosystem types over time. Also see *Improvement*. (Section 2.1)

Appendix: Overview of criteria and standards for inclusion of ecosystem maps in the Global Ecosystems Atlas synthesis map

The Global Ecosystems Atlas is an online platform that includes a synthesis map of the current distribution of all 110 ecosystem functional groups in the Global Ecosystem Typology. Where possible, the Atlas synthesis map is based on existing high-quality maps of ecosystem types, including national ecosystem maps, regional ecosystem maps and ecosystem-specific global maps. For more information visit Global Ecosystems Atlas.

During 2024, a proof-of-concept of the Atlas was developed, including an initial version of the synthesis map. To be included in the Atlas synthesis map, an existing ecosystem map needed to meet several criteria and standards, described below, to ensure it was suitable for representing ecosystem functional groups and of good quality. As the development of the Atlas progresses, these criteria and standards will be further developed and elucidated.

Alignment with the ecosystem concept

Map classes in the source dataset should represent ecosystems as defined by the CBD (see Section 2.3). This is an essential starting point for cross-referencing the map classes to ecosystem functional groups in the Global Ecosystem Typology. There are various datasets representing concepts that may be partially related to ecosystems but that are not sufficiently conceptually aligned to be meaningfully cross-referenced to ecosystem functional groups. Such datasets would not be eligible for inclusion in the Atlas synthesis map. In some cases, some of the classes in a source dataset may represent ecosystems while others do not. In these cases, the classes that do represent ecosystems could be included in in the Atlas synthesis map, subject to meeting the other criteria and standards. The IUCN has developed standards, methods and guidelines for cross-referencing ecosystem classifications and maps to the Global Ecosystem Typology (Keith et al., 2025), which will allow this criterion to be objectively evaluated.

Technical documentation

The source dataset should be accompanied by thorough technical documentation that describes the *data and methods* used to develop the ecosystem map and who was involved in the process. The technical documentation should set out the *ecosystem classification*, including a name and description for each map class (ecosystem type). Usually this documentation would take the form of a technical report, and may also include peer-reviewed publications.

Metadata

The spatial dataset representing the distribution of ecosystems should be accompanied by adequate metadata that includes important details of the dataset, such as date of production, version, etc.

Validation

Map classes in the source dataset should have been validated to assess how accurately they represent ecosystems present on the ground, and the validation process must be described in the technical documentation. A range of validation approaches may be used, from expert review through to quantitative statistical approaches. Validation methods and results should be included in the technical report.

Currency

The source dataset should represent the current distribution of ecosystems. This means it should preferably have been recently developed or updated. There is no fixed cut-off year for datasets to be included in the Atlas synthesis map, as a range of factors will determine whether a particular dataset can be considered sufficiently recent. For example, for ecosystem types that are unlikely to undergo rapid change, such as deep seabed (benthic) ecosystems, an older map may be sufficiently reliable. For ecosystems in areas subject to rapid development and expansion of anthropogenic ecosystems, a map older than a year may be insufficiently reliable. As a rule of thumb, datasets older than ten years are treated with caution and their inclusion in the Atlas synthesis map would need to be clearly motivated. As ecosystem mapping efforts around the world increase in pace and accuracy, this threshold will be reviewed.

Spatial resolution

Spatial resolution of source datasets is assessed relative to the spatial resolution of the Atlas synthesis map. This was 100m for the Atlas proof-of-concept developed in 2024. Source datasets in raster format with coarser resolution than the Atlas synthesis map may not be suitable for inclusion in the synthesis map. However, for certain ecosystems, such as pelagic and deep-sea ecosystems, much coarser resolutions may be sufficient. Decisions about whether the spatial resolution of a source dataset is suitable for the Atlas are made with reference to a range of considerations including the ecosystem type, format, data availability, and pace of change in the ecosystem. In principle the Atlas will always seek to use the finest scale data available, depending on meeting the other criteria above.

Licencing and open data

The source dataset should be freely available for use with an open licence. Typically this would be a Creative Commons licence that requires attribution of the source of the data but does not restrict its use, including for commercial purposes. Datasets that were included in the synthesis map for the Atlas proof-of-concept typically had a Creative Commons Attribution 4.0 International (CC BY 4.0) licence.

Involvement of mandated institutions

For source datasets representing national ecosystem maps, it is preferable for the relevant mandated government institution to be the custodian of the map. In cases where national ecosystem maps have been developed by research institutions, NGOs or other organisations, it is important that relevant national departments or agencies are aware of the map and consider it credible and legitimate. This in turn supports the use of the Atlas synthesis map for applications such as generating headline indicators for the Global Biodiversity Framework and ecosystem metrics for a range of public and private sector applications that require the confidence of governments. This criterion is evaluated on a case-by-case basis, allowing for complexity and context-specific factors.