Assessing ecosystems and their services in LIFE projects

A guide for beneficiaries

Introduction

With the adoption in 2011 of the European Union (EU) Biodiversity Strategy to 2020, halting the loss of biodiversity and ecosystem services in Europe was clearly set as priority of the EU. EU nature legislation, most notably the Birds Directive and the Habitats Directive, forms the backbone of the EU biodiversity policy. Healthy ecosystems are also important to address climate adaptation and mitigation challenges.

One of the policy objectives to be achieved by the LIFE projects is to improve the condition of ecosystems that are relevant to their area of intervention so as to increase their capacity to deliver ecosystem services. In the LIFE programme, all LIFE Nature and Biodiversity projects financed since 2011 are requested to include an action aimed at assessing the project's impact on ecosystems and their services. In other strands of the programme this requirement is not present. Yet, the assessment of ecosystem services is relevant and often carried out also in a number of Climate and Environment projects.

The assessment of ecosystems and their services is an added value of LIFE projects. The assessment results can help explain better to the general public and stakeholders the multiple benefits of LIFE projects in connection to society and the economy with which they interface. This understanding also supports the importance of investing in LIFE projects to society.

For many LIFE projects carrying out an ecosystem services assessment is a novelty and a challenge. A survey held in the beginning of 2017 revealed that only few projects have a clear understanding of ecosystem services and even less of their assessment. Presenting the results of the assessment in the LIFE Key Project Indicators (KPI) Webtool is also often not clear for beneficiaries.

During a LIFE platform meeting on ecosystem services, organised in Estonia in May 2017 and attended by LIFE projects financed in all strands, it became evident that there is a great level of heterogeneity in the way in which LIFE projects assess ecosystem services. The need for guidance on this task was therefore considered.

This document responds to that need. It clarifies key concepts and offers an easy method to implement ecosystem services assessments according to the analytical framework developed under the EU Mapping and Assessment of Ecosystems and their Services (MAES) initiative[1]. Some guidance on how to complete the KPI Webtool is also given.

The current guide has four main components:

1. An introduction to key concepts and methodology.
2. The description of a simple approach to assess ecosystem services applicable to all LIFE projects independently from the method used to quantify them.
3. Guidance on how to complete the relevant sections in the LIFE KPI database.
4. A selection of further resources.

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[1]http://ec.europa.eu/environment/nature/knowledge/ecosystem_assessment/index_en.htm

1. Understanding ecosystem services: key concepts

Ecosystem services are the contributions of ecosystems to benefits obtained in economic, social, cultural and other human activities (based on TEEB 2010 & SEEA-EEA, 2012)[2]. They are manifold, ranging from erosion reduction or flood control to the provision of timber or food. Ecosystem services are categorised into three main groups (see also Section 1.3):

1. Provisioning services (e.g. food, fuel, timber).
2. Regulating and maintenance services (e.g. storm protection, water purification).
3. Cultural services (e.g. recreation, sense of place, aesthetic).

The assessment of ecosystems and their services is sometimes confused with monitoring the socio-economic impact of the project actions. Socio-economic impacts typically relate to questions like 'How has the project engaged minority groups?', 'How has it affected the behaviour of the local community?', 'To what extent has it created jobs or attracted new funding?' or 'Does it affect the way in which a site is governed?' These elements are not captured in an ecosystem services assessment that instead responds to questions like 'How has the project contributed to flood prevention?', 'To what extent has the project influenced the population of pollinating insects?', or 'How much carbon has been fixed through restoration measures?'. Therefore these two types of assessments should be carried out separately, although they should be consistent and synergic when possible and relevant.

For LIFE projects the methodology on Mapping and Assessing Ecosystems and their Services (MAES) is proposed. The EU and its Member States agreed to apply this framework and therefore any result emerging from the assessment of a LIFE project would be consistent with the national and/or EU framework; on the other hand, it offers a coherent and comparable approach across all LIFE projects as well as existing indicators and methodologies.

The MAES framework uses a typology for ecosystem services based on the Common International Classification of Ecosystem Services[3] (CICES; Section 1.3). The use of this classification in ecosystem services mapping and assessment is particularly useful in LIFE projects, to ensure comparability of results across the whole LIFE portfolio but also to ease the reporting on ecosystem services in the LIFE KPI Webtool (also referred here as LIFE KPI database). In fact, in this database projects are requested to input data on ecosystem services (as applicable and/or relevant) on the basis of the CICES structure.
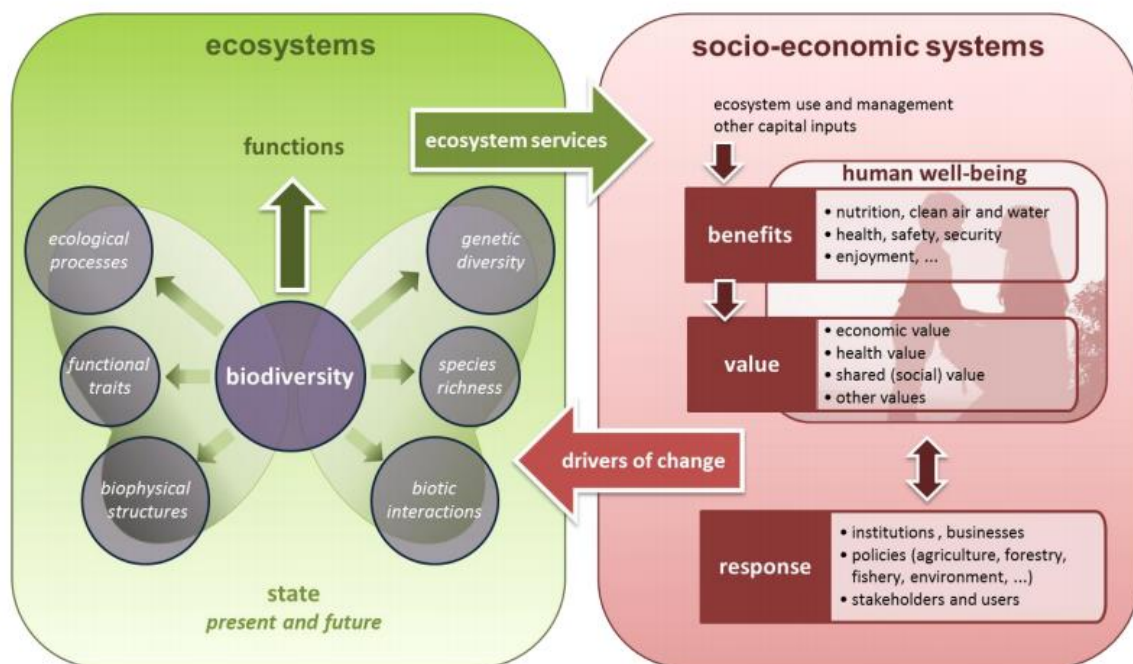
1.1 MAES analytical framework

The MAES conceptual framework links socio-economic systems with ecosystems via the flow of ecosystem services, and through the drivers of change that affect ecosystems either as consequence of using the services or as indirect impacts due to human activities in general (Figure 1).

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[2]The concepts of 'ecosystem goods and services', final ecosystem services', and 'nature contributions to people' are considered to be synonymous with ecosystem services in the MAES context.
[3]http://ec.europa.eu/environment/nature/knowledge/ecosystem_assessment/pdf/MAESWorkingPaper2013.pdf

Figure 1. MAES framework

For the purpose of MAES, 12 aggregated ecosystem types are defined – 7 terrestrial (urban, grassland, cropland, forest and woodland, heathland and shrub, sparsely vegetated land, wetland), 1 freshwater (rivers and lakes) and 4 marine types (marine inlets and transitional waters, coastal, shelf, open ocean). These ecosystem types cover altogether the whole EU territory. The 12 MAES classes are based on Corine and bathymetry data[4].

1.2. MAES indicators of ecosystem condition

For the purpose of MAES, ecosystem condition is usually used as a synonym for 'ecosystem state' (see Figure 1). It embraces legal concepts (e.g. conservation status under the Birds and Habitats Directives, ecological status under the Water Framework Directive and environmental status under the Marine Strategy Framework Directive) as well as other proxy descriptors related to state, pressures and biodiversity. Ecosystem condition is used to assess trends and set targets related to the improvement of environmental health. Drivers of change can have a positive (e.g. conservation) or negative (pressures) impact on ecosystem condition. Pressure refers to a process that alters the condition of ecosystems.

In the framework of MAES, an indicator framework for ecosystem condition has been developed (Table 1). In addition to identifying 6 main classes of pressures, this framework distinguishes between indicators for environmental quality (which express the physical and

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[4] The three main reasons explaining this classification are the following:
1. To standardise assessment, monitoring and reporting across Europe;
2. To link ecosystems to sectoral policies (i.e. grassland and cropland are linked to agriculture; forest and other woodlands are linked to forestry, etc)
3. To have a hierarchical approach which allows integration of more detailed classifications used on local, regional or national levels and the results based on this more detailed information.

chemical quality of ecosystems) and ecosystem attributes (which express the biological quality of ecosystems).

Table 1. Hierarchical structure and classification of pressure and condition indicators

Pressures	Habitat conversion and degradation (land conversion)		
	Introductions of invasive alien species		
	Pollution and nutrient enrichment		
	Over-exploitation		
	Climate change		
	Other pressures		

Ecosystem Condition	Environmental quality (physical and chemical quality)		
	Ecosystem attributes (biological quality)	Structural ecosystem attributes	Structural ecosystem attributes (general)
			Structural ecosystem attributes based on species diversity and abundance
			Structural ecosystem attributes monitored under the EU nature directives
			Structural soil attributes
		Functional ecosystem attributes	Functional ecosystem attributes (general)
			Functional soil attributes

A final selection of key indicators for ecosystem types, made on the basis of policy relevance and data availability, is proposed in the tables contained in Annex II. Additional indicators per MAES ecosystem type are available in the 5th MAES report on mapping and assessment of ecosystem condition[5].

The concept of ecosystem condition is strongly linked to human well-being through ecosystem services. Ecosystems need to be in good condition to provide multiple ecosystem services, which, in turn, deliver benefits and increase well-being. The relation between ecosystem condition and regulating ecosystem services is usually positive (Smith et al., 2017). However, for provisioning or cultural ecosystem services such as recreation in nature reserves a non-linear relationship is often observed. A moderate use of ecosystem services is positively related to ecosystem condition but intensive use of provisioning ecosystem services has mostly a negative impact on ecosystem condition and results in ecosystem degradation.

1.3. MAES typology of ecosystem services

The Common International Classification of Ecosystem Services (CICES)[6] builds on existing ecosystem services classifications and offers a structure that links with the framework of the UN System of Environmental-Economic Accounts.

CICES is based on a five-level hierarchical structure articulated around sections, divisions, groups, classes and class types. Additionally there is a distinction between biotic and abiotic
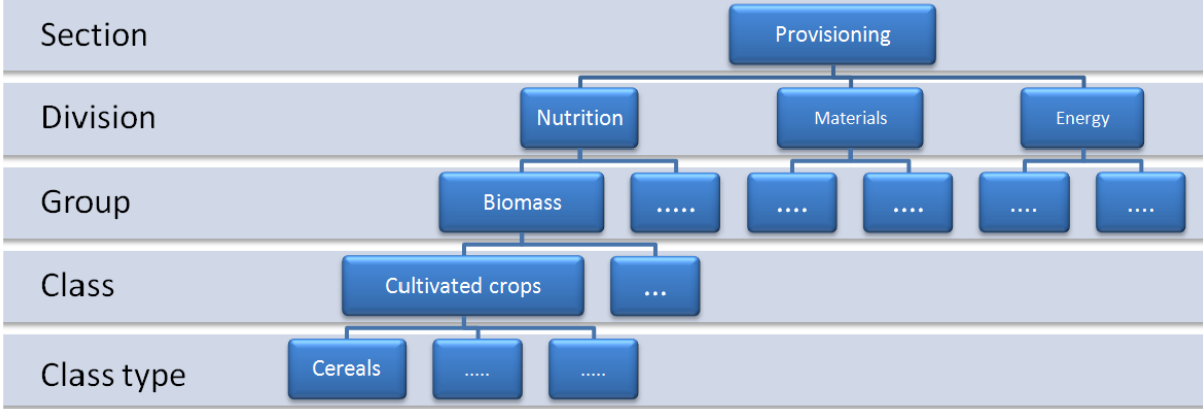
services mainly to take the special role of water into account. *Sections* reflect the three broad groups of services: (i) provisioning, (ii) regulating & maintenance, and (iii) cultural. Within each section specific *divisions* identify main types of output or process provided by a given ecosystem (nutrition, materials, energy, etc.). The *group* level splits divisions by biological, physical or cultural type or process. *Classes* and *class types* allow capturing a further level of detail. Figure 2 illustrates the hierarchy in the CICES classification system.

Figure 2. CICES structure

Source: https://cices.eu/cices-structure/

The hierarchical structure of CICES is adaptable to different scales and geographical contexts as well as to the levels of detail of the respective assessments. In general, if aggregated indicators are available and/or reporting is made on a large scale (i.e. national level) it is cost-effective to consider an assessment of ecosystem services at a high CICES level (e.g. group or division). At finer geographical scales, these broader categories of services might be represented by the specific classes that make sense at the local level.

While a Version 5.1 of CICES is available since January 2018[7], in this guidance reference is made to the Version 4.3 since the LIFE KPI database is built on the basis of this version. The list of MAES indicators for ecosystem services provided by forest, cropland, grassland, freshwater and marine ecosystems based on CICES Version 4.3 is available in Annex I. Its possible use will be further explained in the following sections of this guidance.

2. A practical approach to map and assess ecosystems and their services in LIFE projects

This section illustrates a stepped approach to map and monitor ecosystem services based on the use of the ecosystem services matrix. In an ecosystem services matrix ecosystem services are linked to specific reference units (or contexts) defined as most suitable for the assessment and/or target area. The main advantage of the matrix is that it can integrate in simple tables all kinds of ecosystem services-related data. These may be of varying quality and/or quantity and based on diverse scientific disciplines or quantification methods. Its flexibility makes it suitable

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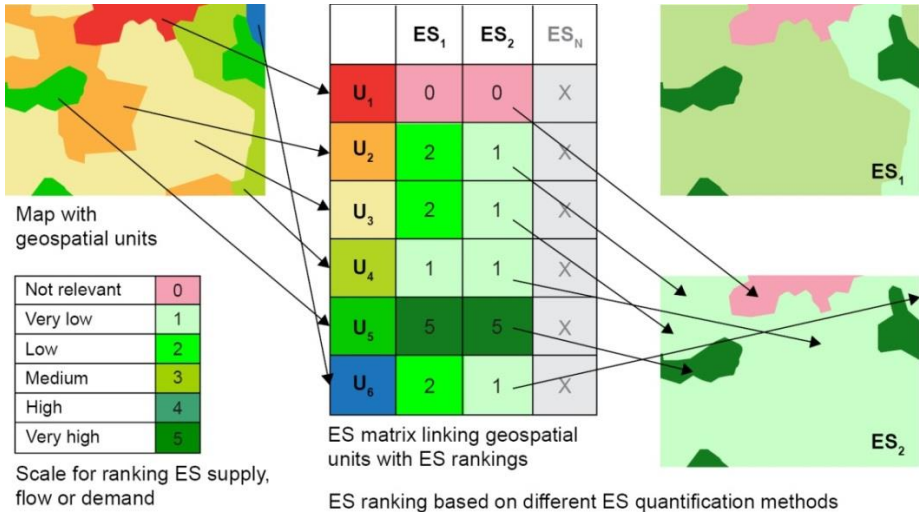[7]More information on CICES version 5.1:https://cices.eu/

in both data-poor and data-rich contexts, on all spatial and temporal scales and for all ecosystem services.

Building and completing the matrix should be seen as a participatory and reiterative process in which relevant stakeholders are involved and different information sources are combined. Typically, in a LIFE project such matrix can be constructed during the project kick-off phase or at an early stage of project implementation. The assessment should be repeated at regular intervals during the project lifetime and five years after to assess what changes the project may have brought about. Beneficiaries can choose the most suitable and/or preferred quantification method(s) and tool(s) to monitor the evolution of the ecosystem conditions and of the ecosystem services provided.

In concrete, the suggested approach consists of the following steps:

1. Identification of relevant ecosystem types and assessment of their condition.
2. Selection and quantification of relevant ecosystem services.
3. Normalisation of ecosystem services values and their inclusion in the matrix.

Figure 3. Overview of the ecosystem services matrix approach and resulting maps

Source: Burkhard & Maes (2017)

Figure 3 shows an example of an ecosystem services matrix and its link with spatial units. The ecosystem services identified are listed in the upper row of the matrix (ES1, ES2, etc.). The reference units describing the specific context to which the assessment of the ecosystems relates are included on the left column of the matrix (U1, U2, etc.). Once all ecosystem services have been quantified and the values normalised (on a scale from 0 to 5; Section 2.3), they have been included in the matrix. The production of maps is not mandatory for LIFE projects. Yet, maps can be useful and practical tools to support decision making and/or to serve as a basis to formulate recommendations from the ecosystem services assessment.

2.1 Identification of relevant ecosystem types and their assessment

In order to identify what ecosystem services are supported in a LIFE project, it is necessary first to identify the MAES ecosystem types (Section 1.1) that are relevant to the area of

intervention. Sometimes this can be straightforward. In other cases, for choosing the most relevant ecosystem types in a project context the following 'translation' tools that have been developed in the context of MAES can be of help:

- Correspondence between Corine Land Cover classes and ecosystem types[8];
- Crosswalk between European marine habitats typologies[9];
- Linkages of habitats/species to ecosystems[10].

Ecosystems need to be characterised in terms of surface or length, condition and trends, where possible underpinned with more detailed information per ecosystem type. For all these parameters, LIFE projects are expected to lead to an improvement in comparison to a baseline situation. The assessment of ecosystem types in terms of surface refers to its physical extent in a given area (expressed in ha or km^2). This value may coincide with all or part of the overall area targeted by the project depending on whether the project covers only one or several ecosystem types. Condition refers to the state or quality of the ecosystems that are expected to deliver ecosystem services (see Section 1.2). Their quantification should make use – to the extent possible - of existing data at the appropriate scale and/or on the basis of literature review (see also Annex II for possible indicators to be used). When data at the scale needed is not available direct measurement may be necessary. Sites that are representative of a relevant ecosystem type can be used as proxy for the whole project area if no ecosystem maps are available. For measurement on a large scale and where possible, the use of indirect methods (including remote sensing and satellite data) or modelling could be envisaged. In general, the most appropriate method should be selected on the basis of the capability, resources and needs of the project.

2.2 Selection and quantification of relevant ecosystem services

At this point, knowing the relevant ecosystem types a set of relevant ecosystem services can be identified. This can be done in a participative approach with stakeholders, initially just listing any type of ecosystem service (in connection to the identified ecosystem types) that one can think of in the context of the project. Once such list is available, the first question to be answered is:

1. Is this ecosystem service relevant in the context of my project (taking into account both the ecosystem types and the socio-economic context)?

Recalling that ecosystem services are such if they produce benefits and values for human well-being, it is important to know the socio-economic context because it allows matching the broad range of possible ecosystem services associated to a given ecosystem type with people's benefits at the most appropriate scale. For instance, in an urban context the beneficiaries of ecosystem services are people that live there, in a rural context farmers or herders will be the main target, but also other stakeholders groups (i.e. hunting associations, tourists, etc.). Ecosystem services are not hypothetical benefits associated with a given intervention; they

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[8] https://biodiversity.europa.eu/ecosystems/mapping-and-assessment-of-ecosystems-and-their-services-maes-1/correspondence-between-corine-land-cover-classes-and-ecosystem-types

[9] https://biodiversity.europa.eu/ecosystems/mapping-and-assessment-of-ecosystems-and-their-services-maes-1/crosswalks-between-european-marine-habitat-typologies_10-04-14_v3.pdf

[10] www.eea.europa.eu/data-and-maps/data/linkages-of-species-and-habitat#tab-european-data

are concrete benefits as perceived by the stakeholders and population in the project area. Locally-relevant ecosystem services can be identified and selected together with the relevant stakeholders via workshops and/or surveys.

The second question allowing fine tuning the selection of the relevant ecosystem services is:

2. Is there any indicator available to measure this ecosystem service and do I have the means/capacity/resources to measure it?

A number of indicators are already available. At EU level, MAES has identified specific indicators at national scale (Annex I). This list of indicators might look overwhelming and complicated. However, for each project and level of experience there will be indicators that fit the purpose. Table 2 includes examples of ecosystem services by different ecosystem types that can be selected by most projects working inside Natura 2000.

Table 2. Examples of ecosystem services for different ecosystem types for projects implemented in Natura 2000 areas

ECOSYSTEM TYPE	DIVISION	GROUP	CLASS	INDICATORS
Forest	Maintenance of physical, chemical, biological conditions	Lifecycle maintenance, Habitat and gene pool protection	Maintaining nursery populations and habitats	Forest area designated for habitat-landscape protection: Natura 2000
Cropland and grassland	Spiritual, symbolic and other interactions with biota, ecosystems, and land/seascapes	Other cultural outputs	Existence	Cropland or grassland in protected agricultural areas (e.g. Natura 2000, Biosphere reserve, World Heritage sites)
Freshwater	Physical and intellectual interactions with biota, ecosystems, and land/seascapes	Physical and experiential interactions	Experiential use of plants, animals and land/seascapes in different environmental settings	*For lakes and rivers*: National Parks and Natura 2000 sites *For wetlands*: Visitors to National Parks or protected areas including wetlands and/or Known bird watching sites
	Spiritual, symbolic and other interactions with biota, ecosystems, and land/seascapes	Other cultural outputs	Existence	Number of visitors (to national parks including lakes, rivers, wetlands or hot mineral spring water)
Marine	Physical and intellectual interactions with biota, ecosystems, and land/seascapes	Physical and experiential interactions	Experiential use of plants, animals and land/seascapes in different environmental settings	Extent of marine protected areas (km²/ha)
	Spiritual, symbolic and other interactions with biota, ecosystems, and land/seascapes	Other cultural outputs	Existence	

In general, a practical way to select the most relevant ecosystem services is to review the MAES list of ecosystem services indicators for the specific ecosystem(s) relevant to the project (see Annex I) starting from the lowest level (class type) and moving upwards in the hierarchy. The chosen ecosystem services are then cross-checked with the information available on the context of the project (i.e. is this service relevant to the people and stakeholders of my project?) and in terms of the feasibility of its measurement. If an indicator is not relevant in connection to the project stakeholders and beneficiaries, or cannot be measured in the project context, then it should not be retained.

The choice on how to measure ecosystem services indicators depends on four main criteria:

1. the overall purpose of the ecosystem services assessment;
2. the availability of data;
3. the type of measurement needed to quantify the indicators;
4. the resources (human and financial) available.

Based on these criteria a 3-tiered approach for ecosystem mapping and assessment has been developed. Table 3 below illustrates this approach (adapted from Maes et al., 2014). The first tier corresponds to the simplest situation of a basic ecosystem services assessment; upper tiers reflect higher levels of complexity.

Table 3. Choice criteria in a tiered approach to ecosystem services mapping

	TIER 1	TIER 2	TIER 3
Purpose	Advocacy/awareness raising and communication	Assessment not implying any decision	Assessment needed to support decision making
Data availability	Largely available (look-up tables, expert knowledge and participatory mapping	Available, also as proxy, and/or possible to get by combining existing data (for composite indicators)	Not immediately available, not harmonised at EU level, need to work on a large number of data
Measurement method	Direct measurement	Direct measurement and indirect measurement	Modelling
Resources (skills and budget)	Basic/any skills Low budget	Average/some skills (e.g. GIS) Medium budget	High skills High budget

When to use which tier?

- Tier 1: Table 3 basically suggests that if the purpose of the assessment of the ecosystems and their services is mainly only to support advocacy and communication around the importance of ecosystem services, if the range of relevant ecosystem services in the project can be represented through simple indicators, if data are available or can easily be obtained (lookup tables), and 'resources' (in terms of both skills and budget) are limited, then the ecosystem services assessment should better fit a tier 1 approach and therefore be simple.
- Tier 2: If information about different ecosystem services is required at a more detailed level, if data can be obtained but require some analysis, mostly relying on the so-called 'causal relationship' (i.e. land use data is linked to different datasets according to known

relationships between land use and ecosystem services provision and supplemented with local/regional/national data) and/or through GIS, remote sensing, earth observations[11] and economic valuation methods, the project would fit a tier 2 approach. Citizen science approaches could also be adopted, including through tools such as MapNat[12].

- Tier 3: If the ecosystem services assessment is to be used to explicitly evaluate management measures or to support policy making a tier 3 approach should be considered. This will apply to projects with a specific focus on mapping and assessing ecosystem services and establishing green infrastructures. In this cases ecosystem assessment and valuation should make use of quantitative regression, socio-ecological system models and economic valuation models that combine field data of ecosystem services as well as information from literature linked to spatial data as well as more advanced participatory mapping methods (i.e. time use methods or photo-elicitation surveys) for cultural value. In general, pursuing a tier 3-type of assessment entails a higher budget and level of expertise than a tier 1 approach. This should have been planned accordingly at the project design stage.

The choice of the most appropriate ecosystem services quantification tools and methods should be based on the tier chosen for the ecosystem services assessment. Most projects can in principle apply a Tier 1 approach. Biodiversity projects supporting Target 2 of the EU Biodiversity Strategy and more specifically green infrastructure related projects that have objectives linked to the delivery of ecosystem services are expected to apply upper tiers.

2.3 Normalisation of indicator values and inclusion in the matrix

When data have been collected or measurements made to feed the indicators for the chosen ecosystem services, it is time to 'normalise' them. By using standardised values, ecosystem services provision may be compared between regions or projects, or over time. In the ecosystem services matrix methodology, indicator values are normalised against a relative scale usually ranging from 0 to 5. '0' represents no relevant ecosystem services supply or demand. It is important to highlight the term 'relevant' because '0' does not necessarily mean absolute zero for all types of ecosystem services. It is supposed to reflect the fact that although an ecosystem service is supplied, it is not perceived as benefit for human well-being or the value of this service is unknown. At the other end of the scale, '5' represents the maximum level of ecosystem services supplied by a given ecosystem type.

The normalisation of the ecosystem services indicators values is suggested to help LIFE project beneficiaries reporting the results of their assessment in the LIFE KPI database, as well as to report changes in this area in the context of the regular reporting of project progress to the Contracting Authority. In fact the normalised values can more easily represent an overall trend and/or a change.

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[11] See for instance the Horizon 2020 project ECOPOTENTIAL for an application of Earth Observations monitoring to ecosystem services potential in protected areas.
[12] http://esmeralda-project.eu/news/13499_mapnat---the-ecosystem-service-mapping-smartphone-app/

3. Reporting values on the assessment of ecosystems and their services in the LIFE KPI Webtool

Once the ecosystem services are known and have been assessed, LIFE project beneficiaries should be in a position to report on the ecosystem services condition and trends in the LIFE KPI Webtool. LIFE project beneficiaries are requested to input data in the LIFE KPI Webtool at the beginning of the project, at the end and 5 years later. In relation to the approach described in Section 2 above, this requires completing the ecosystem services matrix at least two times in the project lifetime (at the beginning and towards the end), as well as 5 years later. Ideally these activities should have been planned and included since the beginning in the project description. For projects that focus on green infrastructures and/or the delivery of ecosystem services it is expected that this assessment is repeated throughout project implementation so as to provide trend information at the time of the regular reporting of the overall project progress to the Contracting Authority.

In the LIFE KPI Webtool there are two specific sections that need to be considered: the 'Indicator context' and the 'Indicator Values/ 7. Nature and Biodiversity'.

In the 'Indicator context' there are two fields *C.1. Overarching context* and *C.2. Specific context.* Both will have to be filled. In section C.1, the field *C.1.4. Ecosystems and their services* needs to be selected. In the resulting screen, the first step is to choose the ecosystem type(s) relevant to the project. For each of them the associated ecosystem services from the MAES list need to be selected as well, to the lowest level that is still relevant for the project context. The various entries are structured on the basis of CICES. First it is necessary to select a *Section* after which one will be able to select from a drop-down list the *Division* and so forth. It is possible to add as many ecosystem type/ecosystem service combinations as needed. In this section do not forget to indicate also if the project contributes to a green/blue infrastructure.

Once section C.1.4 is completed, move to *C.2. Specific context.* Here users fix the reference contexts that are most suitable. Each 'Specific context' needs to have a unique name. This is necessary to be able to give values for these combinations later on.

What and how many ecosystem services-related contexts have to be created depends on the project specificities, and on how many ecosystem types and services have been identified. To report values on the ecosystems condition and trends (KPI under 7.1 Ecosystem assessment) it may be sufficient to create a Specific Context, named after the ecosystem type, including all the ecosystem services linked to it and listed in section C.1.4. In addition to selecting the ecosystem type/ecosystem service combination it is useful to further specify the context in relation to:

- the territorial extents (C.1.2);
- the water body (C.1.3) if the assessment concerns a freshwater ecosystem.

If the project takes place inside Natura 2000, the two indications above can be complemented by an indication of the relevant sites (C1.5) and/or the biogeographical regions (C1.1).

To report values on the ecosystem services (KPI under 7.2 Ecosystem services assessment) there are two options.

1. If the project has identified (and assessed) a limited number of ecosystem services, users can report on them singling them one by one as stand-alone specific contexts. This approach allows capturing changes in different directions or at a difference pace for each ecosystem service associated with a change of the ecosystem conditions. However, when a large number of ecosystem services is assessed this approach is not practical because it would lead to the creation of a long list of specific contexts.

2. For projects having identified and monitored a large number of ecosystem services, users can group the services associated to the same ecosystem type by different CICES categories e.g. Sections (i.e. provisioning, regulation & maintenance, and cultural services) or Divisions (Nutrition, Materials, Energy, Mediation of flows, etc.) and report the project impacts for each of these broad categories. However, this approach works only if the result of the assessment for these ecosystem services is homogeneous in terms of condition and trends (i.e. all the cultural services are poor and showing some deterioration at the beginning of the project, but by the end of the project they all are in good condition and have improved).

As a general rule, no more than 10 specific contexts to report ecosystem services should be created. Users should determine the best combination allowing reporting on them at the most appropriate scale for the project without losing important information. Similarly to the context created to report on the ecosystem conditions, the ecosystem services-related contexts (single ecosystem service or group of ecosystem services) can be further specified in connection to the geographical area in which they are assessed. The name given to each specific context should reflect the rationale behind the choice made (i.e. Provisioning services associated to grassland in region X).

When all the specific contexts needed have been created and given a unique name, beneficiaries should select the left-hand tab 'Project Specific Settings and Indicator Selection' and verify if the respective indicators are marked to be able to add values. To do so:

1. select *E. Environmental and Climate action outputs and outcomes*;
2. scroll down the resulting list;
3. check indicators *7.1 Ecosystem assessment* and *7.2 Ecosystem services assessment*.

Next, users shall select the left-hand tab 'Indicator Values'. From the unfolding list first *7. Nature and biodiversity* and then the indicator *7.1 Ecosystem assessment* have to be selected. By choosing 'Add New Indicator Values' it is possible to select from the drop-down list under 'Specific context' the one on which beneficiaries intend to report. In addition to the information on the surface or length (Ecosystem assessment tabs), beneficiaries are requested also to report the condition of a given ecosystem as being:

- Unknown
- Very poor/bad/non-functional
- Poor/unfavourable
- Moderate
- Good/favourable
- Very good/high

Ecosystem trends need to be expressed in terms of one of the following parameters:

- Overall stable

- Deterioration
- Some deterioration
- Improvement and/or deterioration in different locations
- Some improvement
- Improving

The following indicator is *7.2. Ecosystem services assessment*. Here users choose 'Add New Indicator Values' and select from the drop-down list under 'Specific context' the one for which values are to be reported.

The normalised values from the ecosystem services matrix can easily be translated into the values that are included in the KPI Webtool. The following translation key may be followed:

0   Unknown
1   Very poor/bad/non functional
2   Poor/unfavourable
3   Moderate
4   Good/favourable
5   Very good/high

Table 4. Steps to be considered for filling information on ecosystem and their services in the KPI Webtool

Sections that need to be filled in	Purpose of this section
Indicator Context C.1 Overarching Context C.1.4 Ecosystems and their services	• Specify each ecosystem type and associated service using the CICES system • Indicate whether green or blue infrastructure is created

Indicator Context
C.2 Specific Context
	• For reporting under Ecosystem assessment (7.1) group ecosystem services per ecosystem type e.g. 'heathland'
	• For reporting under the Ecosystem services assessment (7.2):
	   – Option 1: create a specific context for each ecosystem service identified
	   – Option 2: group ecosystem services associated to the same ecosystem type at the most appropriate CICES aggregated level e.g. 'Provisioning services associated to grassland in region X'
	• In both sets of context add territorial extent or water body (and N2000 if appropriate)

Indicator Context 7. Nature and Biodiversity 7.1 Ecosystem assessment	Provide an assessment of the ecosystem's condition and trend and specify the measures taken.
Indicator Context 7. Nature and Biodiversity 7.2 Ecosystem services assessment	Report on the condition and trend of ecosystem services or group of ecosystem services as specified in the specific context (C.2). Note that no reporting on the MAES indicators is required.

4. Tools and other sources of information

In this section we provide a selection of resources for further reading and learning, tools, projects, experiences and websites.

4.1 Platforms and networks

MAES

Full reference information about MAES is available from BISE, the Biodiversity Information System for Europe: https://biodiversity.europa.eu/ecosystems

All the information on the MAES Working Group is available on CIRCABC (Communication and Information Resource Centre for Administrations, Businesses and Citizens)

More information: https://circabc.europa.eu/w/browse/4580a3d6-f93d-4c21-be5c-f46235201aec

Oppla

Oppla is a knowledge platform on ecosystem services and nature-based solutions, created from the joint efforts of two projects under the EU 7th Framework Programme for Research and Innovation: OPERAs and OpenNESS[13]. Oppla is an open platform that is designed for people with diverse needs and interests - from science, policy and practice; public, private and voluntary sectors; organisations large and small, as well as individuals.

More information: www.oppla.eu

Ecosystem Services Partnership

The Ecosystem Services Partnership (ESP) aims to enhance communication, coordination and cooperation, and to build a strong network of individuals and organizations. ESP enhances and encourages a diversity of approaches, while reducing unnecessary duplication of effort in the conceptualization and application of ecosystem services. By raising the profile of ecosystem services and promoting better practice, the ESP also increases opportunities for financial support and help focus the funding of individual organizations for more efficient utilization of existing funds.

The ESP website offers a global community, networking opportunities, case studies, guidelines and more. Every year ESP organizes ecosystem service conferences.

More information: www.es-partnership.org

Eurosite

Eurosite is the network for Europe's natural site managers. It brings together non-governmental and governmental organisations, and individuals and organisations committed to its vision: A Europe where nature is cared for, protected, restored, and valued by all.

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[13] www.openness-project.eu

Founded in 1989, the network has grown to include members across Europe – from the Atlantic islands to the Black Sea; and from Scandinavia to the Mediterranean.

One of Eurosite's working groups is on Economics and Ecosystem Services. Its goals are to increase the number of protected areas implementing ecosystem services planning; and to increase awareness of the economic and environmental benefits of protecting and enhancing ecosystem services.

More information: www.eurosite.org

4.2   Examples of ecosystem services modelling frameworks

TESSA[14]: The Toolkit for Ecosystem Service Site-based Assessment provides guidance on low-cost methods for how to evaluate the benefits people receive from nature at particular sites in order to generate information that can be used to influence decision making.

InVEST: it includes 18 tools for assessing marine, coastal, terrestrial and freshwater ecosystem services.

ESTIMAP: it is a collection of spatially explicit modelling approaches that assess the supply, demand and flow of ecosystem services. It is implemented within a GIS and is designed to be a standardised, replicable system developed for use in the EU.

ARIES: ARtificial Intelligence for Ecosystem Services is a framework that uses artificial intelligence to select the most appropriate modelling components to map ecosystem services at context-appropriate scales.

4.3   References used in this guide

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[14] http://tessa.tools/

ANNEX I - MAES INDICATORS FOR ECOSYSTEM SERVICES PROVIDED BY FOREST, CROPLAND AND GRASSLAND, FRESHWATER AND MARINE ECOSYSTEMS

- Available indicator to measure the condition of an ecosystem, or the quantity of an ecosystem service at a given CICES level for which harmonised, spatially-explicit data at European scale is available and which is easily understood by policy makers or non-technical audiences. Spatially-explicit data in this context refer to data that are at least available at the regional NUTS2 level or at a finer spatial resolution. CICES classifies ecosystem services at 4 hierarchical levels. Sometimes, it is more cost-effective to consider an assessment of ecosystem services at a higher CICES level than at class level, especially if aggregated indicators are available. Indicators that aggregate information at higher hierarchical CICES level can therefore also have a green label.

- Available indicator to measure the condition of an ecosystem, or the quantity of an ecosystem service at a given CICES level but for which either harmonised, spatially-explicit data at European scale is unavailable or which is used more than once in an ecosystem assessment, which possibly results in different interpretations by the user. This is typically the case for indicators that are used to measure ecosystem condition, which are reused to assess particular ecosystem services. This colour also includes indicators that capture partially the ecosystem service assessed.

- Available indicator to measure the condition of an ecosystem, or the quantity of an ecosystem service at a given CICES level but for which no harmonised, spatially-explicit data at European scale is available and which only provides information at aggregated level and requires additional clarification to non-technical audiences. This category includes indicators with limited usability for an ecosystem assessment due to either high data uncertainty or a limited conceptual understanding of how ecosystems deliver certain services or how ecosystem condition can be measured. The ability to convey information to end-users is limited and further refined and/or local level assessments should be used for verifying the information provided by this type of indicators.

- Unknown availability of reliable data and/or unknown ability to convey information to the policy making and implementation processes.

Table S2. Indicators for forest ecosystem services (CICES classification).

Division	Group	Class	Indicators
Nutrition	Biomass	Cultivated crops	
		Reared animals and their outputs	●Meat production (e.g. Iberian pig, reindeer) ●Meat consumption (e.g. Iberian pig, reindeer) ● Number of individuals (e.g. Iberian pig, reindeer)
		Wild plants, algae and their outputs	●Distribution of heathlands and other habitats for bees ●Distribution of plants important for honey production ●Distribution of wild berries, fruits, mushrooms (National Forest Inventory plot data) ● Distribution of wild berries (modelling) ●Honey production ●Honey consumption ●Wild berries, fruits and mushroom harvest
		Wild animals and their outputs	● Amount of meat (hunting) ●Value of game ●Hunting records (killed animals)
		Plants and algae from in-situ aquaculture	
		Animals from in-situ aquaculture	
	Water	Surface water for drinking	● Total supply of water per forest area (modelling) ●Area of forest dedicated to preserve water resources ●Surface water supply per forest area (at river basin level) ●River discharge ●Reservoir water (proxy) ●Population and per capita water consumption
		Ground water for drinking	
Materials	Biomass	Fibres and other materials from plants, algae and animals for direct use or processing	● Forest biomass stock ● Forest biomass increment

Division	Group	Class	Indicators
			● Forest for timber, pulp wood, etc. production ● Commercial forest tree volume & harvesting rates ●Trees (presence): cork oak for cork & pines for resins ●Tree species (timber tress) ● Wood consumption (industrial roundwood, fuelwood) ● Consumption of cork and resins
		Materials from plants, algae and animals for agricultural use	●Distribution of foraging areas in forest; estimate of grassland/shrubland (Net Primary Production) ●Marketed forage
		Genetic materials from all biota	●Distribution of plants species with biochemical /pharmaceutical uses ● Raw materials for medicines
	Water	Surface water for non-drinking purposes	*Same indicators as for drinking purposes*
		Ground water for non-drinking purposes	
Energy	Biomass-based energy sources	Plant-based resources	● Wood fuel stock (fraction of forest biomass stock) ● Wood fuel production (fraction of forest biomass increment) ●Distribution of trees for wood production ● Fuel wood consumption
		Animal-based resources	
	Mechanical energy	Animal-based energy	
Mediation of waste, toxics and other nuisances	Mediation by biota	Bio-remediation by micro-organisms, algae, plants, and animals	
		Filtration/sequestration/storage/accumulation by micro-organisms, algae, plants, and animals	
	Mediation by ecosystems	Filtration/sequestration/storage/accumulation by ecosystems	●Area of forest ●Sulphur (S) and Nitrogen (N) retention and removal
		Dilution by atmosphere, freshwater and marine ecosystems	
		Mediation of smell/noise/visual impacts	
Mediation of flows	Mass flows	Mass stabilisation and control of erosion rates	● Erosion protection (modelling) ●Area of forest ●Area of forest designated to the prevention of soil erosion ●Area eroded by wind and water ●Forest cover in high slope areas (GIS analysis) ●Sediments removed from dams, lakes, rivers
		Buffering and attenuation of mass flows	●Forest area designated for attenuation of mass flows ●Erosion risk mitigation ●Flood risk mitigation
	Liquid flows	Hydrological cycle and water flow maintenance	●Forest area (designated to preserve water resources) ●Number of floods ● Water retention in forest ●Snow cover ●Infiltration ●Capacity for maintaining baseline flow (modelling) ●Water storage/delivery capacity of soil ● Water supply and discharge (hydrological modelling) ●Important areas for water infiltration and headwater surroundings covered by forest ●Drought and water scarcity

Division	Group	Class	Indicators
		Flood protection	●Special protection areas for preventing mass flows linked to the River Basin Management Plans ● Reforestation of forest territories against floods ● Number of floods
	Gaseous / air flows	Storm protection	●Area of forest designated to protect infrastructure and managed nat. resources ● Frequency of storms ●Area of forest
		Ventilation and transpiration	
Maintenance of physical, chemical, biological conditions	Lifecycle maintenance, habitat and gene pool protection	Pollination and seed dispersal	●Number of pollinator species ●Number of bee hives ●Abundance of pollinators (maps) ●Areas managed for gene conservation ● Pollination potential (maps) ●Surface area of dependent crops ●Honey production (modelling) ●Honey consumption
		Maintaining nursery populations and habitats	●Tree species distribution ●Conservation investments ●Protected Areas for nursery populations ●Forest area designated for habitat-landscape protection: Natura2000
	Pest and disease control	Pest control	●Host-species (trees) abundance ● Surface of healthy Forests (quality parameter of forest health) ● Number of pests and diseases ● Surface affected by pests and diseases ● Number of invasive alien species ● Surface occupied by invasive alien species ● Damage costs
		Disease control	None
	Soil formation and composition	Weathering processes	●Area of forest ●Restoration costs ●Forest soil condition: chemical soil properties
		Decomposition and fixing processes	●Soil organic matter ●Amount of dead wood ●Thickness of the organic layer
	Water conditions	Chemical condition of freshwaters	●Area of forest ●Water quality ●Forest area designated to preserve waters resources ● Cost of water purification
		Chemical condition of salt waters	
	Atmospheric composition and climate regulation	Global climate regulation by reduction of greenhouse gas concentrations	● C storage in forest ● C sequestration by forest (Net Primary Production; Net Ecosystem Production) ●Forest growth, growing stock ● Number of CO_2 emissions permits
		Micro and regional climate regulation	●Area of forest ●Albedo maps ● Foliar surface index ● Ozone & particle pollution
Physical and intellectual interactions with biota, ecosystems, and land-/seascapes	Physical and experiential interactions	Experiential use of plants, animals and land-/seascapes in different environmental settings. And physical use of land-/seascapes in different environmental settings	●Distribution of wildlife/emblematic species associated with forest ●Important bird areas associated with forest ●Area of forest accessible for recreation ●Number of visitors ●Number of hunters ●Ecotourism operators ● Area of forests accessible for hunting
	Intellectual and representative interactions	Scientific, educational, heritage, cultural, entertainment and aesthetic	●Citations, distribution of research projects, educational projects, number of historic records ●Number/value of publications sold

Division	Group	Class	Indicators
Spiritual, symbolic and other interactions with biota, ecosystems, and land-/seascapes	Spiritual and/or emblematic	Symbolic and sacred and/or religious	●Distribution of sites of emblematic plants/forest ●Number of sites with recognised cultural & spiritual value ●Number of visitors
	Other cultural outputs	Existence and bequest	●Distribution of important areas for forest biodiversity and their conservation status ●Condition of forest-associated priority species on habitat and birds directives ●Distribution of sites with forest designated as having cultural values ●Number of visitors

Table S3. Indicators for ecosystem services delivered by cropland and grassland (CICES classification).

Division	Group	Class	Cropland	Grassland
Nutrition	Biomass	Cultivated crops	● Yields of food and feed crops (ton/ha; ton dry matter/ha; MJ/ha) ● Food and feed crop area (ha)	● Yields (ton/ha; ton dry matter/ha; MJ/ha) ● Grassland area (ha)
		Reared animals and their outputs	● Livestock data (number/ha, Ton/year/region)	
		Wild plants, algae and their outputs		
		Wild animals and their outputs	● Wild game bag data (merged with forest ecosystems) ● Wild game population estimates	
		Plants and algae from in-situ aquaculture		
		Animals from in-situ aquaculture		
	Water	Surface water for drinking	● High Nature Value farmland	
		Ground water for drinking	● Areas important for groundwater abstraction in agro ecosystems	
Materials	Biomass	Fibres and other materials from plants, algae and animals for direct use or processing	● Yields of fibre crops (ton/ha; ton dry matter/ha; MJ/ha) ● Fibre crop area (ha) ●Manure(ton/year)	
		Materials from plants, algae and animals for agricultural use		
		Genetic materials from all biota	● Yields of crops used for medicinal and cosmetic purposes (ton/ha; ton dry matter/ha; MJ/ha) ● Area of crops used for medicinal and cosmetic purposes (ha)	
	Water	Surface water for non-drinking purposes	*Similar as in Table S4*	
		Ground water for non-drinking purposes	*Similar as in Table S4*	
Energy	Biomass-based energy sources	Plant-based resources	●Yields of energy crops (ton/ha; ton dry matter/ha; MJ/ha) ● Energy crop area (ha) ● Biofuel,	● Yields of grassland for energy production (ton/ha; ton dry matter/ha; MJ/ha)

Division	Group	Class	Cropland	Grassland
			biodiesel, bioethanol (kToe)	● Grassland for energy area (ha)
		Animal-based resources	● Energy from manure treatment systems	
	Mechanical energy	Animal-based energy		
Mediation of waste, toxics and other nuisances	Mediation by biota	Bio-remediation by micro-organisms, algae, plants, and animals		
		Filtration/sequestration/storage/accumulation by micro-organisms, algae, plants, and animals		
	Mediation by ecosystems	Filtration/sequestration/storage/accumulation by ecosystems	● Concentration of pollutants in soil in agricultural areas ● Concentration of nutrient elements (C, N, P, K, Ca, Mg, S) in soil in agricultural areas	
		Dilution by atmosphere, freshwater and marine ecosystems		
		Mediation of smell/noise/visual impacts	● Hedgerow length	
Mediation of flows	Mass flows	Mass stabilisation and control of erosion rates	● Percentage of soil cover in cropland (conservation tillage (low tillage), zero tillage, winter crops, Cover crop or intermediate crop, plant residues ● Density of hedgerows ● Soil erosion risk	● Percentage of grassland cover ● Soil erosion risk
		Buffering and attenuation of mass flows	● Density of hedgerows	
	Liquid flows	Hydrological cycle and water flow maintenance	● Retention capacity of water in agricultural soils	
		Flood protection	● Share of agroforestry within floodplains	
	Gaseous / air flows	Storm protection	● Density of hedgerows	
		Ventilation and transpiration	● Amount of biomass	
Maintenance of physical, chemical, biological conditions	Lifecycle maintenance, habitat and gene pool protection	Pollination and seed dispersal	● Pollination potential ● Pollinators distribution ● Pollinators species richness ● Number of beehives ● Areal coverage of vegetation features supporting pollination (hedgerows, flower strips, High Nature Value Farmland etc.)	
		Maintaining nursery populations and habitats	● Share of High Nature Value farmland ● Traditional orchards	
	Pest and disease control	Pest control	●Density of hedgerows	
		Disease control		
	Soil formation and composition	Weathering processes	● Share of organic farming ● Soil organic matter content ● pH of topsoil ● Cation exchange capacity	

Division	Group	Class	Cropland	Grassland
		Decomposition and fixing processes	● Area of N fixing crops ● Gross nitrogen balance	
	Water conditions	Chemical condition of freshwaters	*Similar as in Table S4*	
		Chemical condition of salt waters	*Similar as in Table S4*	
	Atmospheric composition and climate regulation	Global climate regulation by reduction of greenhouse gas concentrations	●Carbon sequestered by permanent crops	●Carbon sequestered by grasslands
		Micro and regional climate regulation	● Humidity index	
Physical and intellectual interactions with biota, ecosystems, and land-/seascapes [environmental settings]	Physical and experiential interactions	Experiential use of plants, animals and land-/seascapes in different environmental settings	● Number of visitors in agricultural areas ● Number of Number of rural enterprises offering tourism-related services ● Farm tourism ● Walking and biking trails ● Number of hunting licences, number of birdwatchers ● Expenditures related to hunting	
		Physical use of land-/seascapes in different environmental settings		
	Intellectual and representative interactions	Scientific	● Amount of scientific studies on agro-ecosystems	
		Educational	● Number of didactic farms	
		Heritage, cultural	● Number of agricultural-livestock fairs ● Number of monuments in agricultural areas ●Number of certified products that require traditional landscape management	
		Entertainment	● Contests and competitions related to agriculture	
		Aesthetic	● Number of visitors in agricultural areas ● Number of nature/agricultural landscape photos uploaded on web portals	
Spiritual, symbolic and other interactions with biota, ecosystems, and land-/seascapes [environmental settings]	Spiritual and/or emblematic	Symbolic	● Remarkable trees ● Symbolic species	
		Sacred and/or religious	●Religious monuments, pilgrim paths in agro-ecosystems	
	Other cultural outputs	Existence	●Cropland or grassland in protected agricultural areas (e.g. Natura2000, Biosphere reserves, IUCN category V areas, World Heritage Unesco sites related to agricultural landscape, landscape conservation areas) ● Willingness to pay for landscape measures in cropland or grassland areas	
		Bequest		

Table S4. Indicators for freshwater ecosystem services (CICES classification).

Division	Group	Class		Lakes	Rivers	Ground water	Wetlands
Nutrition	Biomass	Cultivated crops					
		Reared animals and their outputs					
		Wild plants, algae and their outputs		● Wild plants used in gastronomy, cosmetic, pharmaceutical uses (data on industries collecting the plants)			*see lakes and rivers*
		Wild animals and their outputs		●Fish production (catch in tonnes by commercial and recreational fisheries) ●Number of fisherman and hunters of waterfowls (anglers, professional and amateur fishermen) ●Status of fish population (Species composition, Age Structure, Biomass kg/ha)			*see lakes and rivers*
		Plants and algae from in-situ aquaculture					
		Animals from in-situ aquaculture		● Freshwater aquaculture production (e.g. sturgeon and caviar production)			
	Water	Surface water for drinking	●Water exploitation index (WEI)	●Water consumption for drinking ●Surface water availability ● Water abstracted			●Nitrate-vulnerable zones
		Ground water for drinking				●Ground water bodies ●Ground water abstraction	
Materials	Biomass	Fibres and other materials from plants, algae and animals for direct use or processing					● Wood produced (tons or volume) by riparian forest ● Surface of exploited wet forests (e.g. poplars) and reeds
		Materials from plants, algae and animals for agricultural use					
		Genetic materials from all biota					

Division	Group	Class		Lakes	Rivers	Ground water	Wetlands
	Water	Surface water for non-drinking purposes	●Water exploitation index (WEI)	●Water use per sector ●Surface water availability ● Water abstracted ●Volume of water bodies			● Surface of flood-prone areas
		Ground water for non-drinking purposes				●Ground water bodies ●Ground water abstraction	
Energy	Biomass-based energy sources	Plant-based resources					● Firewood produced by riparian forests
		Animal-based resources					
	Mechanical energy	Animal-based energy					
Mediation of waste, toxics and other nuisances	Mediation by biota	Bio-remediation by micro-organisms, algae, plants, and animals		●Indicators on water quality (microbiological data for bathing waters, BOD5 nitrate concentration, phosphate concentration, oxygen conditions, saprobiological status) ●Nutrient loads ●Ecological status ●Trophic status ● Area occupied by riparian forests ●Number and efficiency of treatment plants ●Waste treated		● Indicators on groundwater quality (NO3, pesticide, trace metals, emerging pollutants, etc. evolution in GW)	●Carbon storage per unit of area ●Potential mineralization or decomposition ●Ecological status ●Nutrient concentration ●Nutrient retention
		Filtration/sequestration/storage/accumulation by micro-organisms, algae, plants, and animals					
	Mediation by ecosystems	Filtration/sequestration/storage/accumulation by ecosystems					
		Dilution by atmosphere, freshwater and marine ecosystems					
		Mediation of smell/noise/visual impacts					
Mediation of flows	Mass flows	Mass stabilisation and control of erosion rates				● GW level evolution	
		Buffering and attenuation of mass flows		●Sediment retention			●Sediment retention
	Liquid flows	Hydrological cycle and water flow maintenance					
		Flood protection		●Holding capacity flood risk maps ●Conservation of river and lakes banks			●Water holding capacity of soils ● Floodplains areas (and record of annual floods) ● Area of wetlands

Division	Group	Class	Lakes	Rivers	Ground water	Wetlands
						located in flood risk zones ●Conservation status of riparian wetlands
	Gaseous / air flows	Storm protection				●Conservation status of wetlands
		Ventilation and transpiration				
Maintenance of physical, chemical, biological conditions	Lifecycle maintenance, habitat and gene pool protection	Pollination and seed dispersal			● GW level	
		Maintaining nursery populations and habitats	●Biodiversity value (Species diversity or abundance, endemics or red list species and spawning location) ● Ecological status Morphological status			
	Pest and disease control	Pest control	●Alien species (Introduced riparian and aquatic plants ●Number of introduced aquatic invertebrates ●Number of introduced vertebrates in rivers and riparian areas			*see lakes and rivers*
		Disease control				
	Soil formation and composition	Weathering processes	●Fluvisols surface			●Hydromorphic soils (Presence/absence) Surface of floodplains
		Decomposition and fixing processes				●Potential mineralization, decomposition, etc.
	Water conditions	Chemical condition of freshwaters	● Chemical status ●Ecological status		●Indicators of GW quality	● Chemical status ●Ecological status ● Potential of water purification of wetlands
		Chemical condition of salt waters				
	Atmospheric composition and climate regulation	Global climate regulation by reduction of greenhouse gas concentrations	● C sequestration (Annual increase in ● Carbon sequestration in living biomass of riparian forest		● C sequestration (Evolution of annual volumes of CO_2 injected, ● Number of	*see rivers and lakes*

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Division	Group	Class	Lakes	Rivers	Ground water	Wetlands
			● Carbon sequestered by plantations of *Populus* ● Organic carbon stored in fluvisols)		sites for CO_2 deep injections	
		Micro and regional climate regulation			● GW level	
Physical and intellectual interactions with biota, ecosystems, and land-/seascapes [environmental settings]	Physical and experiential interactions	Experiential use of plants, animals and land-/seascapes in different environmental settings	●Number of visitors (to National Parks including lakes or rivers) ● National Parks and Natura 2000 sites ●Known bird watching sites Waterfowl			●Number of visitors (waterfowl hunters and fishermen ● Visitors to National Parks or protected areas including wetlands) ●Known bird watching sites ●Waterfowl ● Tourism revenue
		Physical use of land-/seascapes in different environmental settings	●Number of visitors ●bathing areas and Number beaches ●Fishing reserves ●Fish abundance ●Fish monetary value from angling ●Number fishing licenses ●Quality of fresh waters for fishing		●Number of visitors (to thermal mineral and mud springs and beaches to Natural Reserve areas) speleology sites	●Number of visitors (waterfowl hunters and fishermen) ●Number of fishing licenses ●Tourism revenue
	Intellectual and representative interactions	Scientific	●Monitoring sites (by scientists) ● Number of scientific projects articles, studies ●Classified sites (world heritage, label European tourism)			
		Educational	●Number of visitors ● National Parks and Natura 2000 sites			
		Heritage, cultural	●Number of visitors ●Natural heritage and cultural sites ●Number of annual cultural activities organised			
		Entertainment	●Number of visitors ●Surface or number of wetlands located next to a bike path			
		Aesthetic	●Number of visitors ●Contrasting landscapes (lakes close to mountains) ● Proximity to urban areas of scenic rivers or lakes			
Spiritual, symbolic and other	Spiritual and/or emblematic	Symbolic	●National species or habitat types		●Number of visitors (to	●National species or habitat types

Division	Group	Class	Lakes	Rivers	Ground water	Wetlands
interactions with biota, ecosystems, and land-/seascapes [environmental settings]					places where springs and streams with GW origin made them historic and religious sites)	
		Sacred and/or religious	●Sacred/religious sites (catastrophic events, religious places)			●Sacred/religious sites (catastrophic events, religious places)
	Other cultural outputs	Existence	●Number of visitors (to National Parks including lakes) ●Number of fishing licenses		●Number of visitors (to hot mineral spring waters)	*See rivers and lakes*
		Bequest	● Number of associations registered on animals, plants, environment, naturism			*See rivers and lakes*

Table S5. Indicators for marine ecosystem services (CICES classification).

Division	Group	Class	Marine inlets and transitional waters	Coastal waters	Shelf waters	Open Ocean
Nutrition	Biomass	Cultivated crops				
		Reared animals and their outputs				
		Wild plants, algae and their outputs	● Harvest (ton/year)			
		Wild animals and their outputs	●Landings (ton)	● Landings (ton) ● CPUE (ton)		
		Plants and algae from in-situ aquaculture	●Harvest (ton/year)			
		Animals from in-situ aquaculture	● Harvest (ton/year)			
	Water	Surface water for drinking				
		Ground water for drinking				
Materials	Biomass	Fibres and other materials from plants, algae and animals for direct use or processing	●Harvest (ton/year)	● Landings (ton) ● Harvest (ton/year)		
		Materials from plants, algae and animals for agricultural use		● Landings (ton) ● Harvest (ton/year)		
		Genetic materials from all biota	● Patents (no.) ● Published articles (no.)			

Division	Group	Class	Marine inlets and transitional waters	Coastal waters	Shelf waters	Open Ocean
	Water	Surface water for non-drinking purposes				
		Ground water for non-drinking purposes				
Energy	Biomass-based energy sources	Plant-based resources				
		Animal-based resources				
	Mechanical energy	Animal-based energy				
Mediation of waste, toxics and other nuisances	Mediation by biota	Bio-remediation by micro-organisms, algae, plants, and animals	●Nutrient load to coast (ton/year)			
		Filtration/sequestration/storage/accumulation by micro-organisms, algae, plants, and animals				
	Mediation by ecosystems	Filtration/sequestration/storage/accumulation by ecosystems	● Heavy metal and persistent organic pollutant deposition (ton/year) ●Oxyrisk			
		Dilution by atmosphere, freshwater and marine ecosystems				
		Mediation of smell/noise/visual impacts				
Mediation of flows	Mass flows	Mass stabilisation and control of erosion rates	● Composite indices based on extent of selected emerged, submerged and intertidal habitats, coastline slope and coastal geomorphology, wave regime, tidal range, relative sea level, storm surge			
		Buffering and attenuation of mass flows				
	Liquid flows	Hydrological cycle and water flow maintenance				
		Flood protection	***See buffering and attenuation of mass flows***			
	Gaseous / air flows	Storm protection				
		Ventilation and transpiration				
Maintenance of physical, chemical, biological conditions	Lifecycle maintenance, habitat and gene pool protection	Pollination and seed dispersal				
		Maintaining nursery populations and habitats	●Submerged and intertidal habitats diversity (no.) ● Oxygen concentration (%) ● Turbidity (%) ● Species distribution (km^2/ha) ● Abundance and richness - at age (ton/year) ●Extent of marine protected areas (km^2/ha) ●Nursery areas (km^2/ha)			

Division	Group	Class	Marine inlets and transitional waters	Coastal waters	Shelf waters	Open Ocean
	Pest and disease control	Pest control	● Presence of alien species (no.) ● Distribution of alien species (km^2)			
		Disease control				
	Soil formation and composition	Weathering processes				
		Decomposition and fixing processes	● Nitrogen removal (%) ● Water residence time (months) ● Depth/water residence time (m/year)			
	Water conditions	Chemical condition of freshwaters				
		Chemical condition of salt waters	● Nutrient load to coast (ton/year) ● Heavy metal and persistent organic pollutant loading (ton/year) ●Oxyrisk			
	Atmospheric composition and climate regulation	Global climate regulation by reduction of greenhouse gas concentrations	●Carbon stock (ton C) ● Carbon sequestration (ton C/year) ● pH ● blue Carbon (ton C) ● Primary Production (ton C/year)			
		Micro and regional climate regulation				
Physical and intellectual interactions with biota, ecosystems, and land-/seascapes [environmental settings]	Physical and experiential interactions	Experiential use of plants, animals and land-/seascapes in different environmental settings	● Extent of marine protected areas (km^2/ha) ● Presence of iconic/endangered species (no.) ● In-water activities occurrence (no.) ● Recreation trips (no./year)			● Extent of marine protected areas (km^2/ha) ● Presence of iconic/endangered species (no.)
		Physical use of land-/seascapes in different environmental settings				
	Intellectual and representative interactions	Scientific	● Scientific studies (no.) ● Documentaries, educational publications (no.) ● Visits to scientific and artistic visits exhibits (no.)			
		Educational				
		Heritage, cultural				
		Entertainment	● Documentaries, educational publications (no.) ● Visits to scientific and artistic visits exhibits (no.)			
		Aesthetic				
Spiritual, symbolic and other interactions with biota, ecosystems, and land-/seascapes [environmental settings]	Spiritual and/or emblematic	Symbolic				
		Sacred and/or religious				
	Other cultural outputs	Existence	● Extent of marine protected areas (km^2/ha) ● Presence of iconic/endangered species (no.)			
		Bequest				

Table S6. Indicators for Heathland and shrub ecosystem services

Division	Group	Class	Heathland and shrub
Nutrition	Biomass	Reared animals and their outputs	● Livestock data (number/ha, Ton/year/region)
Maintenance of physical, chemical, biological conditions	Lifecycle maintenance, habitat and gene pool protection	Pollination and seed dispersal	● Pollination potential ● Pollinators distribution ● Pollinators species richness ● Number of beehives ● Areal coverage of vegetation features supporting pollination (hedgerows, flower strips, High Nature Value Farmland etc.)
		Maintaining nursery populations and habitats	● Share of High Nature Value farmland ● Traditional orchards
Physical and intellectual interactions with biota, ecosystems, and land-/seascapes [environmental settings]	Physical and experiential interactions	Experiential use of plants, animals and land-/seascapes in different environmental settings	● Number of visitors in agricultural areas ● Number of Number of rural enterprises offering tourism-related services ● Farm tourism ● Walking and biking trails ● Number of hunting licences, number of birdwatchers ● Expenditures related to hunting
		Physical use of land-/seascapes in different environmental settings	
	Intellectual and representative interactions	Scientific	● Amount of scientific studies on agro-ecosystems
		Educational	● Number of didactic farms
		Heritage, cultural	● Number of agricultural-livestock fairs ● Number of monuments in agricultural areas ●Number of certified products that require traditional landscape management
		Entertainment	● Contests and competitions related to agriculture
		Aesthetic	● Number of visitors in agricultural areas ● Number of nature/agricultural landscape photos uploaded on web portals
Spiritual, symbolic and other	Spiritual and/or emblematic	Symbolic	● Remarkable trees ● Symbolic species

Division	Group	Class	Heathland and shrub
interactions with biota, ecosystems, and land-/seascapes [environmental settings]		Sacred and/or religious	●Religious monuments, pilgrim paths in agro-ecosystems
	Other cultural outputs	Existence	●Cropland or grassland in protected agricultural areas (e.g. Natura2000, Biosphere reserves, IUCN category V areas, World Heritage Unesco sites related to agricultural landscape, landscape conservation areas)
		Bequest	● Willingness to pay for landscape measures in cropland or grassland areas

Table S7. Indicators for sparsely vegetated ecosystem services

Division	Group	Class	Heathland and shrub
Nutrition	Water	Surface water for drinking	● High Nature Value farmland
		Ground water for drinking	● Areas important for groundwater abstraction in agro ecosystems
Maintenance of physical, chemical, biological conditions	Lifecycle maintenance, habitat and gene pool protection	Pollination and seed dispersal	● Pollination potential ● Pollinators distribution ● Pollinators species richness ● Number of beehives ● Areal coverage of vegetation features supporting pollination (hedgerows, flower strips, High Nature Value Farmland etc.)
		Maintaining nursery populations and habitats	● Share of High Nature Value farmland ● Traditional orchards
Physical and intellectual interactions with biota, ecosystems, and land-/seascapes [environmental settings]	Physical and experiential interactions	Experiential use of plants, animals and land-/seascapes in different environmental settings	● Number of visitors in agricultural areas ● Number of Number of rural enterprises offering tourism-related services ● Farm tourism ● Walking and biking trails ● Number of hunting licences, number of birdwatchers ● Expenditures related to hunting
		Physical use of land-/seascapes in different environmental settings	
	Intellectual and representative interactions	Scientific	● Amount of scientific studies on agro-ecosystems
		Educational	● Number of didactic farms

Division	Group	Class	Heathland and shrub
		Heritage, cultural	● Number of agricultural-livestock fairs ● Number of monuments in agricultural areas ●Number of certified products that require traditional landscape management
		Entertainment	● Contests and competitions related to agriculture
		Aesthetic	● Number of visitors in agricultural areas ● Number of nature/agricultural landscape photos uploaded on web portals
Spiritual, symbolic and other interactions with biota, ecosystems, and land-/seascapes [environmental settings]	Spiritual and/or emblematic	Symbolic	● Remarkable trees ● Symbolic species
		Sacred and/or religious	●Religious monuments, pilgrim paths in agro-ecosystems
	Other cultural outputs	Existence	●Cropland or grassland in protected agricultural areas (e.g. Natura2000, Biosphere reserves, IUCN category V areas, World Heritage Unesco sites related to agricultural landscape, landscape conservation areas)
		Bequest	● Willingness to pay for landscape measures in cropland or grassland areas

ANNEX II – CORE SET OF CONDITION INDICATORS FOR DIFFERENT ECOSYSTEM TYPES

Core set of condition indicators for terrestrial and freshwater ecosystem types

Condition class	Indicator	U	C	G	F	H	S	W	RL
Environmental quality	Percentage of population exposed to noise	●							
	Percentage of population exposed to air pollution above the standards	●							
	Concentration of air pollutants	●							
	Percentage of population connected to urban waste water collection and treatment plants	●							
	Fragmentation		●	●	●	●	●	●	
	Tropospheric ozone (ground level ozone) concentration				●				
	Concentration of nitrogen, sulphate, sulphur, calcium and magnesium				●				
	Percentage of forest under management plan or equivalent				●				
	Nutrient and BOD concentration in surface water	●							●
	Water Exploitation Index								●
Structural ecosystem attributes (general)	Percentage area of ecosystem	●			●				
	Share of High Nature Value farmland in agricultural area		●	●					
	Share of organic farming in UAA		●	●					
	Livestock density		●	●					
	Deadwood				●				
	Biomass volume (growing stock)				●				
	Ecological Status								●
Structural ecosystem attributes based on species diversity and abundance	Farmland Bird Indicator		●	●					
	Abundance and distribution of common forest birds				●				
Structural ecosystem attributes monitored under the EU nature directives	Percentage covered by Natura 2000 or by Nationally Designated Areas	●	●	●	●	●	●	●	●
	Conservation status and trends of species of Community interest	●	●	●	●	●	●	●	●
	Conservation status and trends of habitats of Community interest	●	●	●	●	●	●	●	●
	Population status and trends of bird species of Community interest	●	●	●	●	●	●	●	●
Structural soil indicator	Soil organic carbon	●	●	●	●	●	●	●	

Core set of pressure and ecosystem condition indicators for marine ecosystem types

Class	Indicator	TC	SO
Climate change	Acidification	●	●
Pollution and nutrient enrichment	Contaminants	●	●
	Nutrient discharge	●	●
Over-exploitation	Fish catch	●	●
	Fish mortality of commercially exploited fish and shellfish exceeding Fmsy*	●	●
Introductions of invasive alien species	Number of newly introduced non-indigenous species	●	●
Environmental quality	Chemical Status	●	
	Nutrient and BOD concentrations	●	●
	Bathing water quality	●	
Structural ecosystem attributes (general)	Ecological status	●	
Structural ecosystem attributes based on species diversity and abundance	Spawning Stock Biomass	●	●
	Age and size distribution of commercially-exploited species	●	●
	Population abundance	●	●
Structural ecosystem attributes monitored under the EU nature directives	Conservation status and trends of habitats of Community interest	●	●
	Conservation status and trends of species of Community interest	●	●
	Population status and trends of bird species of Community interest	●	●
	Percentage of Natura 2000 and marine protected areas	●	●