European Environment Agency
European Topic Centre on
Biological Diversity

Technical paper N° 12f/2018

Ecosystem service fact sheet on water quality regulation

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December 2018

The European Topic Centre on Biological Diversity (ETC/BD) is a consortium of twelve organisations
under a Framework Partnership Agreement with the European Environment Agency for the period 2014-2018
AOPK-CR Ecologic ILE-SAS ISPRA JNCC MNHN NATURALIS SC-NAT SLU S4E UBA WER

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Context:

The Topic Centre has prepared this Technical paper in collaboration with the European Environment Agency (EEA) under its 2018 work programmes as a contribution to the EEA's work on ecosystem services.

Citation:

Please cite this report as
Götzl, M., Czúcz, B. and Condé, S., 2018. Ecosystem service fact sheet on water quality regulation. ETC/BD report to the EEA.

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ETC/BD Technical paper N° 12f/2018
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1. Introduction

In line with the fundamental role Nature and its services play in the healthy functioning of human society and economy, Target 2 of the EU Biodiversity Strategy to 2020 calls Member States (MS) to maintain and restore the ecosystems and their services. To meet these goals an EU wide ecosystem assessment (the EU MAES assessment: "Mapping and Assessment of Ecosystems and their Services" – Maes et al., 2013; 2014; 2018; Erhard et al., 2016) will evaluate the condition of Europe's ecosystems and the services they provide to the society based on an analysis of available data. The assessment will cover the whole EU territory, including EU regional seas, and it complements the Member States' activities on mapping and assessment of ecosystems and their services. The EU MAES assessment serves two main policy requests: (1) provide an evaluation of Target 2 of the EU Biodiversity Strategy to 2020 and (2) provide support to the definition of smarter targets under the post-2020 biodiversity policy.

Ecosystem condition has a key role in the EU MAES assessment: adequate service provision requires healthy ecosystems in good condition (Fig. 1.1; Maes et al., 2014). The EU MAES assessment will evaluate the condition of ecosystems based on a set of key indicators in the context of 'thematic ecosystem assessments', grouped according to broad ecosystem types (urban ecosystems, agroecosystems (croplands and grasslands), forests, heathlands, wetlands, freshwater, and marine ecosystems; Maes et al., 2018). The assessment aims to evaluate the trends in the condition of Europe's ecosystems relative to a baseline situation (2010) and provide evidence on where ecosystems are in a degraded state. This series of fact sheets produced by ETC/BD gives additional guidance on how ecosystem condition can be meaningfully defined and measured for various services and in various ecosystems, based on a review of scientific studies (Czúcz et al., 2017, 2018).

In the following pages key messages are summarized first from a policy perspective: what can these studies teach about designing a relevant set of ecosystem condition indicators for the EU MAES assessment? Then, in the subsequent chapters these lessons will be expanded, giving a detailed account of how water quality regulation is defined, which characteristics of the various ecosystem types are relevant for water quality regulation, and what kind of indicators are available for these characteristics. A discussion on the options for improving the integration of condition indicators into ecosystem service modelling is particularly relevant for ensuring coherence between the different components of the EU MAES assessment. The fact sheet is concluded by a set of annexes, which contain all relevant metadata behind the whole analysis.

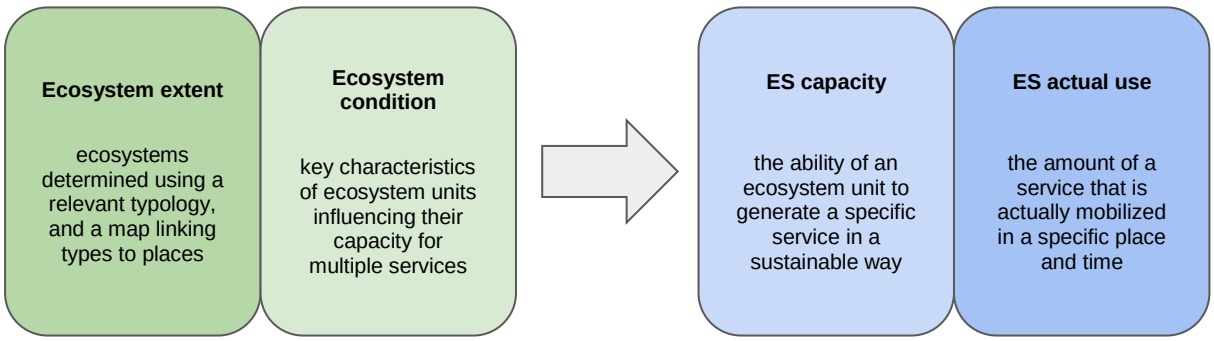

Figure 1.1: A simplified representation of the MAES conceptual framework (based on Maes et al., 2014; Burkhard et al., 2018; and MAES-INCA, 2018). The four boxes describe the main elements which need to be quantified (mapped and assessed) during the EU MAES assessment process.

2. Key messages

In this fact sheet water quality regulation is regarded as the contribution of ecosystems to the maintenance of the chemical conditions of fresh and saltwater. There are two fundamentally different ways how ecosystems can contribute to this, both of which are frequently mapped and assessed in MAES studies:

- by removing pollutants (that are already in the water) ('water purification')
- by not being source of further pollutants ('avoided pollution').

Particularly wetlands and (semi)natural terrestrial buffer zones around water bodies or potential pollutants are contributing to water purification, whereas avoided pollution can be performed by any (semi)natural ecosystem type. There are several key condition aspects of these ecosystems relevant for both types of water quality regulation that have been identified in this fact sheet based on a systematic review of published literature. The availability of potential indicators for these condition aspects has also been assessed similarly systematically (Fig. 2.1).

- The extent / abundance of wetlands or terrestrial buffer zones in the proximity of water bodies is a major landscape feature determining *water purification*. Possible indicators might be 'proximity to wetland' or 'proximity to waters' which could be developed based on the European ecosystem type map (ETM v3.1; Weiss & Banko, 2018). The 'density of embedded (semi)natural elements' in croplands can also be a key indicator here.
- The composition of the landscape (abundance/share of semi-natural ecosystem types) is a key landscape characteristic determining *avoided pollution*. This aspect is however already covered by ETM v3.1, and there is little need to develop additional condition indicators for this.

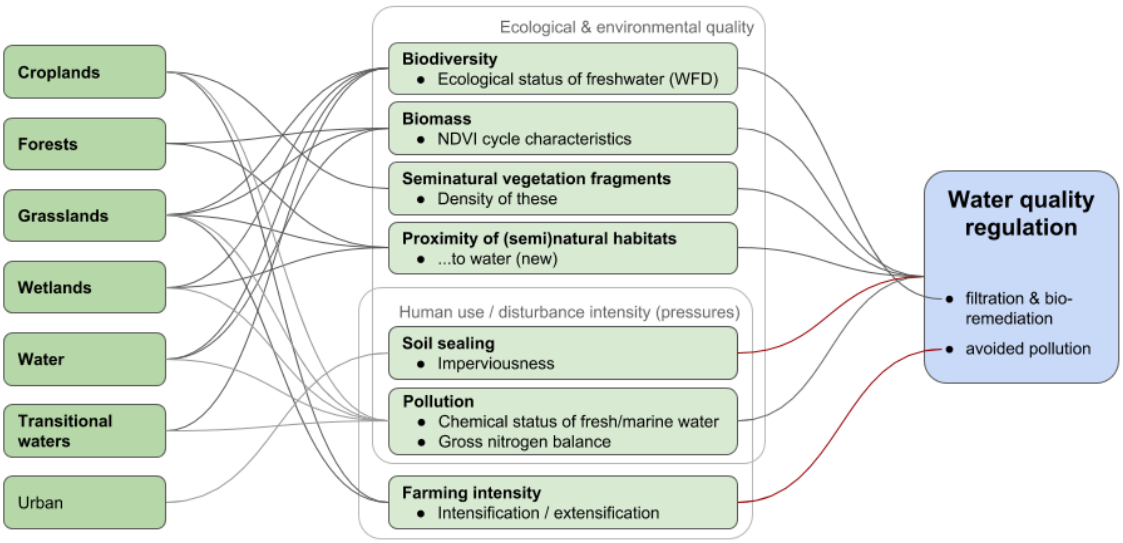

Figure 2.1: A graphical summary of this fact sheet. *Ecosystem types* (column 1) are connected to their *relevant characteristics* ('condition aspects'; column 2) and a possible set of *key indicators* (bullet points in column 2), which determine their *capacity for water quality regulation* (column 3). Characteristics not connected to any ecosystem type are landscape-level characteristics. Condition-service connections are drawn based on a systematic review (Czúcz et al., 2018). The negative relationships and the most important data gaps are highlighted in red.

Biodiversity and naturalness of wetlands are additional aspects important for *water purification*. Even considering general biodiversity indicators as proxies, there are still no biodiversity indicators which would be available with a desirable spatial resolution and coverage. Monitoring programs should be strengthened, and the spatial detail of MS reporting should be enhanced if possible. (The already existing biodiversity indicators are more suitable for ecosystem accounting than for MAES, which involves more spatial detail due to the mapping.)

- Biomass at the site is a relevant condition aspect, too, which can characterize and influence the efficiency of *water purification*. The normalized difference vegetation index (NDVI) and the leaf area index (LAI) are the most accessible proxies to be used.

Several human pressures have a significant direct influence on water quality regulation, and the pressures can be integrated among ecosystem condition indicators in a straightforward way.

- Pressures related to farming are the most critical for water quality (*avoided pollution*). JRC & EUROSTAT offer several useful indicators here (*intensification, pesticide/fertilizer use, share of organic farming, fallow land, crop diversity*), although not all of them are available at the spatial resolution desirable for mapping. The more general '*hemeroby*' or HANPP indicators can also be useful in adding spatial details.
- Grazing intensity may also affect water quality (*avoided pollution*), and this could be accounted for by the JRC pressure indicator '*livestock density*'.
- Urban green surfaces can considerably contribute to *water purification*, while impervious surfaces count as pollution sources (*avoided pollution*). Accordingly, several indicators of urban greenness/greyness can be relevant (e.g. *NDVI*, *imperviousness*).
- Chemical status of surface water is highly relevant for water purification. If loads of nutrients surpass a critical level, species composition and ecosystem functioning change dramatically over short periods of time and the ecosystem often move to a different stable state. This leads to a reduced water purification capacity in this ecosystem, in the worst case the service might be entirely disrupted.

3. Water quality regulation as an ecosystem service

The ecosystem service water quality regulation can be described as the contribution of ecosystems to the maintenance of the chemical condition of fresh or saltwater. Nutrient loading of terrestrial, freshwater and coastal ecosystems as a result of human waste disposal and agriculture can deteriorate their chemical condition which is of concern especially in densely populated areas and intensively farmed regions. There are different pathways of polluting substances into water ecosystems. Nitrates are leaching to the groundwater and subsequently to streams by subsurface runoff and deeper groundwater fluxes. Phosphates are transported through surface runoff into running waters (Verhoeven et al., 2006).

Ecosystems can contribute to the maintenance of water quality in in two fundamentally different ways: they "*have the capacity to purify water but can also be a source of impurities in fresh water*" (Burkhard et al., 2012, p.20; but see also the MA definition in Table 3.1). In the first case ("purify water") ecosystems remove (a part of) the introduced pollutants from the flows that pass through water courses (ditches, streams). This can take place by filtration and bio-remediation processes that transform organic or inorganic substances to mitigate their harmful effects. For example, wetlands have a high and long-term capacity to improve water quality irrespective if they are (semi)natural, such as riparian wetlands or floodplain wetlands, or 'treatment wetlands' which are the most frequently 'human-controlled' ones (Verhoeven et al. 2006).

Nevertheless, ecosystems might also contribute to the maintenance of the water quality of downstream ecosystems in a second, less recognized, but equally important way. Ecosystem types with a more natural management regime are less prone to act as "sources of impurities" as excess nutrients and other kinds of pollutants ('avoided pollution'). In contrast, anthropogenic ecosystem types, like urban or agricultural ecosystems are considerable sources of pollution, depending on their characteristics (e.g. population density, imperviousness, management intensity). Given that the MAES concept of 'ecosystems' encompasses urban and cropland, it is absolutely justified to consider 'avoided pollution' as a subtype of water quality regulation, where natural ecosystem types can have a positive contribution compared to artificial ecosystem types. And the degree to which man-made ecosystems are harmful in this respect, can be roughly indicated through their management characteristics, which is absolutely in line with the purposes of this paper.

It is important to note that the two subtypes of this ecosystem service are supplied by different types of ecosystems: whereas 'water purification' is mostly supplied by wetlands and water bodies, 'avoided pollution' is typically supplied by all terrestrial ecosystem types, especially the (semi)natural ones. Nevertheless, buffer strips of terrestrial ecosystems around potential pollution sources (e.g. motorways) may also provide 'water purification', so there is some degree of overlap between the two processes in these cases.

As far as the removal of nutrients is concerned there are different processes contributing to water purification: (1) nitrates are either converted to atmospheric nitrogen by denitrification processes, or uptaken by plants which results in long-term nitrogen storage, whereas (2) phosphorus is removed by sedimentation, soil adsorption or plant uptake typically in riparian habitats (Verhoeven et al. 2006).

Referring to the papers studied in the OpenNESS review it can be mentioned that there is an apparent bias for papers with a focus on wetland and freshwater ecosystems enabling the 'water purification' component of water quality regulation. But also other ecosystem types (e.g. terrestrial

ones) can supply this ecosystem service particularly the 'avoided pollution' aspect of the service. For a better synthesis, it would be important to involve more papers that study water purification in the context of brackish and coastal ecosystems, too.

Table 3.1: The position of water quality regulation in CICES (v5.1, Haines-Young & Potschin, 2018) and other major ES classification systems (IPBES: Pascual et al., 2017; TEEB, 2010; MA, 2005)

	CICES v5.1	Other classifications
Classification	**Section**: **2** Regulation & Maintenance (Biotic) **Division**: **2.2** Regulation of physical, chemical, biological conditions **2.1** Transformation of biochemical or physical inputs to ecosystems **Group**: **2.2.5** Water conditions **2.1.1** Mediation of wastes or toxic substances of anthropogenic origin by living processes **Class**: **2.2.5.1** Regulation of the chemical condition of freshwaters by living processes **2.2.5.2** Regulation of the chemical condition of salt waters by living processes **2.1.1.1** Bio-remediation by micro-organisms, algae, plants, and animals **2.1.1.2** Filtration/ sequestration/ storage/ accumulation by micro-organisms, algae, plants, and animals	**IPBES**: **NCP 7** Regulation of freshwater and coastal water quality **NCP 8** Formation, protection and decontamination of soils and sediments **TEEB**: Waste-water treatment **MA**: Water purification and waste treatment
Definition	**Scientific**: Maintenance of the chemical condition of fresh/salt waters by plant or animal species that enable human use or health (2.2.5.1-2) Transformation of an organic or inorganic substance by a species of plant, animal, bacteria, fungi or algae that mitigates its harmful effects and reduces the costs of disposal by other means (2.1.1.1) The fixing and storage of an organic or inorganic substance by a species of plant, animal, bacteria, fungi or algae that mitigates its harmful effects and reduces the costs of disposal by other means (2.1.1.2) **Simple**: Controlling the chemical quality of fresh/ saltwater (2.2.5.1-2); decomposing wastes (2.1.1.1); filtering wastes (2.1.1.2)	**IPBES**: Regulation – through filtration of particles, pathogens, excess nutrients, and other chemicals – by ecosystems or particular organisms, of the quality of water used directly (e.g. drinking) or indirectly (e.g. aquatic foods, irrigated food and fibre crops, freshwater and coastal habitats of heritage value) (NCP 7). Filtration, fixation, degradation or storage of chemical and biological pollutants (pathogens, toxics, excess nutrients) in soils and sediments that are important to humans (NCP 8). **TEEB**: Ecosystems such as wetlands filter both human and animal waste and act as a natural buffer to the surrounding environment. Through the biological activity of microorganisms in the soil, most waste is broken down. Thereby pathogens (disease causing microbes) are eliminated, and the level of nutrients and pollution is reduced. **MA**: Ecosystems can be a source of impurities in fresh water but also can help to filter out and decompose organic wastes introduced into inland waters and coastal and marine ecosystems.
Example for service	Use of buffer strips along water courses to remove nutrients in runoff (2.2.5.1); Macrophytes, for example salt marsh grass, can trap particles in their roots, sequestering wastes/toxicants in the sediment (2.1.1.2, Govers et al. 2014)	
Example for benefits	Reduced damage costs nutrient runoff from agroecosystems (2.2.5.1); Reduction in (...) disease (2.1.1.2)	

4. Ecosystem characteristics influencing the supply of water quality regulation

From the 10 papers studied in the systematic review underlying this report (Czúcz et al., 2018) nine papers were related to *water purification*, whereas there was only one paper (Oelmann et al., 2011) which focussed on the *avoided pollution* subtype of the service. Table 4.1 provides an overview on the importance of the characteristics of the main ecosystem types involved in the delivery of water quality regulation – thus focussing primarily on the water purification component of the ES. According to the scientific literature sampled, the most relevant characteristics are the extent / abundance of an ecosystem type or subtype (e.g. wetlands, buffer zones), the coexistence / proximity of the favoured ecosystem (e.g. rivers, lakes) to that ecosystem type which provides water purification or avoids pollution, the kind of biomass at the site, biodiversity in general and the occurrence / abundance of a functional group.

Table 4.1: Results of the systematic review: ecosystem characteristics that have been documented to influence the supply of water quality regulation, and the ecosystem types in which these relationships had been documented (Czúcz et al., 2018). Total / positive / negative / mixed: the number of papers which document any (or positive / negative / mixed) relationships between the studied characteristics and water quality regulation. A more detailed and fully referenced version of table can be found in Annex 1.

Characteristics type	Total	Positive	Negative	Mixed	Ecosystem types*
The extent (abundance) of an ecosystem type (or subtype)	**7**	7	0	0	wet, crop, forest, trans
Biodiversity (in general)	**3**	2	0	1	wet, grass, water
The coexistence / proximity of two different ecosystem types	**3**	3	0	0	crop, urban, grass, water
proximity of … to wetland	**3**	3	0	0	crop, urban, grass, water
Occurrence / abundance of a specific species (functional) group	**2**	2	0	0	wet, water, brackish
macrophytes	**2**	2	0	0	wet, water, brackish
zooplancton	**1**	1	0	0	trans
Biomass at the site	**2**	2	0	0	wet, grass, forest
ground layer	**1**	1	0	0	grass, forest, wet
litter	**1**	1	0	0	grass, forest, wet
Water availability	**2**	2	0	0	wet, trans
Management / disturbance intensity	**1**	1	0	0	crop, grass
Site structure	**1**	1	0	0	wet, water
Soil characteristics	**1**	1	0	0	crop, grass, forest

* MAES ecosystem types: crop: cropland; grass: grassland; forest: woodland and forest; wet: wetlands; water: rivers and lakes; brackish: marine inlets and transitional waters

The **extent / abundance of wetlands** is the most mentioned characteristic because this ecosystem type is the primary agent of *water purification*. Wetlands may create conditions favourable for nitrogen transformation and removal by soil microbial processes such as denitrification (Vought et al., 1995) which transforms nitrate to inert atmospheric nitrogen. Besides retaining nutrients (primarily nitrogen and phosphorus) as well as sediments they also perform additional ecosystem services by sequestering carbon, attenuating flood peaks, and enhancing biodiversity (Hefting et al., 2013). Also recreated or constructed wetlands and man-made lagoons can provide nutrient reduction caused by farmyard runoff (McCartney et al., 2003, Scholz et al., 2007, Rodrigo et al., 2013). But on the other hand, trade-offs may arise if loading rates by fertilizer applications are surpassing certain limits which may lead to emissions of greenhouse gases and loss of biodiversity as a result of prolonged nutrient loading (Verhoeven et al. 2006).

The coexistence / proximity of wetlands and **buffer strips** to water bodies are the second most frequently mentioned ecosystem characteristic to maintain water quality. As mentioned above wetlands provide *water purification* service connected to water bodies, as for example in case of riparian wetlands. Buffer zones of (semi)natural terrestrial vegetation in proximity to rivers may also prevent the transport of nutrition loads into water bodies and supply some kind of purification, too. Vegetated buffer zones surrounding agricultural land (the source of pollutants) or located along streams (the recipients of pollution) can minimize erosion or trap sediment in surface runoff and hence decrease nitrogen and phosphorus loading in surface water, particularly in the upland portions of a catchment. Such shelterbelts can also play a great role in determining catchment hydrology because they have markedly higher infiltration capacity than arable or pasture land (Christen & Dalgaard, 2013).

Biodiversity or naturalness of wetlands is an additional site-level characteristic important for water quality regulation. Both are connected to each other. In the only paper focusing at *avoided pollution*, Oelmann et al. (2011) documented that plant diversity can reduce the negative impact of agricultural nitrogen leaching on ground water resources. The capacity of wetlands to remove nutrients from waters (*purification*) also highly depends on vegetation composition (Fisher et al., 2009). Zooplankton diversity can also play a significant role in water clearing by consuming microalgae (Rodrigo et al., 2013). The purification service by terrestrial buffer strips depends on the naturalness of the biodiversity setting, which is also an important aspect for any terrestrial ecosystem type in order to guarantee avoided pollution.

The amount of **biomass** at a site can also characterize and influence the efficiency of *water purification*, for example by enhancing nitrogen retention. Weisner & Thiere (2010) showed that wetlands with tall emergent vegetation were more efficient at removing nitrogen than those dominated by submerged macrophytes or filamentous algae although the tall emergent vegetation led to less plant diversity in these wetlands. Some dependency of water purification from biomass has also described for riparian buffer systems which were shown to effectively reduce surface movement of pollutants from non-point sources to streams (Schultz et al. 2004). Vegetation types influence mass removal of total phosphorus and nitrogen so that there are differences between different kinds of riparian buffers (e.g. grass buffers, grass-shrub buffers, grass-tree buffers) in reducing nutrients (Mankin et al. 2007, Duchemin & Hogue 2009). Removal of biomass after a few years is an important precondition for maintaining the buffers´ filtration capacity (Bedard-Haughn et al. 2004, Christen et Dalgaard 2013).

Water availability is a further relevant ecosystem characteristic influencing water quality regulation. It was shown that water quantity influences wetland vegetation structure, composition and productivity (McCartney et al. 2003) which are important factors enabling *water purification*. Generally, a wetland with a stable water level can maintain the flora and fauna for water purification much easier than a temporal of highly fluctuating wetland.

5. Ecosystem condition indicators relevant for water quality regulation

The ecosystem characteristics listed in the previous chapter (Table 4.1) are not independent from each other. Biodiversity, for example, is roughly determined by habitat type, landscape context, and land use intensity. Thus not all of the identified / proposed aspects need to be covered by an ideal indicator system in order to be relatively comprehensive, and a focus on 'low hanging fruits' (aspects for which there are better / more readily available data) can be justified. Table 5.1 & Annex 2 provide an overview of the potential condition indicators and their underlying data sources for each of the condition aspects listed in Table 4.1, with the exception of the pressure (management / disturbance intensity) indicators, which will be discussed in the next chapter.

The European map of ecosystem types (ETM v3.1; Weiss & Banko, 2018) can be a key source of relevant condition indicators. Littoral reedbeds, which have shown to be key contributors to *water purification*, are considered to be '**subtype**' of the neighbouring water bodies in ETM v3.1. Further relevant ecosystem types are wetlands, streaming and standing water bodies, riparian forests or waterlogged heathlands which can perform purification of the water passing through these ecosystems. The extent (or share) of the '*littoral zone of inland surface water bodies*' (subtype C3 of MAES ecosystem type 'rivers and lakes') can be seen as a key indicator here. The '*density of embedded (semi)natural elements*' in croplands would indicate possible removal of nutrients from runoff. *High nature value* (HNV) areas could be used as an alternative indicator for areas with a certain degree of naturalness. But the extent of further relevant ETM v3.1 types and subtypes can also characterize water purification, although the extent of the MAES types should rather be considered under the 'ecosystem extent' box of the MAES framework (Figure 1), and not as a part of ecosystem condition. In terms of *avoided pollution* the extent of all ecosystem types can matter. The **proximity of (semi)natural** habitats to streaming or standing water bodies is a further key aspect to reduce their pollution. Map calculations on ETM could highlight cases where (semi)natural vegetation types can prevent pollution coming from urban or agricultural sites from entering standing or streaming water bodies. Buffer stripes around pollution source ecosystems (urban, croplands) and water bodies (streams, lakes) can be critically important here, and indicators like '*proximity to wetlands*' and '*proximity to water*' might be very useful to highlight such situations.

Table 5.1: Indicators available for the ecosystem characteristics relevant for water quality regulation. The 'usefulness' of each indicator is highlighted with a 'traffic lights' colour scheme.* Proposed **key indicators** are highlighted in bold.

U*	Indicator name	Comments
	Biodiversity (diversity/abundance of major species groups)	
	species in general	
2	Conservation status and trends of species of community interest (for multiple ET)	freshwater species – but they are probably more of an ES indicator than an EC indicator in this context
2	Living Planet Index for Mediterranean wetlands	probably more of an ES indicator than an EC indicator in this context
2	Invasive alien species (richness)	freshwater species – but they are probably more of an ES indicator than an EC indicator in this context
	habitats	
1	**Ecological status of surface water bodies**	probably more of an ES indicator than an EC indicator in this context, individual components (fish, macroinvertebrates...) can also be interesting
	Biomass at the site	
1	**Normalized difference vegetation index (NDVI)**	instantaneous values are too variable, but (multi)annual characteristics (especially on long term minima) can make useful condition indicators; a single biomass indicator can be enough
1	Leaf Area Index (LAI)	see above
2	Biomass volume (growing stock)	only available at a very coarse spatial resolution
3	Tree cover density	can also be relevant for non-forest habitats

Table 5.1 continued.

U*	Indicator name	Comments
	Site structure	
2	Structural heterogeneity	index focussing at farmland heterogeneity
	Soil characteristics	
2	Soil organic carbon (SOC)	sampling & database is primarily focussed at croplands
3	Soil biodiversity (DNA-based richness)	under development, not available yet
2	Soil nutrients availability (nitrogen & phosphorus)	sampling & database is primarily focussed at croplands
2	Soil thickness	new proposal for a simple indicator, to follow the degradable stock behind erosion
	Water availability	
1	Water and wetness probability index (WWPI)	stable high water levels are better
2	Normalized difference water index (NDWI)	instantaneous values are too variable, but (multi)annual characteristics can make useful condition indicators
3	Water levels	stable high water levels are better
2	Washlands (regularly flooded areas)	can also be seen as a subtype of any ecosystem (flooding agroecosystems can also reduce water quality!), or a management indicator, to be developed
	The extent (abundance) of a specific subtype (of the target ecosystem type)	
1	**Extent of ETM subtypes**	some EUNIS (level 2) subtypes (e.g. littoral reedbeds) contribute disproportionately to ES
1	**Density of embedded seminatural elements (hedgerows, lines of trees, etc.)**	embedded seminatural elements can efficiently remove nutrients from runoff
1	HNV area	the share of this highly relevant 'subtype' might be redundant with other indicators (seminatural elements, pressures, etc.)
	The coexistence / proximity of two different ecosystem types	
2	Proximity to wetlands	(semi)natural ecosystems bordering wetlands and water bodies, and (in particular) wetlands adjacent to water flows have a high positive influence, which can be mapped (indicators have still to be implemented)
2	**Proximity to water**	see above
	Landscape diversity	
2	Landscape diversity	can be relatively easily developed
	Landscape fragmentation & connectivity	
2	Landscape fragmentation from urban and transport infrastructure	

** U: 'usefulness' score, which follows the 'traffic lights' scheme of the 2nd MAES report (Maes et al., 2014):*

1 *highly relevant for the specified aspect of forest condition, appropriate data are available at European scale, and easily understood by non-technical audiences (relevance, representativity, and data availability are all high – see details in in Annex 2)*

2 *relevant for the specified aspect of forest condition, some data are available, but still needs some work, or the indicator is difficult to be interpreted for non-technical audiences (relevance, representativity, or data availability is moderate)*

3 *relevant for the specified aspect of forest condition, but there are significant data or interpretation challenges (e.g. the indicator is just weakly linked to the characteristics that it is intended to indicate, thus representativity or data availability is low)*

High **biodiversity** of wetlands, water bodies (which include littoral wetlands), and (semi)natural buffers also influences *water purification, and the naturalness / hemeroby of all ecosystem types can be considered to determine their capacity to act as potential pollution sources (avoided pollution)*. For wetlands and water bodies the *EU Water Framework Directive* (WFD) supplies a high number of policy-relevant indicators which describe both the biological, and the chemical status of these wet ecosystem types. The SEBI-indicator 'conservation status and trends of species of community interest for multiple ecosystem types' could be also used in a customized version to address this aspect of ecosystem condition, although it currently lacks appropriate spatial resolution.

The **biomass** of wetlands, water bodies (littoral wetlands), or any other type ecosystem type (buffer zones) can be characterized with remote-sensing based indicators. The *normalized difference vegetation Index* (NDVI) and *leaf area index* are probably the most accessible proxies that can be used.

There are no readily available indicators to describe the continuity of **water availability** in wetlands and water bodies (littoral zones). In the case of rivers and lakes the magnitude of their *littoral zones* can already be seen as an indirect proxy for this condition aspect. For rivers, the availability (share) of *washlands* (i.e. freely floodable adjacent (semi)natural ecosystems) could be used as a new indicator, whereas for wetlands the Copernicus surface *water and wetness probability index* (WWPI), or the 'evenness' of the *normalized difference water index* (NDWI) could be considered as additional, remote sensing-based proxies.

6. Integrating pressures among condition indicators

The intensity (frequency or magnitude) of recurrent human management activities and/or (semi)natural disturbance regimes can be seen as characteristics of the ecosystems that highly influence their capacity to supply various services. In the MAES conceptual framework (Maes et al., 2013; 2014; 2018) these characteristics are listed under the heading 'pressures', which are considered an 'indirect approach' for measuring ecosystem conditions (Erhard et al., 2016, p.31). In the case of water quality regulation there are relatively few characteristics identified in Table 4.1 under management / disturbance intensity. Nevertheless, management intensity (e.g. agrochemicals, grazing) would typically influence the 'avoided pollution' component of the studied ecosystem service; and as this component was not so prominently represented in the underlying systematic review, the list of indicators below is extended with a few additional indicators which are in a relatively straightforward direct relationship with (avoided) pollution.

Following the logic of the systematic review, pressure indicators have been clustered according to the ecosystem types and their typical management activities/disturbance regimes instead of the HIPOC categories. From the HIPOC classes, *pollution* and *overexploitation* can be relatively easily considered as ecosystem characteristics, and thus their indicators are well represented in Table 6.1. *Climate change* and *biological invasions* are, however, much more indirect pressures, which cannot be conceptualized as ecosystem characteristics, and which are only distantly relevant for water quality regulation. *Habitat loss* has two important special cases: (1) when land is transformed to a different ecosystem type (e.g. an 'ameliorated' wetland being transformed to cropland), and (2) for processes 'internal' to a specific ecosystem type (e.g. soil sealing within urban ecosystems). Cases of (1) are best handled under the ecosystem extent 'box' of the MAES framework (Fig. 1.1), and replicating them under the ecosystem condition 'box' creates inconsistencies in the whole MAES assessment framework. However, some 'internal processes, like soil sealing, are indirectly relevant for water quality regulation, so they are represented in Table 6.1 with appropriate state descriptors.

Various aspects of land use and **management intensity** are generally considered as a key pressure for the ecosystems and the environment. These pressures also influence the capacity of the ecosystem types being managed to act as pollution sources (avoided pollution). A general *hemeroby (or naturalness)* score of the various ecosystems (sub)types could be seen as a relatively quick and dirty proxy for avoided pollution, which could potentially be developed relatively easily based on ETM. The *degree of human appropriation* (HANPP), if broadly available, can serve as an alternative indicator here.

Nutrient balance is very closely related to avoided pollution, to the degree that they can even be seen as ES indicators characterizing the avoided pollution component of the ES (so they might belong to the ES box rather than the condition box in Fig. 1.1). There are several highly relevant indicators in this context, which are also correlated with each other so 1-2 of them can be enough for the EU MAES condition assessment. *Gross nitrogen balance* seems to be a good candidate for a general pressure indicator, and the WFD *chemical status of surface waters* (which was already discussed in the previous chapter) or some of its component indicators can be seen as the corresponding state indicator(s).

Indicators targeting specific ecosystem types (e.g. farming indicators) can also be highly relevant in this context. Potential **farming intensity** indicators with relevance for water quality regulation include the *intensification/extensification* of farming, as well as the conceptually problematic *pesticide use* indicator, and potential further indicators on *crop diversity* and *crop rotation* which still

need to be developed. *Share of fallow land* and *share of organic farming* may also indicate farming practices less prone to act as source of excess nutrients and other kinds of pollutants.

In grasslands a high number of **grazing** animals can also be a source of pollution, which might be appropriately characterized with an indicator on *livestock density*. In urban contexts the amount of **sealed surface**s (*imperviousness*) can be a good indicator on the amount of pollutants that will be washed off during runoff events (avoided pollution is higher if imperviousness is lower).

Table 6.1: Indicators available for pressures relevant for water quality regulation. The 'usefulness' of each indicator is highlighted with a 'traffic lights' colour scheme.* Proposed **key indicators** are highlighted in bold.

U*	Indicator name	Comments
	All ecosystems and land uses	
2	Hemeroby	a newly proposed indicator with a long history, conceptually close to 'naturalness', might be a good general indicator for 'avoided pollution'
2	Human Appropriation of Net Primary Production (HANPP)	
	Farming intensity	
1	**Intensification / extensification**	only available at NUTS2 level
2	Mineral fertilizer consumption	only available at NUTS2 level
2	Pesticide use	describes pesticide sales not pesticides use, different pesticides are simply added, at a very coarse spatial resolution
2	Water abstraction	indirectly related to avoided pollution (through increased intensity)
2	Share of organic farming	only available at a very coarse spatial resolution
	Grazing intensity	
2	Livestock density	can be source of pollution
	Nutrient / material balances	
1	**Gross nitrogen balance**	
1	Nitrogen deposition	
1	Gross phosphorus balance	
2	Acidification	
1	**Chemical status of surface/ground water**	probably more of an ES indicator as an EC indicator in this context, individual components can also be interesting
2	Heavy metal concentrations in soil	
	Soil loss	
2	Soil erosion	indirectly (for avoided pollution), could also be seen as an ES indicator (for erosion control)
3	Loss of organic matter	indirectly (for avoided pollution), could also be seen as an ES indicator (for erosion control)
1	**Imperviousness**	indirectly (for avoided pollution), the stock (imperviousness) is much better to indicate condition than its change (soil sealing)

** U: 'usefulness' score, which follows the 'traffic lights' scheme of the 2nd MAES report (Maes et al., 2014):*

1 *highly relevant for the specified aspect of forest condition, appropriate data are available at European scale, and easily understood by non-technical audiences (relevance, representativity, and data availability are all high – see details in in Annex 2)*

2 *relevant for the specified aspect of forest condition, some data are available, but still needs some work, or the indicator is difficult to be interpreted for non-technical audiences (relevance, representativity, or data availability is moderate)*

3 *relevant for the specified aspect of forest condition, but there are significant data or interpretation challenges (e.g. the indicator is just weakly linked to the characteristics that it is intended to indicate, thus representativity or data availability is low)*

7. Integrating condition indicators into water quality regulation capacity models

InVEST (integrated valuation of ecosystem services and trade-offs) is a set of open-source software models which were designed by the 'Natural Capital Project' to be used by a wide range of practitioners to assess and value different ecosystem services. All of these models have been produced to utilize ecosystem service concepts in decision-making. The InVEST 'nutrient delivery ratio model' is a tool to assess the service of nutrient retention by natural vegetation which is of particular interest for surface water quality issues. Thus the model will be reviewed briefly in this fact sheet. Generally, the 'nutrient delivery ratio model' describes the movement of mass of nutrient through space and this spatial information can be used to assess the service of nutrient retention by natural vegetation (Sharp et al. 2018). The model was designed to map (avoided) pollution from non-point source nutrient pollutants (nitrogen and phosphorus). Depending on the availability of data on other contaminants (e.g. persistent organics, pathogens) it can be used to map these substances, too.

The model represents the long-term flow of nutrients, addressing both nutrient sources (*avoided pollution*) and the subsequent pathway of these nutrients down to the recipient water bodies (and *water purification* on this pathway). Sources of nutrients across the landscape (nutrient loads) are determined based on the LU/LC map and associated 'loading rate' scores. These nutrient loads are then divided in a staying (sediment-bound, i.e. retained) and a dissolved part, which is transported through surface and/or subsurface flow. Based on a second 'retention efficiency' score assigned to each ecosystem type, 'delivery factors' (retention/delivery ratios) can be calculated along the flow path. The sum of nutrients which were not bound by soil or vegetation are exported at the watershed and might reach a streaming water. Table 7.1 links InVEST's key input data and scoring tables to the ecosystem characteristics and indicators reviewed and proposed in this fact sheet.

Table 7.1: Ecosystem characteristics important for water quality regulation addressed by input data used in the InVEST nutrient delivery model. Input data in brackets are considering the characteristic type only in the broader sense.

Relevant characteristics type (from this fact sheet)	Key indicators proposed for the EU MAES condition assessment (from this fact sheet)	Data used by InVEST nutrient delivery model (Sharp et al., 2018)
Water purification		
Biodiversity (including functional groups)	Ecological status of surface water bodies, ETM subtypes (littoral zones), density of embedded seminatural elements (hedgerows, lines of trees, etc.) in croplands	**LULC type** with the assigned **retention efficiency** scores
The coexistence / proximity of two different ecosystem types (buffer strips)	Proximity to water, ETM subtypes (littoral zones)	an exact geographic representation of the nutrient flow pathways
Biomass at the site	NDVI, ETM subtypes	**LULC type** with the assigned **retention efficiency** scores
Water availability	(NDWI, washlands)	**LULC type** with the assigned **retention efficiency** scores
Avoided pollution		
The extent (abundance) of an ecosystem type (or subtype)	Hemeroby	**LULC type** with the assigned **loading rate** scores
Management / disturbance intensity	Intensification/extensification, gross nitrogen balance	**LULC type** with the assigned **loading rate** scores

The ecosystem characteristics with importance for water quality regulation mentioned in chapter 2 are almost exclusively represented through the land use / land cover typology constituting the key input data source for the InVEST model. This LU/LC map is then translated into 'raw ES scores' using

two scoring tables (loading rate and retention efficiency) that are approximately equivalent to the *avoided pollution* and the *water purification* 'components' which were distinguished consistently throughout this fact sheet. Accordingly, the usefulness and reliability of the results that can be obtained by InVEST very highly depend on the level of detail and the reliability of the LU/LC map. For good results, the InVEST nutrient delivery model should be used with a relatively detailed LU/LC map customized for this purpose, and all potential sources of variance in 'loading rates' or 'retention efficiency' should be distinguished as distinct LU/LC types in the underlying LU/LC (=ecosystem) typology. The review presented in this fact sheet can thus also help users in efficiently preparing their INVEST application: the condition aspects & indicators highlighted in Table 7.1 are the ones which have to be taken into consideration (LU/LC classes should be refined until they are not homogeneous with respect to these characteristics).

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Annex 1: The papers studied in the systematic review

Table A1: This table identifies the scientific papers related to the ES water quality regulation, that were reanalysed from the OpenNESS systematic review (Smith et al., 2017). The table follows the structure of Table 4.1, linking each 'functional relationship' documented to the underlying papers using unique IDs, which are resolved below this table. The codes in brackets (e.g. "[T mi]") link the main types of characteristics to the types listed in Czúcz et al. (2017), where all further details about the characteristics typology and the reanalysis work can be found. Columns TI and NI give an overview on the importance of each characteristics for water quality regulation:

- **TI**: total influence (the number of papers which document an effect of the characteristics on any of the studied ES in any ecosystem type);
- **NI**: net influence (the number of papers documenting a positive ES effect minus the number of papers with a negative effect; mixed effects are not counted).

Higher values of TI are highlighted in darker shades in order to give a better visual overview of the importance of each line, and negative numbers in column NI are highlighted in red. All of the remaining columns refer to specific MAES ecosystem types (urb: urban; cro: cropland; gra: grassland; for: woodland and forest; hea: heathland and shrub; SVL: sparsely vegetated land; wet: wetlands; wat: rivers and lakes; bra: marine inlets and transitional waters). The values in these columns are the unique IDs of the scientific papers, which document a 'functional relationship' and the specific ecosystem characteristic in the given ecosystem type. The IDs of the paper are resolved in a reference list at the end of this Annex.

Characteristics type	TI	NI	urb	cro	gra	for	hea	SVL	wet	wat	bra
Management / disturbance intensity [T mi]	1	1		704	704						
Biodiversity (in general) [T di]	3	2			198				169, 654	654	
Occurrence / abundance of a specific species (functional) group [T ab]	2	2							654	654	331
macrophytes	2	2							654	654	331
zooplancton	1	1									331
Biomass at the site [T bi]	2	2			704	704			169		
ground layer	1	1			704	704					
litter	1	1			704	704					
Site structure [T st]	1	1							169	169	
Soil characteristics [T so]	1	1		704	704	704					
Water availability [T wa]	2	2							184		331
The extent (abundance) of an ecosystem type (or subtype) [E ab]	7	7		704		230			92, 184, 230, 375, 482		331
The coexistence / proximity of two different ecosystem types [E pr]	3	3	375, 482	92, 375, 482	375					375	
proximity of … to wetland	3	3	375, 482	92, 375, 482	375					375	

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Annex 2: Annotated list of potential MAES ecosystem condition indicators

Table A2: This table lists all indicators available and feasible to describe ecosystem characteristics relevant for water quality regulation in the context of the EU MAES ecosystem condition assessment. All indicators are scored according to three aspects of 'usefulness':

- **rel**: relevance for water quality regulation (1: relevant, 2: slightly/indirectly relevant);
- **rep**: the degree to which the indicator represents the underlying condition aspect (1: good representation, e.g. indicator fully covers a major aspect → 3: poor representation);
- **ava**: availability of indicator (1: available with a good quality & spatial resolution (at least NUTS2) for most of the EU (might still need some feasible update), 2: there is something available (but needs more work), 3: still to be developed (or needs major enhancements));

Relevance (rel), representativeness (rep), and availability (ava) are highlighted with a colour scheme following that of the 2nd MAES report (Maes et al., 2014). The overall 'usefulness' of each indicator (the coloured numbers in Tables 5.1 & 6.1) is calculated as the maximum (=worst) of these three scores. The remaining columns contain the following informations / metadata:

- **HI**: link to the HIPOC categories (just for pressures! – H: habitat loss, I: invasion, P: pollution, O: overexploitation, C: climate change);
- **indi.set**: link to high-level European indicator sets, if relevant (SEBI: Streamlining European Biodiversity Indicators, AEI: Agri-Environmental Indicators);
- **source**: the name of the data source / host institution, complemented with a weblink reference to a good description of the indicator where available;
- **unit**: the unit of the indicator;
- **pilot**: a list of previous studies (mainly MAES pilots: Maes et al., 2018) that had mentioned/proposed the indicator before (a: agroecosystems pilot; f: forest pilot; n: nature pilot);
- **date**: the reference period / years for which values of the indicator are available;
- **s.resol**: spatial resolution of the already available values of the indicator;
- **s.cover**: spatial coverage of the already available values of the indicator.

Unimplemented indicators (indicators under development) are highlighted in grey text, indicator families (which can/should be customized to the specific ecosystem types) are highlighted in *italics*, whereas the names of newly proposed indicators for filling gaps are highlighted in **bold**. The spatial resolution of indicators that don't reach the expected level of detail (at least NUTS2 region) is also highlighted in **bold**.

HI	rel	rep	ava	indicator name	indi.set	source	unit	pilot	date	s.resol	s. cover
				Biodiversity (diversity/abundance of major species groups)							
				species in general							
	2	1	2	*Conservation status and trends of species of community interest (for multiple ET)*	SEBI 003	Art17 DB	%	afn	2013, 2018	**MS x BGR**	EU
	2	2	2	Living Planet Index for Mediterranean wetlands		WWF	index	n	1970-2005	**MS**	Mediterr countrie s

HI	rel	rep	ava	indicator name	indi.set	source	unit	pilot	date	s.resol	s. cover
	2	1	2	Invasive alien species (richness)	SEBI 010	JRC-EASIN	1/area	f	?	10km	EU+
				habitats							
	1	1	1	*Ecological status of surface water bodies*	SEBI 016	WISE	index		1992-	RBMP	EU
				Biomass at the site							
	1	1	1	Normalized difference vegetation index (NDVI)		Copernicus	index	f	1998-	1km	Global
	1	1	1	Leaf Area Index (LAI)		Copernicus	index	f	1998-	1km	Global
	1	2	2	Biomass volume (growing stock)	SEBI 017	EEA	m3/ha	f	1990-2010	**MS**	EEA39
	2	1	2	Tree cover density		JRC, MS?, Copernicus?	%	f	?	?	?
				Site structure							
	2	1	1	Structural heterogeneity		JRC	index	f	2006	250m	EU27
				Soil characteristics							
	2	1	1	Soil organic carbon (SOC)		LUCAS	% or g/kg	afn	2009, 2015	1km	EU25, EU28
	1	1	3	Soil biodiversity (DNA-based richness)		LUCAS	1/area	afn	2018		EU28
	1	2	1	Soil nutrients availability (nitrogen & phosphorus)		LUCAS	mg/kg	afn	2009, 2015	1km?	EU25, EU28
	2	1	1	**Soil thickness**		LUCAS?	cm		?	?	?
				Water availability							
	1	1	1	**Water and wetness probability index (WWPI)**		Copernicus	%		2009-	100m	EEA39
	2	1	1	**Normalized difference water index (NDWI)**		JRC	index		?	1km	Europe
	1	1	3	**Water levels**		?	?		?	?	?
	1	1	2	**Washlands (regularly flooded areas)**		ETM, DEM, ?	binary		2012	?	?
				The extent (abundance) of a specific subtype (of the target ecosystem type)							
	1	1	1	Extent of ETM subtypes	SEBI 004	CLC	%		1985-	100m	EU27
	1	1	1	Density of embedded seminatural elements (hedgerows, lines of trees, etc.)		JRC	%	a	2006	1km	EU27
	1	1	1	HNV area		JRC	%	a	2000, 2006	100m	EU27
				The coexistence / proximity of two different ecosystem types							
	1	2	1	**Proximity to wetlands**		ETM	km (or m)		2012	?	EU28+, TR, W. Balkan
	1	2	1	**Proximity to water**		ETM	km (or m)		2012	?	EU28+, TR, W. Balkan
				Landscape diversity							
	2	1	1	**Landscape diversity**		ETM	index		2012	?	EU28+, TR, W. Balkan
				Landscape fragmentation & connectivity							
	2	1	2	Landscape fragmentation from urban and transport infrastructure	LSI 004, CSI 054	EEA	km2	af	2012	1km	EU28+, TR, W. Balkan

HI	rel	rep	ava	indicator name	indi.set	source	unit	pilot	date	s.resol	s. cover
	2	1	1	Connectivity of seminatural elements (hedgerows...)		JRC	index	a	2006	1km	EU27
				Management / disturbance intensity (pressures)							
				All ecosystems and land uses							
O	2	1	1	**Hemeroby**		CLC, CAPRI, AFOLU			2006	100m	EU27
O	2	1	2	Human Appropriation of Net Primary Production (HANPP)		UNI Klagenfurt	kg/m2 /y of C	a	1990, 2000, 2006	1km	25 MS
				Farming intensity							
OP	1	1	1	Intensification / extensification	AEI12	Euro-stat	index (EUR)	an	1996, 2006	NUTS2	EU 27
OP	1	2	1	Mineral fertilizer consumption	~SEBI 019, AEI5	CAPRI	kg/ha/y	a	2000-2015	NUTS2	EU28
P	1	2	1	Pesticide use	AEI06	Euro-stat	kg/ha/y of act. ingred	a	2011-2014	**MS**	EU28
	2	2	1	Water abstraction	AEI20	JRC?	10^6 m3/y	a	2006	5km	some MS
OP	2	1	1	Share of organic farming	SEBI 020, AEI4	FSS	%	a	2005, 2012-2016	**MS**	EU28
				Grazing intensity							
O	2	1	1	Livestock density		FSS, CAPRI	LU/ha	a	2010, 2012	5km, HSU(?)	EU28
				Nutrient / material balances							
OP	1	1	1	Gross nitrogen balance	~SEBI 019, AEI15	CAPRI	kg/ha/y	a	1990-	1km (HSU)	EU28
P	1	1	1	Nitrogen deposition		IMAP, LRTAP	kg/ha/y	af	2005	5km	EU
OP	1	1	1	Gross phosphorus balance	AEI16	CAPRI	kg/ha/y of P	a	1990-2016	**MS**	EU
P	2	1	2	Acidification	IND-30, CSI 005, AIR 004	JRC	kg/ha/y of S	f	?	?	?
P	1	1	1	*Chemical status of surface/ground water*	SEBI 016	WISE	index	a	1992-	RBMP	EU
P	2	2	2	Heavy metal concentrations in soil		JRC D3	mg/kg /y	af	2009, 2020	1km	EU27-28
				Soil loss							
OH	2	2	1	Soil erosion	AEI21		t/ha/y	afn	2010	1km	EU28
OH	2	3	1	Loss of organic matter		LUCAS	%/y of SOC	an		1km	EU28
H	1	1	1	Imperviousness		Copernicus	%		2006-2015	20m	EEA39

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Annex 3: Key definitions

Actual use or **flow** (of an ecosystem service): The amount of an ecosystem service that is actually mobilized in a specific area and time (based on OpenNESS, 2014).

Benefits: Positive change in wellbeing from the fulfilment of individual or societal needs and wants (based on TEEB, 2010).

Biodiversity: 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 (based on CBD, 1992).

Capacity (for an ecosystem service): The ability of a given ecosystem to generate a specific ecosystem service in a sustainable way (based on SEEA-EEA, 2012).

Conceptual framework: A model describing the relevant elements of a physical or social system and the main connections between them for the purposes of understanding and communication.

Condition aspect: Meaningful groups / types of ecosystem characteristics, which should be taken into consideration for quantifying ecosystem condition in a particular assessment context. 'Condition aspects' are related to 'ecosystem condition' in the same way as 'ecosystem service types' are related to the concept of 'ecosystem services'. All condition aspects identified as relevant should be represented by quantitative condition indicators in the assessment process.

Conservation status (of a natural habitat): The sum of the influences acting on a natural habitat and its typical species that may affect its long-term natural distribution, structure and functions as well as the long-term survival of its typical species (EEC, 1992).

Conservation status (of a species): The sum of the influences acting on the species concerned that may affect the long-term distribution and abundance of its populations (EEC, 1992).

Ecosystem: 1 (in a general context): A dynamic complex of plant, animal, and microorganism communities and their non-living environment interacting as a functional unit. Humans may be an integral part of an ecosystem, although 'socio-ecological system' is sometimes used to denote situations in which people play a significant role, or where the character of the ecosystem is heavily influenced by human action (based on CBD, 1992 and MA, 2005). 2 (in a MAES context): An instance of an ecosystem type.

Ecosystem accounting: Ecosystem accounting is a coherent and integrated approach to the measurement of ecosystem assets and the flows of services from them into economic and other human activity (SEEA-EEA, 2012)

Ecosystem assessment: A social process through which the findings of science concerning the causes of ecosystem change, their consequences for human well-being, and management and policy options are brought to bear on the needs of decision-makers (UK NEA, 2011).

Ecosystem characteristic: Key attributes of an ecosystem unit describing its components, structure, processes, and functionality, frequently closely related to biodiversity. The term characteristics is intended to be able to encompass all of the various perspectives taken to describe an ecosystem. (based on SEEA-EEA).

Ecosystem condition: The overall quality of an ecosystem unit, in terms of its main characteristics underpinning its capacity to generate ecosystem services. The concepts of 'ecosystem state', 'ecosystem health', 'ecosystem integrity', 'ecosystem quality', and 'naturalness' are closely related to the concept of ecosystem condition.

Ecosystem degradation: A persistent decline in the condition of an ecosystem.

Ecosystem extent: The spatial area covered by an ecosystem or ecosystem type (based on SEEA-EEA, 2012).

Ecosystem service (ES): The contributions of ecosystems to benefits obtained in economic, social, cultural and other human activity (based on TEEB, 2010 & SEEA-EEA, 2012). The concepts of 'ecosystem goods and services', 'final ecosystem services', and 'nature's contributions to people' are considered to be synonymous with ecosystem services in the MAES context.

Ecosystem status: Ecosystem condition defined among several well-defined categories with a legal status. It is usually measured against time and compared to an agreed target in EU environmental directives (e.g. Habitats Directive, Water Framework Directive, Marine Strategy Framework Directive), e.g. "conservation status".

Ecosystem type (ET): A specific category of an ecosystem typology.

Ecosystem typology: A classification of ecosystem units according to their relevant ecosystem characteristics, usually linked to specific objectives and spatial scales.

Habitat: 1. (in a general context): The physical location or type of environment in which an organism or biological population lives or occurs, defined by the sum of the abiotic and biotic factors of the environment, whether natural or modified, which are essential to the life and reproduction of the species (based on EEC, 1992). 2 (in a MAES context): A synonym of 'ecosystem type'.

Human well-being: A state that is intrinsically (and not just instrumentally) valuable or good for a person or a societal group, comprising access to basic materials for a good life, health, security, good physical and mental state, and good social relations (based on MA, 2005).

Indicator: An indicator is a number or qualitative descriptor generated with a well-defined method which reflects a phenomenon of interest (the indicandum). Indicators are frequently used by policy-makers to set environmental goals and evaluate their fulfilment (based on Heink & Kowarik, 2010).

MAES framework: The conceptual framework for the EU Mapping and Assessment of Ecosystem Services (MAES) programme (Target 2 Action 5 of the EU Biodiversity Strategy to 2020). The main elements of the MAES framework are the extent and condition of ecosystem types, and the capacities and flows of ecosystem service types, which need to be valuated with appropriate methods.

Mapping: The process of creating a cartographic representation (map) of objects in geographic space. In the MAES context mapping means a spatially detailed assessment of the elements of the MAES framework, which aims inter alia at creating cartographic representations of the studied elements (based on OpenNESS, 2014).

Pressure: 1 (in a general context): Human induced processes that alter the condition of ecosystems. 2. (in the context of this study): recurrent patterns (regimes) of human land use activities or natural disturbances that can characterize an ecosystem in a particular place.

This glossary of terms is principally based upon **Czúcz & Condé (2017)** and **Maes et al. (2018)**. The definitions for *actual use*, *ecosystem condition* and *pressure* have been adjusted, and the terms *condition aspect* and *MAES framework* are new.

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Annex 4: List of abbreviations

AEI	Agri-Environmental Indicators
AFOLU	agriculture, forestry and other land use
Art12	Article 12 (assessments of species under the EU Birds Directive)
Art17	Article 17 (assessments of habitats and species under the EU Habitats Directive)
BGR	biogeographic region
CAPRI	Common Agricultural Policy Regionalised Impact
CBD	Convention of Biological Diversity
CICES	Common International Classification of Ecosystem Services
CLC	Corine land cover
Corine	Coordination of Information on the Environment
DB	database
DEM	Digital elevation models
EASIN	European Alien Species Information Network
EBCC	European Bird Census Council
EEA	European Environment Agency
EC	Ecosystem condition
EEC	European Economic Community
ES	ecosystem service(s)
ESTIMAP	European Ecosystem Services Mapping tool
ET	ecosystem type(s)
ETC/BD	European Topic Centre on Biological Diversity
ETC/SIA	European Topic Centre for Spatial information and Analysis
ETC/ULS	European Topic Centre on Urban, Land and Soil Systems
ETM	ecosystem type map
EU	European Union
EUNIS	the European Nature Information System (habitat classification)
Eurostat	the statistical office of the European Union
FSS	farm structure surveys
GIS	geographic information system
HANPP	human appropriation of net primary production
HIPOC	habitat change, invasive species, pollution, overexploitation, climate change (a common list of the main drivers of environmental change)
HNV	high nature value farmlands
HSU	homogeneous spatial units (of farmlands)
IAS	invasive alien species
IMAP	Integrated Monitoring and Assessment Programme
InVEST	integrated valuation of ecosystem services and tradeoffs
IPBES	Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services
IUCN	International Union for Conservation of Nature
JRC	Joint Research Centre
KIP INCA	Knowledge Innovation Project on an Integrated system for Natural Capital and ecosystem services Accounting
LAI	Leaf Area Index
LRTAP	Long Range Transfer of Air Pollution

LU	livestock units
LUCAS	Land Use/land Cover Area frame Survey
LU/LC	Land use / land cover
MA	Millennium Ecosystem Assessment
MAES	mapping and assessment of ecosystems and their services
MS	EU Member States
NCP	Nature´s Contribution to People
NDVI	Normalized Difference Vegetation Index
NDWI	Normalized Difference Water Index
NUTS	nomenclature of territorial units for statistics
OpenNESS	Operationalisation of natural capital and ecosystem services (EU FP7 project)
RBMP	River Basin Management Plan
SEBI	Streamlining European biodiversity indicators
SEEA-EEA	System of Environmental Economic Accounts - Experimental Ecosystem Accounts
SOC	soil organic carbon
SVL	sparsely vegetated land
TEEB	The Economics of Ecosystems and Biodiversity
TR	Turkey
UK NEA	United Kingdom National Ecosystem Assessment
UNI	University
W.Balkan	West Balkan
WFD	Water Framework Directive
WISE	Water Information System for Europe
WWF	World Wildlife Fund