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Ecosystem type fact sheet on grasslands

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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). This fact sheet also relies on a previous ETC/BD work on grassland ecosystem condition (Hönigova et al., 2011).

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 grasslands are defined, which grassland characteristics are relevant for various ES, and what kind of indicators are available for these characteristics. The fact sheet is then concluded by a set of annexes, which contain all relevant metadata behind the whole analysis.

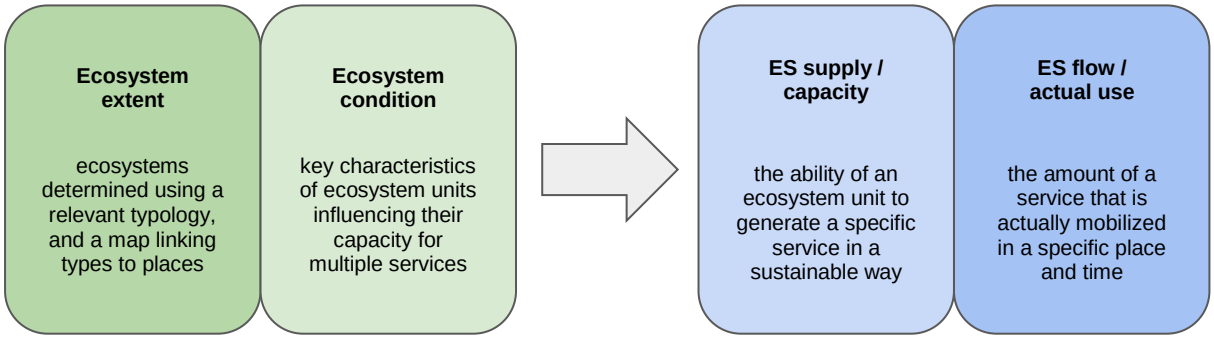

Figure 1.1: A simplified representation of the MAES conceptual framework (based on Maes et al., 2014; Burkhard et al., 2018; and MAES-INCA, 2018). The four boxes describe the main elements which need to be quantified (mapped and assessed) during the EU MAES assessment process.

2. Key messages

In most parts of Europe grasslands are a fundamentally anthropogenic ecosystem type generated and maintained by millennia of human management activities. Natural grasslands are mostly confined to high altitudes and latitudes in Europe, and to relatively continental (steppic) climates, which have mostly been transformed to agricultural lands during the past centuries. The continuity of these human activities highly influences the condition of grasslands and consequently the services they provide. Both intensification and cessation of management could threaten the existence of many grasslands. Accordingly, considering human management activities as 'ecosystem characteristics' is highly justified in the case of grasslands.

The European map of ecosystem types (ETM v3.1, Weiss & Banko, 2018) distinguishes six main subtypes of grasslands (Fig. 2.1), and this distinction is relevant in terms of land use and ecological functioning. There are several key aspects of ecosystem condition relevant for grasslands, that have been identified in this fact sheet based on a systematic review of published literature, and the availability of potential indicators for these aspects has been assessed similarly systematically.

- **Biodiversity** is a key factor determining the multifunctionality of grasslands. Nevertheless, there is a clear gap here, as none of the available indicators comes with a desirable spatial resolution and coverage. Monitoring programs should be strengthened, and the spatial detail of member state reporting should be enhanced if possible. The already existing biodiversity indicators are more suitable for ecosystem accounting than for MAES (i.e. mapping). The (bio)diversity of grasslands is a key factor in ensuring pollination and pest control, and has documented role in the regulation of erosion and floods, as well as in carbon sequestration.

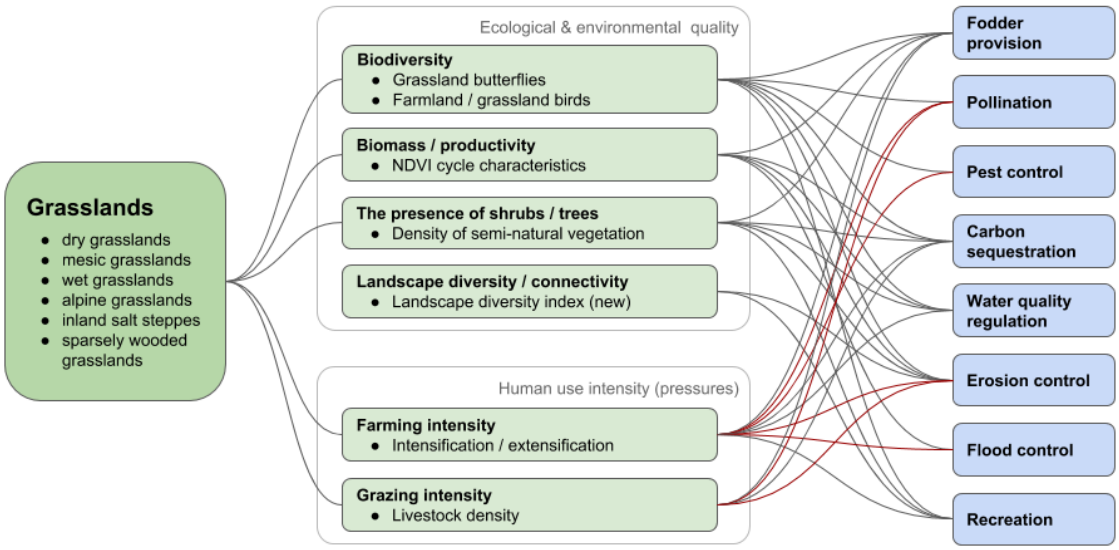

Figure 2.1: A graphical summary of this fact sheet listing *relevant aspects of grassland condition*, together with their *key indicators*, and connecting them to the *ecosystem services* they influence. Condition–service connections are drawn based on a systematic review (Czúcz et al., 2018). The negative relationships and the most important data gaps are highlighted in red.

- The most important aspect of **grassland use intensity** is the intensity of grazing or hay making, which influences pollination and carbon sequestration inter alia. Grazing rates can be characterized with a relatively simple indicator (**livestock density**). Several more general pressure indicators (e.g. intensification) also exert a direct influence on a broad range of services in grasslands (e.g. recreation, erosion control, pest control…). Land use intensity indicators affect most services negatively.
- **Biomass** can also be important for grasslands (influencing e.g. flood control or carbon sequestration). There are several characteristics and indicators that can be relevant here, but preferably only a single (or very few) carefully selected indicator (e.g. annual mean NDVI) should be included in EU MAES, as most of the potential indicators are correlated / redundant.
- The presence of **shrubs and trees on grasslands** affects a broad range of ES (e.g. recreation, water quality regulation), and should be characterized with a condition indicator (e.g. based on García-Feced et al., 2015).
- The diversity of grassland landscapes affects recreation and erosion capacities, and a new **landscape diversity** indicator could be relatively easily developed based on ETM v3.1.

3. Grasslands as an ecosystem type

Grasslands are dry (or only seasonally wet) non-coastal ecosystems dominated by grasses and other non-woody plants (EUNIS definition, EEA, 2012). Grasslands represent approximately 25% of the world land area and 70% of the world agricultural area, and contain about 20% of the world's soil carbon stocks (FAOSTAT, 2009 and Ramankutty et al., 2008 cit. Hönigová et al., 2011). In Europe most of the grasslands are created and maintained by centuries of human activities. Both historically and nowadays, the most important use and function of grasslands is to provide fodder for domestic animals through grazing or mowing. Accordingly, grasslands are typically considered as a type of agricultural area in the legal system of most European countries.

According to EUNIS there are 6 major subtypes of grasslands (Table 3.1). These subtypes are well justifiable both in terms of land use and ecological functioning. In order to make this information available for the EU MAES assessment, the European map of ecosystem types (ETM) addresses this level of thematic resolution based on a CLC crosswalk refined with the most recent available spatial datasets (Weiss & Banko, 2018; Table 3.1). According to ETM v3.1, 17% of all European ecosystems are grasslands. The share of each grassland subtype is also shown in Table 3.1.

Table 3.1: The most important subtypes (EUNIS level 2) of grasslands available in the European map of ecosystem types (ETM v3.1), linked to CLC classes and other datasets used during the map generation (based on Weiss & Banko, 2018). The share of each subtype is given in parentheses after the subtype names.

EUNIS level 2 subtypes (+their share)		Original CLC class	Assignment rules
E1	Dry grasslands (20%)	321 Natural grassland**	if no other rule applies
E2	Mesic grasslands (61%)	231 Pastures*	if no other rule applies
		242 Complex cultivation patterns	if HANTS = grassland
		242 Land principally occupied by agriculture, with significant areas of natural vegetation	if HANTS = grassland
E3	Seasonally wet and wet grasslands (8%)	231 Pastures*	if soil = wet (priority 4)
		321 Natural grassland**	if soil = wet (priority 2)
E4	Alpine and subalpine grasslands*** (9%)	231 Pastures	if elevation zone = subalpine (priority 1)
		321 Natural grassland**	if elevation zone = subalpine (priority 1)
E6	Inland salt steppes (0.5%)	321 Natural grassland**	if within the E6 distribution in Art 17. DB (priority 3)
E7	Sparsely wooded grasslands (1.6%)	231 Pastures*	if (potNatVeg = forest steps OR mediterranean scrubs) AND (HRL Forest TCD >10%) (priority 3)
		244 Agro-forestry areas	always

* grid cells with (1) >50% classified as grassland in HRL Grassland 2012, and (2) N2000 code 4111 (managed grasslands) in LoCo N2000 were also considered as CLC 231, irrespective of their initial CLC code

** grid cells with N2000 code 4211 or 4212 (Semi-natural grassland with/without trees) in LoCo N2000 were also considered as CLC 321, irrespective of their initial CLC code

*** grid cells with N2000 code 4221 (Alpine and subalpine natural grassland) in LoCo N2000 were considered as E4 irrespective of their initial CLC code and/or any other rules

Delineating grasslands from other MAES ecosystem types is not easy: there are several transitional cases and mosaic ecosystems, which can be difficult to classify. In accordance with the EUNIS definitions and the ETM assignment rules, the most important borderline cases are the following:

- Regularly (> every 5 years; Eurostat, 2017) tilled habitats dominated by cultivated herbaceous vegetation are considered as croplands (subtype: I1). On the other hand, parcels cropped with permanent fodder crops without regular tillage, or the successional weedy vegetation of recent oldfields should typically be considered as grassland (subtype: E2).
- Grasslands in EUNIS 2012 explicitly include urban lawns (e.g. park lawns, sports fields, etc) under the level 3 subtype E2.6. Nevertheless, in ETM v3.1, urban grasslands in gardens,

parks, or cemeteries (e.g. CLC 141, 142; or the corresponding categories under OpenStreetMap) are classified as cropland ecosystems (subtype: I2). This seems to be a contradiction, which should be resolved explicitly, as soon as possible. (In the new EUNIS such heavily managed herbaceous habitats will be moved to the *cropland* and *urban* sections, which is probably a more logical choice from an ecosystem assessment perspective.)

- Wet 'grasslands' with the water table at or above ground level for at least half of the year should be considered as wetlands. This includes salt marshes (CLC 421) which used to be classified as inland salt steppes (E6) in the previous versions of ETM, but they now also belong to wetlands (subtype: D6).
- Encroached grasslands, like transitional woodlands-shrubs (CLC 324) can contain a significant 'grassland' component, but the whole mosaic still belongs under forests (subtype: G5). This involves many stages of natural succession or forest degradation processes. Semi-arid steppes with scattered Artemisia scrub are, however, always considered as grasslands.
- Very open (< 30% vegetation cover) or coastal grasslands, like beaches, dunes and sand plains (e.g. CLC 331) belong to the ecosystem type sparsely vegetated land (SVL, subtype: H2). Severely burnt grasslands should also be classified as SVL (subtype: H5).

In a national pilot study, Hönigová et al. (2011) proposed a simple management typology for grasslands, and also proposed mean ES scores for four relevant grassland ecosystem services, which could be used in a simple matrix (or benefit transfer) model in a European MAES study (Table 3.2). For fodder provision and carbon sequestration the scores rely on biophysical ES capacity values, and in the case of all four studied ES, they rely on an extensive review of scientific literature. Unfortunately, it is very difficult though to link these categories to the grassland types of ETM v3.1, without additional external information.

Table 3.2: A grassland typology linked to typical management levels and ES capacity scores (from Hönigová et al., 2011).

	Fertilisation [kg N ha-1 yr-1]	Mowing [No of cuts]	Fodder provision [t C ha-1 yr-1]	Carbon sequest. [t ha-1 yr-1]	Pollination	Recreation
HNV grassland	0	0-1 (late in season)	moderate [< 4]	moderate to high [1.2–6.4]	high	high
Extensive meadows	0	1–2	moderate [3–6]	moderate to high*	moderate to high	moderate to high
Intensive meadows	N: > 200	(2)3–6	high [6–12]	negative to moderate [-0.9–1.1]	insignificant*	insignificant
Grass-Legume mixtures	N: 0–100	2–7	high [5–18]	moderate [0.3–0.75]	moderate*	insignificant*
Abandoned meadows	0	0	moderate to insignificant^1 [< 3]	moderate [0.2–0.5]	moderate*	moderate to high*
Pastures	excreta	0	moderate to high*	moderate [0.27–1.01]	insignificant to moderate	moderate to high*
Abandoned arable land**			insignificant to moderate**	negative** [-0.95–1.7]	insignificant to moderate**	insignificant**
Fields for biofuel production			insignificant*	negative to moderate	insignificant*	insignificant*

4. Relevant characteristics of grasslands

Table 4.1 provides an overview on the importance of various characteristics in enabling grasslands to supply services. This table is based on two systematic reviews: the one done by the OpenNESS community underlying this series of fact sheets (Czúcz et al., 2018), and a second one which was used to identify trade-offs between grassland ecosystem services in an earlier ETC/BD report (Hönigová et al., 2011). In this second review four ES were studied in detail: *fodder provision* (for domestic animals, also called as *herbage productivity*), *carbon sequestration*, *pollination*, and *recreation*; three of which overlaps with the services studied in the OpenNESS review. The most relevant grassland characteristics are the various aspects of grassland management, their biodiversity, and the amount of grassland biomass. These attributes of the grasslands influence almost all of the studied ES, except for timber provision and air quality regulation.

Table 4.1: Grassland characteristics that have been documented to influence the supply of various services. Total / positive / negative / mixed: the number of papers which document any (or positive / negative / mixed) relationships between the studied characteristics and any ecosystem service (based on Czúcz et al., 2018). Relationships between characteristics and services, that have also been documented by Hönigová et al. 2011 are highlighted in bold in the last column.

Characteristics type	Total	Positive	Negative	Mixed	Ecosystem services*
Management / disturbance intensity	10	2	7	1	**pollin**, erosion, **recr**, pest, **carbon**, flood, w.qual, **fodder**
fire frequency	3	0	3	0	erosion, flood, **carbon**
grazing intensity	3	1	1	1	**pollin**, **carbon**, erosion, **fodder**
fertilizers, pesticides					**pollin, fodder, recr**
Biodiversity (in general)	9	8	0	1	pollin, carbon, erosion, pest, w.qual, recr, **fodder**
diversity of plants	7	6	0	1	**pollin**, erosion, pest, carbon, **recr**, **fodder**
pollinators	1	1	0	0	pollin
Biomass at the site	7	7	0	0	carbon, flood, erosion, w.qual
belowground biomass	4	4	0	0	carbon, erosion, w.qual
ground layer	2	1	1	0	carbon, w.qual
litter	2	1	1	0	carbon, w.qual
The extent (abundance) of the target ecosystem type (or a specific subtype)	7	6	0	1	erosion, recr, pollin, w.qual
hedgerows, lines of trees	3	3	0	0	flood, fish
Occurrence / abundance of a specific species (functional) group	4	4	0	0	**carbon**, pollin, erosion, **fodder**
shrubs	2	2	0	0	carbon, erosion, **recr**
nectar source plants	1	1	0	0	pollin
pollinators	1	1	0	0	pollin
legumes					**fodder, carbon**
Water availability	4	4	0	0	flood, fish
washland (regularly flooded land)	4	4	0	0	flood, fish
Landscape diversity	4	4	0	0	recr, fish, erosion
Age of site / community	3	3	0	0	erosion, carbon
since abandonment	3	3	0	0	erosion, carbon
Functional traits of a major species group	2	2	0	0	carbon, w.qual
traits of herbs/grasses	2	2	0	0	carbon, w.qual

** Ecosystem services: fish: freshwater fishing; pollin: pollination; pest: pest regulation; carbon: carbon sequestration; erosion: erosion protection; flood: flood protection; w.qual: water quality regulation; recr: recreation, fodder: fodder provision*

In accordance with the fact that most grasslands depend on continuous human management for their subsistence, the **type and intensity of management activities** seems to be the most influential factor determining the supply of grassland ecosystem services. The traditional main use of grasslands in Europe is to provide fodder for domestic animals, and all of the key grassland management activities are related to this main use: in situ *grazing*, *mowing* (i.e. cutting, typically for

fodder), and the application of agrochemicals (typically *fertilizers*) to maintain or enhance their productivity. Whereas mowing only removes (harvests) biomass, and fertilizing only aims at replenishing soil mineral resources, grazing can be seen as a combined treatment as it allows that nutrients are returned to the land through livestock excreta (Menneer et al., 2004).

Low levels of management intensity are typically considered to be beneficial for most ecosystem services, including *recreation* (Lindemann-Matthies et al., 2010ab; van Berkel & Verburg, 2014), *erosion control* (Cammeraat, 2004; Maetens et al., 2012), and *carbon sequestration* (Lavorel & Grigulis, 2012). A low intensity grazing can increase *pollination* (Carvell, 2002; Sjödin et al., 2008; Batáry et al., 2010), and *pest control* (Anderson et al., 2013), and intermediate cutting frequencies result in the highest levels of *fodder* productivity (Cop et al., 2009; Weigelt et al., 2009). Nevertheless, the levels of these 'treatments' can interact in a complex way (Hejcman et al., 2010; Weigelt et al., 2009).

Intensive / excessive levels of management, as well as a **complete abandonment** (*pollination*: Carwell, 2002; *recreation*: Matzdorf et al., 2010) are typically considered to be negative for most ES. Excessive grazing or mowing can even reduce the productivity of grasslands, i.e. the very service that this management activity is aimed to harvest (Frank et al., 2002; Vinther, 2006). High level of grazing can exert a negative impact on several pollinator groups and biodiversity (Le Féon et al., 2010; Sjödin et al., 2008; Carvell, 2002; Loeser et al., 2007), and it can also create soil disturbance leading to *erosion* and *flood* problems (Delgado et al. 1999; Butler et al., 2008). Continuous excessive grazing and other intensive management practices can diminish soil *carbon* stocks (Conant et al., 2001) releasing carbon and other greenhouse gases into the atmosphere (Zhang et al., 2011). Fertilizers can also lead to a decline in several groups of wild *pollinators* through a reduction in floral diversity (Kremen et al., 2007; Le Féon et al., 2010; Greenleaf et al., 2007).

The intensity and frequency of natural disturbances can also play a role in determining the ES portfolio of grasslands. The **frequency of fires** can exert a negative influence on several ES, including *carbon* sequestration (Hönigová et al., 2011), *flood* regulation (Cosandey et al., 2005), and *erosion* control (Cammeraat, 2004; Maetens et al., 2012).

The **biological diversity** of the grasslands, and particularly **plant diversity**, influences 7 of the 11 studied ES. Shrubs (Beier et al., 2009; de Baets et al., 2009), legumes (Nyfeler et al., 2009; Kirwan et al., 2007; Fornara & Tilman, 2008), and flowering plants with reliable nectar flows (Ebeling et al., 2008; Fenster et al., 2004; Steffan-Dewenter & Tscharntke, 2001) seem to be the most important plant functional groups in grasslands for providing services, influencing *carbon*, *erosion*, *recreation*, *fodder*, and *pollination*. In addition to the diversity of grassland plants, their mere amount (**biomass**) is also a relevant factor. Diversity seems to be more important than biomass for *pollination* (Batary et al., 2010), *pest control* (Anderson et al., 2013), and *erosion control* (Bautista et al., 2007); whereas for *carbon sequestration* (Lavorel & Grigulis, 2012) and *flood control* (Lana-Renault et al., 2014) the relevance of biomass seems to be superior.

From all aspects of functional diversity, the **presence of** embedded **trees and shrubs** in grasslands is perhaps the most important factor, which exerts a positive influence on *carbon sequestration* (Beier et al., 2009), *erosion control* (de Baets et al., 2009), and *water quality regulation* (Christen & Dalgaard, 2013). Groups of shrubs and trees in an (extensively) managed grassland landscape are generally considered positive for *recreation* (Oreszczyn & Lane, 2000; Lindemann-Matthies et al., 2010a), whereas shrubs indicating abandonment are seen negatively (Matzdorf et al., 2010). Grasslands with shrubs and trees as embedded elements can also be considered as a subtypes of grasslands, which is critically relevant for multiple services.

Water availability of grasslands, especially their flooding regime can also be relevant for several services. Soil moisture is a key factor for herbage (*fodder*) productivity (Hönigová et al., 2011). Regularly inundated grasslands (also known as "**washlands**") can be highly important in the *regulation of floods* (Morris et al., 2005; Acreman et al., 2011), and morphologically diverse washlands can also serve as important breeding sites for several *fishes* (Lapointe et al., 2014).

In agricultural landscapes (co-)dominated by grasslands, **landscape diversity** seems to be a relevant landscape characteristic. For grasslands that are old-fields from former agricultural use, the **time since abandonment** can also be a relevant condition aspect characterizing carbon sequestration (Hönigová et al., 2011; Emran et al., 2012) and erosion (Nadal-Romero et al., 2013). In regulating erosion the **connectivity of grasslands** can also be an important factor (Bautista et al., 2007).

5. Ecosystem condition indicators for grasslands

The ecosystem characteristics listed in the previous chapter (Table 4.1) are not fully 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. A well-chosen set of key indicators can largely describe all aspects of grassland condition that are relevant from the perspective of services.

A lot of efforts have been already invested into developing relevant ecological and environmental indicators, both at the global and the European level. Indicators broadly vary in terms of their spatial, temporal and thematic scope, their spatial and temporal resolution, and their reliability. With some additional efforts, further indicators may become available. In the EU MAES context, the 5th MAES report (Maes et al., 2018) compiled a good starting set of condition indicators for all of the MAES ecosystem types. Annex 2 matches this list to the outcomes of the systematic review, giving a detailed overview of all indicators that can be seen as relevant for grasslands. Table 5.1 is a shorter version of Annex 2, which gives a diagnostic overview for each potential condition indicator (with the exception of the pressure / management / disturbance intensity indicators, which will be discussed in the next chapter).

One key gap apparent in Table 5.1 is that there are no readily available indicators for local grassland **biodiversity**. There is a relatively large number of existing indicators, but most of them seem to be problematic in terms of data availability, spatial and temporal resolution. In terms of thematics the "grassland butterfly indicator" (under SEBI 001) could be a perfect match, but unfortunately, this indicator is only quantified at a national level, and in most parts of Europe there are no data that could support a spatial refinement. The only taxonomic group for which there is a chance that an EU-level relatively high resolution biodiversity index can be generated in the foreseeable future is birds. Given the enormous overlap in the avifauna of these ecosystem types, a European farmland bird index can be relatively relevant for grasslands too (Donald et al., 2006).

As EUNIS subtypes are highly different in terms of their typical naturalness, the subtype information in ETM v3.1 can potentially be used as a relatively rough surrogate for grassland biodiversity. In general, alpine grasslands (E4) and inland salt steppes (E6) are relatively diverse, which are followed by dry (E1), wet (E3) and wooded (E7) grasslands, and mesic grasslands (E2) often under intensive agricultural use are the poorest in terms of biodiversity. Thus **assigning simple naturalness / hemeroby scores to each ETM subtype** could generate a 'quick and dirty' condition indicator. This approach could be improved if these condition scores would be assigned *during* the process of generating the ETM map, and not after that: if the rules that assign specific habitat types to each grid cell could also assign a naturalness score to each (grassland) cell, then even the various cases that lead to the same EUNIS class could have different naturalness scores (see Table 3.1).

There are several **biophysical / physiological properties** of grasslands, including productivity, biomass, and/or soil characteristics, which could make meaningful ecosystem condition indicators for grasslands. There are several sophisticated data products based on a combination of remote sensing and modelling techniques (e.g. NPP, NDVI or soil C/N ratio), that can be more or less readily used as grassland condition indicators. It should nevertheless be noted that instantaneous values of highly fluctuating parameters (e.g. NDVI) are useless as condition indicators. Instead of instantaneous values longer term averages, or other (multi)annual characteristics should be used.

Table 5.1: Indicators available for the ecosystem characteristics relevant for grasslands. 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)	multiple indicators (one for each ET), only available at a very coarse spatial resolution
2	Red List Index of threatened species	multiple indicators (one for each ET), at a very coarse spatial resolution
2	Invasive alien species (richness)	the number of IAS can be negatively correlated with general biodiversity
3	Species diversity, richness (number and abundance of species, including vascular plants, vertebrates, etc)	proposed by forest pilot but can be relevant for more ETs, needs to be developed, data source unclear
	plants	
3	Plant functional types (diversity)	proposed by forest pilot but can be relevant for more ETs, needs to be developed, data source unclear
3	Bryophyte, moss, liverwort, lichen and fungal species richness (index)	
	birds	
2	EU Population status and trends of bird species (%)	only available at a very coarse spatial resolution
2	**Bird indices (farmland, forest...)**	multiple indicators (one for each ET), the most accessible biodiversity indicator (probably the only one which can be refined to a spatial resolution beyond NUTS2 based on existing data)
	insects	
2	**Grassland Butterfly Indicator**	only available at a very coarse spatial resolution
3	Wild pollinators (richness, abundance, or diversity)	still needs to be developed
3	Rove and ground beetles (richness)	needs to be developed, data source unclear
	habitats	
2	Conservation status and trends of habitats of community interest	multiple indicators (one for each ET), only available at a very coarse spatial resolution
2	Threatened habitat cover	multiple indicators (one for each ET), at a very coarse spatial resolution
1	Naturalness (index or typology)	is conceptually close to "hemeroby", still needs to be implemented
2	Red List Index of threatened habitats	multiple indicators (one for each ET), still needs to be developed, will be of a low resolution, & no time series
	Age of site / community	
3	Community age (time since last major intervention/ disturbance: felling, fire, abandonment, etc)	this could be a conceptually important indicator for grasslands, feasibility on a remote sensing basis should be tested
	Primary productivity (& ecosystem exchange processes)	
2	Plant productivity (NPP)	
2	Carbon sequestration (Dry matter productivity)	this is perhaps more of an ES indicator than a condition indicator
	Biomass at the site	
2	**Normalized difference vegetation index (NDVI)**	instantaneous values are too variable, but (multi)annual characteristics can make useful condition indicators
2	Leaf Area Index (LAI)	
	Soil characteristics	
2	C/N ratio in soil	
1	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
1	Soil thickness	new proposal for a simple indicator, to follow the degradable stock behind erosion
	Water availability	
1	Normalized difference water index (NDWI)	instantaneous values are too variable, but (multi)annual characteristics can make useful condition indicators
2	Washlands (regularly flooded areas)	could also be considered as a subtype or a (generally positive) pressure, to be developed
	The extent (abundance) of a specific subtype (of the target ecosystem type)	
1	**Extent of ETM subtypes**	EUNIS (level 2) subtypes themselves can be considered as being of different levels of condition (or naturalness, hemeroby, etc.)
1	**Density of embedded seminatural elements (hedgerows, lines of trees, etc.)**	if these elements are seen as parts of the embedding grassland ecosystem type
1	HNV area	the share of this highly relevant 'subtype' might be redundant with other indicators (seminatural elements, pressures, etc.)

Table 5.1 continued.

U*	Indicator name	Comments
3	**Tree cover density**	
	The coexistence / proximity of two different ecosystem types	
2	Proximity to forests	
2	Proximity to wetlands	
2	Proximity to water	
	Landscape diversity	
1	**Landscape diversity**	can be relatively easily developed
	Landscape fragmentation & connectivity	
2	Landscape fragmentation from urban and transport infrastructure	a new EEA indicator based on the joint fragmentation (effective mesh size) of all natural & managed ecosystems
2	Fragmentation patterns of natural/seminatural landscapes	could be (re)calculated using effective mesh sizes for coherence (fragm.geom: nat. ecosystems vs. everything else)
2	Connectivity of seminatural elements (hedgerows...)	can be redundant with the density of seminatural elements

** 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)*

The **presence of shrubs and trees** significantly enhances the capacity of grasslands for a broad range of ES. Hedgerows and trees are not only relevant for croplands (García-Feced et al., 2015), thus the "embedded seminatural vegetation" and the HNV farmlands indicators by JRC can also be relevant for grasslands. Grasslands with a lot of trees/shrubs (but still below 10%) are also delimited on ETM as 'sparsely wooded grasslands' (E7).

The **diversity of the broader landscape** can also be relatively easily characterized with a relevant new indicator consisting of a landscape metric computed on ETM (e.g. Shannon diversity with a moving window). The **connectivity / fragmentation of grasslands** can also be relatively easily quantified relying on ETM. There are several available metrics, most of which are expected to be highly correlated, so there is not much point in calculating more than one of them. An effective mesh size (Jaeger et al., 2011) either for all grasslands, or for all (semi)natural ecosystems could be a good choice for a single connectivity / fragmentation indicator.

6. Integrating pressures among grassland condition indicators

The intensity (frequency or magnitude) of recurrent human management activities and/or (semi)natural disturbance regimes can also be conceptualised and considered as ecosystem characteristics. These 'management/disturbance characteristics' highly influence the capacity of the ecosystems 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 condition (Erhard et al. 2016, p.31). However, most pressures (e.g. erosion, drainage/desiccation, fragmentation, pollution, etc.) can be associated to a state variable (e.g. soil thickness, water table level, connectivity, the concentration of specific pollutants, etc.) which is directly affected by the pressure. In most cases there are indicators available for both the 'pressure' (as a flux, flow or rate of change) and the underlying state variable. Wherever available, variables describing such 'degradable environmental stocks' **(**that are being degraded due to the specific pressures) are highly appropriate for use as condition indicators for the EU MAES assessment. This choice makes it possible to link pressures to changes in condition without compromising the conceptual integrity of the assessment.

Table 6.1: Indicators available for pressures relevant for grasslands. 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	
1	Hemeroby	a newly proposed condition indicator with a long history, conceptually close to "naturalness", still needs to be implemented
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	Share of organic farming	only available at a very coarse spatial resolution
	Grazing intensity	
1	**Livestock density**	would be great to correct for non-grassland-based fodder inputs (a 'net/grazing livestock density'?)
	Nutrient / material balances	
1	Gross nitrogen balance	
2	Nitrogen deposition	
2	Critical load exceedance for nitrogen	multiple indicators (one for each ET)
2	Gross phosphorus balance	only available at a very coarse spatial resolution
1	Chemical status of surface/ground water	
2	Heavy metal concentrations in soil	
	Soil loss	
2	Soil erosion	the related 'stocks' (soil thickness, carbon content) are better state indicators
3	Loss of organic matter	the related 'stocks' (soil thickness, carbon content) are better state indicators
	Fire regime	
2	Number of fires	

** 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)*

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, *overexploitation* and *pollution* 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, and that's why there are very few climate related indicators (frequency of fires) and no invasion-indicators among the ones proposed for grasslands below (Table 6.1). Finally, most of the processes related to *habitat loss* should not be considered as ecosystem condition changes. The extent of each ecosystem type belongs to the 'ecosystem extent' box in Figure 1.1, and should be accounted for in other parts of the MAES assessment report. This is does not mean that grassland loss (e.g. to ploughing, or urban development) is not important: it is of key importance indeed. But, grassland loss (as any other habitat transformation) is already accounted for in the ecosystem extent assessment (mapping) part of the work, and including this topic also into the condition chapters, would be a sort of 'double counting'.

In the case of grasslands there are several meaningful land use intensity metrics available. The most important indicator is probably the one describing the intensity of the main use of grasslands: feeding domestic animals. **Livestock density** can be directly expressed from public statistical data, however care must be taken that some of the modern intensive husbandry techniques are primarily based on farmland outputs (grain, arable fodder crops, food industry side products) instead of grassland outputs. A 'net livestock density' indicator, which is largely corrected with the ratio of non-grassland fodder inputs, would be a better condition indicator for grasslands.

More **general land use intensity indicators** (hemeroby, HANPP), as well as **farming intensity indicators** (e.g. intensification, fertilizer use) can also be used as relevant ecosystem condition indicators for the whole agricultural mosaic complex in which grasslands are nested. Nutrient balance data can also be a useful general and indirect pressure indicator, especially as such data are already well embedded in most environmental policy domains. There are several broadly available (and partly redundant) indicators for farming intensity nutrient pressures, which should be handled parsimoniously (a few carefully selected indicators can be enough for the EU MAES assessment – e.g. a single one for each condition aspect).

To follow the state of grassland ecosystems with respect to the process of **erosion** there are also some potential indicators, which still need some development. The amounts of the underlying 'degradable environmental stocks' (*soil thickness* or *soil carbon content*) seem to be better indicators for the state of erosion ('erodedness') than the related matter fluxes (erosion, organic matter loss).

In an era of increasing climate change, the **frequency / magnitude of fires** can also be considered as a relevant indicator of grassland condition, which can be efficiently tracked with remote sensing approaches. The presence of **washlands** could also be potentially delineated on the ETM using data on elevation and hydrological infrastructure. However, as there are very little washlands in Europe, a washland 'flag' might not be relevant enough to be included among the EU MAES condition indicators.

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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 pollination, 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 TT and NN give an overview on the importance of each characteristics for pollination:

- **TT**: total influence (the number of papers which document an effect of the characteristics on any of the studied ES in any ecosystem type);
- **NN**: 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 TT are highlighted in darker shades in order to give a better visual overview of the importance of each line, and negative numbers in column NN are highlighted in red. All of the remaining columns refer to the studied ecosystem services (tim: timber production; fish: freshwater fishing; poll: pollination; pest: pest regulation; carb: carbon sequestration; ero: erosion protection; flo: flood protection; w.q: water quality regulation; rec: recreation; a.q: air quality regulation). 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 papers are resolved in a reference list at the end of this Annex.

Characteristics type	TT	NN	tim	fish	poll	pest	carb	ero	flo	w.q	rec	a.q
Management / disturbance intensity [T mi]	10	-5			140, 272	172	557	445, 642	279	704	466, 470	
grazing intensity	3	0			272		557	445				
fire frequency	3	-3						445, 642	279			
Biodiversity (in general) [T di]	9	8			243, 272	172	9, 507	121, 282		198	466	
diversity of plants	7	6			243, 272	172	9	121, 282			466	
pollinators	1	1			243							
Occurrence / abundance of a specific species (functional) group [T ab]	4	4			58		9, 368	571				
shrubs	2	2					368	571				
nectar source plants	1	1			58							
pollinators	1	1			58							
Functional traits of a major species group [T ft]	2	2					557			704		
traits of herbs/grasses	2	2					557			704		
Age of site / community [T ta]	3	3					486	22, 414				
since abandonment	3	3					486	22, 414				
Biomass at the site [T bi]	7	7					9, 507, 557	121	205, 279	704		
belowground biomass	4	4					9, 507	121		704		
total [cover]	2	2							205, 279			
ground layer	2	0					557			704		
litter	2	0					557			704		
Water availability	4	4		525					242, 255, 267			
washland (regularly flooded land)	4	4		525					242, 255, 267			
The extent (abundance) of the target ecosystem type (or a specific subtype) [E ab]	7	6			140			22, 282, 445		704	175,215, 466	
hedgerows, lines of trees	3	3								704	215, 466	
The co-existence / proximity of the target ET and an other ET [E pr]	2	2			58					375		
Landscape diversity [L di]	4	4		525				282			175, 470	

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Annex 2: Annotated list of potential MAES ecosystem condition indicators

Table A2: This table lists all potential wetland condition indicators that are available and/or feasible in the context of the EU MAES assessment. All indicators are scored according to three aspects of 'usefulness':

- **rel**: relevance for grasslands (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; o: the old version of this fact sheet: Götzl et al., 2016);
- **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							
	1	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
	1	1	2	*Red List Index of threatened species*	SEBI 002	EEA, IUCN	index	afn	1980s 2004, ...?	**EU (MS?)**	EEA39

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+
	1	1	3	Species diversity, richness (number and abundance of species, including vascular plants, vertebrates, etc)			index	f	?	?	?
				plants							
	1	3	3	Plant functional types (diversity)			?	f	?	?	?
	2	3	3	Bryophyte, moss, liverwort, lichen and fungal species richness (index)			?	f	?	?	?
				birds							
	1	2	2	EU Population status and trends of bird species (%)	SEBI 003	Art12 DB	index	afn	2013, 2018	**MS**	EU
	1	2	1	*Bird indices (farmland, forest...)*	SEBI 001	EBCC	index	afn	2002-	**MS**	EU
				insects							
	1	2	2	Grassland Butterfly Indicator	SEBI 001	EEA	index	a	1990-2015	**MS**	22 MS
	1	2	3	Wild pollinators (richness, abundance, or diversity)			?	a	?	?	?
	2	2	3	Rove and ground beetles (richness)			1/area	f	?	?	?
				habitats							
	1	1	2	*Conservation status and trends of habitats of community interest*	SEBI 005	Art17 DB	%	afn	2013, 2018	**MS x BGR**	EU
	1	2	2	*Threatened habitat cover*		Art17 DB	%	fn	2013, 2018	**MS x BGR**	EU
	1	1	1	Naturalness (index or typology)			index	f	?	?	?
	1	2	2	Red List Index of threatened habitats		IUCN EU RL	index	f	2017	?	?
				Age of site / community							
	1	1	3	**Community age (time since last major intervention/ disturbance: felling, fire, abandonment, etc)**		?	y		?	?	?
				Primary productivity (& ecosystem exchange processes)							
	2	1	1	Plant productivity (NPP)		MODIS	t/ha/y	f	2000-	500m	Global
	2	2	1	Carbon sequestration (Dry matter productivity)		Copernicus	t/ha/y	f	2014-	300m	Global
				Biomass at the site							
	2	1	1	Normalized difference vegetation index (NDVI)		Copernicus	index	f	1998-	1km	Global
	2	1	1	Leaf Area Index (LAI)		Copernicus	index	f	1998-	1km	Global
				Soil characteristics							
	2	2	2	C/N ratio in soil		IMAP, LRTAP	%	f	2005	5km	EU
	1	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
	2	2	1	Soil nutrients availability (nitrogen & phosphorus)		LUCAS	mg/kg	afn	2009, 2015	1km?	EU25, EU28
	1	1	1	**Soil thickness**		LUCAS?	cm		?	?	?
				Water availability							

HI	rel	rep	ava	indicator name	indi.set	source	unit	pilot	date	s.resol	s. cover
	1	1	1	**Normalized difference water index (NDWI)**		JRC	index		?	1km	Europe
	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
	1	1	3	Tree cover density		JRC, MS?, Copernicus?	%	f	?	?	?
				The coexistence / proximity of two different ecosystem types							
	2	2	1	**Proximity to forests**		ETM	km (or m)		2012	?	EU28+, TR, W. Balkan
	2	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							
	1	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
	2	1	1	Fragmentation patterns of natural/seminatural landscapes	SEBI 013	CLC (ETM?)	index	fn	2006-2012	100m	EEA39
	2	1	1	Connectivity of seminatural elements (hedgerows...)		JRC	index	a	2006	1km	EU27
				Management / disturbance intensity (pressures)							
				All ecosystems and land uses							
O	1	1	1	**Hemeroby**		CLC, CAPRI, AFOLU			2006	100m	EU27
O	1	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	2	2	1	Pesticide use	AEI06	Euro-stat	kg/ha/y of act. ingred	a	2011-2014	**MS**	EU28
OP	2	1	1	Share of organic farming	SEBI 020, AEI4	FSS	%	a	2005, 2012-2016	**MS**	EU28
				Grazing intensity							
O	1	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	2	1	1	Nitrogen deposition		IMAP, LRTAP	kg/ha/y	af	2005	5km	EU

HI	rel	rep	ava	indicator name	indi.set	source	unit	pilot	date	s.resol	s. cover
P	2	1	1	*Critical load exceedance for nitrogen*	SEBI 009	EEA	% of nat. area	n	2000, 2010	50km	EU27+
OP	2	1	1	Gross phosphorus balance	AEI16	CAPRI	kg/ha/y of P	a	1990-2016	**MS**	EU
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
				Fire regime							
C	2	1	2	Number of fires		JRC-EFFIS	1/ha/y	f	1980-	Point data	EU+
C	2	2	2	Burnt area		JRC-EFFIS	%/y	f	1980-	250m	EU+

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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 indicator
AFOLU	agriculture, forestry and other land use
Art17 DB	Article 17 (assessments of habitats and species under the EU Habitats Directive)
Art12 DB	Article 12 (assessments of species under the EU Birds Directive)
BGR	biogeographic region
CAPRI	Common Agricultural Policy Regionalised Impact
CBD	Convention of Biological Diversity
CLC	Corine land cover
Copernicus	the Earth observation programme of the European Commission
Corine	Coordination of Information on the Environment
DB	database
DEM	digital elevation model
DNA	deoxyribonucleic acid
EBCC	European Bird Census Council
EEA	European Environment Agency
EEC	European Economic Community
ES	ecosystem service(s)
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	European Union Nature Information System
Eurostat	the statistical office of the European Union
FSS	farm structure surveys
HANPP	human appropriation of net primary production
HANTS	harmonic analysis of NDVI time series
HIPOC	habitat change, invasive species, pollution, overexploitation, climate change (a common list of the main drivers of environmental change)
HNV	high nature value farmlands
HRL	high resolution data layer (of Copernicus)
HSU	homogeneous spatial units (of farmlands)
IMAP	Integrated Monitoring and Assessment Programme
IUCN	International Union for Conservation of Nature
JRC	Joint Research Centre
EASIN	European Alien Species Information Network
EFFIS	European Forest Fire Information System
KIP INCA	Knowledge Innovation Project on an Integrated system for Natural Capital and ecosystem services Accounting
LAI	Leaf Area Index
LoCo	local component (of Copernicus)
LRTAP	Long Range Transfer of Air Pollution
LU	livestock units
LUCAS	Land Use/Cover Area frame statistical Survey
MA	Millennium Ecosystem Assessment

MAES	mapping and assessment of ecosystems and their services
MODIS	Moderate Resolution Imaging Spectroradiometer
MS	EU Member States
N2000	Natura 2000 (network of nature protection areas in the European Union)
NDVI	normalized difference vegetation index
NPP	net primary production
NUTS	nomenclature of territorial units for statistics
OpenNESS	Operationalisation of natural capital and ecosystem services (EU FP7 project)
potNatVeg	potential natural vegetation
SEBI	Streamlined European Biodiversity Indicators
SEEA-EEA	System of Environmental Economic Accounts - Experimental Ecosystem Accounts
SOC	soil organic carbon
SVL	sparsely vegetated land
TCD	tree cover density
TEEB	The Economics of Ecosystems and Biodiversity
UK NEA	UK National Ecosystem Assessment