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# Ecosystem service fact sheet on pollination

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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 previous ETC/BD work exploring requirements for pollination (Götzl et al., 2016).

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 pollination is defined, which characteristics of the various ecosystem types are relevant for pollination, 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.

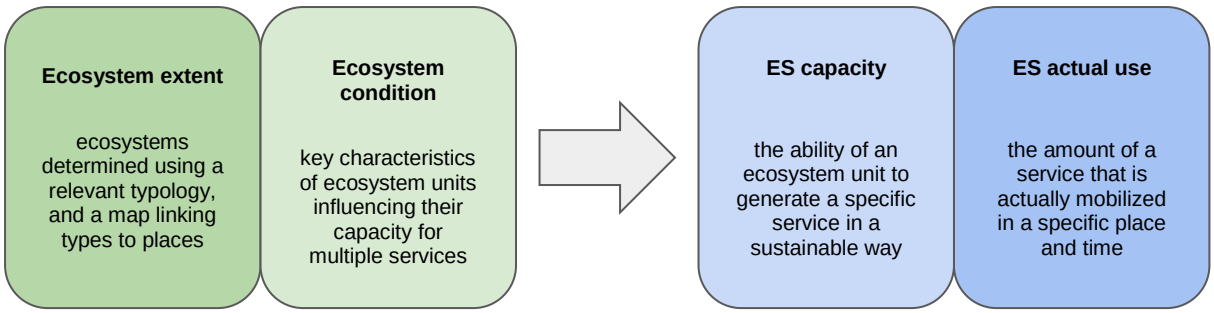


**Figure 1.1: A simplified representation of the MAES conceptual framework** (based on Maes et al., 2014; Burkhard et al., 2018; and MAES-INCA, 2018). The four boxes describe the main elements which need to be quantified (mapped and assessed) during the EU MAES assessment process.

# 2. Key messages

Pollination is the process of pollen transport between flowers, which is an essential step for fruit setting in most plant species. Globally, approximately 75% of the human food crops require the contribution of pollinating organisms, while in Europe, insect pollination is vital for more than 80% of the cultivated crops. In an agro-ecological context, pollinators have been recognised as an integral part of healthy ecosystems. Insect pollination can thus be seen as a critical regulating service limiting agricultural productivity.

There are several key aspects of ecosystem condition relevant for pollination, 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 (Fig. 2.1).

- The spatial proximity of croplands to natural habitats is a key aspect. This aspect can be addressed using (newly proposed) *proximity indicators*, which can be relatively easily implemented based on the European map of ecosystem types (ETM v3.1; Weiss & Banko, 2018).
- Biodiversity (diversity and abundance of pollinators and flowering plants) is also a key aspect. 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.)

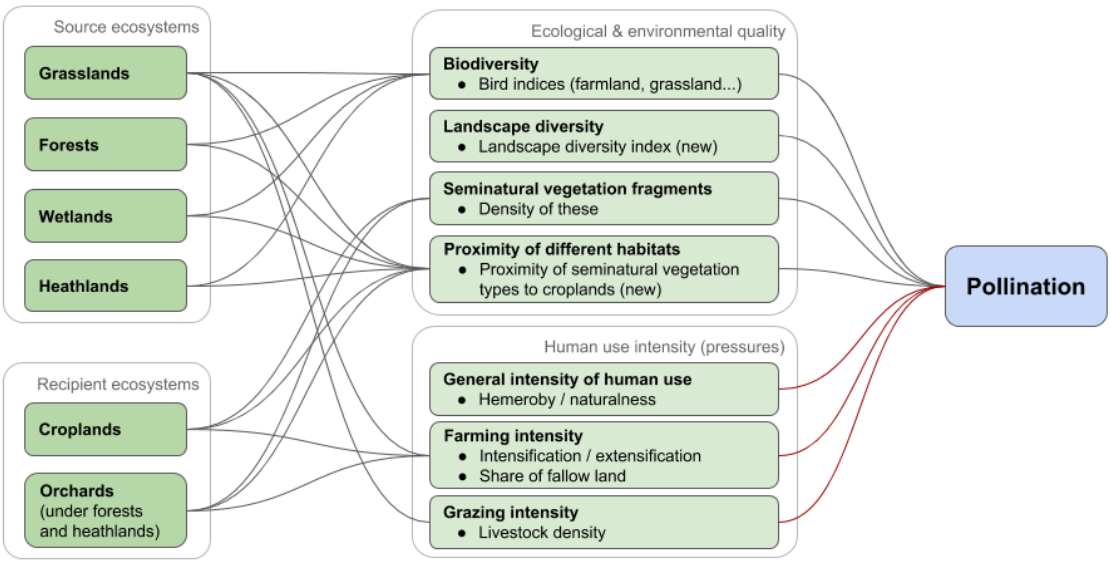


**Figure 2.1: A graphical summary of this fact sheet**. *Ecosystem types* (column 1) are connected to their *relevant characteristics* ('condition aspects'; column 2) and a possible set of *key indicators* (bullet points in column 2), which determine their *capacity for pollination* (column 3). Characteristics 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.

- The abundance of *tiny fragments of (semi)natural habitats in croplands* is also a key factor. JRC has a good indicator for this which should be included into the MAES condition assessment and updated regularly.
- The diversity and fragmentation of the landscape is also a relevant aspect, with several available or easily implementable indicators ('*landscape diversity*' as Shannon diversity of the ecosystem type map; or the *connectivity / fragmentation of (semi-)natural landscapes* as effective mesh sizes).

Several human pressures have a significant direct influence on pollination, and these pressures can be integrated among ecosystem condition indicators in a straightforward way.

- Pressures related to farming are the most critical for pollination. 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*' indicator can also be useful in adding spatial detail.
- Grassland use (grazing) intensity also affects pollination, and this could be accounted for by the JRC pressure indicator '*livestock density*'.

Most of the proposed ecosystem condition indicators are already well represented in ESTIMAP, the model used for mapping ES capacities for pollination service at a European scale. The two key lessons here are that:

- *hemeroby*, *grazing intensity*, and *pesticide use* could be considered for inclusion during a possible update related to the EU MAES assessment delivery, and
- the design details of ESTIMAP should be consulted when setting the specifications of several EU MAES condition indicators (including the *connectivity/fragmentation* and the *proximity* indicators).

# 3. Pollination as an ecosystem service

The process of pollen transport between conspecific flowers / individuals is an essential step for reproduction in most plant species. The means of transport depends on the plant species, most commonly it is either air currents (wind) or animal species (pollinators). Pollinators have been coevolved with pollination-dependent plants and they are mutually interdependent: animals collect floral resources (i.e. pollen, nectar) for food, while they carry pollen on their bodies and transfer it from flower to flower. For plants this is the way genetic information is exchanged before being passed on to the next generation in the form of the seeds.

**Table 3.1: The position of pollination 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)<br>**Division: 2.2** Regulation of physical, chemical, biological conditions<br>**Group: 2.2.2** Lifecycle maintenance, habitat and gene pool protection<br>**Class: 2.2.2.1** Pollination (or 'gamete' dispersal in a marine context) | **IPBES**: NCP 2 Pollination and dispersal of seeds and other propagules<br>**TEEB**: Pollination<br>**MA**: Pollination |
| **Definition** | **Scientific**: The fertilisation of crops by plants or animals that maintains or increases the abundance and/or diversity of other species that people use or enjoy<br>**Simple**: Pollinating our fruit trees and other plants | **IPBES**: Facilitation by animals of movement of pollen among flowers, and dispersal of seeds, larvae or spores of organisms important to human<br>**TEEB**: Insects and wind pollinated plants and trees which is essential for the development of fruits, vegetables and seeds. (...). |
| **Example for service** | Providing a habitat for native pollinators | |
| **Example for benefits** | Contribution to yield of fruit crops | |

Accordingly, the process of pollination is inherently necessary for the maintenance of biodiversity, and the resilience and regeneration of all ecosystems. Nevertheless, as modern ES definitions restrict the scope of the ES concept to the outputs / benefits from nature directly used / enjoyed by society (Boyd & Banzhaf, 2007), this fundamental "supporting role" of pollination cannot be considered as a (final) ES. (It should rather be considered as an ecosystem function or an intermediate service, see e.g. Potschin-Young et al., 2017.) On the other hand, pollination contributing to agricultural production can be considered as an ES[1]. In agro-ecosystems, pollinator diversity allows crop benefits through higher yields (compared to in the low abundance or absence of pollination) but also stabilisation in yield because of the possibility of having backup solutions. In fact, as for many agricultural crops the main outputs are seeds, pollination by insects (or other animals in rare cases) can be seen as the critical regulating service limiting agricultural productivity (Table 3.1).

Globally, approximately the 75% of the human food crops requires the contribution of pollinating organisms, which corresponds to 35% of the global production volumes (Klein et al., 2007; Nieto et al., 2014). In Europe, insect pollination is vital for more than 80% of the cultivated crops (Williams, 1994). Pollination as an ES in Europe is mostly supplied by wild insect communities (bees, hoverflies, etc.; Aizen et al., 2009; Rader et al., 2016), however human-managed honeybee colonies also play a

[1] Depending on where the 'production boundary' (the system boundary delimiting the spheres of nature and economy) is set by the coordinators of an assessment process, it is either the natural inputs to agriculture (pollination, pest control) or the agricultural products themselves that should be considered as (final) ecosystem services -- but not both.

significant role. As pollination by honeybees can be seen as a human-managed process, often consciously tailored according to pollination needs, the concept of the ES pollination is restricted to **pollination by free-living wild species** in the following discussion.

According to these conceptual limitations and considerations, pollination as an ES typically requires **spatial interaction between two distinct ecosystems**, a 'source component' (or 'service provisioning area', i.e. a natural ecosystem which supplies the service), and a 'recipient component' (or 'service beneficiary area', i.e. an agricultural ecosystem which transforms the benefits from pollination into economic products; see also Syrbe & Walz, 2012). The supply of the service particularly depends on the ecological state (biodiversity) of the source component. Through their capacities to host and feed pollinating insects, different ecosystems (and the landscapes consisting of them) have different potentials for providing pollination to the agricultural fields nearby.

As it can be seen from its position in the CICES and IPBES classifications, pollination is considered to be closely related to seed dispersal, and partly also to crop pest control, which means that those characteristics of the ecosystems that enhance pollination probably support seed dispersal and pest control too.

# 4. Ecosystem characteristics influencing the supply of pollination

The most important ecosystem types benefitting from pollination are the ones carrying agricultural crops, most typically *croplands*. However, according to the terminology of the European map of ecosystem types (ETM v3.1; Weiss & Banko, 2018), *forests*, *heathlands*, and *grasslands* can also serve as recipient ecosystems. *Forests* in ETM v3.1 include fruit trees, *heathlands* include orchards of shrubs and vineyards; while *grasslands* can include permanent fields of herbaceous crops. Fruit trees and shrub orchards are typically highly dependent on insect pollination, which makes them an important recipient ecosystem type. The 'natural system' supplying the service can be any (semi)natural ecosystem type (e.g. *grassland*, *heathland*, *forest*, *wetland*...), as well as 'subgrid' (semi)natural elements nested into the main human-transformed ecosystem types (e.g. *hedgerows* or *grassland strips* nested into *cropland* or *urban* ecosystems).

Table 4.1 provides an overview on the importance of the characteristics of the main ecosystem types involved in the delivery of the pollination ES. According to the scientific literature sampled in the underlying systematic review, the most relevant characteristics are the proximity of crops to (semi)natural ecosystems (source component), the (bio)diversity of the source components, and the various aspects of agricultural management.

**Table 4.1: Results of the systematic review: ecosystem characteristics that have been documented to influence the supply of pollination, 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 pollination. A more detailed and fully referenced version of this table can be found in Annex 1.

| Characteristics type | Total | Positive | Negative | Mixed | Ecosystem services* |
|---|---|---|---|---|---|
| **The co-existence / proximity of farmlands and specific ecosystem types** | 7 | 6 | 1 | 0 | crop, grass, forest, heath |
| proximity to forest | 1 | 1 | 0 | 0 | crop, grass |
| proximity to grassland | 1 | 1 | 0 | 0 | crop |
| proximity to any (semi)natural ecosystem type (forest, grassland, wetland) | 5 | 4 | 1 | 0 | crop, forest, heath |
| **Biodiversity (in general)** | 5 | 4 | 0 | 1 | crop, grass, forest, heath |
| diversity of plants | 2 | 2 | 0 | 0 | grass, crop, forest, heath |
| pollinators | 4 | 3 | 0 | 1 | crop, grass, forest, heath |
| **The extent (abundance) of a specific ecosystem (sub)type** | 5 | 4 | 1 | 0 | crop, grass, forest |
| any seminatural feature (hedgerows, lines of trees, roadsides, oldfields) | 3 | 2 | 1 | 0 | crop, forest |
| **Pressures (management / disturbance intensity)** | 3 | 0 | 2 | 1 | crop, grass |
| grazing intensity | 1 | 0 | 0 | 1 | grass |
| farming intensity (fallows) | 1 | 0 | 1 | 0 | crop |
| **Occurrence / abundance of a specific species (functional) group** | 2 | 2 | 0 | 0 | crop, grass, forest, heath |
| nectar source plants | 1 | 1 | 0 | 0 | crop, grass, forest, heath |
| pollinators | 2 | 2 | 0 | 0 | crop, grass, forest, heath |
| **Landscape diversity** | 1 | 1 | 0 | 0 | crop, forest, heath |

** MAES ecosystem types: crop: cropland; grass: grassland; forest: woodland and forest; heath: heathland and shrub*

The presence/proximity/density of relatively undisturbed ecosystems (source components) determines the availability of nesting sites, and they can also be important feeding sites if there is nothing to find in the neighbouring agricultural fields (Ricketts et al., 2008). The **presence/absence of (semi)natural habitat types** (grasslands, forests, etc) on a landscape scale; particularly **in the**

**proximity of croplands,** has a well-documented beneficial influence on pollination (Albrecht et al., 2007; Garibaldi et al., 2011; Ricketts et al., 2008). **Small scale semi-natural features** embedded into agroecosystems, like hedgerows, roadsides, or ditches, can also play a substantial role as source components in creating pollination capacities (Brittain et al., 2010; Holzschuh et al., 2012). From an ecosystem mapping perspective, such small-scale features can be seen as 'sub-grid' elements, which are mostly considered to be part of the 'parent' ecosystem type (i.e. croplands; García-Feced et al., 2015). In the case of **forests**, the **edges** provide more attractive habitats for pollinators than the interiors (Westrich, 1990). On the other hand, **fragmentation** can also increase the distance between food sources and nesting sites, which can weaken pollinators and reduce their breeding success (Schmid-Hempel & Wolf, 1988; Williams & Kremen, 2007; Zurbuchen et al., 2010).

The biodiversity of the source components strongly determines their capacity to supply pollination. Obviously, **the abundance/diversity of pollinator communities** (e.g. the number of pollinator functional groups (guilds), number of species or individuals in a specific group, etc.) strongly determines pollination (Klein et al., 2003; Vamosi et al 2006; Hoehn et al., 2008; Garibaldi et al., 2011; Holzschuh et al., 2012). The most important pollinating insect species for annual and perennial arable crops and orchards are bees, but hoverflies, butterflies and beetles can also be important (Rader et al., 2016). For most of the crops wild bees are more efficient than honeybees (Westerkamp, 1991), which are often used as a managed solution to pollinate mass flowering crops (e.g. rapeseed: Rader et al., 2009). For the maintenance of wild plant species dependant on insect pollination all pollinator species are essential.

A second, closely related factor determining pollination capacity is the **abundance/diversity of plant species** offering food source and sometimes also nesting sites for pollinators (Fontaine et al., 2006; Batáry et al., 2010). Bee species richness is affected by the diversity of nectar sources, the ratio of pollen to nectar energy content, and floral morphology (Potts et al., 2003), and the frequency of pollinator visits is increasing linearly with the number of (flowering) plant species (Ebeling et al., 2008). Most important are species of the plant families Fabaceae, Brassicaceae, Asteraceae and Lamiaceae (Zurbuchen & Müller, 2012). The reduced availability of nectar- and pollen-producing flowers is one of the most important threats for wild bee species (Knop et al., 2006).

**Pressures** from **intensive agriculture** are also a key factor shaping pollinator communities, and thus pollination capacity. These factors equally affect the recipient and the source components necessary for pollination. The intensive cultivation of cash crops creates a massive lack of nesting sites and reliable food sources (Knop et al., 2006). *Insecticides* are particularly harmful by either direct intoxication, or a persistent contamination of nectar, pollen and water sources (indirect intoxication, Gill et al., 2012; Whitehorn et al., 2012; Goulson, 2015). The use of *herbicides and fertilizers* can lead to a loss of plant species and a monotonous weed flora with less food for the pollinators (Crawley et al., 2005; Carvell et al., 2007). *Extensive / organic management* leads to higher numbers of flowering plants and ecological niches, which increases the diversity of pollinators (Clough et al., 2007; Rundlof et al., 2008; Holzschuh et al., 2008; 2010). The benefits of a reduced management intensity can depend on the landscape context (Rundlof et al., 2008; Brittain et al., 2010). Farming practices can also influence pollinator food availability through the *choice of crops and crop varieties*. *Genetically homogeneous* mass flowering crops are unreliable food sources that are available only for a short period, and can be contaminated with insecticides (Steffan-Dewenter & Tscharntke, 2001; Carvell, 2002; Knop et al., 2006; Hatfield & LeBuhn, 2007). An increased use of fertilizers, furthermore, generally comes with reduced *share of legumes* in the rotation schemes, which also contributes to the disappearance of the relatively reliable nectar sources (Holzschuh et al., 2007). Crop rotation contributes to higher food availability and the distribution of resources across seasons allows a wide range of (sometimes specialised) species to have access to them (Holzschuh et al., 2008).

The management of other ecosystem types can also affect pollinators and pollination. In grasslands, a high **grazing pressure** greatly reduces the availability of floral resources for pollinators (Kruess & Tscharntke, 2002; Hatfield & LeBuhn, 2007; Iserbyt et al., 2008). *Frequent mowing* also leads to reduced abundance of flowers (Albrecht et al., 2007; Kleijn & Rademakers, 2008), whereas a low frequency and relatively late mowing can have a positive effect on the abundance and diversity of flowers (Iserbyt et al., 2008). *Agri-environment schemes* for managing pastures and meadows are generally found to increase capacities for pollination (Albrecht et al., 2007; Batáry et al., 2010). *Nitrogen enrichment* generally causes a reduction in plant diversity and the disappearance of important nectar sources connected to poor nutrient availability (Stevens et al., 2004), leading to a reduction in the abundance and diversity of wild bees (Le Féon et al., 2010). Moreover, risks of domination of ecological niches from the honeybees' increasing population from intensive beekeeping constitutes a threat to wild bees (Henry & Rodet, 2018). The proximity to honeybee niches can also be a threat to disease transmission, especially to bumblebees (Fürst et al., 2004).

# 5. Ecosystem condition indicators relevant for pollination

The ecosystem characteristics listed in Table 4.1 are dependent on 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 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.

Local **biodiversity**, especially that of *pollinator communities* (e.g. the number of pollinator functional groups (guilds), number of species or individuals in a specific group, etc.) is probably an aspect of ecosystem condition for which there are no good data sources. The indicator "Wild pollinators (richness, abundance, or diversity)" is still under development, and it will probably only be implemented at the MS level, so its spatial resolution would still limit its usefulness for the EU MAES assessment. Pollinator diversity and abundance can also be closely correlated with the diversity of other major guilds (e.g. *plants*), as well as *general biodiversity indicators*, but all of these direct biodiversity indicators seem to be problematic in terms of data availability, spatial and temporal resolution. The already existing biodiversity indicators are more suitable for ecosystem accounting than for MAES, which involves more spatial detail due to the mapping.

More detailed information on the type of the habitat (EUNIS level 2 subtypes) might offer a 'quick and dirty' partial solution for the lack of biodiversity indicators. This is based on the observation that the different EUNIS habitat types come with different levels of typical 'naturalness' (or 'hemeroby'), even at the relatively coarse 'level 2' thematic resolution. An improved version of this 'quick and dirty' solution would be to allocate these 'naturalness' scores *during* the process of generating the ETM map (Weiss & Banko, 2018), and not subsequently. This way the same rules that are used to assign specific habitat types to each grid cell of the ETM, could also be updated to assign a naturalness score to each cell, enabling finer distinctions in the naturalness of the different cells.

A major condition for efficient pollination is that pollinators have to be able to find their homes in (semi) natural habitats in close vicinity of the croplands being pollinated. The **density of (subgrid) semi-natural elements in croplands**, addressed by a JRC dataset (García-Feced et al., 2015), is a highly relevant aspect of this. The **proximity** of croplands to other (semi)**natural habitats**, can be of similar importance, however, this condition aspect seems to be unaddressed by the available indicators as yet. Potential gap-filling indicators (proximity of farmland to (any) natural habitat) can be relatively easily deduced from the ETM v3.1, however care must be taken that 'source' and 'recipient' components would be appropriately distinguished during these calculations. (The EUNIS level 2 subtypes of ETM make this more or less possible, as permanent crops are marked as subtypes of heathland and forest ecosystem types there.). Similarly, simple 'distance to forest' or 'distance to water' indicators calculated for each location may still be relevant for pollination, and these simple indicators come with the advantage that they are more easily relevant for other ES as well (e.g. recreation, pest control), just like simple **landscape diversity & fragmentation** metrics.

**Table 5.1: Indicators available for the ecosystem characteristics relevant for pollination.** 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 low resolution |
| 2 | Red List Index of threatened species | multiple indicators (one for each ET), only available at a very low resolution |
| 2 | Living Planet Index for Mediterranean wetlands | only available for the Mediterranean Basin, at a low 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 |
| 2 | Forest tree species (richness) | |
| 3 | Understory vegetation (richness) | still needs to be developed |
| | *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 low 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 low resolution |
| 2 | Threatened habitat cover | multiple indicators (one for each ET), only available at a very low resolution |
| 2 | Deadwood | only available 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 |
| | *The extent (abundance) of a specific subtype (of the target ecosystem type)* | |
| 1 | **Extent of ETM subtypes** | many of the EUNIS (level 2) subtypes mapped in ETM v3.1 can be seen as meaningful w.r.t pollination (e.g. orchards vs. other forest types) |
| 1 | **Density of embedded seminatural elements (hedgerows, lines of trees, etc.)** | a key determinant of pollination |
| 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* | |
| 1 | **Proximity to (any) natural habitat** | a key determinant of this ES, which can be relatively easily developed |
| 2 | Proximity to forests | can be relatively easily developed |
| 2 | Proximity to wetlands | can be relatively easily developed |
| | *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 |
| 1 | Fragmentation patterns of natural/seminatural landscapes | could be (re)calculated using effective mesh sizes for coherence (fragm.geom: nat. ecosystems vs. everything else) |
| 1 | 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)*

# 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 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.

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, and there are no indicators proposed for pollination in Table 6.1, which would represent these pressures that can hardly be conceptualized as ecosystem characteristics. 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 rather should be accounted for in dedicated figures/tables in other parts of the MAES assessment report. This is does not mean that habitat loss (e.g. to ploughing, or urban development) is not important: it is of key importance indeed. But, any 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'. Accordingly, there are no condition indicators proposed for pollination in Table 6.1, which would be directly related to this pressure, either.

Various aspects of **land use / management intensity** are, for example, generally considered as a key pressures for the ecosystems and the environment. These pressures directly influence the supply of pollination (see Table 4.1), and thus the relevant management characteristics of these ecosystems can be considered as meaningful condition indicators. This includes quite general land use intensity indicators (hemeroby, HANPP), as well as indicators targeting specific ecosystem types (e.g. farming or grazing intensity indicators). There is a very high number of potential farming intensity indicators, from the perspective of pollination the most directly relevant ones are the ones relating to pesticide use (including intensification) or crop diversity (including rotation). Organic farmlands and fallows can potentially also be relevant as these "management subtypes" can offer additional habitats for some wild pollinators. Nutrient balance data can also be considered as indirectly relevant for pollination. As most of the indicators covering a similar 'thematics' are expected to be relatively correlated, so there is not much point in including too many of them into the EU MAES assessment. A relevant but still parsimonious set, like hemeroby, intensification/extensification, and livestock density can be a good option.

**Table 6.1:** **Indicators available for pressures relevant for pollination**. 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 |
| 1 | Share of organic farming | only available at a very coarse spatial resolution |
| 1 | **Share of fallow land** | |
| 2 | Crop diversity | |
| 2 | Crop rotation (functional crop groups) | still needs to be developed |
| | *Grazing intensity* | |
| 1 | **Livestock density** | |
| | *Forest use intensity* | |
| 2 | Long term ratio of annual fellings to net annual increment | |
| 2 | Length of the felling cycle | |
| | *Nutrient / material balances* | |
| 2 | 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 |
| 2 | Acidification | |
| 2 | Chemical status of surface/ground water | |

** 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 pollination capacity models

To ensure a high level of consistency across the different elements of the EU MAES assessment (=the main 'boxes' in Fig. 1.1), it is important that these elements would be interlinked as much as possible. The integration of condition indicators into ecosystem service modelling is particularly relevant for ensuring the internal coherence of the EU MAES assessment. This means that if ecosystem condition can be described with indicators that are really relevant in terms of a specific service, then it is important, that those indicators would be integrated into the model(s) used for mapping (and/or assessing) the capacities for that service. The main EU toolkit for modelling pollination is ESTIMAP, an EU-level GIS model integrating mechanistic and rule-based components (Zulian et al., 2013; 2018). (The other internationally popular pollination modelling tool, InVest (Sharp et al., 2015) follows a very similar approach, so the subsequent discussion will also be valid for it.) The following paragraphs discuss the degree to which the proposed condition indicators are compatible with the ESTIMAP model, and make tentative recommendations in order to increase this compatibility.

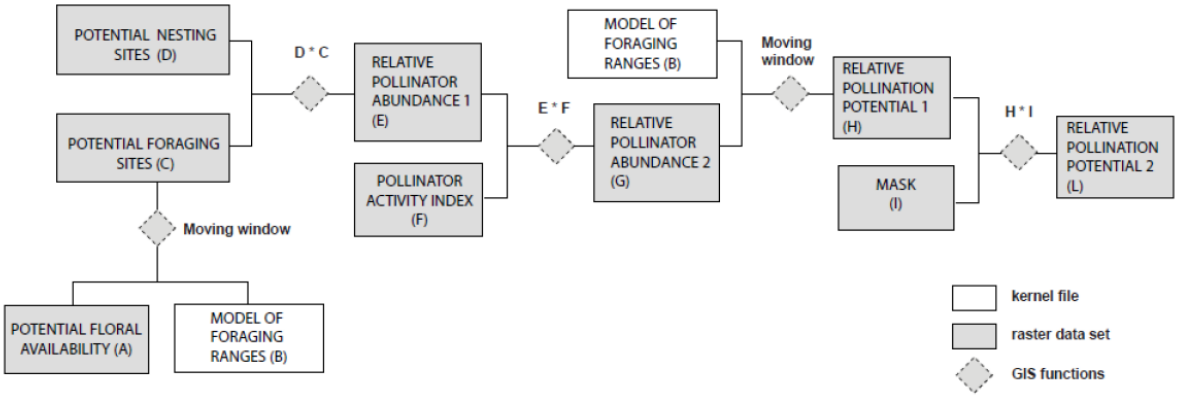


**Figure 7.1: The structure of the ESTIMAP pollination module after Zulian et al. (2013).**

The pollination module of ESTIMAP (Fig. 7.1) relies on estimating the availability of two key factors determining local capacity for pollination by wild pollinators: the availability of **nesting sites** (NS) and **floral resources** (floral availability, FA) within their flight ranges. Based on the spatial overlap of these two components 'relative pollinator abundance' values are assigned to each cell (100 m) of the study area (all Europe). ESTIMAP then uses a second spatial overlap with the flight ranges to quantify a 'relative pollination potential' for all of the cells.

The key spatial inputs of the model are the maps of the nesting sites and the floral availability. These two maps are calculated by rule-based models starting out from the CLC maps, refining the initial 'lookup' map with additional landscape elements that can possibly serve as nesting or foraging sites, including various crop types, forest margins, roadsides and river/lake sides. Table 7.1 provides an overview how the main input variables considered are related to the condition aspects and indicators.

**Table 7.1: Overview of the main spatial input variables of the ESTIMAP pollination module (Zulian et al., 2013), and some potential refinement options, based on the condition aspects and indicators highlighted in this fact sheet**. A-F: the model components as shown in Figure 7.1.

| Condition aspects | ESTIMAP 2013 approach (Fig. 7.1) | Potential refinements |
|---|---|---|
| **Biodiversity** | | |
| pollinators | Pollinators and their distributions are highly generalized, spatial variation is only taken into consideration in the form of a 'pollinators activity index' (F) increasing from north to South. | There are still no fine-resolution spatial data available on the abundance or diversity of pollinators, nor any general biodiversity indicator that could be used as a suitable proxy. Nevertheless, general pressure indicators could perhaps be integrated into the calculation of the activity index (F) adding an east-west gradient to it. |
| plants (& general) | Plant (floral) diversity is addressed indirectly through the floral availability component (A). | No refinement possibilities/needs foreseen (still no fine resolution plant diversity indicators available). |
| **The extent (abundance) of a specific subtype of an ecosystem type** | ESTIMAP relies extensively on lookup tables and adjustment rules based on subtypes to the MAES ecosystem types. CLC classes are further refined by other typologies (e.g. HNV farmlands: Paracchini et al., 2008). Subgrid seminatural elements in croplands (Garcia-Feced et al., 2015) are also considered, and linear infrastructure (road network), as well as the contours of wetlands/water are also used as further proxies for subgrid pollinator habitats (A, D). | No refinement possibilities/needs foreseen (but the types of linear infrastructure taken into consideration could be harmonized with the way how *connectivity / fragmentation* will be calculated for the MAES condition assessment). |
| **The coexistence / proximity of two different ecosystem types** | Through the spatial modelling of pollinator movements (B) ESTIMAP is able to identify spatial configurations of habitat types that are favourable to pollinators in a very efficient and sophisticated way, which is superior to the simple proximity indicators proposed in this fact sheet. | No refinement possibilities/needs foreseen. (The details of the *'distance to wetland'* / *'distance to forest'* condition indicators proposed in this fact sheet, should be harmonized with the way how ESTIMAP quantifies these distances.) |
| **Landscape diversity** | Landscape diversity is only indirectly included into ESTIMAP, through the identification of specific proximity relationships. | No refinement possibilities/needs foreseen. (At the high spatial resolution of ESTIMAP there is no need to rely on 'overall' diversity measures as a proxy for the direct relationships between neighbouring habitats.) |
| **Pressures** | | |
| General overexploitation | ESTIMAP does not consider any metrics here | It should be checked if the JRC hemeroby map could be added in a sensible way (A, D or F) |
| Farming intensity | ESTMAP considers various CAPRI-based datasets (crop shares) (A, D) | It should be checked if any of the indicators related to intensification / pesticide-use could be added (unfortunately they are only available at relatively coarse resolution) (A, D, or F) |
| Grazing intensity | Not included | Livestock density could probably be added in a relatively straightforward way (e.g. with rules adjusting relative scores for grasslands) (A, D?) |
| Nutrient / material balances | Not included | No refinement possibilities/needs foreseen (these pressure indicators are in a relatively distant and indirect relationship with pollination capacities) |

Altogether most of the proposed ecosystem condition indicators are already well represented in ESTIMAP, with the exception of a few (hemeroby, grazing intensity, pesticide use) which could be considered for inclusion during a possible update related to the EU MAES assessment delivery. But there should be harmonization efforts also in 'the other direction': the design details of ESTIMAP should be consulted when setting the specifications of several EU MAES condition indicators (including *connectivity / fragmentation*, *distance to forest*, and *distance to wetland*).

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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 TI and NI give an overview on the importance of each characteristics for pollination:

- **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). 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 |
|---|---|---|---|---|---|---|---|---|---|---|
| Management / disturbance intensity [T mi] | 3 | -2 | | 98 | 140, 272 | | | | | |
| grazing intensity | 1 | 0 | | | 272 | | | | | |
| farming intensity (fallow) | 1 | -1 | | 98 | | | | | | |
| Biodiversity (in general) [T di] | 5 | 4 | | 31, 111, 243 | 243, 272 | 8 | 8 | | | |
| diversity of plants | 2 | 2 | | 243 | 243, 272 | | | | | |
| pollinators | 4 | 3 | | 31, 111, 243 | 243 | 8 | 8 | | | |
| Occurrence / abundance of a specific species (functional) group [T ab] | 2 | 2 | | 58, 111 | 58 | | | | | |
| nectar source plants | 1 | 1 | | 58 | 58 | | | | | |
| pollinators | 2 | 2 | | 111 | 58 | | | | | |
| The extent (abundance) of the studied ecosystem type (or a specific subtype) [E ab] | 5 | 3 | | 98, 111, 318 | 140 | 58 | | | | |
| any seminatural feature (hedgerows, treerows, roadsides, oldfields) | 3 | 1 | | 98, 111, 140 | | | | | | |
| The co-existence / proximity of the studied ET and another ET [E pr] | 7 | 5 | | 31, 58, 83, 98, 111, 140, 318 | 58 | | | | | |
| forest | 1 | 1 | | 58 | 58 | | | | | |
| grassland | 1 | 1 | | 140 | | | | | | |
| any (semi)nautral ecosystem type (forest, grassland, wetland) | 5 | 3 | | 31, 83, 98, 111, 318 | | | | | | |
| any (semi)nautral ecosystem type (forest, grassland, wetland) [proximity] | 2 | 2 | | 31, 83 | | | | | | |

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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 pollination in the context of the EU MAES ecosystem condition assessment. All indicators are scored according to three aspects of 'usefulness':

- **rel**: relevance for pollination (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 |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 2 | 2 | Living Planet Index for Mediterranean wetlands | | WWF | index | n | 1970-2005 | **MS** | Mediterr countrie s |
| | 1 | 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 | | | | | | | |
| | 2 | 3 | 3 | Plant functional types (diversity) | | | ? | f | ? | ? | ? |
| | 2 | 2 | 2 | Forest tree species (richness) | | AFOLU, MS? | 1/area | f | ~1998 | 100m | EU28, BY, MD |
| | 1 | 3 | 3 | Understory vegetation (richness) | | | 1/area | f | ? | ? | ? |
| | | | | birds | | | | | | | |
| | 2 | 2 | 2 | EU Population status and trends of bird species (%) | SEBI 003 | Art12 DB | index | afn | 2013, 2018 | **MS** | EU |
| | 2 | 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 | ? | ? | ? |
| | 1 | 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 |
| | 2 | 2 | 2 | Deadwood | SEBI 018 | EEA | m3/ha | f | 2000-2010 | **MS** | 25 from EEA39 |
| | 1 | 1 | 1 | Naturalness (index or typology) | | | index | f | ? | ? | ? |
| | 1 | 2 | 2 | Red List Index of threatened habitats | | IUCN EU RL | index | f | 2017 | ? | ? |
| | | | | **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 | 1 | 1 | **Proximity to (any) natural habitat** | | ETM | km (or m) | | 2012- | ? | EU28+, TR, W. Balkan |
| | 1 | 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 |
| | | | | **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 |

| HI | rel | rep | ava | indicator name | indi.set | source | unit | pilot | date | s.resol | s. cover |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 1 | 1 | 1 | Fragmentation patterns of natural/seminatural landscapes | SEBI 013 | CLC (ETM?) | index | fn | 2006-2012 | 100m | EEA39 |
| | 1 | 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 | 1 | 2 | 1 | Pesticide use | AEI06 | Euro-stat | kg/ha/y of act. ingred | a | 2011-2014 | **MS** | EU28 |
| OP | 1 | 1 | 1 | Share of organic farming | SEBI 020, AEI4 | FSS | % | a | 2005, 2012-2016 | **MS** | EU28 |
| O(H) | 1 | 1 | 1 | Share of fallow land | | FSS, CAPRI | % | a | 2010; 2012 | 5km; HSU | EU28 |
| O(I) | 1 | 2 | 1 | Crop diversity | | FSS, CAPRI | 1/area | a | 2010; 2012 | 10km | EU28,HR : NUTS2 |
| O | 1 | 2 | 1 | Crop rotation (functional crop groups) | | FSS, CAPRI | 1/area | a | 2010 | 10km | EU28,HR : NUTS2 |
| | | | | Grazing intensity | | | | | | | |
| O | 1 | 1 | 1 | Livestock density | | FSS, CAPRI | LU/ha | a | 2010, 2012 | 5km, HSU(?) | EU28 |
| | | | | Forest use intensity | | | | | | | |
| O | 2 | 1 | 2 | Long term ratio of annual fellings to net annual increment | SEBI 017 | EEA | % | f | 1990-2010 | **MS** | EEA39 |
| O | 2 | 1 | 2 | **Length of the felling cycle** | | EEA, MS | y | | ? | ? | ? |
| | | | | Nutrient / material balances | | | | | | | |
| OP | 2 | 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 |
| 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 | 2 | 1 | 2 | Acidification | IND-30, CSI 005, AIR 004 | JRC | kg/ha/y of S | f | ? | ? | ? |
| P | 2 | 1 | 1 | *Chemical status of surface/ground water* | SEBI 016 | WISE | index | a | 1992- | RBMP | 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

| | |
|---|---|
| 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 |
| EASIN | European Alien Species Information Network |
| EBCC | European Bird Census Council |
| EEA | European Environment Agency |
| 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 |
| Eurostat | the statistical office of the European Union |
| FA | availability of floral resources |
| 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 |
| 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 |
| LRTAP | Long Range Transfer of Air Pollution |
| LU | livestock units |
| MAES | mapping and assessment of ecosystems and their services |
| MS | EU Member States |
| NS | availability of nesting sites |
| NUTS | nomenclature of territorial units for statistics |
| OpenNESS | Operationalisation of natural capital and ecosystem services (EU FP7 project) |
| RL | red list |

| | |
|---|---|
| SEEA-EEA | System of Environmental Economic Accounts - Experimental Ecosystem Accounts |
| SVL | sparsely vegetated land |
| TEEB | The Economics of Ecosystems and Biodiversity |
| UK NEA | UK National Ecosystem Assessment |
| WWF | World Wildlife Fund |