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Elements for a better knowledge on biological characterisation of ecosystems, their pressures and conditions

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Context:

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Contents

1 Introduction

1.1 Context

The EU target 2 aims to maintain and restore ecosystems and theirs services. In this respect, the state or condition of the ecosystems must be assessed for the sake of biodiversity as aimed by the 2020 Headline target, halting the loss of biodiversity and the degradation of ecosystem services.

Levels of conditions can be defined according to several values (historical, ecological, socio-cultural values) but also based on policy targets. That can lead to lengthy discussions on what should be the reference underlying the assessment.
With a pragmatic approach and due to the importance of the role of services highlighted in the policy context, we decided to consider ecosystem condition with a service perspective.

1.2 Methodological approach

The main goal of this case study is to examine the possibilities of linking the biological characteristics of ecosystems (ES) that are relevant in determining the local capacity of ecosystem services (ESS) to the components of EEA's ecosystem assessment framework (ecosystem types, pressure and condition data). The ESS in the focus of this case study are pollination and recreation, but a similar analysis could be done for other ecosystem services as well.

For these two examples, the aim is to identify possible links between ecosystem characteristics and the components of the EU-level ecosystem assessment, creating a list of biophysical characteristics of the habitats that greatly influence the supply of the studied service. To achieve this we relied on examples from the scientific literature.

1.3 Integrating biological characteristics into the EEA ecosystem assessment framework

There are several ways how relevant information on the supply of ecosystem services can be integrated into EEA's MAES process. The possible information pathways can be classified into two main types (or "entry points" into the MAES process). Information can be used to:

- be considered during the creation of an ecosystem pressure map, or as a factor determining (one of the) ecosystem condition map(s) (EC), or
- directly feed into the models underlying an ecosystem service map (ESS).

These entry points correspond to the main elements of the EEA ecosystem assessment process, as well as the steps of the cascade framework. Following the cascade logic, information can easily spread downstream: EC can influence ESS (in general: those relevant ecosystem characteristics should be conceptualized as EC which determine the supply of several ESS at the same time). Thus, the selection of EC indicators should be preceded by a careful analysis of the factors determining the most important ESS, so that the resulting EC maps could be used most effectively in the ES models, and then ensuring scientifically sound high policy relevance for them.

In addition to the characteristics, there were several fine-scale ecological measurements (e.g. visitation rates, quantity of pollen transported, seed set rates, etc) that were used as ESS indicators in research studies. Nevertheless, we did not include indicators related to fine-scale processes into our list, as they are less useful at a landscape, yet continental scale. The selected biological characteristics are interpretable at a coarse scale, but they are also highly correlated (e.g. functional diversity, species richness and abundance of pollinators). So it would not make sense to address each of them separately at a European scale, and it might be possible to effectively characterize service capacity of European landscapes with a small number of indicators (e.g. one indicator characterizing the biodiversity (plant and pollinator communities) of patches, and another describing the landscape-level availability of nesting sites).

1.4 Format of the fact sheet and attached tables

CICES classification Section Division Group Class
Coverage (geographical)
Introduction
Key biodiversity parameters essential for the supply of pollination service
Ecosystems and habitats providing pollination service in Europe
Condition of ecosystems and habitats providing pollination service in Europe
Causality (functional relationship): What is the Cause impact relationship between ES condition and pollination service? What ES conditions have to be maintained to guarantee a high level of ESS supply? Which pressures are the most impacting on the essential ES conditions? / What are the consequences of altered landscape use or measures taken? Are there different pressures (threats) on different scales? What are the consequences of BD-loss on the (ES condition and) ESS supply?
Main findings
Key questions
Challenges

2 Pollination service

CICES classification

Section: **Regulation and Maintenance**
Division: **Maintenance of physical, chemical, biological conditions**
Group: **Lifecycle maintenance, habitat and gene pool protection**
Class: **Pollination and seed dispersal**

CICES regards habitat services as part of a broader 'regulating and maintenance' theme. Habitat services form a sub-class that captures aspects of natural capital that are important for the regulation and maintenance of 'biotic' conditions in ecosystems (that are for e.g. pollination, seed dispersal, pest and disease control, gene-pool protection etc.), and are equivalent to other biophysical factors that regulate the ambient conditions such as climate regulation (Haines-Young & Potschin, 2011).

Coverage
Europe
The spatial resolutions found in the literature can be obtained from the annexes and template. The possible most recent data and time series are used.

Introduction

Pollination is an essential step in the production of seeds in all spermatophytes. It is the process by which pollen is transferred to the female reproductive organs of a plant for fertilizing. By producing reproductive units, the seeds, genetic information is passed on to the next generation.

By collecting floral resources (i.e. pollen, nectar) for feeding, pollinators, mostly bees carry pollen on their bodies and transfer it from flower to flower. They can fertilise plants this way through pollination, allowing the plants to reproduce sexually. The ubiquity of bees and their tight association with flowering plants make their role in pollination a global keystone in wild and agricultural ecosystem dynamics.
According to the European red list of bees (IUCN 2014) 35% of the global production volumes come from crops that depend on pollination. The ecosystem service "crop pollination" that is mainly provided by bees is estimated to be 153 billion Euros worldwide and 22 billion Euros a year in Europe (Gallai et al 2008).

Key biodiversity parameters essential for the supply of pollination service

To identify possible links between ecosystem characteristics and the components of the EU-level ecosystem assessment, we created a list of biological parameters that greatly influence the supply of pollination. To achieve this we relied on examples from the literature. Results are summarized in Annex I - Table 1.

Ecosystems and habitats providing pollination service in Europe

Table 2 classifies CLC-types according to their suitability for pollinators as well as nutrient provision and nesting sites. Literature research underpins the classification. Further EUNIS-classes were allocated to CLC-types considering pollination. Table 3 is based on scores of floral availability (FA) and nesting suitability (NS) following JRC-Report '*ESTIMAP: Ecosystem services mapping at European scale'* (2013).

Condition of ecosystems and habitats providing pollination service in Europe

Mapping ecosystem conditions are useful to deliver additional information about the quantity and quality of services each ecosystem is able to provide (EC 2014). ETC SIA[1] has mapped the ecosystem conditions based on the ecosystem map using additional information on habitat quality and species assessment by integrating information reported for the Habitat Directive Article 17, WFD, MSFD and LUCAS. The conservation status of species and habitats reported under Article 17 of the Habitat Directive provides useful information particularly on grassland (unfortunately less for cropland).

Although the ETC SIA map on ecosystem conditions provides an overview of the condition of the European agro ecosystems, it is not precise enough to assess the condition of ecosystems and habitats providing pollination service as it considers data only of parts of the relevant ecosystems (of HD Article 17 reporting).

There are two complementary approaches to assessing ecosystem conditions:

- an indirect approach by evaluating and mapping of pressures acting on ecosystems and
- a direct assessment of habitat conditions, biodiversity and environmental quality.

These two approaches have been applied to evaluate ecosystem conditions (EC 2016). Information on pressures can be used as proxy to assess the condition of ecosystems.

The most important ecosystems/habitats providing pollination services are grassland and cropland. In general main pressures are habitat change (fragmentation, urban sprawl, abandonment, land take…), overexploitation (e.g. intensification) nutrient and pollution load (e.g. pesticide use). Climate change can have positive (extension of the vegetation period) and negative (damage of crops) effects on pollination and biodiversity. Invasive species also can have positive as well as negative effects on pollination and biodiversity.

Particularly for pollination the land management has a crucial influence on the condition/state of cropland and grassland ecosystems.

The table below provides a list of habitats supporting pollination and related indicators (see also EC 2014).

The Parameters influencing ecosystem conditions are given in Annex 1 table 4. This table assesses parameters (Column 1) with supporting or deteriorating effects on ecosystems or habitat conditions and their pollination services. The column “Influence on ecosystem or habitat condition” provides more detailed and literature based information on selected parameters. Related indicators and their data sources in the next two columns present the indicator’s measurability and availability.

[1] Source Banko et al. (2013): http://projects.eionet.europa.eu/eea-ecosystem-assessments/library/draft-ecosystem-map-europe

ES/habitat providing pollination service	Condition: drivers/pressure and state	Data source	Comments
Extensive farmland	I. AEI 23:HNV farmland indicator;	AEI 23:HNV farmland indicator; EEA	HNV is by definition: extensively used farmland with high agrobiodiversity (e.g. extensively used grassland and variable landscape with low intensity farming or a mosaic of semi-natural and cultivated land and small-scale features, supporting rare species)
	I. Extensive Farming (cropland areas <60% avg. yield; grassland max. 1 LU /ha) II. total N input on cropland and grassland in 2010 III. JRC Semi natural database (http://publications.jrc.ec.europa.eu/repository/handle/JRC86617)	EC 2012	Map 5.7.MAES 3rd report (Mapping and assessing the condition of Europe's ecosystems: Progress and challenges) Map comprises N input from mineral fertilizer, manure, atmos. deposition, biological fixation (map 3.6., EEA tech.report 6/2015) An extensive dataset on tiny seminatural vegetation fragments nested in agricultural areas over EU.
Natural Grassland	I. CLC II. SEBI 03 and 05 species and habitat conservation Status III. Total N input to agroecosystems IV.AEI 12 Intensification Extensification	CLC class 3.2.1 ; EEA Article 17 reporting ETC SIA 2014 AEI 12, EUROSTAT	Condition depends on management Map 5.15, MAES 3rd report (Mapping and assessing the condition of Europe's ecosystems: Progress and challenges)
Extensive pastures	I. CLC II. SEBI 03 and 05 species and habitat conservation Status III. Livestock density of grassland AEI 12 Intensification Extensification,	CLC class 2.3.1, EEA Article 17 reporting ETC SIA 2014 AEI 12, EUROSTAT	Condition depends on management Map 5.14, MAES 3rd report (Mapping and assessing the condition of Europe's ecosystems: Progress and challenges)

Permanent crops	I.CLC II.AEI 4: organic farming III. AEI 26: Soil quality IV. AEI 12 Intensification Extensification	CLC classes 2.1.1;2.1.2;2.1.3 EUROSTAT data on crops; EUROSTAT	Orchards and vineyards, olive groves are feeding sites (nesting sites) for bees and thus promote pollination, extensive management is crucial (reduced use of pesticide…)
Cropland (eg. oil seed rape, sunflowers)	I.CLC II.AEI 4: organic farming III.AEI 26: Soil quality III. Land use intensity on arable land IV. Intensity pressure on cropland as combination of land management (fertilizer and Irrigation) and yield V. AEI 12 Intensification Extensification; VI. JRC semi natural database (see above) VII. CAPRI database: crop shares	CLC class 2.1.1 EUROSTAT ETC SIA 2014	Specific mass flowering crops are feeding site for bees and thus promote pollination; condition depends on management Map - land use intensity on arable land derived from crop yield and N fertilizer application (map 3.4., EEA tech.report 6/2015) Aggregated indicator for management intensity map 3.8., EEA tech.report 6/2015) VII: The CAPRI modelling framework is used for modelling European agriculture in several EU research projects. The databases created contain crop share data on a 1x1km grid over whole Europe, for several past time periods and future scenarios as well.
Forest land	HNV forest indicator SEBI 018 (deadwood) MCPFE/FE: Protected Areas	JRC? EEA Forest Europe/MCPFE	Intensity of forest management is a crucial criterion for habitat quality for pollinators. Close-to nature management provides higher diversity in forests and consequently better nutrition and nesting possibilities.

Causality (functional relationship): What is the Cause impact relationship between ES condition and pollination service?

Habitat loss, intensification of agricultural land use, soil sealing, the frequency of fires and climate change are regarded as the main threats to wild bees in Europe. Changes in habitat areas or their availability do not have the same impact on all wild bee species. While generalists can cope with a greater variety of ecological conditions, specialists depend on specific food sources and places to nest. The reduced availability of flowers to feed bees is one of the main reasons that a high percentage of wild bee species are now classed as threatened. For maintaining a bee fauna that is rich in species and individuals the availability of nectar- and pollen-producing flowers, both in quantitative and qualitative terms, is the most important factor. Also the reduced availability of flower-rich meadows leads to an increase in spatial distance between abundant food sources and nest sites, which also drives wild bee population decline. It is therefore absolutely necessary that, in the vicinity of nesting sites, enough food, produced by certain plants, is available

What ES conditions have to be maintained to guarantee a high level of ESS supply?
The value of a habitat for wild bees depends to a large extent on how the land is used, as this is the decisive factor when it comes to the availability of food plants and nesting sites. Extensive regimes where no fertilisers and herbicides are applied increase the density of flowering plants and thus the availability of food for bees. Fields should be mowed, at least in certain areas, as late in the year as possible, e.g. after mid-July. Extensification on previously intensively used meadows has a positive impact on wild bee diversity. Given that the pollination performance on cropland declines with increasing distance to extensively used meadows, a small-scale mosaic, in terms of landscape architecture, has a positive effect on the overall pollination performance. Mass flowering crops are also a valuable food source for pollinators provided that the crop management is rather extensive.

Which pressures are the most impacting on the essential ES conditions? / What are the consequences of altered landscape use or measures taken?
Reduced agricultural structures resulting from the intensification of agricultural land use lead to the loss of important nesting sites for wild bees and also for a loss of food sources. Intensive grazing reduces the abundance of flowers and also leads to a decline in wild bee populations.

Are there different pressures (threats) on different scales?
Direct pressures are measures that concern habitat use, for e.g. soil sealing and habitat management. These pressures reduce the natural habitat of pollinators, like housing development and agricultural intensively used areas. Indirect pressures are more or less global factors like nutrient deposition or climate change. These pressures can change the composition of ecosystems; concerned are vegetation types and their respective fauna.

According to the IUCN Report "European Red list of bees" (2014) the "agricultural expansion and intensification" is seen to be the major habitat threat, followed by "livestock farming and ranching" and "pollution by agricultural and forestry effluents". As major threat also count "residential and commercial development", "fire", "climate change" and other ecosystem modifications.

What are the consequences of BD-loss on the (ES condition and) ESS supply?
Biodiversity loss leads on one hand to a loss in flowering plant species. Some of the wild bee specialists are dependent on specific plant sources to feed on or to nest in (for e.g. in plant stems). So if pollinators pollinate their flowering surroundings they maintain the diversity of their habitats. On the other hand, if food sources and/or nesting sites decrease this will have a strong influence on pollinator populations. Changes in habitats or the availability of food and nesting sites does not have the same impact on all wild bee species. Generalists can cope with a lot of changes as they often have a broader range of food and will adapt to new environmental conditions more easily than the specialists (Umweltbundesamt 2015a).

Main findings
From an agronomical aspect and for the maintenance or improvement of biodiversity wild bees and honey bees are more important that other pollinators (like hover flies, butterflies and beetles). Nonetheless the whole range of pollinators is important for sustainability and resilience of ecosystems (Key question 1)

The essential preconditions to support pollination service are the maintenance or improvement of habitat quality for pollinators. They need constant availability of nectar and pollen producing plants and a high diversity in flowering plants. The generalists of e.g. wild bee species can cope with a greater variety of ecological conditions and are not so selective in their choice of food. But specialists depend on specialised food sources, sometimes even on one single plant species and also on special places to nest. For wild bees nesting site and food source need to be close together. A small radius below 300m from nesting site to food source is important for successful breeding. Undisturbed nesting sites are essential, like open soil, sand cavities, dead wood or plant stems. Mass flowering plants i.e. rape or orchards can play an important role as feeding site for bees particularly in spring time. It is vital that those areas are managed with little or no pesticides otherwise the pollinator might be damaged (Key question 2)

Suitable habitats are cultivated land rich in landscape structures, extensively used meadows, field margins rich in wild herbs, flowering shrubs, richly structured forest edges and also vegetation of riparian strips. Wild bees inhabit open landscapes if they support their food and nesting requirements. Therefore a number of ecosystems/habitats that are not predominantly influenced by human activity (e.g. open alluvial forest or alpine dry grasslands) are suitable to support insect pollination. (Key question 3)

Datasets of land use are necessary to characterise agriculturally managed habitats and their characteristics. In order to estimate the intensity of land use datasets and maps on small scale are needed. Therefor the use of IACS datasets and LPIS maps are useful. Further information can be obtained from several agri-environment indicators (e.g. AEI 12, 14, 15, land take indicator CSI14, SEBI 018 (deadwood), MCPFE/FE: Protected area, ETC/SIA 2014 and the EEA Technical Report No. 6/2015 June. (Key question 4)

The most important pressures (threats) on ecosystems can be divided into direct and indirect ones. Indirect pressures show effects on large scale and do not (only) originate from local activities (e.g. climate change and nutrient deposition). Local factors like land management intensity and soil sealing are directly influenced by human activity and can be called direct pressures. Focusing on intensive land use the main pressures (threats) are habitat loss by intensification of agricultural land on crop land and on meadows. For e.g. the production of silage instead of hay leads to a strong reduction of flowering plants. Earlier and more frequent mowing reduces the food supply by flowers. Intensive grazing reduces the number of flowers and also leads to a decline in wild bee populations. Further pressures /threats are the use of insecticides and herbicides in agriculture, horticulture and public areas, as well as the reduction in landscape elements like windbreaks, flower strips and field margins and also fragmentation of flower rich landscapes (Key question 5)

The most important measures to improve the pollination situation are (Key question 6):
- Extensification of land use with regard to fertilisation, pesticide use and fallow management, above all the extensive use of pastures and hay meadows (late mowing)
- Continuous availability of nutrient sources (flowers)
- Establishment of flower rich patches
- Higher diversity of crop plants and catch crops (using local/autochthonous species)
- Small scale mosaics in terms of landscape architecture enhance pollination (windbreaks, field margins, waysides, slopes, riparian strips, flower strips,…)
- Pollen and nectar rich deciduous trees and shrubs in forestry and windbreaks, richly structured forest edges including herbs and shrubs
- Conducting a survey and breeding program for autochthonous flowering wild plants for regional flowering areas
- Generally creating flowering landscapes (field margins, extensive pastures, house gardens, forest edges, forest clearing)

Key questions

(1) What are the most important insect pollinators (agriculture and wild plants)?
Most important are wild bees and honey bees, but also hover flies, butterflies and beetles.

(2) What are the preconditions essentially to support pollination service?
Pollinators need constant availability of nectar and pollen, a high diversity of flowering plants and adjacent suitable nesting sites.

(3) Which ecosystem or habitat characteristics support insect pollination?

Open landscapes if they support their food and nesting requirements, like open land rich in landscape structures, extensively used meadows, field margins rich in wild herbs, flowering shrubs or richly structured forest edges.

(4) Which kinds of datasets are available to characterise these ecosystems/habitats and their characteristics ?
Datasets to estimate the intensity of land use and small scale maps, like the IACS datasets and LPIS maps are useful; additionally agri-environmental indicators can give beneficial information.

(5) What are the most important pressures on ecosystems which are delivering pollination service?
Focusing on land use the main pressures (threats) are habitat loss by intensification of agricultural land on crop land and on meadows.

(6) What are the most important measures to be taken to improve the pollination situation in the EU?
The most important measures can be summarised as extensification of land use with regard to fertilisation, pesticide use and fallow management, as well as extensification of pastures and hay meadows, additionally flowerings landscapes are very important.

Challenges

- Description and classification of ecosystems and habitats providing pollination service: Ecosystems have been classified but descriptions for their recent condition aren´t available, therefore also no thresholds for their recent pollination service are available or can be elaborated on basis of the present data. Therefore a monitoring regarding the recent status of ecosystems is needed.

- In Annex 1 (habitat suitability) and Annex 2 (parameters supporting pollination) the classification into excellent/good/moderate and poor and into +/- is based on expert judgement and on scientific literature. Still there are no clearly defined thresholds but transition ranges.

- Data availability on species groups that can be reported on European level would be very helpful to find indicator species. Therefore it is important to improve the availability of scientifically validated observation data on wild bees (e.g. via the global biodiversity information facility www.gbif.at).

- Most proposed measures have either a trade-off or a co-benefit effect, also depending on which perspective is chosen (e.g. extensification – food security but also organic agriculture – food security for future decades). These measures also need to be seen in a political context for future developments.

- Pressures (threats) on pollination service are described individually but there are also interactions with each other. These effects on pollinators are still not defined.

- On these mentioned issues more research to close existing knowledge gaps would be useful.

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Annex 1

Table 1- Biological parameters relevant for pollination at a European scale

Parameter name	Parameter definition	Literature examples	Recommended MAES integration options*	Comments
Functional groups of pollinators	number of pollinator functional groups (guilds), pres/abs of specific functional groups	solitary bees vs social bees (Klein et al 2003), FUNCTIONAL BEE GUILD DIVERSITY (Hoehn et al 2008)	EM: scores should reflect the appropriateness of the ecosystem types for pollinators (as foraging and nesting sites)	
Richness of pollinating insect species	number of pollinator species, pres/abs of certain species	regional species richness (Vamosi et al 2006), native beetle species per 100 flowers (Blanche & Cunningham 2005)	EM: scores should reflect the appropriateness of the ecosystem types for pollinators (as foraging and nesting sites)	Mainly bee species (solitary bees, bumble bees and honey bees), hover flies, butterflies and beetles. The most important pollinating insect species for annual and perennial crops, orchards and grassland are bees in general. While wild bees are more effective as they collect nectar and pollen at the same time (Westerkamp 1991), honeybees are, due to their high numbers of individuals per hive, adapted to pollinate mass flowering crops, like rape for example (Rader et al. 2009). For maintenance of wild plant species dependant on insect pollination all pollinator species are essential. 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).
Abundance of pollinating insects	number of pollinator individuals (of a certain species or functional group) number/density	…	EM: scores should reflect the appropriateness of the ecosystem types for pollinators (as foraging and nesting sites)	Frequency of pollinator visits is increasing linearly with both the blossom cover and the number of flowering plant species (which is closely related to the total number of plant species) (Ebeling et al. 2008).

Functional groups of plants	number of plant functional groups (e.g. flowering types), pres/abs of specific functional groups	…	EM: scores should reflect the appropriateness of the ecosystem types for pollinators (as foraging sites)	
Richness of flowering plant species	number of plant species, pres/abs of certain species	…	EM: scores should reflect the appropriateness of the ecosystem types for pollinators (as foraging sites)	All flowering species producing pollen and nectar. Most important are species of the plant families Fabaceae, Brassicaceae, Asteraceae and Lamiaceae.
Abundance of flowering plants	number (cover) of plant individuals (of a certain species or functional group), flower area / density	…	EM: scores should reflect the appropriateness of the ecosystem types for pollinators (as foraging sites)	"The availability of nectar- and pollen-producing flowers, both in quantitative and qualitative terms, is the most important factor in maintaining a bee fauna that is rich in species and individuals. The reduced availability of flowers to feed on is one of the main reasons for the fact that a high percentage of wild bee species now has to be classed as threatened. Mass flowering plants are a food source but are available only during a short period of time and can be contaminated with insecticides". (Umweltbundesamt 2015 a)
Habitat availability	availability (density) of nesting sites for pollinators	distance (isolation) from natural habitat (Ricketts et al 2008), proportion of natural habitat in the landscape (Greenleaf & Kremen 2006)	EC: distance from high quality pollinator nesting sites can be quantified from maps of high enough resolution (Copernicus HRL and the JRC's Seminatural database (García-Feced et al 2015: Agron. Sustain. Dev. 35: 273))	
Continuity of flowering	temporal evenness of resource (nectar) availability for pollinators	sunflower continuity (Greenleaf & Kremen 2006)	EM: scores should ideally consider this aspect of habitat quality too	

EM through ecosystem map (v3.0), using a matrix approach: assign scores to each ecosystem/habitat type, so that the scores would describe the typical level of that characteristic for that habitat type (should be reliable at a BGR / European scale)
EC through ecosystem pressures / ecosystem condition layers (identifying of ecosystem characteristics relevant for specific ES can help in optimizing the EC layers of Ecosystem Assessment v2.0)

Table 2 - Ecosystems and habitats providing pollination service in Europe

Habitat suitability	CLC level 3*	EUNIS level 1**	EUNIS level 2(3)**	Ecosystem or habitat providing pollination service	Parameters for Ecosystem or habitat condition supporting pollination
Excellent	3.2.2 Moors and heathland	E, F	**E5**, F2 - **F3, F9**	MOORS and HEATHLAND GRASSLAND: - calcareous grasslands - HNV grasslands - extensive meadows FORESTS and SHRUB: - broadleaved forests - transitional woodland-shrub	The mentioned grasslands offer a rich supply of floral resources due to a high plant diversity from early spring to late fall and provide diverse microhabitats for nesting and larval development, too (DUELLI & OBRIST, 2003). In particular if broad-leaved forests contain species of *salix sp., acer sp., quercus sp., tilia sp., cornus sp., sorbus sp., crataegus sp., prunus sp.*(WESTRICH, 1990; WERMELINGER & DUELLI, 2002)
	3.2.4 Transitional woodland-shrub	E	**E1**, E5		
	3.2.1 Natural grassland	E	**E1** - E6		
	3.1.1 Broad-leaved forests	B, **G**	B1, **G1 - G2**		
	3.2.3 Sclerophyllous vegetation	B, E, **F**	B1, E5, **F5-8**		
Good	2.4.4 Agro-forestry areas***	E	E7	GRASSLAND: - extensive pastures - Grass-legume mixtures FORESTS: - fruit and nut tree orchards - mixed forests	Rather extensively managed areas cause longer flowering peroids. Extensive cattle grazing maintains a flowering-rich grassland with a more structurally and floristically diverse sward that benefits bees and bumblebees (CARVELL, 2002). Fruit tree orchards: In particular *Rosaceae* (apple, pear, plum, peach…) offer a high level of floral availability.
	2.4.3 Land principally occupied by agriculture, with significant areas of natural vegetation	I	I1		
	3.1.3 Mixed forests	G	G4		
	2.2.2 Fruit trees and berry plantations****	F, G	FB, G1 - G2		
	2.2.3 Olive groves *extensive*	G	G2		

	3.1.2 Coniferous forests***	B, **G**	B1, **G3**, G5		
	4.1.1 Inland marshes****	C, **D**	C2 - C3, **D2, D4 - D6**		
	3.3.3 Sparsely vegetated areas***	E, F	E4, F1 - F2		
	2.3.1. Pastures	E	E2, E7		
Moderate	2.2.1 Vineyards	F	FB4	GRASSLAND: - abandonded meadows - abandoned pastures - less intensively used meadows and pastures CROPLAND: - abandoned arable land - less intensively used arable land - main crops depending on pollination: rapeseed, sunflower	Abandonment meadows tend to overgrowing (shrubs), shift in vegetation. Abandonment of grazing for more than two years leads to a decreased number of forage plants. A succession of suitable forage plants is enabled by y regular form of controlled rotational grazing if the area is large enough (CARVELL, 2002). Less frequency in mowing and grazing leads to more flowering plants (KRUESS & TSCHARNTKE, 2002; HATFIELD & LEBUHN, 2007, ISERBYT et al., 2008). Flowering plants gradually colonizing abandoned arable land are of value for pollinators. Less intensively used arable land: Smaller field size, wider crop rotation and reduced pesticied use, combined with flowering field edges (CLOUGH et al., 2007; HOLZSCHUH, 2008 & 2010; RUNDLOF et al., 2008). Main crops depending on pollination: These are mainly intensively used rape and sunflower; valuble food source for generalists, but only available during short time of flowering, can be contaminated with pesticide residues (ZURBUCHEN & MÜLLER, 2012; SCHAFLER & DÖTTERL, 2011; HATFIELD & LEBUHN, 2007; CARVELL 2002; STEFFAN-DEWENTER & TSCHARNTKE, 2001; KNOPP et al., 2006).
	2.4.1 Annual crops associated with permanent crops	-	-		
	4.2.1 Salt marshes	A	A2.5		
	4.1.2 Peat bogs	D	D1, D3		
	2.4.2 Complex cultivation patterns	I	I1 - I2		
	2.2.3 Olive groves intensive	G	G2		
	1.4.1 Green urban areas	E, I	E2, I2		
	2.3.1 Pastures	E	E2, E7		

Poor	3.3.1 Beaches, dunes and sandplains	E, F, H	E1, F3 - F4, H5	GRASSLAND: - intensive meadows or pasture CROPLAND: - arable land - fields for biofuel production	Lack of floral resources are the consequence of intensive animal husbandry or high number of cuts. Flowering crops like oil seed rape on arable land nevertheless offer resources for some pollinator species (WESTPHAL et al., 2003). For bumblebees certain key forage plant species are more important than a high plant diversity (GREENLEAF et al., 2007; REDPATH et al., 2010). There are rarely resources for pollinators provided if fast growing trees for biofuel production are cultivated.
	2.1.1 Non-irrigated arable land	I	I1		
	1.4.2 Sport and leisure facilities	E	E2.6		
	2.1.3 Rice fields	I	I1.4		
	2.1.2 Permanently irrigated land	C, **I**	**I1**, C3.4		

*	**CLC-types are listed in descending order according to the average value of their floral availability (FA) and nesting suitability (NS)**			
**	**red characters indicate the main habitats in EUNIS**			
***	**Nesting suitability significant higher than floral availability**			
****	**Floral availability significant higher than nesting suitability**			

Table 3 - Habitat suitability based on CLC types and Floral availability and Nesting suitability (source: JRC, 2013)

Habitat suitability	CLC-types and Description	CLC-Type	FA*	NS*	Average value of FA and NS
Poor	212 Permanently irrigated land	212	0,05	0,20	0,125
	213 Rice fields	213	0,05	0,20	0,125
	142 Sport and leisure facilities	142	0,05	0,30	0,175
	211 Non-irrigated arable land	211	0,20	0,20	0,200
	331 Beaches, dunes and sandplains	331	0,10	0,30	0,200
Moderate	231 Pastures	231	0,20	0,30	0,250
	141 Green urban areas	141	0,25	0,30	0,275
	223 Olive groves *intensive*	223	0,20	0,40	0,300
	242 Complex cultivation patterns	242	0,40	0,40	0,400
	412 Peat bogs	412	0,50	0,30	0,400
	421 Salt marshes	421	0,55	0,30	0,425
	241 Annual crops associated with permanent crops	241	0,50	0,40	0,450
	221 Vineyards	221	0,60	0,40	0,500
Good	333 Sparsely vegetated areas	333	0,35	0,70	0,525
	411 Inland marshes	411	0,75	0,30	0,525
	312 Coniferous forests	312	0,30	0,80	0,550
	223 Olive groves *extensive*	223	0,60	0,60	0,600
	222 Fruit trees and berry plantations	222	0,90	0,40	0,650
	313 Mixed forests	313	0,60	0,80	0,700
	243 Land principally occupied by agriculture, with significant areas of natural vegetation	243	0,75	0,70	0,725
	244 Agro-forestry areas	244	0,50	1,00	0,750
Excellent	323 Sclerophyllous vegetation	323	0,75	0,90	0,825
	311 Broad-leaved forests	311	0,90	0,80	0,850
	321 Natural grasslands	321	1,00	0,80	0,900
	324 Transitional woodland-shrub	324	0,85	1,00	0,925
	322 Moors and heathland	322	1,00	0,90	0,950

FA . Floral availability **NS Nesting suitability** **Nesting suitability significant higher than floral availability** **Floral availability significant higher than nesting suitability**

Table 4 - Parameters supporting or deteriorating ecosystem or habitat conditions providing pollination service

Parameters	Influence on ecosystem or habitat condition	Indicators	data source	Comments (e.g. thresholds, references)
Agro-Ecosystems				
Grazing + −	Low grazing has positive effect on abundance of flowering plants. Intensive grazing reduces the food supply offered by flowers and therewith pollinator populations (Kruess & Tscharntke 2002; Hatfield & LeBuhn 2007, Iserbyt et al 2008))	Frequency of grazing per year	IACS datasets, LPIS: is useful but not fully accessable / available. Eurostat: no data.	thresholds bearing in minds, difficult and time consuming
Mowing + −	reduced (1 - 2 times) and late (after mid July) mowing has a positive effect in the abundance (number of species and flowers) (Umweltbundesamt 2015, Iserbyt et al 2008). Frequent mowing, also for production of silage, leads to reduced abundance of flowers (Kleijn & Rademakers 2008)	Frequency of cutting/mowing per year	IACS datasets, LPIS: is useful but not fully accessable / available. Eurostat: no data.	
Cultivation of mass flowering crops + −	wild pollinators and honeybees pollinate mass flowering crops (rape, sunflower, fruit orchards, vinyard…) whereas wild pollinators improve pollination efficiency and thereby increasing foodset twice (Garibaldi et al 2013, Schindler & Peters 2011, Westerkamp 1991, Bosch & Kemp 2001). Mass flowering crops are an important food source for pollinators, but are mostly only availble during a short time slot. Whereas the management intensity is a crucial factor which influences the pollination service. During the entire summer period (half year) a high food supply offered by flowers is essential (Zurbuchen & Müller 2012, Cane et al 2011, Schafler & Dötterl 2011, Hatfield & LeBuhn 2007, Carvell 2002, Steffan-Dewenter & Tscharntke 2001, Knopp et al	crop diversity, field size	IACS datasets, LPIS: is useful but not fully accessable / available. EUROSTAT has data national level	

	2006).			
HNV Areas +	defines extensively used agricultural land with high agrobiodiversity (eg extensively used grassland and variable landscape with low intensity farming or a mosaic of semi-natural and cultivated land an small-scale features, supporting rare species)	AEI23: HNV per km²	Agri environment indicator IRENA 26 , currently updated by EEA ; using CLC 2012	HNV: proxy used for plant species richness; currently updated based on CLC 2012
General parameters on various ecosystems and habitats				
Loss of habitats −	Habitat loss by soil sealing and intensive land use lead to a linear reduction in pollination service (Schwick et al 2010, Walter et al 2010). Disappearance of individual feeding and nesting sites lead to local extinction of pollinators (Westrich 1990, Zurbuchen et al 2010).	fieldsize, HNV per ha (also for past decades?)	land take indicator CSI014 (2000-2006), in EEA Technical report No 6/2015: European Ecosystem Assessment — concept, data, and implementation, June 2015	land use change indicator based on CLC 2000, 2006: also possible, but detailed elaboration related to pollination would be necessary
Fragmentation (general) −	intensive agriculture - large field size - high fragementation of habitats + reduction of stepping stones (Westrich 1990). Distance between food source and nesting site increases (Zurbuchen et al 2010), this weakens pollinators and reduces breeding success (Williams & Kremen 2007, Zurbuchen et al 2010, Neukirch 1982, Schmid-Hempel & Wolf 1988).	baseline data set for fragmentation	landscape fragmentation map - 1x1km grid human made barriers 2009; source EEA/FOEN in EEA Technical report No 6/2015: European ecosystem assessment — concept, data, and implementation.	databasis of map 3.1 (p.26) in European ecosystem assessment — concept, data, and implementation. EEA Technical Report No 6/2015 June 2015 is unclear; therefore to check: is this indicator suitable?

Fragmentation Forest +	Earth roads, small-scaled harvesting methods might lead to positive fragmentation and high structured forest edges, which provide atractive habitats for pollinators (KUDERNATSCH, 2012; WERMELINGER & DUELLI, 2002; WESTRICH, 1990)	no appropriate indicator available Appraoch: - landscape pattern (length of forest edges) - HNV-Forest area (because of extensive use)	no appropriate data for small-scaled fragmentation in EEA Technical report No 6/2015: European ecosystem assessment — concept, data, and implementation.	Small scale fragmentation of forest has more positiv effect on pollinators. Large scale fragmentation is more neutral.
Pollution and nutrient enrichment –	N-enrichment leads to a shift in plant species , species rich and nutrient poor to poor in species and rich in nutrients. Species depending on poor soils disapear and therewith food sources for pollinators (Stevens etal 2004).	kg nitrogen per ha per year	available at EAA	nitrogen deposition
Climate change + –	increasing temperature influences larval development (Müller et al. 1997), reduced synchronisation between time of flowering of food plants and development stages of pollinators (Schweiger et al 2010) leading to poor pollination as well as reduced flower supply for pollinators (Bradshaw & Holzapfel 2008).	decoupling: problems in synchronisation of flowering and breeding	estimates/examples available; environmental sensitivity to climate change in europe: map - 1x1km grid, 2011; source ESPON Climate Map 3.2 (p.27) in European ecosystem assessment — concept, data, and implementation. EEA Technical Report No 6/2015 June	databasis of map 3.2 (p.27) in European ecosystem assessment — concept, data, and implementation. EEA Technical Report No 6/2015 June 2015 is unclear
Invasive species + –	Alien plants can provide resources for generalist native pollinators (e.g. Stout & Morales 2009), which can lead to declines in specialist native pollinators (e.g. Traveset & Richardson 2006). Invasive alien plants can displace native plant species and deteriorate ecosystem or habitat conditions, and disrupt ecological plant-pollinator networks (Traveset & Richardson 2006). Invasive alien animals (including alien pollinators!) can have a direct negative impact on native pollinators, e.g. via competition (Goulson &	Number of invasive alien plant or animal species; Distribution of selected invasive alien plant or animal species hold responsible to having a negative effect	several databases (Daisie, Nobanis, Easin), but often imprecise; currently not fit-for-purpose possible source: Map 3.3 (p. 28) in European ecosystem assessment — concept, data, and implementation. EEA Technical Report No 6/2015 June	map 3.3 (p. 28) in European ecosystem assessment — concept, data, and implementation. EEA Technical Report No 6/2015 June is based on obeserved alien species in vegetation plots distributed over different habitats - extrapolated by relating it to the respective CLC classes favourable to alien species (see p. 28) in European ecosystem assessment — concept, data, and implementation. EEA Technical

	Sparrow 2009), predation (e.g. Vespa velutina, Monceau et al. 2014), as parasites (e.g. Varroa destructor, Rosenkranz et al. 2010), via hybridization and genetic dilution (e.g. bumble-bees, Goulson et al. 2008) or as hosts and reservoirs of diseases increasing the risk of pathogen spread (Stout & Morales 2009).	on pollinators; european map estimating the level of invasion by alien plant species		Report No 6/2015 June; has to be checked whether this indicator would be sufficient. further aspects: a specific, targeted monitoring program would be needed to collect such data at the local to regional scales
Management related parameters				
Forest management intensity	Habitat quality for pollinators depends besides forest types on kind and intensity of forest management: close-to-nature silvicultural measurements, mixture, small-scaled interventions (harvesting, thinning etc.), deadwood, old growth trees… (KUDERNATSCH, 2012; WERMELINGER & DUELLI, 2002; WESTRICH, 1990)	HNV-Forst area (in progress?) SEBI 018 (deadwood) MCPFE/FE: Protetected Areas	HNV-Forest: JRC? SEBI: EEA MCPFE/FE: Protected Areas, Class 1.1 and 1.2	

Land management intensity + −	extensive/organic land management leads to higher numbers of flowering plants and more ecological niches - increases the diversity of pollinators (Clough et al 2007; Holzschuh 2008 & 2010; Rundlof et al 2008)	land management intensity of cropland derived from crop statistics and nitrogen application; Organic farming, • AEI 12 Intensification Extensification and CCI Farming intensity; AEI 15,16 and CCI 40: Gross Nutrients Balance	EEA Technical Report No 6/2015 June - European ecosystem assessment — concept, data, and implementation: agricultural management intensity from crop statistic and rel. nitrogen application (Source ETC SIA 2014 - map 3.4, p.29); aggregated indicator for management intensity pressure on cropland (arable land) as combination of land management (fertiliser and irrigation) and crop yield, (source: ETC/SIA 2014 a;map 3.8. p. 35); organic farming: number of farms, areas with different crops and heads of different types of animals by agricultural size of farm (UAA) and NUTS 2 regions; EUROSTAT: http://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=ef_mporganic&lang=enhttp://appsso.eurostat.ec.europa.eu/nui/show.do?dataset=ef_mporganic&lang=en	Frequency of mowing, crop rotation (IACS-Data), land take (soil sealing) indicators. Map on Expenditure, crude data level; http://ec.europa.eu/eurostat/statistics-explained/index.php/File:Average_yearly_inputs_expenditures_(EURha),_2005-2007,_EU-27_and_change_between_the_average_yearly_(1995-1997)_and_(2005-2007)_inputs_expenditures_(%25),_EU-27.png; EUROSTAT DATA on intensification/exentensification t national level under : http://ec.europa.eu/eurostat/statistics-explained/index.php/Agri-environmental_indicator_-_intensification_-_extensification - new data in 09/2016
Land abandonment + −	Land abandonment of agricultural areas causes vegetational succession. Pollination service quality depends on starting situation (dry grassland, arable land) and on state of succession (shrub to forests). Reversion to scrub and forest can destroy valuable habitats for pollinators but might as well lead to those.	land abondonment/lack of management	risk of farmland abandonment probability of occurence - CLC land cover flows 1990-2000-2006 in EEA Technical report No 6/2015: European Ecosystem Assessment — concept, data, and implementation. EEA Technical Report No 6/2015 June AEI 14 Risk of land abandonment: http://ec.europa.eu/eurostat/statistics-explained/index.php/Agri-environmental_indicator_-_risk_of_land_abandonment	to be checked, if this data source is sufficient, if indicator suitable

Yield improvement	high harvest intensity associated with intensive use of fertiliser, cultivation of cash crops, low number of crops per area and **intensive** pesticide use. Influence on ecosystem: lack of other food sources, contanimation with pesticide residues of pollen and nectar, possible lack in nesting sites, possible lack of waterholes and if available than contaminted with pesticide residues (Walter et al 2010, Westricht 1990, Knop et al 2006).	crop diversity, field size, fertilizer quantities used	crop diversity, field size, quantities of fertilizer and pesticide use; EUROSTAT at national level cropping pattern: http://ec.europa.eu/eurostat/statistics-explained/index.php/Agri-environmental_indicator_-_cropping_patterns	Crop yield data based CAPRI-model: availibilty? (JRC technical report, ESTIMAP: Ecosystem services mapping at European scale, Joint Research Center, 2013)
Livestock	the higher the livestock density - the more intensively used are the UAA	Livestock density index; Livestock units per ha	EUROSTAT: at country level for EU 28 + map+ graph: http://ec.europa.eu/eurostat/tgm/graph.do?tab=graph&plugin=1&language=en&pcode=tsdpc450&toolbox=type und EUROSTAT at national level: Livestock pattern: http://ec.europa.eu/eurostat/statistics-explained/index.php/File:Livestock_pattern_%E2%80%93_total_and_grazing_livestock_densities,_EU-28,_IS,_NO,_CH_and_ME,_2005-2010.png	no data at NUTS 2 or 3 level
Use of pesticides	Use of herbicides (Carvell etal 2007, Westrich 2013) leads to a lack of flowering food sources, while use of insecticides lead to direct intoxication or indirect via contamination of nectar, pollen and water sources (direct and indirect intoxications) (Pistorius etal 2008, Westrich 1990, Gill et al 2012, Whitehorn et al 2012, Goulson 2015, Decourtye et al 2003, Schacker 2008, Doucet-Personeni et al 2003, Grimm et al 2012).	pesticide application frequency and rate (insectides and herbicides)	records of pesticide use (per area), only on country level	data on county level, rough segmentation into field of application, partly old data: http://ec.europa.eu/eurostat/statistics-explained/index.php/Agri-environmental_indicator_-_consumption_of_pesticides

Use of fertilizer	rising fertilzer use leads to a reduction of of plant species, also to monotonous weed flora and as a result reduces food for pollinators (Walter et al 2010, Crawley et al 2005). Use of Fertiliser reduces cultivation of legumes as important food source (Holzschuh et al 2007)	total nitrogen input to cropland and organic grassland	total nitrogen input to agro ecoystem (kg/ha/yr) in EEA Technical report No 6/2015: European Ecosystem Assessment; Map 3.6 ev auch map 3.4 und map 3.7; source ETC SIA 2010	information seems sufficient, but has to be checked; suitable increasing nitrogen input reduce abundance and diversity of wild bess (Le Féon et al., 2010); http://ec.europa.eu/eurostat/statistics-explained/index.php/Agri-environmental_indicator_-_mineral_fertiliser_consumption (on MS-level, partly old sources)