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PART 4/12

COMMISSION STAFF WORKING DOCUMENT

IMPACT ASSESSMENT REPORT

ANNEX VI-a

Accompanying the

proposal for a Regulation of the European Parliament and of the Council

on nature restoration

{COM(2022) 304 final} - {SEC(2022) 256 final} - {SWD(2022) 168 final}

Annex VI: Analysis by ecosystem

(VI-a: Chapters 1-5)

Summaries of Impact Assessments of ecosystem-specific EU restoration targets

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6. Freshwater: Rivers, lakes and alluvial habitats

7. Marine ecosystems

8. Urban ecosystems

9. Soils

10. Pollinators

11. Cost estimates for different speeds of restoration

1. Inland wetlands

1.1 Scope

This assessment covers ‘inland wetlands’ which are defined here according to the EUNIS habitats[1] classification as ‘Mires, bogs and fens’. These wetland categories can be divided into two very different groups: peatlands and inland marshes.

Peatlands (EUNIS D1, D2, D3 and D4) are categorised by their development of a layer of peat[2] (i.e. partly decomposed plant material), which builds up because of waterlogged conditions. Peatland wetlands mainly occur in cool and wet climates in north-west Europe. They are largely covered by the habitat types of EU importance that are listed in Annex I of the Habitats Directive (HD). Twelve HD Annex I habitats comprise peatlands.

Due to their peaty substrates, this impact assessment also considers two wet heathland, one wet grassland and two bog woodland HD Annex I habitats together with the EUNIS peatland wetlands. Together, these eighteen HD Annex I peatland habitat types cover approximately **136 572 km^2** in the EU (**3.6 %** of the EU terrestrial area)[3].

Inland marshes (EUNIS D5 and D6) are nutrient rich wetlands that are characterised by emergent rooted vegetation such as reeds (e.g. *Phragmites* spp). They are widely distributed in Europe, typically occurring around lakes, rivers and lagoons, in floodplains, and in areas with permanently or temporarily high groundwater levels. HD Annex I habitats do not include any inland marsh habitats. Some coastal and inland salt meadows / marshes are classified as HD Annex I habitats, and these are included in the impact assessments covering coastal habitats. According to CORINE data, inland **marshes cover 10 641 km^2** in the EU.

Detailed data on the geographical distribution, area (km²), conservation status and condition of inland wetland habitat types of Annex I of the Habitats Directive in EU Member States is provided in Annex VIII-a.

1.2 Problem, current trends and ecosystem-specific baseline

Inland wetlands are widely considered to be of very high importance for their biodiversity and associated ecosystem services. As such they have been the focus of longstanding nature conservation action, in particular through the Ramsar Convention on Wetlands of International Importance signed in 1971. This has been in response to widespread losses. For centuries, wetlands, especially peatlands, were targeted for drainage and conversion to agriculture, resulting in two-thirds being lost across Europe between 1900 and the mid-1980s[4]. Consequently, they receive very high coverage under the EU Nature Directives, as most peatlands are HD Annex I habitat types. Europe holds a relatively large proportion of some types

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[1] EUNIS habitat types

[2] Generally considered to be “A wetland soil composed largely of semi-decomposed organic matter deposited in-situ, having a minimum organic content of 30 % and a thickness greater than 30 cm.” Finlayson & Milton (2016).

[3] According to the State of Nature report 2020 - Area of habitats calculated from the area reported by Member States (but excluding Romania due to their severely overestimated data) as 'best estimate' or 'average of minimum/maximum'; minimum area is 133 640 km^2 and the maximum area is 142 511km^2.

[4] European Commission COM(1995)189 final: Wise Use and conservation of wetlands.

of the world's peatlands. Marshes are particularly important for birds listed on Annex I of the Birds Directive, as well as other migratory species that require special conservation measures under the Directive.

Peatlands are of particular importance for their carbon stores, because peatlands in good condition store more carbon per unit area than any other ecosystem, while they become important net carbon emitters when inappropriately managed. All wetlands, and especially upland peatlands, also provide a wider range of ecosystem services. Of these, water retention (which helps maintain supplies during droughts and alleviates floods during extreme weather events) and water filtration are considered to be the most important.

Despite the EU Nature Directives providing high coverage to such habitats and their associated EU protected species, the vast majority (**84 %**) of the peatland habitat type assessments at EU level made in the frame of the State of Nature reporting in the period 2013-2018 revealed an **unfavourable conservation status**: 32 % poor and 52 % bad. Furthermore, at the EU level, **55 %** show an unfavourable **deteriorating** trend. According to the European Red List of Habitats[5], all but two of the 13 EUNIS mire habitat types (85 %) are threatened to some degree, which is the highest proportion of any terrestrial and marine groups of habitats.

Member State reports on the condition (i.e. the quality) of habitat types, indicate that at least 14 % of the total peatland area is known to be in not-good condition. However, almost 48 % of the total area of the habitat area is reported as in 'unknown' (or not reported) condition. The true proportion in a poor condition is more likely to be the proportion of the total habitat area where Member States reported on the condition of the habitat that had a not-good status. Therefore, **it is assumed that 27 % of the habitat area is in a poor condition (i.e. 36 874 km^2).**

According to Member States reports for 2013-2018, the top three groups of pressures affecting HD Annex I peatlands were inadequate habitat management (e.g. grazing, burning, tillage), different forms of water/soil/air pollution (direct or diffuse), and drainage and water abstraction for different purposes (e.g. agriculture, human consumption).

The condition of marshlands and the pressures affecting them are less well known as they are not Annex I habitats and are not subject to standardised EU level monitoring and reporting. CORINE land cover data suggests that the previous extensive losses of wetlands due to drainage have largely halted (probably in part due to high Natura 2000 coverage). On average peatlands declined by 0.03% each year between 2000 and 2018, whilst marshlands increased slightly. In accordance with the baseline 2030 scenario for this impact assessment, whilst small scale losses of some wetlands are expected to continue, they may decline due to improved protection, and some wetland expansion is expected. Therefore, this assessment assumes **no further significant net loss of Annex I peatlands or marshlands to 2030**. However, the trend in increasing wetland fragmentation is predicted to continue.

[5] Janssen et al (2016) European Red List of Habitats Part 2. Terrestrial and freshwater habitats. European Commission.

Nevertheless, evidence of pressures on wetland species suggest that a substantial proportion of marshlands are degraded and requiring restoration mainly due to hydrological modifications and low water tables (e.g. due to diversions for hydropower or abstraction for agriculture). Whilst some pressures are stable or declining (such as nitrogen deposition) and improved river catchment management is expected under the Water Framework Directive, there is little indication of large-scale restoration. On the contrary, the trend in condition of Annex I wetlands is showing that while only 4% of the assessments show an improving trend, 29% show a deteriorating one. Furthermore, direct and indirect climate change impacts (e.g. increasing water demands) will increase, and exacerbate existing pressures. Therefore, **it is assumed that degradation levels in HD Annex I peatlands will increase slightly, from 27 % to 30 % by 2030**. It is assumed that **by 2030 50% of marshlands will be degraded, lowering their ability to provide habitat for EU protected species.**

1.3 Target options screened in/out

Based on the importance of the ecosystems for biodiversity and ecosystem services, and their current levels of degradation, four broad over-lapping restoration objectives are evident for HD Annex I peatlands as set out in the Table I-1 below. In practice, these biodiversity and ecosystem service objectives are closely related and require very similar restoration actions. The achievement of each objective would also synergistically contribute to other objectives.

Therefore, as the main aim of the restoration targets is to restore ecosystems for biodiversity, option 1 (presented below) is taken to be the primary goal and the basis of the target, with the other objectives achieved as a co-benefit. However, given the slow recovery of peatlands to good condition (which would require a long-term target), and the exceptional importance of reversing the losses of carbon stores from peatlands, it is recognised that **re-wetting peatlands that are degraded Annex I habitats is a particularly urgent priority sub-objective**. A restoration and **rewetting target for degraded peatland under agricultural land (cropland and grassland) is included in the soil section** of the impact assessment, with an important difference in target conditions: while the peatland target of this section is fully focused on the recovery of Annex I habitats, the target assessed in the soil section (on peatland under agricultural use) is still about the restoration and rewetting of peatlands but not requiring that Annex I habitat quality is reached necessarily.

The context and rationale for the restoration and re-creation of **marshlands** is very different to that for HD Annex I peatlands. This is primarily because their main biodiversity value is being a habitat for a wide range of EU protected species. **As a result of this, it is appropriate for the EU restoration target to focus on the (measurable) recovery of EU protected species populations** by restoring their habitat rather than achieving 'good condition' of the habitat. Furthermore, there are no current monitoring mechanisms which report on the condition of these habitats. It would also be appropriate to focus on those species that are most dependent on the habitat and its restoration to achieve their favourable conservation status for HD species and secure status for birds. As the list of EU protected species of marshlands includes a large number and variety of species that are dependent on such habitats, it can be expected that their conservation and recovery would also indirectly provide substantial benefits for a wider range of other species. Overall, the species objectives would lead to improvements in the ecosystem as a whole, and related ecosystem service benefits (e.g. improved water resources and quality, flood alleviation, fish production, sport hunting, nature recreation).

As regards EU protected species predominantly associated with peatlands, the achievement of favourable conservation status of HD Annex I peatlands would be expected to meet most requirements for their recovery. Whilst some of these species may require specific habitat actions, there would be little added value of a species-focused habitat restoration target for them. Similarly, there would be little added value from extending the EU protected species target across all wetlands, as peatlands and marshlands and their species communities, and restoration requirements differ considerably. Therefore, the EU protected species target is only considered for marshlands.

Table I-1: Summary table of screened target options

Target option	Screened in/out for assessment	Key reason(s) for screening in/out
HD Annex I peatlands		
1. Achieving the favourable conservation status of Habitats Directive Annex I peatlands.	Included as primary goal of restoration target	Biodiversity is the primary aim of the nature restoration policy, and this objective will in addition fully meet the objective for carbon if urgent re-wetting is undertaken
2. Increasing carbon sequestration and storage in Habitats Directive Annex I peatlands.	Included as an urgent re-wetting measure, as a sub-objective of Option 1	Could be achieved as an urgent measure under Option 1.
3. Improving water retention in wetlands in flood prone catchments (potentially linking to the targets for rivers and associated habitats).	Not included	Largely achieved under Option 1, with targeting to appropriate areas
4. Improving raw water storage and quality in catchments supplying drinking water.	Not included	Largely achieved under Option 1, when targeting to appropriate areas
Marshlands		
5. General habitat restoration and re-creation of marshlands	Not included	Definition of good condition is primarily dependent on its suitability for key species (therefore largely covered by target option 7.)
EU protected species		
6. Achieving favourable conservation status of protected species predominantly associated with HD Annex I peatlands	Not included	Would provide little added value by itself and would not cover a large number of EU protected species of marshlands.
7. Achieving favourable conservation status of protected species predominantly associated with marshlands	Included	Complements the objective for HD Annex I habitats
8. Achieving favourable conservation status of protected species predominantly associated with all wetlands	Not included	Would cover habitats with very different species and habitat requirements without adding value.

Peatlands

Based on the above considerations, and the high priority for restoring degraded habitat areas, this impact assessment considers the following potentially feasible targets:

- The full recovery of Habitats Directive Annex I peatlands to good ecosystem status (i.e. favourable conservation status), including through the following:

- Restore all HD Annex I peatland habitat area to good condition (thereby also restoring relevant species habitats), with all necessary restoration measures completed on 15 % / 30 % of degraded areas by 2030, 40 % / 60 % by 2040 and 100% by 2050.
    - Sub-target: Re-wetting at least 25 % of HD Annex I peatland habitat area degraded due to drainage by 2030, 50 % by 2040 and 100 % by 2050 so that the water table is at, or with 15 cm of the surface.[6]
- Re-create the area necessary to achieve Favourable Conservation Status of HD Annex I peatlands[7] at national biogeographical level by 2050, with 15 % / 30 % achieved by 2030 and 40 % / 60 % by 2040, and 100 % achieved by 2050.

Marshlands

- Restore and re-create marshes as necessary to achieve the favourable conservation status of species that are listed in Annex II, IV and V of the Habitats Directive as well as all birds predominantly associated with marshes, with 15 % / 30 % of all necessary actions carried out by 2030 and 40 % / 60 % by 2040 and 100 % 2050.

1.4 Impacts of assessed target options

The costs of restoration of peatlands and inland marshes were estimated by calculating the area of degraded ecosystems to be restored and re-created annually to meet each target and applying average per hectare capital costs for restoration and re-creation, and annual costs for maintenance taken from Tucker et al (2013)[8]. The costs of restoration include the capital costs of restoration and re-creation actions such as ditch blocking, re-establishment of peat vegetation, removal of topsoil / reprofiling, scrub and tree clearance, fencing; and, annual maintenance costs, including monitoring and regulation of water levels, maintenance of sluices etc., integrated catchment management, mowing and removal of vegetation, and grazing management. The required management will be undertaken largely by private landowners and land managers, in return for incentive payments which include compensation for opportunity costs relating directly to land management (e.g. income forgone through reduced grazing). Maintenance costs were applied to

[6] While this rewetting target is fully focused on the recovery of Annex I habitats, another rewetting target, on peatland under agricultural use, is assessed in the section on soils.

[7] According to Member States information on 'favourable reference areas' for their HD Annex I habitats, at least 3 000 km^2 would need to be re-created to achieve their FCS. However, the exact area required is uncertain as a significant proportion of Member States have not estimated favourable reference areas.

[8] Tucker et al., (2013) Estimation of the financing needs to implement Target 2 of the EU Biodiversity Strategy. Report to the European Commission. Institute for European Environmental Policy, London. Available at: https://ec.europa.eu/environment/nature/biodiversity/comm2006/pdf/2020/Fin%20Target%202.pdf

the entire ecosystem area, since meeting the targets requires further degradation of ecosystems to be avoided.

Benefits estimates were based on an extensive review of literature on the value of benefits of peatland and marshland restoration, which identified changes in per hectare values of ecosystem services for restored vs degraded ecosystems. Median per hectare values were taken from per hectare estimates given by 22 studies. This provided per hectare benefits estimates for peatlands (carbon storage and sequestration, total ecosystem service values) and marshlands/other inland wetlands (total ecosystem service values). Per hectare benefits estimates were applied to the area of ecosystem restored to give annual estimates of total benefits. Annual costs and benefits were estimated over the period 2022 -2070, recognising that, while restoration takes place to 2050, further maintenance costs continue beyond that date, while restored ecosystems continue to provide benefits into the future. Annual cost and benefit estimates were discounted, applying a 4% social discount rate, and summed to calculate their total present value. This enabled total net present value (benefits – costs) and benefit: cost ratios to be calculated.

Peatlands

The estimated costs of achieving good status of HD Annex I peatlands are summarised in Table I-2. The costs are broadly based on the area of habitat that is not in good condition or affected by specific pressures, multiplied by the costs of key measures to maintain the habitat, address the pressures and re-create habitat. The costs are additional to measures that are already in place (CAP measures) and do not include general supporting measures (e.g. creation of restoration plans), administration costs, or broad actions that apply to multiple ecosystems, such as the need to reduce nitrogen deposition below critical levels.

Table I-2: Summary of projected costs (EUR) of achieving restoration targets for HD Annex I peatlands in relation to current trends & expected 2030 baseline

NB Costs exclude Romania, due to missing reliable data on habitat extent.

Targets: 15-40-90 % [9]

Period	% Full restoration	Maintenance costs	Restoration costs	Re-creation costs	Combined costs	Total over period
Average annual costs						
2022-2030	15%	129 041 420	58 636 619	13 826 839	201 504 878	1 813 543 900
2031-2040	40%	130 134 987	87 954 929	20 740 258	238 830 174	2 388 301 743
2041-2050	90%	131 957 600	175 909 857	41 480 516	349 347 974	3 493 479 736

[9] Although the 2050 target aims to restore 100 % of the habitat, the 2050 cost estimation is for 90 % restoration as this is the maximum percentage that can be expected in practice. Furthermore, an extrapolation of current restoration costs would no longer provide reliable estimates in the range between 90 and 100 %.

Cost over full period (29 years)						
2022-2050	90%	3 782 298 653	3 166 377 434	746 649 293	**7 695 325 379**	

Targets 30-60-90 %

Period	% Full restoration	Maintenance costs	Restoration costs	Re-creation costs	Combined costs	Total over period
Average annual costs						
2022-2030	30%	129 041 420	117 273 238	27 653 678	273 968 336	2 465 715 021
2031-2040	60%	131 228 555	105 545 914	24 888 310	261 662 779	2 616 627 791
2041-2050	90%	133 415 690	105 545 914	24 888 310	263 849 914	2 638 499 141
Cost over full period (29 years)						
2022-2050	90%	3 807 815 228	3 166 377 434	746 649 293	**7 720 841 954**	

Marshlands

Table I-3I shows the projected costs of achieving 15 % / 40 % and 30 % / 60 % restoration targets, in relation to current trends and expected 2030 baseline data based on overall degradation extent and combined measures. Unlike for peatlands, due to inadequate data on degradation levels, this is based on an illustrative level of 50 % degradation. The required re-creation area of 558 km^2 is also illustrative, based on re-creating the area of marshlands lost since 1990.

Table I-3I: Summary of projected costs (EUR) of achieving restoration targets for marshlands in relation to illustrative degradation levels and re-creation requirements, and the costs of combined measures

Targets: 15-40-90 %

Period	% Full restoration	Maintenance costs	Restoration costs	Re-creation costs	Combined costs	Total over period
Average annual costs						
2022-2030	15%	156 954 750	7 812 268	367 350	165 134 368	1 486 209 308
2031-2040	40%	159 423 900	11 718 401	551 025	171 693 326	1 716 933 263
2041-2050	90%	163 539 150	23 436 803	1 102 050	188 078 003	1 880 780 025
Cost over full period (29 years)						
2022-2050	90%	4 642 223 250	421 862 445	19 836 900	**5 083 922 595**	

Targets 30-60-90 %

Period	% Full restoration	Maintenance costs	Restoration costs	Re-creation costs	Combined costs	Total over period
Average annual costs						
2022-2030	30%	156 954 750	15 624 535	734 700	173 313 985	1 559 825 865
2031-2040	60%	161 893 050	14 062 082	661 230	176 616 362	1 766 163 615
2041-2050	90%	166 831 350	14 062 082	661 230	181 554 662	1 815 546 615
Cost over full period (29 years)						
2022-2050	90%	4 699 836 750	421 862 445	19 836 900	**5 141 536 095**	

The main stakeholders affected by the targets are landowners and land managers (e.g. farmers), who would undertake the required restoration actions, in return for incentive payments funded by the taxpayer. The restoration works will create employment and income for land managers and contractors.

The restoration targets will deliver substantial benefits for biodiversity and a range of ecosystem services, most importantly carbon sequestration and storage, water quality improvements, flood risk management, erosion control and cultural services for both visitors and society at large. Peatland and marshland restoration will benefit the entire population and economy (through carbon and biodiversity benefits), as well as water companies and consumers, property owners, insurers and the tourism sector.

The ranges of per hectare values of benefits of restoration from the above studies are summarised in Table I-4. Studies estimating carbon sequestration and storage benefits of peatland restoration find estimated values ranging from €146 to 3,140 per hectare per year, with a median value of €287 per hectare per year. Studies estimating the value of two or more ecosystem services (typically including carbon, water, flood management, biodiversity and cultural services) find benefits estimates ranging from €164 to €4,895 per hectare per year, with a median value of €1,045 per hectare per year. Benefits of restoration of marshes (typically including flood alleviation, water quality improvements, carbon sequestration, biodiversity, recreation and other cultural services) range from €142-10 ,411 per hectare per year, with a median value of €1,258 per hectare per year.

Table I-4: Summary of Benefits Estimates from the restoration of inland wetlands

Ecosystem	Service valued	Range (EUR/ha/year)	Median estimate (EURO/ha/year)
Peatlands	Carbon storage	146 – 3,140	287
	Multiple ecosystem	164 – 4,895	1,045

	services		
Marshes and other inland wetlands	All ecosystem services	412 – 10,411	1,258

The monetised **benefits** for carbon storage and sequestration from **peatland restoration** are estimated to outweigh the estimated costs of full ecosystem recovery (i.e. to good status). The benefit cost ratio ranges from 2.2 for the 15% 40% 90% targets to 2.5 for the 30% 60% 90% target. **If overall ecosystem service benefits are applied, the estimated net benefits increase markedly, with a benefit cost ratio of between 7.1 and 8.3.**

Table I-5: Benefits and costs of restoration of Annex 1 peatlands (Present value, 2022-2070, M EURO)

	15 % 40 % 90 % target	30 % 60 % 90 % target
Costs		
Maintenance	2 784	2 802
Restoration – full recovery	1 614	1 880
Re-creation	381	443
TOTAL (full recovery)	**4 779**	**5 125**
BENEFITS (full recovery)		
Carbon only	10 629	13 042
Total Ecosystem Services	38 702	47 488
Net Present Value (full recovery)		
Carbon only	5 850	7 917
Total Ecosystem Services	33 923	42 362
Benefit: Cost Ratio (full recovery)		
Carbon only	2.2	2.5
Total Ecosystem Services	7.1	8.3

For marshlands, benefit cost ratios for restoration are estimated at 1.8 - 2.1, depending on the target chosen.

Table I-6: Benefits and costs of restoration of marshlands (Present value, 2022-2070, M EUR)

	15 % 40 % 90 % target	30 % 60 % 90 % target
COSTS		
Maintenance	3 418	3 459

Restoration – full recovery	215	250
Re-creation	10	12
TOTAL (full recovery)	**3 643**	**3 721**
BENEFITS (full recovery)		
Carbon only	n/a (included in total ecosystem services)	n/a (included in total ecosystem services)
Total Ecosystem Services	6 388	7 838
Net Present Value (full recovery)		
Carbon only	n/a	n/a
Total Ecosystem Services	2 745	4 117
Benefit: Cost Ratio (full recovery)		
Carbon only	n/a	n/a
Total Ecosystem Services	1.8	2.1

1.5 Synthesis

Table I-5 provides a summary of the analysis of options and conclusions in relation to the effectiveness, efficiency, coherence, and proportionality of each target. The overall conclusion is that there are strong arguments for legally binding targets for achieving favourable conservation status of HD Annex I peatland habitats and of EU protected species associated with marshland. Whilst both targets slightly overlap, they also complement each other. Due to the exceptionally high importance and urgency to halt carbon losses, there is a strong argument to include a specific target for re-wetting drained peatlands used as cropland and productive grasslands and thereby extending and complementing the targets for Annex I restoration with a target for halting carbon losses from organic soils under agricultural use (see **soils** impact assessment where such a target is taken up and analysed in detail). While rewetting contributes to and is part of the restoration of Annex I habitats, a specific target for rewetting is not maintained here, but a target for rewetting drained peatland under agricultural use is proposed and analysed in the soil section.

Table I-7: Overview table assessing options on EU impact assessment criteria

	Habitats Directive Annex I peatlands	EU protected species of marshlands
Feasibility / effectiveness	High feasibility and potential for restoration. Re-creation is limited to areas retaining deep peat soils. Effective in maintaining carbon stores, and with time recovery of vegetation, carbon sequestration and several other ecosystem services.	High feasibility and potential for restoration. Re-creation may be limited by the availability of water and suitable sites. Restoration is highly effective for biodiversity and contributes to several other ecosystem services.
Efficiency	Strong evidence of benefits of restoration for biodiversity and ecosystem services, including climate mitigation. Available valuation evidence suggests carbon benefits alone exceed restoration	Restoration of marshlands benefits biodiversity and a range of ecosystem services. Benefits estimated to outweigh costs for inland marshes restoration targets

	costs; inclusion of wider ecosystem service values gives high estimated benefit: cost ratios.	by a factor of 2:1.
Coherence	Full coherence with EU environmental policies and climate goals. Potential to make substantial contributions to climate mitigation, and significant contributions to climate adaptation.	Full coherence with EU environmental policies and climate goals. Potential to make substantial contributions to climate adaptation and some contribution to mitigation.
Proportionality	Proportionate to the very high importance of the habitats for biodiversity and associated ecosystem services	Proportionate to the high importance of the habitats for biodiversity and associated ecosystem services.
Conclusions	**Include in targets with very high priority, including with target to halt carbon losses through re-wetting.**	**Include with high priority.**

2. Coastal and other saline wetlands

2.1 Scope

In the MAES framework, coastal wetlands are defined as “marine” and “marine inlets and transitional waters” ecosystem types. The latter are considered as “ecosystems on the land-water interface under the influence of tides and with salinity higher than 0.5% which, beside coastal wetlands, also include ‘lagoons, estuaries and other transitional waters, fjords and sea lochs as well as embayments’. The study defined coastal wetland habitats in more detail by using habitat types as defined in Annex I of the Habitats Directive (HD Annex I habitats), but excluding the HD Annex I habitat type ‘Large shallow inlets and bays’ which is considered in the marine ecosystems thematic impact assessment (IA), and including four HD Annex I habitat types not considered as coastal wetlands under the MAES typology. Two are Mediterranean coastal habitat types on wet soils dependent on marine saline influences, and two are inland habitat types dependent on saline conditions caused by high evaporation of mineral-rich groundwater. Moreover, only the intertidal EUNIS habitats of the HD habitat types of estuaries, mud-and sandflats and coastal lagoons were included, while others were left to the marine IA. Based on EU Member States’ estimates, the total area of the 11 HD Annex I habitat types is 37 780 km^2, of which the tidal habitats cover 83 %.

Detailed data on the geographical distribution, area (km^2), conservation status and condition of coastal and other saline wetland habitat types of Annex I of the Habitats Directive in EU Member States is provided in Annex VIII-a.

2.2 Problem, current trends and ecosystem-specific baseline

Coastal wetlands have remained relatively stable in terms of area coverage in the EU-28 between 2000 and 2018 with a slight increase of 0.2 % according to CORINE land cover. Yet, status reporting under the Habitats Directive according to Article 17 found that only 5% of the Annex I habitat assessments showed good status, and 82% a poor or bad status. In addition, only 11% of the coastal wetlands’ assessments deemed unfavourable is showing signs of improvement, while more than 36% are further deteriorating. While there have been several efforts to improve the status of these habitat types, the EU Ecosystem Assessment in 2020[10] showed that tangible improvements are far from being achieved. Based on Habitats Directive data, a best estimate on total area to be restored would amount to **45 % or 16727,33 km^2**.

Coastal wetland restoration directly and indirectly serves the political and policy objectives of the European Union due to their vast ecosystem services. Coastal wetlands also offer unique habitat conditions for threatened species, especially bird species protected under the EU Birds Directive. Despite representing a comparatively small area among all wetland habitats, coastal wetlands provide significant carbon sequestration services, thus acting as a critical carbon sink for the Union, which seeks to cut carbon emissions by 55% by 2030. Further, as our communities become increasingly urban and coastal, some projections estimate that by 2060, 55.7 million people in Europe will live in low-elevation coastal zones[11]. As coastal storms

[10] Maes et al. (2020). Mapping and Assessment of Ecosystems and their Services: An EU ecosystem assessment

[11] Neumann et al. (2015) Future coastal population growth and exposure to sea-level rise and coastal flooding--a global assessment.

become more unpredictable and violent, the more we will need coastal wetlands to serve as protective barriers. Therefore, the ecosystem services provided by coastal wetlands are not only important to successfully realise a myriad of EU environmental policy objectives, but also to human security.

Without additional efforts, the rate of degradation of coastal- and inland saline ecosystems will continue to worsen as the effects of climate change, tourism development, and the coastal squeeze effect worsen with time and an increasing population in coastal communities. Amongst the wide range of threats that coastal wetlands face, the IA identified the following as the highest pressures impacting these groups of habitats: changing agricultural practices (e.g. overgrazing or abandonment of grassland management), construction and use of residential, commercial, industrial, and recreational infrastructure, invasive alien species, pollution, and extraction and cultivation of biological living resources (e.g. shell-fishing). It is worth noting that these pressures and threats differ considerably between habitat types in scope of this assessment. Furthermore, intensifying effects of climate change towards 2030, 2040 and 2050 will accelerate sea level rise and related coastal erosion. While this would normally simply transgress coastal wetlands further inland, in most EU coasts protected by flood defence networks it will result in a loss of coastal habitats. In the first phases of restoration action, particular attention shall therefore be given to wetlands which have suffered from the '*coastal squeeze effect'*, which describes the combined pressure of sea-level rise and urban development along the coast, which leaves little to no room for coastal wetlands to retreat.

Since many of the challenges to restore coastal wetlands are transboundary in nature, EU cooperation can help address them: For example, the agricultural-related pressures and threats can be mitigated by an increase in efforts towards restoration in policies such as the Common Agricultural Policy.

2.3 Target options screened in/out

Restoration actions can take various forms and depend not only on the ecological ambitions but also the socio-economic context under which the restoration action is taking place. Restoration actions can be classified into different measures that are ultimately dependent on the needs of the habitat but also the scale of restoration needed. Actions for coastal wetland habitats that are degraded could include the following:

- Add sediment to raise land above the water level and allow wetland plants to colonize
- Re-wetting of drained coastal wetlands
- Removing/bypassing anthropogenic barriers to restore hydrological connectivity
- Transplantation of vegetation to assist in re-vegetation
- Removal of invasive alien species
- Improved agricultural management of meadow and marshland habitats

In terms of restoring, re-creating, and maintaining coastal wetlands to/in a good condition, the first step will usually require re-wetting and resedimenting wetlands which have suffered from the 'coastal squeeze effect'. These type of restoration measures have been successfully implemented in the EU through so-called LIFE projects, which co-fund and assist member states, in restoration projects. Based on these restoration actions and the baseline and trends of pressures, there are four possible options to target setting that we have identified and screened for their effectiveness, relevance, coherence, and proportionality (Table II-1).

Table II-1 Summary table screened target options

Target option	Screened in/out for assessment	Key reason(s) for screening in/out
Option 1: HD Annex I restoration target	Screened in	• The feasibility of this option should be high, as it builds on an existing legal framework which includes a detailed monitoring and reporting system. • Coastal wetland restoration in the framework of the HD has demonstrated effectiveness where it took place. • The option would be proportional in scope, as it would focus primarily on habitats of EU interest from a biodiversity perspective, the restoration of which is already a long-standing and widely accepted need recognized in EU policy.
Option 2: Nature Directives coastal species target	Screened in	• Like the HD Annex I option, such a species target would be based on an existing implementation framework with monitoring and reporting requirements. However, it would need to assess progress based on a much bigger body of data, as there are many more listed species than habitats and their restoration needs are more diverging. • The target could be very effective if implemented with adequate resources to follow-up on individual species • the option would be proportional in scope, as it would focus primarily on species habitats of EU interest from a biodiversity perspective.
Option 3: Salt marsh re-creation target	Screened out	• There is available data in percentage terms of degraded and lost salt marshes; however as not all salt marshes are HD Annex I habitat types, it would require an additional monitoring and reporting requirement. • However, since a very large share of salt marshes is Annex I habitat and inside Natura 2000, they would likely sufficiently benefit from an Annex I habitat restoration target Option 1 while not excluding other habitat types.
Option 4: Bottom-disturbing (shell-) fishing phase out target in Natura 2000 sites	Screened out	• As commercial fishing in Natura 2000 sites is usually subject to permitting, there should be both data available as well as a legal means to gradually phase out the most harmful fishing/harvesting techniques applied in coastal wetlands. Legally it would correspond to objectives under the EU Nature Directives, MSFD and Common Fisheries Policy. • The option would be limited in scope, as it would only target a single pressure and only a share of coastal wetland habitat. The proportionality of such a target at EU level would likely be questioned on subsidiarity grounds.

The following three targets were selected for more detailed impact assessment. The targets are all connected to one another, and are sub-targets of options 1 and 2 above:

- Target 1a: Restore all HD Annex I coastal- and inland saline wetland habitat area to good condition, with all necessary restoration measures completed on 30 % (or 15 %) of degraded areas by 2030, 60 % (or 40 %) by 2040 and 100 % by 2050.
- Target 1b: Recreate 30 % (or 15 %) of additional habitat area required to achieve FCS of HD Annex I coastal- and inland saline wetland habitats by 2030, 60 % (or 40 %) by 2040 and 100 % by 2050.
- Target 1c: Restore and re-create coastal- and inland saline wetland habitats as necessary to achieve the favourable conservation status of species that are listed in Annex II, IV and V of the Habitats Directive and all birds predominantly associated with coastal- and inland saline wetland ecosystems, with 15 % of all necessary actions carried out by 2030 and 40 % by 2040 and 100 % 2050.

2.4 Impacts of assessed target options

The costs of restoration of coastal wetlands were estimated by calculating the area of degraded ecosystems to be restored and re-created annually to meet each target and applying average per hectare capital costs for restoration and re-creation, and annual costs for maintenance taken from Tucker et al.[12] The costs of restoration include the capital costs of restoration actions such as revegetation and rewetting works, removal of alien species, and creation of wetlands to treat agricultural water pollution, as well as restrictions on fishing. The costs of re-creation include managed realignment, works to reclaim land through sedimentation, and introduction of appropriate grazing. Annual maintenance costs include appropriate grazing management, regulation of water levels and re-sedimentation. The required management will be undertaken largely by private landowners and land managers, in return for incentive payments which include compensation for opportunity costs relating to management of land and fisheries (e.g. income forgone through re-creation of coastal wetlands on agricultural land, restrictions on fishing effort). Maintenance costs were applied to the entire ecosystem area, since meeting the targets requires further degradation of ecosystems to be avoided.

Benefits estimates were based on an extensive review of literature of the value of benefits of coastal wetlands and their restoration, which identified changes in per hectare values of ecosystem services for restored vs degraded ecosystems. Median per hectare values were taken from per hectare estimates given by 13 studies. This provided per hectare benefits estimates for carbon storage and sequestration, and for total ecosystem service values. Per hectare benefits estimates were applied to the area of ecosystem restored to give annual estimates of total benefits. Annual costs and benefits were estimated over the period 2022 -2070, recognising that, while restoration takes place to 2050, further maintenance costs continue beyond that date, while restored ecosystems continue to provide benefits into the future. Annual cost and benefit

[12] Tucker et al., (2013) Estimation of the financing needs to implement Target 2 of the EU Biodiversity Strategy. Report to the European Commission. Institute for European Environmental Policy, London. Available at: https://ec.europa.eu/environment/nature/biodiversity/comm2006/pdf/2020/Fin%20Target%202.pdf

estimates were discounted, applying a 4% social discount rate, and summed to calculate their total present value. This enabled total net present value (benefits – costs) and benefit: cost ratios to be calculated.

Those that would be responsible for implementing regulations that help restore and recover coastal wetlands are primarily government actors. Wetlands in Europe are managed at different governmental levels depending on their organisational structure. In Germany, for instance, coastal wetlands are managed by the environmental ministries of the *Länder* (regional governments), whereas in other countries, wetlands are managed on a federal level. Nevertheless, the planning, financing and implementation of coastal wetlands restoration involves a plethora of different actors across Europe, regardless of how and by whom coastal wetlands are legally managed. Actors such as local banks and private companies (e.g. in tourism), nature site managers, research institutions and civil society have all, to varying degrees, been consulted, and sought for involvement in coastal wetland restoration in several EU LIFE projects. This multi-actor involvement is crucial to ensure that restoration projects are well understood by all actors concerned by the marsh, either directly or indirectly, and that these projects can receive funding from as many sources as possible. These mutually beneficial, public-private-partnerships can help stemming the funding challenges for saltmarsh restoration projects and motivate the private sector to ensure their success.

The stakeholders impacted the most by coastal wetland restoration and re-creation are those that depend on these ecosystems for their economic livelihoods. As previously outlined, coastal ecosystems provide vital services for agriculture and fisheries. Those working directly and indirectly in the fisheries industry may be impacted by coastal wetland restrictions, but on the longer term may benefit from higher and more resilient catches as habitat for commercially important (shell-)fish species recover. Farmers may be impacted by coastal wetland regulations, such as those that limit the amount of nutrient run-off and pollution from entering protected coastal wetland. Similarly, the tourism industry is heavily concerned by wetland restoration as these ecosystems are primary targets of a variety of touristic activities. This is compounded by the significant threat that tourism places on coastal wetlands in terms of grey infrastructure and pollution.

The total cost of all regenerative coastal wetland activities falls within the range of € 5.1billion to € 5.9 billion (present value of total costs to 2070). While these costs may be high given the relatively small area of coastal wetlands, they are comparatively low to the benefits that these ecosystems provide in terms of their total ecosystem services. Services such as storm surge mitigation, protection against coastal erosion, water filtration, fish stock restoration, biodiversity, recreation and other cultural services, are valued between € 182 billion and € 223 billion (present value of benefits flows to 2070).

The analysis estimates that the monetized benefits for carbon storage and sequestration amount to approximately 20% of the estimated costs of full ecosystem recovery (i.e. to good condition). However, if overall ecosystem service benefits are applied, the estimated net benefits increase markedly, with a benefit cost ratio of between 35 and 38. This reflects the large value of regulating, cultural and provisioning services of restored cultural wetlands, with carbon values accounting for only a small proportion of total service values. Some caution is needed in interpreting these figures, which are based on median benefits values. The source studies give a very wide range of benefits estimates, and the median values applied, while very conservative compared to the upper range estimates found in the review, exceed the lower bound estimates found by some studies.

Table II-2: Summary of projected costs (EUR) of achieving restoration targets for HD Annex I coastal wetlands in relation to current trends & expected 2030 baseline based on overall degradation extent and combined measures

Targets: 15-40-90 %[13]

Period	% Full restoration	Maintenance costs	Restoration costs	Re-creation costs	Combined costs	Total over period
Average annual costs						
2022-2030	15 %	38 193 020	154 114 338	3 015 598	195 322 956	1 757 906 601
2031-2040	40 %	38 193 020	231 171 507	4 523 397	273 887 924	2 738 879 236
2041-2050	90 %[14]	38 193 020	462 343 014	9 046 793	509 582 827	5 095 828 273
Cost over full period (29 years)						
2022-2050	90 %	1 107 597 577	8 322 174 259	162 842 274	**9 592 614 110**	

Targets: 30-60-90 %

Period	% Full restoration	Maintenance costs	Restoration costs	Re-creation costs	Combined costs	Total over period
Average annual costs						
2022-2030	30 %	38 193 020	308 228 676	6 031 195	352 452 891	3 172 076 023
2031-2040	60 %	38 193 020	277 405 809	5 428 076	321 026 904	3 210 269 043
2041-2050	90 %[15]	38 193 020	277 405 809	5 428 076	321 026 904	3 210 269 043
Cost over full period (29 years)						
2022-2050	90 %	1 107 597 577	8 322 174 259	162 842 274	**9 592 614 110**	

[13] Although the 2050 target aims to restore 100 % of the habitat, the 2050 cost estimation is for 90 % restoration as this is the maximum percentage that can be expected in practice. Furthermore, an extrapolation of current restoration costs would no longer provide reliable estimates in the range between 90 and 100 %.

[14] Although the 2050 target aims to restore 100 % of the habitat, the 2050 cost estimation is for 90 % restoration as this is the maximum percentage that can be expected in practice. Furthermore, an extrapolation of current restoration costs would no longer provide reliable estimates in the range between 90 and 100 %. (See methodology section in SWD)

[15] Although the 2050 target aims to restore 100 % of the habitat, the 2050 cost estimation is for 90 % restoration as this is the maximum percentage that can be expected in practice. Furthermore, an extrapolation of current restoration costs would no longer provide reliable estimates in the range between 90 and 100 %. (See methodology section in SWD)

Table II-3: Summary of Benefits Estimates from Ecosystem Restoration

Ecosystem	Service valued	Range (EUR/ha/year)	Median estimate (EURO/ha/year)
Coastal Wetland	Carbon storage	-	74
	Multiple ecosystem services	909-89 000	12 318

Table II-4: Cost-benefit ratio table for the HD Annex I habitat restoration + re-creation target (1a+ 1b) for 2 different scenarios of restoring 15-40-90 % or 30-60-90 % of coastal wetland area by 2030-40-50 (in present value, million EUR)

	15 % 40 % 90 % target	30 % 60 % 90 % target
COSTS		
Maintenance	815	815
Restoration – full recovery	4 243	4 941
Re-creation	83	97
TOTAL (full recovery)	**5 141**	**5 852**
BENEFITS (full recovery)		
Carbon only	1 091	1 339
Total Ecosystem Services	181 614	222 842
Net Present Value (full recovery)		
Carbon only	-4 050	-4 514
Total Ecosystem Services	176 473	216 990
Benefit: Cost Ratio (full recovery)		
Carbon only	0,2	0,2
Total Ecosystem Services	35,3	38,1

2.5 Synthesis

The analysis demonstrated the urgency of coastal wetland restoration in the face of growing anthropogenic pressures including climate-change driven sea-level rise and related coastal squeeze. Despite the limited time available for an in-depth review, the analysis uncovered a wealth of evidence on successful past coastal restoration project as well as studies on its costs and benefits. The urgency of action required in combination with the large benefits for biodiversity and climate change mitigation and adaptation -the two core objectives of the legally binding initiative- make coastal wetlands a priority ecosystem for short-term action. Table II-5 provides an overview of the key findings of assessing the three screened-in targets against the five key IA criteria. In short, the assessment found that all three targets have a high feasibility and potential to help meet the initiative's primary objectives, would be fully coherent with EU nature- as well as climate mitigation adaptation policies and proportional to the urgency of action required on them, would help increase the efficiency of implementing existing policy commitments and/or legal requirements and would do so against very favourable cost-benefit ratios. As a result, the IA study recommends prioritising all three target options in a legal proposal, with a particularly high priority for the habitat restoration- and re-creation targets.

Table II-5: Overview table assessing options on EU impact assessment criteria

	Habitats Directive Annex I coastal wetlands restoration	Habitats Directive I coastal wetlands re-creation	EU protected species of coastal wetlands
Feasibility / effectiveness	High feasibility and potential for restoration. Restoration is highly effective for biodiversity, other ecosystem services, and can also contribute to human security and bring other socio-economic benefits.	High feasibility and potential for re-creation of habitats, although feasibility is slightly lower than for Target 1 as there will be impacts on the users of the land to be used for the re-creation project. Re-creation would bring similar benefits than Target 1.	High feasibility and potential for restoration, with this Target combining Targets 1 and 2.
Efficiency	Strong evidence of benefits of restoration for biodiversity and ecosystem services, including climate mitigation. Benefits have shown to significantly outweigh costs by a factor of 30.	Strong evidence of benefits of habitat re-creation for biodiversity and ecosystem services, including climate mitigation. Habitat recreation is a relatively low cost, given that the costs are fixed and not recurring, with significantly higher benefits.	Strong evidence of benefits of habitat restoration and re-creation for biodiversity and ecosystem services, including climate mitigation. Benefits have shown to significantly outweigh costs, although this option would entail the highest costs.
Coherence	Full coherence with EU environmental policies as this option builds on existing legislation (i.e. the HD). Important benefits for other EU objectives such as on water- and flood risk management are also expected.	Full coherence with EU environmental policies as this option builds on existing legislation (i.e. the HD). Benefits for other EU objectives such as on water- and flood risk management are also expected.	Full coherence with EU environmental policies as this option builds on existing legislation (i.e. the HD and BD). Benefits for other EU objectives such as on water- and flood risk management are also expected.
Proportionality	Proportionate to the very high importance of the good status of habitats for biodiversity and associated ecosystem services.	Habitat re-creation is necessary to achieve the favourable conservation status of some HD Annex I habitats, and to enable to the recovery of some threatened coastal wetland habitats.	Proportionate to the high importance of the habitats for biodiversity.
Conclusion	**Include with very high priority.**	**Include with very high priority.**	**Include with high priority.**

3. Forests

3.1 Scope

Woodland and forest ecosystems according to the EU MAES typology[16] are areas dominated by woody vegetation of various age or they have succession climax vegetation types on most of the area supporting many ecosystem services. Under the EUNIS typology[17], 'G: Woodland, forest and other wooded land' include the following four broad habitat types each of which contain a large number and diversity of sub-habitat types:

- T1: Broadleaved deciduous forest
- T2: Broadleaved evergreen forest
- T3: Coniferous forest
- T4: Lines of trees, small anthropogenic forests, recently felled forest, early-stage forest and coppice

This diversity is also reflected in the 80 different forest habitat types included in Annex I of the Habitats Directive (out of 233 in total, or 34 %). Out of these 80 habitat types, 69 were included in the scope of this mini-Impact Assessment (IA) and include the following broad habitat types:

- Boreal forests (6 types)
- Temperate forests (32 types)
- Mediterranean and Macaronesian forests (18 types)
- Mountainous coniferous forests (13 types)

Alluvial forests (8 types) and wooded meadows (3 types) were excluded from this mini-IA and instead included in separate mini-ecosystem assessments on rivers & lakes ecosystems and agro-ecosystems respectively. Forests are the largest terrestrial ecosystem type in the EU-27 and in 2018 covered 1 770 997 km^2 or 39% of the EU27 land area following the EUNIS-based approach taken for the European Ecosystem Map[18].

In addition, actions are considered for forest areas beyond those covered by the Annex I habitats types under the Habitats Directive; see section 3.6.

Detailed data on the geographical distribution, area (km²), conservation status and condition of forest habitat types of Annex I of the Habitats Directive in EU Member States is provided in Annex VIII-b.

[16] Maes J. et al (2013) Mapping and Assessment of Ecosystems and their Services. An analytical framework for ecosystem assessments under action 5 of the EU biodiversity strategy to 2020. Publications office of the European Union, Luxembourg. Available at: https://ec.europa.eu/environment/nature/knowledge/ecosystem_assessment/pdf/MAESWorkingPaper2013.pdf

[17] The European nature information system or EUNIS habitat classification is a comprehensive pan-European system for habitat identification. The classification is hierarchical and covers all types of habitats from natural to artificial, from terrestrial to freshwater and marine. The habitat types are identified by specific codes, names and descriptions. The full EINIS https://eunis.eea.europa.eu/habitats-code-browser.jsp

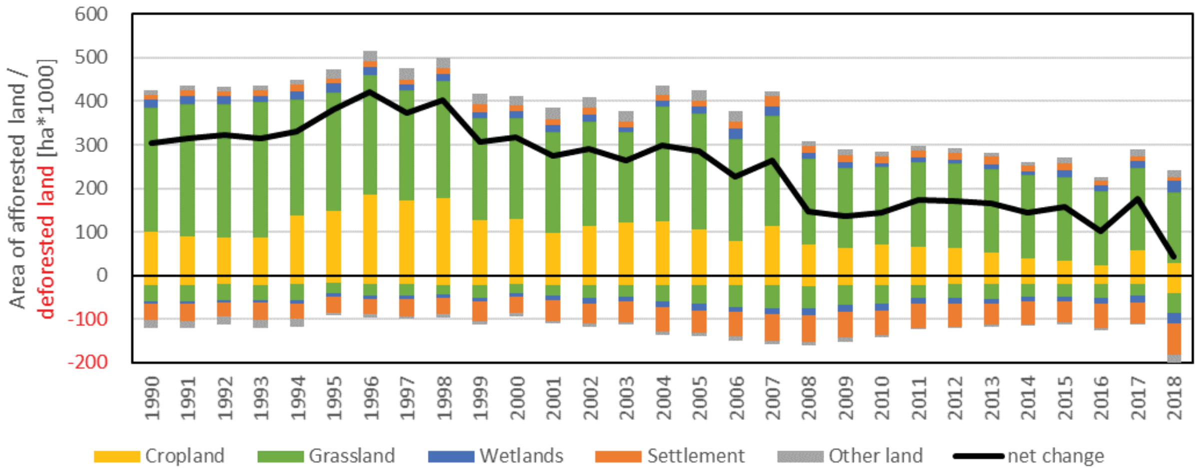
[18] EEA (2020) Mapping Europe's ecosystems. Available at: https://www.eea.europa.eu/themes/biodiversity/mapping-europes-ecosystems/mapping-europes-ecosystems

Problem, current trends and ecosystem-specific baseline

As the largest terrestrial ecosystem type in the EU, forests are of vital importance for biodiversity, and ecosystem services including climate change mitigation and adaptation.

Forest cover in Europe has been relatively stable since 2000 according to Corine Land Cover mapping. The total area had increased by 1 807 km^2 between 2000 and 2018. Despite this apparent stability, within each time period there was reasonable amounts of turnover in extent with approximately equal amounts of forest cover loss and forest cover gain. In addition, the annual natural expansion of forests and net area of land converted to forest by man are both falling in the EU, suggesting a change in trend towards future reductions in extent (Figure III-1).

Figure III-1 Area of annually afforested land / deforested land in the EU27 for the period 1990-2018. Source: EU Member States' GHG inventory submission of 2020).



Over the last centuries, most of Europe's natural forests have been replaced by managed forests. Most of the EU's forests are semi-natural (93 %) and are available for wood supply (FAWS). Currently, more than 70 % of the FAWS is even aged, and almost 30 % un-even aged. 30 % have only one tree species (mainly conifers), 51 % have only two to three tree species, and only 5 % of forests have six or more tree species.[19]

Although no major net change in forest cover area in the EU has been observed in recent decades, and certain structural condition indicators have improved (e.g. biomass volume and deadwood), in general the condition of EU forests is considered poor.[20] Several indicators point to a degrading trend, for example one out of four trees show defoliation levels indicating compromised condition. Also the amount of deadwood is below the desirable threshold levels for biodiversity in various forest habitat types which has been estimated to be at

[19] Forest Europe (2020) State of Europe's Forests 2020. Available at: https://foresteurope.org/state-europes-forests-2020/

[20] Maes, J. et al (2020) Mapping and Assessment of Ecosystems and their Services: An EU ecosystem assessment. Available at: https://publications.jrc.ec.europa.eu/repository/handle/JRC120383.

least 20-50 m3/ha for most central European forests[21], and 43 % of forests in the EU is affected by pressures from Invasive Alien Species.

Evidence from reporting under the Habitats Directive (HD) reveals the deteriorating condition of EU's forests: The vast majority (84 %) of the assessments of 69 forest habitats in scope of this mini-IA have an unfavourable conservation status (of which 58 % poor and 26 % bad). Only 16 % have a good conservation status. Among the habitat assessments that do not have a good status, under one-fifth have a deteriorating trend (17 %) while 18 % have an improving trend.

Regarding species associated to forest habitats, if populations of common forest bird species remained relatively stable[22] several species, in particular, species relying on mature forests and dead wood are under pressure. In Sweden, 69 % of the red-listed forest insects are saproxylic species; on the other hand, more than 20 % of long-horned beetle species have declined in abundance since the 1950s and 10 % have become extinct in the last 200 years, linked to the development of intensive industrial forestry[23]. In Finland, at least 2 % of the national fauna has been driven to extinction since 1800, 20 % of saproxylic beetles are currently red-listed, and the reduction of dead wood in forests is considered the dominant threat to 34 % of these listed species.[24] In France[25] and Germany[26], the proportion of rare or threatened saproxylic beetles reaches 35 %. The European Red List assessment of 653 of the best known saproxylic beetle species reports 17 % endangered or vulnerable species.[27]

Forests provide a wide range of ecosystem services, including timber provisions, non-wood goods, carbon sequestration, flood control, water purification and nature-based recreation. Combined, these forest services are estimated at a total economic value €81 413 million (EU28, 2012), wood production representing 18 %. Forestry and logging employs almost 500 000 people in the EU27 and the wider sector around 4,5 million people (EU28). Forests currently sequester around 10 % of the EU's annual emissions. While the EU forest sink is currently declining, there is a vast potential to enhance this forest function for climate change mitigation. Forests are considered to play an increasing role to the EU's climate targets for 2030 and 2050. Further degradation of EU forests undermines their capacity to sustain biodiversity and provide ecosystem services.

Forest pressures indicators can be categorised in: (i) habitat conversion and degradation; (ii) climate change; (iii) pollution and nutrient enrichment; (iv) overharvesting; (v) introduction of invasive alien species; and (vi) other pressures such as pests, parasites, insect infestations and

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[21] Müller, J. & Bütler, R. (2010) A review of habitat thresholds for dead wood: A baseline for management recommendations in European forests. European Journal of Forest Research. 129. 981-992. 10.1007/s10342-010-0400-5. Available at: https://www.researchgate.net/publication/226995213_A_review_of_habitat_thresholds_for_dead_wood_A_baseline_for_management_recommendations_in_European_forests.

[22] Maes, J. et al (2020) Mapping and Assessment of Ecosystems and their Services: An EU ecosystem assessment. Available at: https://publications.jrc.ec.europa.eu/repository/handle/JRC120383.

[23] Lindhe (2010) Longhorn beetles in Sweden - changes in distribution and abundance over the last two hundred years. Available at: https://www.researchgate.net/publication/220000768_Longhorn_beetles_in_Sweden_-_changes_in_distribution_and_abundance_over_the_last_two_hundred_years

[24] Martikainen (2013) Saproxylic beetles in boreal forests: temporal variability and representativeness of samples in beetle inventories. Pp 83-86 in: F. Mason, G. Nardi & M. Tisato (eds). Proceedings of the International Symposium ''Dead wood, a key to biodiversity''Mantova, Italy, May 29th-31st 2003, Sherwood 95.

[25] Bouget et al., (2019). Les Coléoptères saproxyliques de France: Catalogue écologique illustré.

[26] Totholzkäfer in Naturwaldzellen des noerdlichen Rheinlandes. Vergleichende Studies zur Totholzkäferfauna Deutschlands und deutschen Naturwaldforschung. Landesamt für Agrarordnung NordRheinWestfalen.

[27] Cálix et al (2018) European Red List of Saproxylic Beetles. Brussels, Belgium: IUCN. Available at: https://portals.iucn.org/library/node/47296

soil erosion.[28] Table III-1 shows an overview of these pressure categories and indicators. Climate change and human activities are found to be the most severe causes of the pressures identified on forest habitats and species. Article 17 of the HD states that Forest habitats are subject to a wide diversity of pressures resulting in their degradation and extirpation. According to Member States reports under Article 17 of the HD, the top three groups of pressures (in percentage of the total) are:

- Habitat management with close to 61 % of all pressures; these include inadequate forestry practices like removal of dead and old trees (30 %), clearcutting (10 %), reduction of old growth forest (8 %);
- Conversion and land use change amounts to 13 %; from these, 45 % correspond to conversion to other forest types (including monocultures), 22 % to construction of urban, commercial, industrial and leisure areas, and 12 % to transport infrastructure;
- Natural processes, with about 8 %; this is mainly due to interspecific relations (competition, parasitism and pathogens) (43 %) and changes in species composition (34 %).

Equally important is alien and problematic species with over 7 %, mainly invasive alien species (58 %), and plant diseases, pathogens, and pests (26 %).

On balance it seems likely that pressures on forests will continue to grow, primarily as a result of forest management and accelerating climate change. Continuous pressures are expected to negatively affect various ecosystem services that forests provide, including wood production, biodiversity protection as well as the role forest have for climate change mitigation. Forests' ability to sequester carbon from the atmosphere is projected to decline further towards 2030 and beyond, under a baseline scenario. A policy analysis (covering the BHD, the CAP, the revision of the LULUCF Regulation and the Carbon Farming Initiative) suggests that even considering ongoing policy reviews and new initiatives, in the absence of additional action to establish legally binding targets, there will likely be a continuous *policy gap* to adequately address the need to restore forest ecosystems and protect them from further deterioration.

Table III-1 Pressure categories and indicators

Pressure category	Indicators
Forest management	• Inadequate forestry practices (e.g. excessive removal deadwood / old trees) • Clear-felling • Harvesting intensity (ratio annual fellings to annual increment) • Absence of the terminal and decline phases (natural silvigenetic cycle) • Reducing of old growth forests • Drainage of peatland forest and wet forests • Simplification of the composition of the dendrological composition
Conversion and Land Use Change (LUC)	• Forest cover change (e.g. semi-natural forests > monoculture plantation of one-age class) • Forest land take • Tree cover loss • Forest fragmentation
Climate change	• Extreme Droughts • Fires (scale, frequency) • Effective rainfall • Mean annual temperature

[28] Maes et al (2020) Mapping and Assessment of Ecosystems and their Services: An EU ecosystem assessment. Available at: https://publications.jrc.ec.europa.eu/repository/handle/JRC120383.

	• Soil moisture • Tree mortality • Storms • Droughts and heat induced tree mortality • Effect of droughts on forest productivity
Pollution and nutrient enrichment	• Tropospheric ozone (AOT40) • Exceedances of critical loads for acidification • Exceedances of critical loads for eutrophication
Invasive Alien Species	• Pressure by invasive alien species
Other pressures	• Diseases, • Pathogens • Pests • Parasites • Insect infestations • Soil erosion • Changes in species composition

Target options screened in/out

A comprehensive approach to preserve and restore the diversity of an ecosystem must consider its structural, compositional, and functional characteristics. The favourable conservation status of forest habitats at local level is often characterized by different parameters as such habitat extent, parcelling and fragmentation, trees species composition's integrity (dendrological integrity and absence of invasive species), forest dynamics (number of large living trees, living trees with microhabitats and renewal process), vertical vegetation structure that allows the multiplication of habitats for a wide diversity of species, the matter cycle (volume of dead wood) and absence of deterioration (e.g. soil damage - compaction, hydrological disturbances, etc.).

The main forest biodiversity issues include elements (species, populations) that are found only in forests or that are particularly sensitive to management, or that are threatened. Moreover, composition of forest species and the genetic diversity of populations of a given species are largely determined by the management practiced; animal species sensitive to disturbance, fauna and flora of the soil sensitive to compaction, threatened taxa (as defined by IUCN), rare species or populations and species or populations whose abundance is declining.

Options for targets are:

Table III-2 Summary table screened target options

Target option	Screened in/out for assessment	Key reason(s) for screening in/out

Option 1a: Target to restore all HD Annex I forest area to good condition, with all necessary restoration measures completed on 15 % of degraded areas by 2030, 40 % by 2040 and 90 % by 2050 and recreate 15 % of additional habitat area required to achieve Favourable Conservation Status (FCS) of HD Annex I forest habitats by 2030, 40 % by 2040 and 100 % by 2050.	In	This option targets the restoration of Annex I forests habitat area and could help enhance biodiversity in these forests, as well their ecosystem services, including for climate change mitigation and adaptation. This target is based on already established indicators and reporting under Habitats Directive Article 17 and while some data gaps remain, availability of data is largely sufficient to support a target. Reporting would be integrated in existing reporting flows. Complementary reporting on measures taken by Member States to implement the target would be necessary. There are no immediate legal or political barriers for this option while there is a strong coherence with existing EU policies and policy objectives. This option would cover only forest habitats under Annex I of the HD and would therefore be limited in its effectiveness to gradually restore all forest ecosystems in the EU.
Option 1b: Target to restore all HD Annex I forest area to good condition, with all necessary restoration measures completed on 30 % of degraded areas by 2030, 60 % by 2040 and 90 % by 2050 and recreate 30 % of additional habitat area as required to achieve Favourable Conservation Status (FCS) of Annex I forest habitats by 2030, 60 % by 2040 and 100 % by 2050.	In	Idem as above but with a different timeline / trajectory.
Option 2: Restore and re-create forest habitats as necessary to achieve the favourable conservation status of wild birds and species that are listed in Annex II, IV and V of the Habitats Directive and predominantly associated with forests, with 30 % (or 15 %) of all necessary actions carried out by 2030 and 60 % (or 40 %) by 2040 and 100 % by 2050.	In	This option provides a target for improving the condition status of certain species. Many species depend on forests, and this option is based on the assumption that efforts to improve their status will involve the restoration of forests habitat area, which will, in turn, also result in the improvement of other forest-associated species. Improving the condition of species listed in Annex II, IV and V of the Habitats Directive as well as wild birds' species is already a legal objective under the BHD and a target would add a deadline for action to deliver a contribution towards that objective. This target is based on already established indicators and reporting under Habitats Directive Article 17 and Birds Directive Article 12 and while some data gaps remain, availability of data is largely sufficient to support a target. Reporting would be integrated in existing reporting flows. Complementary reporting on measures taken by Member States to implement the target might be necessary. There are no immediate legal or political barriers for this option while there is a strong coherence with existing EU policies and policy objectives. This target does not exclusively address Annex I forest habitat areas, so this option could complement option 1.
Option 3a: Restore degraded non-Annex I habitats forest area to a good condition, with all necessary restoration measures completed on 15 % of degraded areas by 2030, 40 % by 2040 and 100 % by 2050.	In	This target would have a wide scope, covering 72 % of the EU forest area. Assessments suggest that there is a significant potential to restore non-Annex I forests and improve the condition of biodiversity, and ecosystem services including climate mitigation and adaptation. However, there is currently no systemic EU-wide methodology for assessing ecosystems condition nor a definition of "good ecosystem condition" for non-Annex I forests habitats. Furthermore, there is no reporting mechanism on the ecological condition or status for forest ecosystems outside of the scope of the HD Annex I. Consequently, this option would involve establishing a set of indicators to define ecological status/condition, a monitoring and reporting system for these indicators and baselines and target values for each of them. Assessment and monitoring could be based on national forest inventories, other monitoring systems and remote sensing resources such as those in the Copernicus Land Services, to monitor restoration targets. Similar indicators to assess conservation status under the Habitats Directive (structure, composition and function, deterioration) could already be used to already define priority forest habitats for restoration action, thus allowing time to develop indicators and baseline for assessing progress to the good ecosystem condition. Until then, a first analysis of the level of degradation can already be undertaken based on available

		reporting data on parameters such as trees species composition (currently, 30 % have only one tree species) or stand structure (currently, more than two-third of Europe's forests are even-aged).
Option 3b: Restore degraded Annex I and non-Annex I habitats forest area to a good condition, with all necessary restoration measures completed on 15 % of degraded areas by 2030, 40 % by 2040 and 100 % by 2050.	In	This option combines option 1 and 3.

3.4 Impacts of assessed target options

The costs of restoration of forests were estimated by calculating the area of degraded ecosystems to be restored and re-created annually to meet each target and applying average per hectare capital costs for restoration and re-creation, and annual costs for maintenance taken from Tucker et al.[29] The costs of restoration include the capital costs of restoration actions such as removal of invasive species, restructuring plantations, planting or regeneration of trees, controlled burning, pest and disease control, hydrological works and sustainable forest management planning/ certification. The costs of re-creation include site preparation works, planting trees and/or creating appropriate conditions for natural regeneration, and initial management of newly created forests. Annual maintenance costs include sustainable forest management, fire prevention & control, control of grazing / deer management, and costs of avoiding or sustainably maintaining timber harvesting. The required management will be undertaken largely by private landowners and land managers, in return for incentive payments which include compensation for opportunity costs relating to land management (e.g. income forgone through reduction/cessation of timber harvests, loss of crop or grazing income through creation of forests on agricultural land). Maintenance costs were applied to the entire ecosystem area, since meeting the targets requires further degradation of ecosystems to be avoided.

Benefits estimates were based on an extensive review of literature of the value of benefits of forest restoration, which identified changes in per hectare values of ecosystem services for

[29] Tucker et al., (2013) Estimation of the financing needs to implement Target 2 of the EU Biodiversity Strategy. Report to the European Commission. Institute for European Environmental Policy, London. Available at: https://ec.europa.eu/environment/nature/biodiversity/comm2006/pdf/2020/Fin%20Target%202.pdf

restored vs degraded ecosystems. The analysis applied an estimate of the per hectare value of the total ecosystem service benefits of forest restoration taken from a meta-analysis by De Groot et al[30], which was based on 58 source studies. The carbon-specific value used in this assessment are based on a study by Welle et al[31]. This study calculated the carbon sink potential of European forests, according to various scenarios with different harvest intensities. This assessment assumes that harvesting is a main pressure that would need to be addressed, reflecting the pressures reported in section 3.2. In the Welle study, the baseline is calculated with reported data from Member States and with the applicable IPCC methodology to estimate biomass- and carbon stock and takes into account the 'state of naturalness' of EU forests. The carbon sequestration potential is calculated with the use of biomass expansion factors. The carbon calculation was performed considering only above and below-ground biomass. Dead wood, litter, and soil were not included. The carbon values used for this assessment reflect the results from the 'Back in Time'' scenario in the study, which assumes a reduction in average felling for the period of 2018-250 to the levels of 2003 – 2007 for felling of pulpwood and firewood. This assumption is rather conservative in respect of the restoration needs of European forests. For example, this assumes still a harvest intensity of 100% for Sweden. Therefore, the relatively limited estimated impact in terms of carbon benefits compared to other ecosystem types in this study should be interpreted with caution, and should be seen as an absolute minimum that could be achieved through conservative reductions in felling intensity only.

Per hectare benefits estimates were applied to the area of ecosystem restored to give annual estimates of total benefits. Annual costs and benefits were estimated over the period 2022 -2070, recognising that, while restoration takes place to 2050, further maintenance costs continue beyond that date, while restored ecosystems continue to provide benefits into the future. Annual cost and benefit estimates were discounted, applying a 4% social discount rate, and summed to calculate their total present value. This enabled total net present value (benefits – costs) and benefit: cost ratios to be calculated.

For all options, the principal actors involved in the restoration of forest habitats will be forest owners and forest managers. Forest ownership varies from very small and fragmented private-owned to large scale state-owned forests, and from small family-owned holdings to large estates owned by private companies. Around 40 % of the forest area in the EU is publicly owned. Around 60 % of the EU's forests are in private ownership, with about 16 million private forest owners. Across the EU there are major variations in ownership of forests.

The impact of restoration activities can involve certain costs for forest owners and forest managers, while it may impact their own use of forests or the related value of marketable goods and services (i.e. the opportunity cost of reduced harvesting levels). On the other hand, restoration activities might improve the resilience of forests and ensure a certain economic value of marketable products and services in the future (e.g. due to a reduced risk of damage). These

[30] De Groot et al., (2013) Benefits of Investing in Ecosystem Restoration.
[31] Welle et al., (2020) Waldvision für die Europäische Union. Available at: https://naturwald-akademie.org/wp-content/uploads/2020/11/Waldvision-fuer-die-Europaeische-Union.pdf

dynamics could also have an indirect impact on the forest-based industries which are dependent on forest biomass resources. Across the options, the ‘opportunity costs’ of options 2 and 3 are assumed to be the highest, because those would involve restoration of forests that are more intensely managed for wood production. In addition, more ‘nature-based’ or ‘climate smart’ forest management would to some degree depend on the willingness, know-how and adaptability of foresters.

For public governance and oversight of the different options, it is likely that option 1 and 2 would be least impactful in comparison to option 3. The main reason for this is that options 1 and 2 build on existing legal framework of the Birds and Habitats Directives, while option 3 would involve setting up a new set of formalised indicators to identify forest restoration and a new reporting and monitoring framework. The latter would thus involve more direct costs for implementation. But the benefits for option 3 are much more significant considering the share of non-Annex I forests and their poor condition.

Forest restoration actions will benefit society, as well as specific sectors and groups benefiting from particular forest ecosystem services:

- Healthy forest ecosystems can generate additional income to society and ensure employment in the forest-based sectors;
- Recreational users and the tourism and recreation sector will benefit from enhanced recreational use of forests;
- Conservation organisations and contractors will benefit from investments in restoration, which will enhance revenues and employment in restoration actions;
- Local communities could benefit from positive effects of restoration, e.g. by helping them adapt to climate change, and because of enhanced biodiversity values, water -and soil quality;
- All EU citizens and economic sectors will benefit from mitigation of climate change and the reversal of biodiversity loss.

Costs and benefits of forest restoration are merely outlined in abstract below.

Forest restoration involves benefits for:

- **Biodiversity.** Restoring forests to favourable conservation status will enhance biodiversity. Biodiversity is widely recognised to have intrinsic value, such that there are benefits in enhancing biodiversity, in addition to the ecosystem services it delivers to people. Biodiversity also provides significant value to the health, functioning and resilience of ecosystems as such;
- **Provisioning services**, including timber products and non-timber forest products. This can include indirect economic benefits for the broader forest-based sector, in terms of market value, and employment for rural communities;
- **Regulating services,** including water- and soil quality, flood prevention, carbon sequestration and storage, and increased resilience against natural disturbances (droughts, fires, pests, and diseases);
- **Social and cultural services** that forests provide (aesthetic, spiritual, recreational and existence values).

- **Economy and employment.** Restoration work provides employment opportunities and income for conservation organisations, as well as contractors and suppliers. Restoration is also assumed to increase employment in the tourism and recreation sectors, while restored ecosystems have the potential to attract more visitors, stimulating expenditure and supporting employment in rural economies;

Forest restoration can involve costs for:

- **Changes in forest management practices, active restoration measures**, **or recreation** of additional land to achieve FCS**.** These may depend on the current status of habitats and specific measures needed to improve their condition.
- **Provisioning services.** Costs can include the opportunity costs of biomass harvests, in the case restoration activities involve a decrease in harvest intensity. This can involve indirect economic costs for forest owners and the forest-based sector, in terms of market value and employment. **Implementing afforestation and reforestation** may include foregone income of landowners and practitioners from production on agricultural land, and costs for the preparation of the soil in case of plantation, for acquiring and planting trees, and for the maintenance and management practices. Costs depend on specific situation factors, including the type of tree species planned to be used.
- **Regulating services;** afforestation and reforestation may involve negative impacts on regulating services, including biodiversity and soil organic carbon.
- **Administrative burden for forest owners and forest managers** may increase, depending on potentially new monitoring and reporting requirements in relation to the options considered.

A cost-benefit analysis for forest restoration in the EU is complicated by several factors, including the variety of forests across the EU, gaps in data at EU level, uncertainties regarding baselines and future developments (e.g. markets, climatic) which may affect the estimated costs for action or non-action of forest restoration in the longer term. Due to the constraints outlined above, the cost estimates below are a highly *indicative* range of the scale of monetary costs and benefits from forest restoration. They need to be interpreted with caution. The following issues should be considered:

- **Restoration required:** (i) for option 1 the average estimated restoration potential of Annex I forests provided by the EEA based on the share of Annex I forest area reported as not in good condition by Member States has been used; (ii) To estimate the restoration potential (area) for option 3, the indicator of the share of single-species forest out of total forest area (25 %) has been used; (iii) To estimate the restoration required for option 2, it has been assumed to restore degraded Annex I forest habitat area in combination with the restoration potential for non-Annex I forests.
- **Unit values:** The cost-benefit analysis for three options is based on the same unit values for both maintenance, forest restoration and re-creation, as well as benefits of restoration. This is rather speculative, while significant variations can be assumed across biogeographical regions, as well as between Annex I and non-Annex I forests. The analysis further uses the same value unit value per hectare for restoration and recreation.
- **Gaps:** the assessment below does not include costs for the development of indicators and a monitoring and reporting system. Because of the complexity and lack of data, the assessment

provides conservative minimum also does not include separate estimates of the benefits from increased carbon sequestration, which are almost certainly underestimates.

Table III-3: Summary of projected costs (MEUR) of achieving restoration targets for HD Annex I forests in relation to current trends & expected 2030 baseline based on overall degradation extent and combined measures. (Option 1a)

Period	% Full restoration	Maintenance costs	Restoration costs	Re-creation costs	Combined costs	Total over period
Average annual costs						
2022-2030	15 %	1,282	790	25	2,097	18,875
2031-2040	40 %	1,290	1,185	38	2,513	25,130
2041-2050	90 %[32]	1,306	2,370	75	3,751	37,514
Cost over full period (29 years)						
2022-2050	90 %	37,504	42,661	1,355	**81,520**	

Table III-4: Summary of projected costs (MEUR) of achieving restoration targets for HD Annex I forests in relation to current trends & expected 2030 baseline based on overall degradation extent and combined measures. (Option 1b)

Period	% Full restoration	Maintenance costs	Restoration costs	Re-creation costs	Combined costs	Total over period
Average annual costs						
2022-2030	30 %	1,285	1,580	50	2,916	26,241
2031-2040	60 %	1,298	1,422	45	2,765	27,648
2041-2050	90 %	1,310	1,422	45	2,777	27,770
Cost over full period (29 years)						
2022-2050	90 %	37,643	42,661	1,355	**81,569**	

Table III-5: Summary of Benefits Estimates from Ecosystem Restoration

Ecosystem	Service valued	Benefits (EUR/ha/year)
Forests	Carbon storage and sequestration	39*
Forests	Total ecosystem services	2 072

**Likely to underestimate true carbon benefits*

[32] Although the 2050 target aims to restore 100 % of the habitat, the 2050 cost estimation is for 90 % restoration as this is the maximum percentage that can be expected in practice. Furthermore, an extrapolation of current restoration costs would no longer provide reliable estimates in the range between 90 and 100 %. (See methodology section in SWD)

Tables III-6 summarise the cost and benefit estimates. The analysis finds that the ecosystem service benefits of restoring Annex 1 forests will exceed the costs by a factor of 4, while benefit cost ratios for wider forest restoration targets (Options 2 and 3) are estimated at 6:1. The estimated carbon benefits represent only 10% of estimated costs, but are likely to be a significant underestimate. In addition, forest restoration delivers substantial benefits for biodiversity, water, flood management, landscape, cultural heritage and recreation.

Table III-6: Cost-benefit ratio table (2022-2070) (MEUR, Present Value)

	Cost estimate Option 1a 15 % -40 % -90 %	Cost estimate Option 1b 30 % -60 % -90 %
COSTS		
Maintenance	27,641	27,720
Restoration	21,751	25,326
Re-creation	691	804
TOTAL (full recovery)	50,082	53,850
BENEFITS		
Carbon only	3,832	4,701
Total Ecosystem Services	203,564	249,775
Net Present Value (full recovery)		
Carbon only	-46,251	-50,019
Total Ecosystem Services	153,482	195,925
Benefit: Cost Ratio (full recovery)		
Carbon only	0.1	0.1
Total Ecosystem Services	4.1	4.6

Table III-7: Cost-benefit ratio table Options 2 and 3 (2022-2070) (MEUR)

	Cost estimate Option 2	Cost estimate option 3
COSTS		
Generalised restoration measures and costs	124 416	80 241
BENEFITS		
Carbon only	13,998	9,028
Total Ecosystem Services	743 700	479 635
Net Present Value (full recovery)		
Carbon only	-110 418	-71 213
Total Ecosystem Services	619 284	399,395
Benefit: Cost Ratio (full recovery)		
Carbon only	0.1	0.1
Total Ecosystem Services	6.0	6,0

3.5 Synthesis

Table III-8 provides a summary of the analysis of target options and conclusions in relation to their effectiveness, efficiency, coherence, and proportionality. The overall conclusion is that there are strong arguments for legally binding targets for achieving favourable conservation status of HD Annex I forest habitats; for targets to improve the condition of forest dependent species, as well as to restore non-HD Annex I forests.

The available valuation evidence suggests that even without carbon benefits included, the benefits from restoration would far exceed the costs in all three options. All options have however certain constraints. The first option is constrained by its geographical scope and does not address the condition of forests outside of the scope of HD Annex I habitats. This means that this option has a natural limit in terms of its effectiveness for enhancing biodiversity and climate change mitigation- and adaptation.

The second option overlaps with both option 1 and 3 and is in principle unlimited in terms of forest area covered. This means that its potential in terms of area covered may be the highest across options. The effectiveness of this option may however depend on the specific actions taken to improve condition of species and their effect on overall ecosystem health, both in- and outside of the Annex I.

Option 3 addresses non-Annex I forests and is mutually exclusive to option 1. This option would be more complex to implement, while indicators and a monitoring and reporting system would need to be established, involving certain costs. However, this option has a high potential considering the poor state of forests outside of the HD Annex I, for biodiversity as well as climate change mitigation- and adaptation.

In conclusion, while all options have certain benefits and constraints, policy options include: (i) one of the three target options; (ii) a combination of option one and three; (iii) a combination of option 1 and 2; and (iv) a combination of option 1 and 2; and (iv) a combination of option two and three.

Table III-8: Overview table assessing options on EU impact assessment criteria

	HD Annex I forests	EU protected species	Non-HD Annex I forests
Feasibility / effectiveness	Very high feasibility and potential for restoration. Effective in maintaining carbon stores, recovery of vegetation, carbon sequestration and other ecosystem services.	High feasibility and potential for restoration. Effective in maintaining carbon stores, and recovery of vegetation, carbon sequestration and other ecosystem services. Certain dependence on actions taken to enhance species' condition.	Moderate/high feasibility, very high potential for restoration. Effective in enhancing carbon sinks and recovery of vegetation, and other ecosystem services.
Efficiency	Strong evidence of benefits of restoration for biodiversity and ecosystem services, including climate mitigation. Available valuation evidence suggests ecosystem benefits exceed restoration costs.	Strong evidence of benefits of restoration for biodiversity and ecosystem services, including climate mitigation. Available valuation evidence suggests ecosystem benefits exceed restoration costs.	Strong evidence of benefits of restoration for biodiversity and ecosystem services, including climate mitigation. Available valuation evidence suggests ecosystem benefits exceed restoration costs;

Coherence	Full coherence with EU environmental policies and climate goals. Moderate potential to make contribution to climate adaptation and mitigation.	Full coherence with EU environmental policies and climate goals. High potential to make contributions to climate adaptation and mitigation.	Full coherence with EU environmental policies and climate goals. High potential to make contributions to climate adaptation and mitigation.
Proportionality	Proportionate due to the very high importance of forest habitats for biodiversity and associated ecosystem services.	Proportionate due to the high importance of forest habitats for biodiversity and associated ecosystem services.	Proportionate due to the high importance of forest habitats for biodiversity and associated ecosystem services.
Conclusions	**Include with very high priority.**	**Include with high priority.**	**Include with high priority.**

3.6 Forest ecosystem indicators

Many forest ecosystems across the EU provide evidence of the decline of biodiversity. For this reason, options for restoration action need to be considered for forests areas in addition to those covered by the Annex I habitats types under the Habitats Directive. Methods already exist to determine good condition of the Annex I habitat types and options for restoration targets for these were described in the previous sections. For habitat types or ecosystems not covered by the Habitats Directive, specific indicators can be used to provide evidence of enhancement of biodiversity. This section provides an assessment of introducing an obligation for Member States to provide evidence of increasing trends for a set of indicators that indicate the improvement of condition and biodiversity.

The European Union (EU) is home to approximately 5% of the world's total forest area. The EU27 has approximately 180 million hectares (ha) of forest and other wooded land in 2020 (European Commission, 2021b) which would account for approximately 40% of the EU's total land area – although estimates do vary. Six Member states (Sweden, Finland, Spain, France, Germany and Poland) account for two thirds of the EU's forested areas.

Forests are the largest terrestrial ecosystem in the EU[33], but the amount of forest area in the EU varies widely by Member State. In Finland for example, over three quarters of total land area is wooded, while in the Netherlands less than 10% is wooded, and in Malta less than 1%.

Forest coverage in the EU increased year-on year-from 2000–2015, by approximately 413 000 ha per year and 6.2 million hectares (Mha) in total[34]. According to the latest data from Forest Europe (Forest Europe, 2020), forest area in the EU-28 continued to increase between 2015–2020, by more than 1 Mha. Forest area in Europe altogether has increased by 9% since 1990, reaching 227 Mha[35].

However, the rate of forest expansion in the EU has overall declined since 2010[36] and recent data suggest there has also been an important increase in the amount of clear-cut harvested forest area[37].

The N2000 network, which covers almost 18% of EU land area, is about half forest. This means that around 23% of forest area in the EU-28 is protected under Natura 2000[38,39,40].

Definition of degraded forest ecosystems[41]

The notion of degradation is associated with a persistent decline of the ecological condition of an ecosystem[42]. Where ecosystem condition refers to the physical, chemical and biological

[33] Rendon, Paula, et al. "Analysis of trends in mapping and assessment of ecosystem condition in Europe." *Ecosystems and People* 15.1 (2019): 156-172.
[34] (EC JRC, 2018)
[35] (Forest Europe, 2020).
[36] EC JRC, 2018
[37] Ceccherini, Guido, et al. "Abrupt increase in harvested forest area over Europe after 2015." *Nature* 583.7814 (2020): 72-77.
[38] Sotirov, Metodi. "Natura 2000 and forests: Assessing the state of implementation and effectiveness." *What science can tell us* 7 (2017).
[39] Maes et al., 2020
[40] EC, 2015
[41] generic definition, valid for all forest-related targets and indicators

condition or quality of an ecosystem at a particular point in time[43]. The Millennium Ecosystem Assessment has defined ecosystem condition as the capacity of an ecosystem to deliver ecosystem services, relative to its potential capacity[44]. The SEEA-EA of the United Nations[45] defines ecosystem condition as the overall quality of an ecosystem asset in terms of its characteristics.

A moderate use of forest ecosystem services is often positively related to ecosystem condition. However, intensive use of provisioning ecosystem services has mostly a negative impact on ecosystem condition and may results in ecosystem degradation. The overuse of provisioning services such as wood can effectively act as a pressure on forest ecosystems. To avoid over-exploitation of provisioning services, safe thresholds need to be set and well-designed indicators could reflect these limits[46].

European forests are far from a natural, stable and resilient, showing largely ‘moderate’ ecological spatial structure as otherwise typical of undisturbed vegetation, especially in northern latitude forests[47]. According to Potapov et al[48], some areas in Europe are extremely poor of intact forest landscapes. According to Forest Europe, in 2020, 67% of the forest area consists of two or more tree species, with single-species forest being most common in South-East Europe, with a share of 62.3% of its forest area.

Tree health is deteriorating in the European forests (ICP-Forests Brief 5[49]). The crown defoliation indicator shows that the proportion of fully foliated trees has declined over the past 30 years, while mean defoliation has increased, particularly since 2010.

Insects (among biotic factors) and drought (among abiotic factors) are the most frequently reported causes of tree damage. Recent episodes of severe drought have increased crown defoliation and reduced tree growth. This may be exacerbated by air pollution.

The implementation of EU policy on air pollution has reduced the direct pressure of air pollutants on forests. However, nitrogen deposition remains very high in many European regions. There is increased evidence of nutrient imbalances in forest trees across Europe[50].
Canopy mortality has consistently increased across Europe in the past three decades. An important indicator of increasing pressure on forest ecosystems is tree mortality, that is, the proportion of canopy trees dying per year from both natural and human causes. An analysis of

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[42] United Nations et al., 2021
[43] Maes, Joachim, Benjamin Burkhard, and Davide Geneletti. "Ecosystem services are inclusive and deliver multiple values. A comment on the concept of nature's contributions to people." *One Ecosystem 3 (2018)* (2018).
[44] (MA 2005)
[45] UN, System of Environmental-Economic Accounting, Ecosystem Accounting (2021) https://seea.un.org/sites/seea.un.org/files/documents/EA/seea_ea_white_cover_final.pdf
[46] Maes et al, 2018
[47] De Rigo, D., et al. "Forest resources in Europe: an integrated perspective on ecosystem services, disturbances and threats." *European Atlas of Forest Tree Species; San-Miguel-Ayanz, J., de Rigo, D., Caudullo, G., Houston Durrant, T., Mauri, A., Eds* (2016): 8-19.
[48] Potapov, Peter, et al. "Mapping the world’s intact forest landscapes by remote sensing." *Ecology and Society* 13.2 (2008).
[49] Almost **a third** of monitoring plots (monitoring plots: 7440 in 36 countries) show moderate to severe defoliation. Mean defoliation between 2010 and 2019 remained unchanged on 68.3% of plots, increased on **22.3%** of plots and decreased on only 9.4%. https://icp-forests.org/pdf/ICPForestsBriefNo5.pdf
[50] https://icp-forests.org/pdf/ICPForestsBriefNo2.pdf; https://icp-forests.org/pdf/ICPForestsBriefNo3.pdf; https://icp-forests.org/pdf/ICPForestsBriefNo4.pdf

satellite data at 19,896 plots shows that canopy mortality in 35 European countries increased from 1985 to 2018 (+1.5% yr^{-1}). Similarly, in Europe's temperate forests canopy mortality increased by +2.40% $year^{-1}$, doubling the forest area affected by mortality since 1984. Changes in climate and land-use are likely causes of large-scale forest mortality increase. These changes might have important implications for carbon storage and biodiversity conservation[51].

A number of other references are available on forest degradation[52].

Forest and restoration

A comprehensive approach to preserve and restore the diversity of an ecosystem must consider its structural, compositional, and functional characteristics, which are derived from quantifiable and/or quantitative ecosystem indicators and parameters (attributes). The good ecological condition of forest habitats is found when these characteristics correspond to a target condition of a nature-close, resilient ecosystem state (reference condition, habitat and site-specific)[53].

Ecological restoration[54] aims to re-establish a self-organizing ecosystem on a trajectory to reach full recovery. While restoration activities can often place a degraded ecosystem on an initial trajectory of recovery relatively quickly, full recovery of the ecosystem can take years, decades, or even hundreds of years. For example, while we can initiate a forest restoration process by planting trees, for full recovery to be achieved, the site should be a fully functioning forest with mature trees in the age-classes representative of a mature native forest.

In the absence of definition of what good condition is for specific forests (for example for forests habitats beyond the Annex 1 habitats of habitat directive), one can use a set of indicators that provide evidence of the enhancement of biodiversity in forest ecosystems.

Indicator selection

For the initial stage in this analysis, a broad set of indicators were considered as a means of gauging the improvement of biodiversity in forest ecosystems. Even though ecosystem condition for these ecosystems is not defined, evidence of an increasing trend in a set of indicators would

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[51] https://www.sciencedirect.com/science/article/pii/S259033222100227X; https://www.nature.com/articles/s41467-018-07539-6

[52] Dajoz, R. (2000). Insects and forests: the role and diversity of insects in the forest environment. Intercept Limited, Andover, UK 668 pp.;
FAO (2010). Global Forest Resources Assessment 2010 - Main report. Food and Agriculture Organisation of the United Nations (FAO).
Innes, J.L., and Tikina, A.V. (2017). Sustainable Forest Management - From Concept to Practice. Routledge, UK.
MA, 2005. Ecosystems and Human Wellbeing: Current State and Trends, Volume 1, Island Press, Washington D.C.
Maes J, Teller A, Erhard M, Grizzetti B, Barredo JI, Paracchini ML, Condé S, Somma F, Orgiazzi A, Jones A, Zulian A, Vallecilo S, Petersen JE, Marquardt D, Kovacevic V, Abdul Malak D, Marin AI, Czúcz B, Mauri A, Loffler P, Bastrup-Birk A, Biala K, Christiansen T, Werner B (2018) Mapping and Assessment of Ecosystems and their Services: An analytical framework for ecosystem condition. Publications office of the European Union, Luxembourg.
Millar, C.I., and Stephenson, N.L. (2015). Temperate forest health in an era of emerging megadisturbance. Science, 349 (6250), 823-826
Raffa, K.F., Aukema, B., Bentz, B.J., Carroll, A., Erbilgin, N., Herms, D.A., Hicke, J.A., Hofstetter, R.W., Katovich, S., Lindgren, B.S., Logan, J., Mattson, W., Munson, A.S., Robison, D.J., Six, D.L., Tobin, P.C., Townsend, P.A., and Wallin, K.F. (2009). A Literal Use of "Forest Health" Safeguards against Misuse and Misapplication. Journal of Forestry, 107 (5), 276-277.
United Nations et al. (2021). System of Environmental-Economic Accounting—Ecosystem Accounting (SEEA EA). White cover publication, pre-edited text subject to official editing.
van Lierop, P., Lindquist, E., Sathyapala, S., and Franceschini, G. (2015). Global forest area disturbance from fire, insect pests, diseases and severe weather events. Forest Ecology and Management, 352, 78-88

[53] Examples for such parameters are: habitat extent; forest landscape: parcelling and fragmentation outer edge structure and length; trees species composition; forest regeneration dynamics (species abundance in natural regeneration patches and its spatial coverage; inner edge structure: patches, gaps); structural stand attributes (following successional or management development stages): vertical vegetation structure, volume of dead wood); signs of mechanical disturbance (e.g. soil damage - compaction, landslides, road-side erosion, hydrological disturbances, etc...).

[54] https://www.ser-rrc.org/what-is-ecological-restoration/

act as a proxy for improvement in biodiversity. A set of such indicators could thus constitute specific legal obligation of improvement of the indicators in the legal proposal.

The process of indicator selection is grounded on extensive work carried out over several years as part of the MAES[55] and the UNSEEA EA[56] initiatives that have been developing methodologies and indicators to reflect the condition of a number of ecosystems. These initiatives have led to identify indicators describing trends in forest ecosystems condition, that are relevant, based on available data, repeatable through time, and ecologically meaningful in terms of ecosystem structure, function and composition. Moreover, these indicators have undergone various consultation processes based on scientific expertise, as well as including MS experts and stakeholders.

Based on the above, a broad number of potential indicators were first identified and a set of criteria were developed to select the most promising indicators as potentially acting as a good proxies for improvements in biodiversity. In order to be operational in the short term, such indicators would have to satisfy a number of criteria, such as being based on data that are already available or will shortly be available in the EU. Therefore the criteria chosen for the purpose of the current evaluation of indicators were:

1. The indicator gives direct information about the state of biodiversity or the ecological quality of the ecosystem. Based on this, pressure indicators were excluded as often being indirect indicators of biodiversity.
2. The data are readily available or will shortly be available in the EU, and the data are reliable and is updated periodically.

The indicators outlined below were evaluated against these criteria (see Table 1). Indicators need first to offer key information or proxy about the condition and biodiversity quality of forest ecosystems. Data availability and data robustness, in particular periodicity of updates and reliability, are also essential elements to consider. In particular indicators for which there are already obligations for reporting under other legislation (such as CAP or LULUCF), or already used in other pan European or international processes (Forest Europe or FAO), were considered favourable elements in this respect.

The evaluation allowed a reduction to a final assessment of six indicators satisfying the criteria considered: Structure diversity (age structure), forest connectivity/fragmentation, tree cover density, amount of deadwood, organic carbon content in forest soils, and common forest birds indicator. Further information about these selected indicators is provided in the subsequent sections.

Table III-9: Considered forest ecosystem indicators

SEEA Typology	Indicator	Direct indicator of ecological/biodiversity quality	Temporal series available	Data Stream	Final assessment
Class A1 **Physical state**	**Normalized difference water index (NDW)**	No, indirect measure of ecological/biodiversity quality	yes	Mapping	No

[55] Mapping and Assessment of Ecosystems and their Services - MAES - Environment - European Commission (europa.eu)
[56] Ecosystem Accounting | System of Environmental Economic Accounting

Class A1 **Chemical state**	**Air pollutants**	No, indirect measure of ecological/biodiversity quality	yes	EU reporting (NEC Directive)	No
	Exceedance of critical loads for acidification	No, indirect measure of ecological/biodiversity quality	Yes	Mapping	No
	Exceedance of critical loads for eutrophication	No, indirect measure of ecological/biodiversity quality	Yes	Mapping	No
	Organic carbon content in forest soils	Yes, strongly associated with key services like water holding capacity, resilience improvement, and is related to management practices	Yes, reported in Forest Europe	Mapping Source : LUCAS Soil,, ICP Forests	Yes
Class B1 - **Compositional state**	**Common Forest Bird indicator**	Yes, strongly associated with associated biodiversity and is related to management practices	Yes	Mapping Source : PECBMS	Yes
	Tree species composition	Yes and No, measure of ecological/biodiversity quality but not completely relevant	Yes	Mapping Source : National Forest Inventories (NFI), Forest Europe, FAO-FRA	No
Class B2 - **Structural state**	**Forest biomass**	No, indirect measure of ecological/biodiversity quality	Yes/no	Mapping Source : NFI, Forest Europe	No
	Growing stock	No, indirect measure of ecological/biodiversity quality	Yes	Mapping Source : NFI, Forest Europe	No
	Tree cover density	Yes, key aspect in ecological condition, biodiversity, ecosystem structure, biogeochemical processes, animal habitat, biomass and carbon sequestration, and anthropogenic demand for building materials	Yes	Mapping Source : Copernicus	Yes
	Deadwood	Yes, strongly associated with associated biodiversity and is related to management practices	Yes	Mapping Source: NFI, Forest Europe	Yes
	Age structure	Yes, strongly associated with associated biodiversity and is related to management practices	Yes	Mapping Source: NFI, Forest Europe	Yes
Class C1 – **Landscape & seascape**	**Forest connectivity**	Yes, strongly associated with key aspect in biodiversity, ecosystem services and the ever-increasing pressure from anthropogenic land use	Yes	Mapping based on CLC (JRC, Forest Europe)	Yes

Age structure - share of uneven-aged structure

Background

According to Forest Europe (2020), even aged forest dominate in Europe's forests available for wood supply (FAWS)[57].

[57] According to FOREST EUROPE most EU forests, 85%, are FAWS, i.e. potential sources of wood. FOREST EUROPE defines FAWS as "forests where any environmental, social or economic restrictions do not have a significant impact on the current or potential supply of wood. These restrictions can be established by legal rules, managerial/owner's decisions or because of other reasons".

Species-rich communities thrive within forests that are diverse in structure – for example, bird diversity has been shown to be strongly influenced by the vertical heterogeneity of forest stands; tree communities with differing bark characteristics can support high biodiversity by providing numerous different microhabitats; and saproxylic organisms (which depend on decaying wood) prefer environments with differing volumes and decay classes of deadwood[58].

A variety of layers of vertical vegetation (co-existing on the same square) allows the multiplication of habitats for a wide diversity of species.

Emberger, Larrieu and Gonin (2017)[59] suggest that forest management for both wood production and high taxonomic biodiversity could be guided by key principles as such increasing the number of living environments: promoting structural and compositional heterogeneity (in terms of species and ages of forest stands and stages of decomposition of dead wood) will in turn promote a varied range of habitats, which will increase the chances of meeting the varied ecological requirements of forest species.

Figure III-2 Schematic representation of the difference at the stand scale between (a) stands subjected to even-aged silviculture at four different developmental stages and (b) stand subjected to uneven-aged silviculture. Source: Nolet et al, 2017

Details of the indicator

This indicator describes the age-class structure of forests available for wood supply (FAWS). The vast majority of forest in Europe are FAWS and they represent 85% of EU forests. Information on age structure is key for understanding the history of forests and their likely future development.

[58] Storch, Felix, Carsten F. Dormann, and Jürgen Bauhus. "Quantifying forest structural diversity based on large-scale inventory data: a new approach to support biodiversity monitoring." *Forest Ecosystems* 5.1 (2018): 1-14.

[59] Emberger, Larrieu, Gonin, Dix facteurs clés pour la diversité des espèces en forêt, Forêt Entreprise, Forêt Privée Française, 2017, mars (233), pp.53-53. ⟨hal-02624397⟩

This indicator is important for understanding not only for wood supply but also to describe the ecological condition of forest ecosystems because provides insights regarding the provision of essential ecosystem services and biodiversity. These are in general more favourable in uneven-aged forest, and in old even-aged forests compared to young even-aged forests.

In Europe more than 70% of FAWS are reported as even-aged. Therefore, uneven-aged forests cover barely 30% of the FAWS area. It is noticeable that some countries report only aggregated information without distinguishing even-aged and uneven-aged forests, which might require improvements in reporting.

Description: This indicator describes the age-class structure of forest available for wood supply.

Source: NFI, Forest Europe

Units: Share (%) of area of even-aged forest (development phases) and of uneven-aged forest.

Time series: Information on historical trends (time series) of this indicator is limited. The last Forest Europe report on the State of Europe's Forest of 2020 indicates that data for the analysis of trends on age structure is limited and covers only 15% of FAWS in Europe for the period 2000-2015.

Use and references of this indicator:
Forest Europe

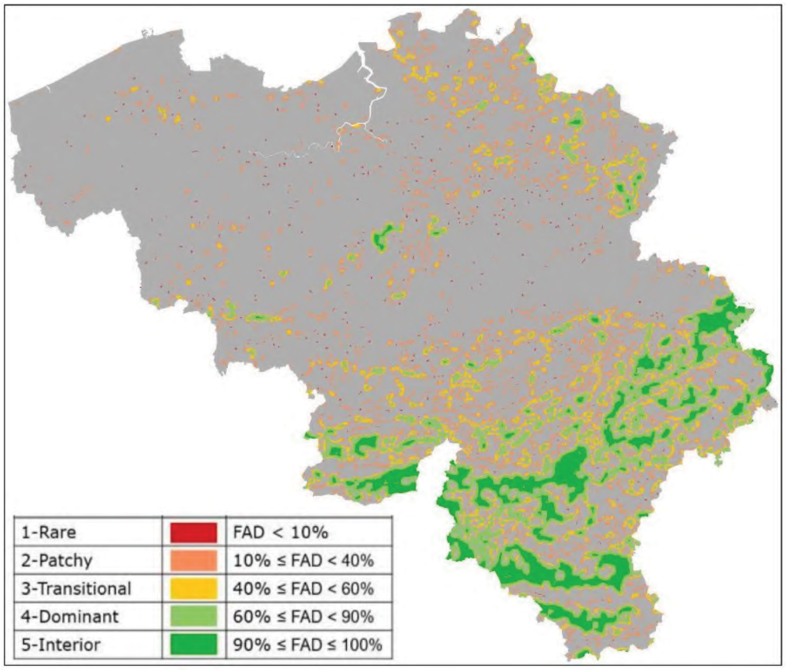
Forest connectivity

Background

Forest connectivity quantifies the degree of spatial intactness of forest cover. The higher the connectivity, the more thriving the forest ecosystem.

Forest connectivity is the opposite of forest fragmentation, i.e., highly connected ~ little fragmented and vice versa. The narrative of forest connectivity/fragmentation is of high importance in forest management.

Figure III-3 Forest Connectivity: Example for CORINE 2018 forest mask of Belgium showing five-class locally detailed reporting scheme. Source: Joint Research Centre (JRC)



Forest connectivity is a key aspect in biodiversity, ecosystem services and the ever-increasing pressure from anthropogenic land use. Forest fragmentation may lead to the isolation and loss of species and gene pools, degraded habitat quality, and a reduction in the forest's ability to sustain the natural processes necessary to maintain ecosystem health.

By affecting ecological processes, fragmentation affects ecosystem services such as habitat provision, pollination, and has also an impact on pest propagation in different ways.

Definition

Forest connectivity measures the degree of connectivity in forest ecosystems.

The methodological concept measures Forest Area Density (FAD) in the range of [0, 100] % at local (pixel) level, meaning at the highest spatial detail available. FAD is then grouped into five categories, showing varying degrees of connectivity/fragmentation within forest patches. The naming scheme of the five classes provides intuitive information for effective communication, i.e., the proportion of dominant or interior forest. Spatially detailed maps of connectivity/fragmentation are crucial to locate hotspots of fragmentation. Temporal changes in FAD allow to detect and to quantify changes in percent points, enabling monitoring of progress as well as measuring the overall outcome of policy directives.

Figure III-4 – Forest Connectivity: extract of statistical summary table for EU in 2018. Source: Joint Research Centre (JRC)

	A	B	C	D	E	F	G	H	I	J	K	L
1		Names & Codes		Base Statistics			Fragmentation Statistics					
2	Original sorting	COUNTRY	CNRTY_CODE	CNRTY_AREA 2018 (in ha)	FORES_AREA 2018 (in ha)	PERC_FOR 2018 (in %)	PERC_RARE (in %)	PERC_PATCH (in %)	PERC_TRANS (in %)	PERC_DOM (in %)	PERC_INT (in %)	FAD_AV (in %)
3	1	CLC	clc	584,572,992	200,918,750	34.37	0.42	7.37	8.99	83.00	0.22	71.90
4	2	EU28	eu28	439,019,328	159,505,733	36.33	0.47	7.79	9.14	82.36	0.24	72.01
5	3	Albania	AL	2,866,485	1,106,904	38.62	0.27	7.04	10.12	82.57	0.00	67.56
6	4	Austria	AT	8,394,356	3,715,822	44.27	0.19	5.87	9.81	84.12	0.00	69.05
7	5	Bosnia_Herzegovina	BA	5,121,534	2,656,470	51.87	0.14	5.07	3.94	90.84	0.00	74.54
8	6	Belgium	BE	3,064,066	628,981	20.53	1.28	18.63	15.50	64.59	0.00	60.89
9	7	Bulgaria	BG	11,098,772	4,237,649	38.18	0.45	7.14	8.15	84.26	0.00	73.21
10	8	Switzerland	CH	4,128,829	1,306,994	31.66	0.24	11.63	23.92	64.21	0.00	58.70
11	9	Cyprus	CY	924,891	189,190	20.46	0.31	4.71	6.92	88.06	0.00	77.44
12	10	Czechia	CZ	7,887,377	2,783,957	35.30	0.43	11.38	18.95	69.23	0.00	64.00
13	11	Germany	DE	36,057,024	11,042,562	30.63	0.73	12.00	17.04	70.23	0.00	63.72
14	12	Denmark	DK	4,363,230	521,455	11.95	3.01	36.39	31.39	29.05	0.17	44.57

The statistical summary chart provides details on forest cover (column E-F), five categories of forest connectivity/fragmentation (column G-K), and the average amount of connectivity within forest cover (column L) for each reporting unit (i.e., MS).

Indicator key advantages

- Map product: values at local level, identify hot spots and locations to act.
- Summary statistics by reporting unit: useful for charts and dashboards.
- Flexibility to adopt to various spatial analysis scales.
- Flexible reporting scheme to match any user requirement.
- Compatible to any kind of forest definition, i.e. FAO or CLC
- Applicable to any kind of land cover data source (CLC, Copernicus, etc)
- Normalized indicator in percent [%], facilitating interpretation and communication.
- Quantifying amount of change allows measuring progress and evaluate policy outcome.
- Possibility to aggregate to various reporting units (NUTS 1, 2 and 3, country, eco-region, etc.).
- Endorsed for official reporting by UN-FAO, Forest Europe, US-Forest Service.
- Endorsed for reporting in the upcoming EU Observatory on deforestation and forest degradation
- Harmonized assessment scheme across all MS.
- Peer-reviewed and well-established procedure.
- Operational processing implemented on JRC-BDAP and FAO-SEPAL

To be noted: requires user decision on appropriate forest map, forest definition, analysis scale and reporting scheme.

Data source:

JRC, CORINE, COPERNICUS

➢ Granularity, Periodicity & Timeliness:
- CORINE: EU and MS, 6Y, (T-3).
- CORINE Plus: once available
- any other suitable land cover map, i.e., Copernicus: Global, annual since 2015

Relevance:
Spatially explicit maps of forest connectivity are key elements for the assessment of forest biodiversity, habitat quality and ecosystem integrity. Temporal trends in forest connectivity form the baseline of sustainable forest management including targeted conservation and restoration

efforts. Locating and quantifying changes in forest connectivity allows for monitoring progress in policy directives (NRL, 8EAP, Green Deal, Biodiversity Strategy, Forest Strategy, 3 billion trees, SDG15 “Life on Land”) and improving forest ecosystem health by mitigating forest risks.

Use and references of this indicator:
Resilience dashboard, Biodiversity Strategy, Green Deal, 8EAP, Forest Strategy.

Use in Commission publications and reports:

- ScienceHub: Forest Europe
- Forest Europe JRC Technical Report
- Science Hub: UN-FAO
- FAO: JRC Technical Report
- Technical factsheet on forest fragmentation
- Fact sheet 3.3.103, MAES 2020 report

Others uses*:*
Both, Forest Europe and UN-FAO have requested and adopted the proposed methodology for inclusion in their flagship reports State of Europe’s Forest 2020 and The State of the World’s Forests 2020. The methodology/indicator has been co-developed in the context of a Collaborative Research Arrangement with the United States Forest Service (USFS) for the past 18 years.

Hence, the indicator is fully operational and can be applied to any suitable land cover dataset. The reporting of the indicator can be fine-tuned to match various reporting requirements, for example number of connectivity classes or detail of spatial aggregation. The same indicator is also used for more than 15 years for official reporting by the USFS for reporting to the RPA assessment[60]. Forest connectivity/fragmentation is also used in the MAES 2020 report.

Tree cover density

Background

The amount and density of trees in forest is a fundamental trait of ecosystem structure, which underpin, among other processes, biogeochemical processes, and habitat for biodiversity, productivity and carbon sequestration.

An understanding of the extent and density of forest trees is necessary for monitoring the condition of forest ecosystems and assess the role of sustainable forest management.

Definition
Tree Cover Density is defined as the "vertical projection of tree crowns to a horizontal earth’s surface".

Description

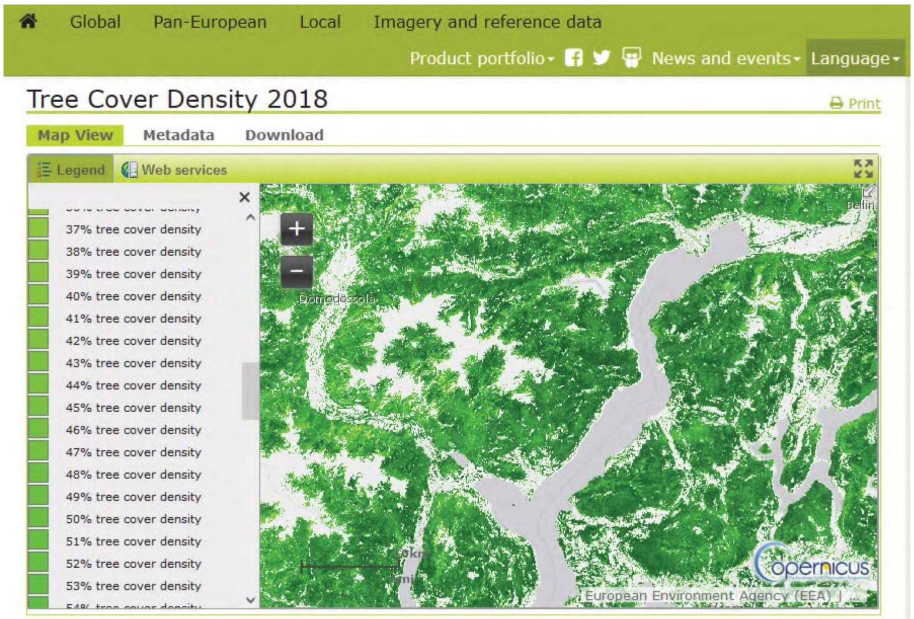
60 https://www.fs.fed.us/research/rpa/

The indicator on tree cover density measures the proportional forest crown coverage per grid cell at very high resolution of 10-m using satellite data.

Tree cover density describes the level of tree cover in a range from 0-100% on 10-m grid cells.

Units: Percent

Figure III-5 - Tree Cover Density in 2018



Time series

The muti-temporal character of the indicator facilitates monitoring and tracking changes of forest tree cover. So far, the indicator was produced for 2012, 2015 and 2018. In addition, a change product (tree cover change mask) showing gains, losses and stable tree cover is available for 2012-2015 and 2015-2018.

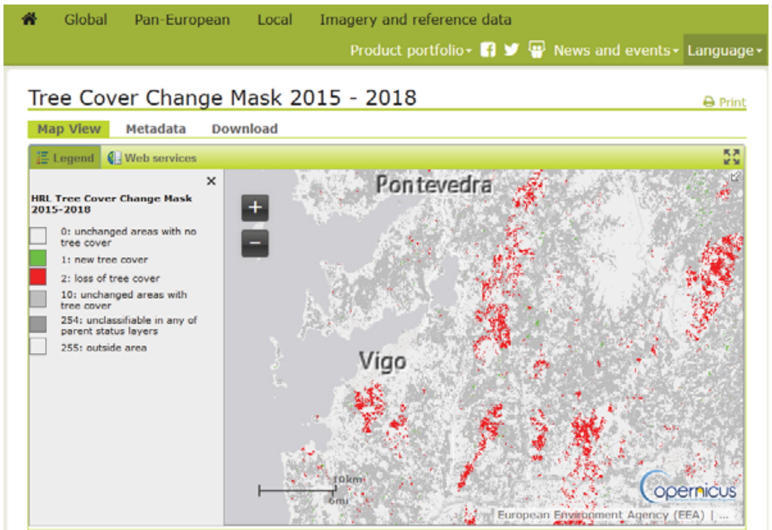
However, note that the tree cover change mask is a change product based on the binary tree cover masks of the primary status layers Dominant Leaf Type 2015 and 2018. Therefore, not derived directly from the data set of tree cover density.

Indicator key advantages

- Tree cover loss (a decrease in density) can be the result of natural and/or man-made pressures. While an increase in tree cover density is the result of e.g. planting or natural regeneration. That means that the indicator is sensible to the effects of pressures such as fires, storms, insect infestations and harvesting. But also to the effects of restoration e.g. tree planting.
- Considering the limitations of remotely sensed imagery small changes in tree cover density at grid cell level could be the results of e.g. calibration effects. Nevertheless, the data set is appropriate for describing stand replacement disturbances, which might affect e.g. a cluster of grid cells representing a forest stand, therefore resulting in a reduction of tree cover density.

- In addition to tree cover density data, Copernicus disseminate high resolution forest change products for 2012-2015 and 2015-2018. The tree cover change mask (TCCM) 2015-2018 is a change product based on the binary tree cover masks (TCMs) of the primary status layers Dominant Leaf Type 2015 at 20m spatial resolution and Dominant Leaf Type 2018 at 10m spatial resolution. The change maps describe four categories at 20-m grid cells:
    - Unchanged areas with no tree cover
    - New tree cover
    - Loss of tree cover
    - Unchanged areas with tree cover

Figure III-6 Tree Cover Change Mask 2015. Source: Copernicus



- The high-resolution forest change products could be used complementarily for assessing changes in tree cover.
- Tree cover density data can be used for mapping stand replacement disturbances, and new treed areas e.g. resulting from regeneration, using data for two years, e.g. 2015 vs 2018. The resulting map can be summarised in tabular form at country or sub-national level for accounting. Alternatively, the high resolution forest change products are readily available for tabular accounting tasks.

Source of data: Copernicus (HRL)[61]

Use and references of this indicator:
New data set (indicator) part of the Copernicus "Forests - high resolution layers".

Dead wood

Background

[61] Copernicus, tree cover density https://land.copernicus.eu/pan-european/high-resolution-layers/forests/tree-cover-density

The amount of dead wood as a critical environmental variable.

Dead wood is a crucial proxy for biodiversity, representing the substrate (material base) for a large number of animal and plant species[62].

- Certain forest species – for example, some fungi, mosses and insects – are dependent on the presence of dead wood in a forest;
- Dead wood serves as a living environment for several thousand species.
- In Europe, it has been estimated that 20-40% of forest species are dependent on dead or dying wood, at some point in their life cycle[63]. These are known as 'saproxylic' species.

From the ecological point of view, there are two major explanations for why an increase in the amount of dead wood increases the number and density of species and diversifies the species composition.

- First, higher amounts of available dead wood lead to more dead-wood surface area and higher resource availability[64]. According to the island theory, we can therefore expect a higher species number on sampling units with a larger ''island''[65]
- Secondly, larger surface areas lead to more different available habitats[66].

Dead wood also contributes to the decomposition and circulation of organic matter and to the structural stability of soils, carbon sequestration, nutrient supply and water retention[67].

Many studies have shown the importance of different types of dead wood, i.e., tree species, decomposition stage, diameter, etc[68,69]. A critical consideration of most of these studies as well as an analysis of data revealed that in most survey data sets, there is a clear correlation between the amount and the diversity of dead wood.

A wide variety of deadwood types (standing and lying deadwood species, size, saproxylation stage etc.) is necessary to host a wide variety of saproxylic species and promote biogeochemical cycles.

In consequence, an adequate level of deadwood is crucial for the functioning of forest ecosystems.

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[62] Maes et al, Mapping and Assessment of Ecosystems and their Services: An EU ecosystem assessment. EUR 30161 EN, Publications Office of the European Union, 2020. ISBN 978-92- 76-17833-0, doi:10.2760/757183, JRC120383.

[63] Bauhus, Baber and Müller, Deadwood in forest ecosystems, Ecology, Oxford bibliographies, 2018. doi: 10.1093/OBO/9780199830060-0196

[64] Raabe et al, Drivers of bryophyte diversity allow implications for forest management with a focus on climate change, Forest Ecology and Management, Volume 260, Issue 11, 2010. https://doi.org/10.1016/j.foreco.2010.08.042.

[65] MacArthur, Robert H., and Edward O. Wilson. The Theory of Island Biogeography: By Robert H. MacArthur and Edward O. Wilson. Princeton University Press, 1967.

[66] Boecklen, W., Effects of Habitat Heterogeneity on the Species-Area Relationships of Forest Birds, Journal of Biogeography, Vol. 13, No. 1 (Jan., 1986), pp. 59-68 (10 pages), 1986.

[67] Lachat et al, Deadwood: quantitative and qualitative requirements for the conservation of saproxylic biodiversity, in Managing Forest in Europe, 2013

[68] Similä et al, Saproxylic beetles in managed and seminatural Scots pine forests: quality of dead wood matters, Forest Ecology and Management, Volume 174, Issues 1–3, 2003, Pages 365-381.

[69] Heilmann-Clausen and Christensen, Does size matter?: On the importance of various dead wood fractions for fungal diversity in Danish beech forests, Forest Ecology and Management, Volume 201, Issue 1, 2004, Pages 105-117.

The state of saproxylic species

Regarding species associated to forest habitats, several species, in particular, species relying on mature forests and dead wood are under pressure.

- In Sweden, 69% of the red-listed forest insects are saproxylic species; on the other hand, more than 20% of long-horned beetle species have declined in abundance since the 1950s and 10% have become extinct in the last 200 years, linked to the development of intensive industrial forestry.
- In Finland, at least 2% of the national fauna has been driven to extinction since 1800, 20% of saproxylic beetles are currently red-listed, and the reduction of dead wood in forests is considered the dominant threat to 34% of these listed species.
- In France and Germany[70], the proportion of rare or threatened saproxylic beetles reaches 35%.
- The European Red List assessment of 653 of the best known saproxylic beetle species reports 17% endangered or vulnerable species.

Deadwood volume at country level

At country level, the amount of deadwood ranges from 5.6 to 33.1 m3 / ha, with an average value of 15.8 m3 /ha[71].

Deadwood is mostly present in Central Europe, particularly in Slovenia (more than 30 m3 ha−1), Germany (29.6 m3 /ha), Slovak Republic (27.3 m3/ ha), Latvia (26.4 m3/ ha), Austria (23.7 m3/ ha), and France (22.3 m3/ ha) but high values are found also in Cyprus (26.9 m3 ha−1) and Sweden (24.4 m3/ ha)[72,73].

Definition

- According to FAO-FRA (2020) deadwood is “all non-living woody biomass not contained in the litter, either standing, lying on the ground, or in the soil. Dead wood includes wood lying on the surface, dead roots, and stumps larger than or equal to 10 cm in diameter or any other diameter used by the country.”
- **EAA**[74]
- Terminology is well defined for international reporting by Forest Europe. Deadwood (coarse woody debris) as such, and the methodology for reporting its volume are thus defined according to Forest Europe standards.

Measurement units

Status: m3/ha or tonnes/ha - Changes: m3/ha/yr.

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70 Kohler, F. "Totholzkafer in Naturwaldzel-len des nordlichen Rheinlandes. Vergleich-ende Studien zur Totholzkdferfauna Deutsch-lands und deutschen Naturwaldforschung [Saproxylic Beetles in Nature Forests of the Northern Rhineland. Comparative Stud-ies on the Saproxylic Beetles of Germany and Contributions to German Nature For-est Research]. Recklinghausen: Landesamt Agrarordnung NRW. 351 pp." (2000).

71 Mean values of deadwood volume (m3 ha-1) and their 95% confidence interval estimates distinguished by Country and deadwood type (see the text for acronyms). From Puletti, N., Canullo, R., Mattioli, W. *et al.* A dataset of forest volume deadwood estimates for Europe. *Annals of Forest Science* **76,** 68 (2019). https://doi.org/10.1007/s13595-019-0832-0

72 EEA, Forest: deadwood (2017) https://www.eea.europa.eu/data-and-maps/indicators/forest-deadwood-1

73 Forest Europe https://foresteurope.org/deadwood-2/

74 Ibid 43.

Figures to be reported on

- Volume of dead standing trees (snags) and lying trees (logs) on forest area and other wooded land, classified by forest type.
- Minimum length and diameter of standing and lying dead trees: Length: 2 m.
- Diameter: It is up to the countries to define the minimum size of diameter to be reported. It is recommended that the minimum size be: Standing deadwood: 10 cm diameter at breast height/ Lying deadwood: 10 cm mean diameter.

Continuous improvement of methodology:

- On a national scale, the monitoring of deadwood is carried out in several National Forest Inventories (NFIs). Work towards the harmonisation of terminology is carried out by the COST E43 action. This comprises type classification (standing, bending, lying) as well as potentially important additional parameters (uprooted stems, clear-cuts stems, pieces of stems, cut branches, uprooted staves, logging residues, fine woody debris, intact snags, broken snags, broken, lying stems without uprooting). There are several approaches to register state of decay, most commonly this is classified in five classes.
- The EU forestry strategy 2021 has highlighted the need to better harmonize and improve NFIs. This should be the subject of a proposal in the Commission next year.

Sources

- NFIs,
- Annual report of emissions and absorptions associated with dead wood within the framework of decision 529/2013 (LULUCF decision), which has been replaced by LULUCF regulation 841/2018.
  - The EU National Inventory Report (NIR) contains a brief description of the methodologies implemented by each Member State[75]
  - The more general methodological framework is set by the 2006 IPCC guidelines: see section 2.3. of chapter 2 of volume 4 and section 4.2.2 of chapter 4 of volume 4.
  - This annual reporting does not mean that there is annual reported data. Most of the data sets used by the Member States come from national forest inventories (NFI), the frequency of which is generally 5 to 10 years. An interpolation is then performed from two measurement points in time to arrive at an annualized report.

Use and references of this indicator

Biodiversity Strategy, Green Deal, 8EAP, Forest Strategy, Forest Europe, FAO-FRA.

Soil organic carbon in forest (SOC)

Background

Forests play a key role in the global carbon cycle as they contain enormous quantities of organic carbon, most of which is stored in soil with a smaller part being held in vegetation. The storage and distribution of organic matter (thus SOC) in forest soils can be seen as an indicator of forest ecosystem health. At sites where coniferous forests prevail instead of natural broad-leaved or

[75] UNFCC, 2021 https://unfccc.int/documents/275968.

mixed forests, soil carbon stocks in the mineral soil are usually lowered compared to broad-leaved or mixed forests (while SOC in the forest floor is typically higher indicating reduced biological activity). Among others, this is because broad-leaved forests have higher above- and belowground biomass thus higher SOC stocks[76], while the quality of broad-leaved forest litter favors higher biological activity, bioturbation, and eventually higher SOC storage[77].

Case studies across Europe indicate that current soil carbon pools may be significantly reduced below their potential SOC storage capacity[78]. While this effect is in detail site-specific (thus: large variation across Europe), some general effects can be assumed to having caused extensive historic SOC losses in forests:

- the continued removal of forest biomass through harvesting has extracted biomass and nutrients leaving less residues for decomposition and organic matter stabilization;
- historic biomass extraction (woody debris collection, litter raking, plaggen, forest grazing, stump removal) has additionally degraded forest soils;
- higher temperatures after harvesting favour decomposition thus loss of topsoil carbon; losses are also triggered through erosion (loss of SOC-rich topsoils along skidding trails, and on clear cuts);
- the drainage of wet mineral and organic forest soils has caused SOC losses;
- the introduction of coniferous tree species at many sites (which are otherwise stocked with natural, site-adapted broad-leaved tree species) has introduced lower quality and acidic litter, which slows and shifts decomposition into the forest floor (reduced bioturbation, less stabilized SOC in the mineral soil);
- at loamy and silty sites, typically shallow-rooting Norway spruce has conditioned longer phases of stagnic water, reducing decomposition;
- extensive historic long-range deposition of acids has lowered forest biomass productivity, and has contributed to shift decomposition from the mineral soil into the forest floor

It can be concluded that the capacity of forests to store organic carbon is strongly influenced by management practices (species selection and regeneration method), but also through disturbances such as forest fires and storms. Historic management has contributed to SOC losses (in some cases these losses may have been masked by gains in the forest floor as a typical sign of forest soil biological degradation). Carbon in the forest floor is more labile to decomposition than in the mineral soil[79]. Nowadays, climate change and increased disturbances threaten this fragile equilibrium (losing the mostly labile carbon in the forest floor), as it can be observed at many plantations and regeneration systems which remove most of the canopy, and which introduce coniferous species where otherwise broad-leaved species would thrive.

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[76] Finér, Leena, et al. "Variation in fine root biomass of three European tree species: Beech (Fagus sylvatica L.), Norway spruce (Picea abies L. Karst.), and Scots pine (Pinus sylvestris L.)." Plant Biosystems 141.3 (2007): 394-405.

[77] Wellbrock, Nicole, and Andreas Bolte. Status and Dynamics of Forests in Germany: Results of the National Forest Monitoring. Springer Nature, 2019.

[78] Eg. Clarke, Nicholas, et al. "Influence of different tree-harvesting intensities on forest soil carbon stocks in boreal and northern temperate forest ecosystems." Forest Ecology and Management 351 (2015): 9-19.

[79] Crow, Susan E., et al. "Increased coniferous needle inputs accelerate decomposition of soil carbon in an old-growth forest." Forest Ecology and Management 258.10 (2009): 2224-2232.

The **protective role of forest soils to store water, carbon, nitrogen and nutrients, and to filter and buffer contaminants,** can be ensured through restoration of SOC-declined forest soils. Restauration involves site-specific silvicultural systems and nature-close forestry.
Some functions of SOC of intact and healthy forest ecosystems are mentioned:

- Nature close forests, showing optimal mineral soil carbon storage, accompanied with thin, biologically active forest floors, provide species-diverse ecosystems rich in ecological niches.
- Forests and ground vegetation in multi-layered, diverse forest ecosystems protect and stabilise soils by storing excess rain water, and by slowing down the lateral movement of water, soil and nutrients. These functions go parallel with replenished SOC pools and stable topsoils and soil structure, of particular importance in areas where landslides likely occur, and/or where floods are largely initiated.
- Naturally developed forest soils, including biologically active forest floors, offer a habitat for a large variety of decomposers and soil fauna[80], while holding a natural forest seed bank for forest regeneration.
- Forest soils, in particular organic soils, are the largest terrestrial carbon and nutrient reservoirs of managed terrestrial ecosystems.

Soil organic carbon (SOC) dynamics in forests depend on the amounts and quality of litter, climate and type and location of soil biological activity. Management activities can influence soil C stocks in forests by altering the rates of input or release of C from soils. In degraded forest ecosystems, a large proportion of decomposition and biological activity happens in the forest floor, accompanied by reduced bioturbation, and increase in fungal activity and reduced bacterial activity.

***Indicator**:* Change in forest SOC stock.

$\Delta SOC_{total} = SOC_{0\text{-}30} + SOC_{OF+OH\ horizons}$[81]

Description: Increase stock of $SOC_{0\text{-}30}$[82] in mineral soils while avoiding net loss of total forest SOC stock [t/ha/yr]

***Source*:** Forest SOC change is a subindicator of Forest Europe's Indicator 2.2 Soil condition (currently only mineral soil) as well as reported by countries in their annual greenhouse gas inventories (for soil as well as forest floor humus horizons[11]).
Data from LUCAS Soil, ICP Forests.

***Methodology*:**

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[80] Hale, Cindy M., et al. "Effects of European earthworm invasion on soil characteristics in northern hardwood forests of Minnesota, USA." Ecosystems 8.8 (2005): 911-927.

[81] The organic layer in aerated (vs. water logged) conditions may consist of one or more of the following organic subhorizons: litter (OL), fragmentation horizon (OF) and/or humus (OH) (UNECE 2020). IPCC (2006) distinguishes 5 terrestrial carbon pools, among them 'litter' and 'soil'. Countries allocate carbon stocks differently to these pools: in some cases, OF and OH horizons are reported under the 'soil' pool, in other cases part of 'litter'. In some cases, litter (defined fine woody debris, dead leaves and needles in the OL horizon) is part of the 'dead wood' pool. Several countries assume certain pools are not changing, thus do not report; in other cases, global default values are use, in others country-specific data.

[82] In forest soils, a subdivision of topsoil sampling depths is advisable. Also, ICP Forests soil sampling foresees monitoring below 30, because some SOC lost from the topsoil may be found at lower depths.

Based on IPCC (2006), methods that are available to use and evaluate the national forest soil monitoring data in order to develop country-specific data, applying a standardized soil depth 30 cm, while it is good practice to also cover lower soil depths.

In UNFCCC reporting, there is often confusion whether all forest floor horizons are counted towards the 'litter' pool. Strictly following soil nomenclatures, litter represents only the hardly decomposed top horizon of the forest floor (OL). Because OL is difficult to sample and because it has very high spatial and temporal variability, the OL horizon is excluded here[83].

Countries have conducted two consecutive forest soil surveys in a European sampling grid, called ICP Forests Level I (the second survey has been conducted in the BioSoil project under the Forest Focus Regulation). National surveys were conducted 1986-1996, and 2004-2008. The primary objective of the BioSoil project was to improved member states' UNFCCC reporting.

A subsample of the ICP Forests soil monitoring is used to report under the NEC Directive Art 9, and a monitoring exchange mechanism has been established.

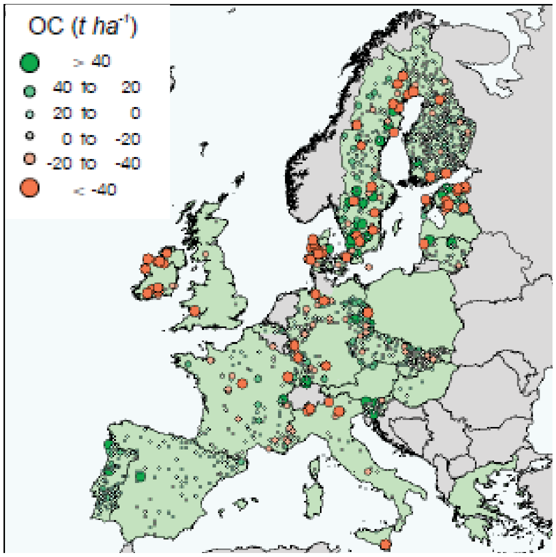
Considering also the developments of LUCAS Soil (see below) and the continued discussion in the ICP Forests Soil Expert Panel, in conclusion, countries are prepared to engage in further forest soil surveys while they have continued to improve their survey manuals and analytical comparability.

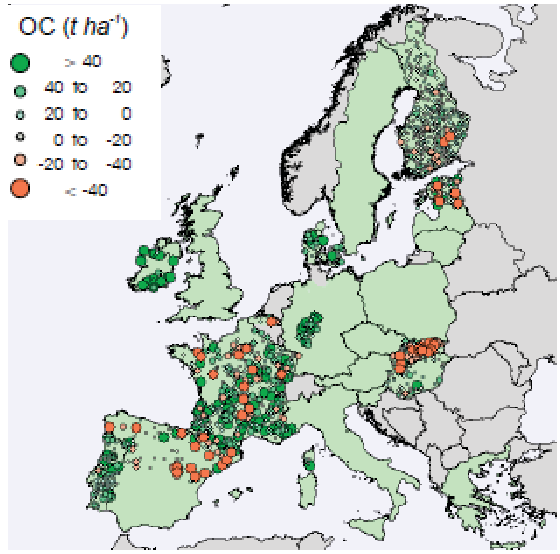
Time series:

- Multidate data are available based on LUCAS Soil and the UNECE ICP Forests Programme.
- LUCAS data are field observations of forest topsoils (0-20 cm, starting 2022: 0-30 cm), which are collected every 3-4 years for all Member States.
- Data exist for 2009, 2015 and 2018.
- The next LUCAS sampling will take place in 2022 has been designed to provide statistically robust assessments of soil carbon stocks for forests at NUTS 0 Level.

Figure III-7 - Change in organic carbon stock between 1996 and 2006 (t ha-1): organic layers OF+OH (left) and mineral soil 0-20 cm. Source: Hiederer 2011

[83] it is also not mandatory in the International Co-operative Programme on Assessment and Monitoring of Air Pollution Effects on Forests (ICP Forests) manual





Proposal for a period of assessment:
Changes of SOC stocks in the mineral soil are generally slow with significant change expected over a decade. Robust evidence exists to show that forest management practices have an impact (both positive and negative on SOC stocks). This means that a 'proxy indicator' could be used to show potential change based on the adoption of specific practices on a more frequent basis but a LUCAS-style verification campaign should be considered every 10 years.

Improvements of the UNFCCC reporting towards the so-called Tier 3 quality standard, and considering developments in research and monitoring, soil modelling in combination with field surveys seem to be very successful in order to extrapolate between longer return intervals of field sampling. Modelling also allows to connect data from sampling grids to management practices.

Use and references of this indicator:
LULUCF, UNFCCC, SDG, Forest Europe, ICP Forests, to some degree also for Member States to report on NEC Art. 9.

Common Forest Bird indicator

Background

The association between avifauna and the ecological condition of ecosystems, and biodiversity, is described in a robust body of scientific evidence[84].

Declines in global biodiversity levels are the result of the interactions of pressures with the multifaceted nature of biodiversity. Different indicators describe different dimensions of biodiversity. This further increases the need for extensive biota data for monitoring, which in this case can support annual tracking of changes as well as long-term monitoring of common forest birds.

[84] https://pecbms.info/use-of-the-results/publications

Common forest birds are proxies of the ecological condition and extent of forest ecosystems. Monitoring is a critical requirement in assessing the environmental policy process and effectiveness of various conservation measures.

- The abundance of species at a local scale in forests is largely dependent on the local forest structures[85,86,87]. However, the surrounding landscape may influence the local abundance of the species, due to e.g. spill-over of individuals from neighbouring patches[88].
- The patchiness of a specific habitat type in the landscape influences the distribution of a given species[89,90], and eventually, the species diversity of a given site[91,92].
- The landscape context can also influence the relative abundance of specialist and generalist species, altering species composition[93]. The amount of habitat in the landscape may affect species composition, as species have different habitat requirements, especially in relation to habitat area[94].
- A reduced habitat area means also an increase in edge-area ratio with potentially negative consequences – generally referred to as 'edge effects' - for habitat specialist bird populations[95,96]. In contrast, in forested areas, open habitat, edge and early-successional species might take advantage of altered habitats, depending on their traits[97,98].

According to European Bird Census Council[99] (EBCC), there are some likely drivers explaining changes in the forest bird indicator. There is growing evidence that specialist species' populations decline at faster rates compared to generalist species due to land-use change and habitat degradation[100]. The declines observed in some EU regions, specifically in North and South Europe, could be the result of changes in forest area, forest composition, forest age and structure. These factors influence bird community composition and species trends, both positively and negatively depending on the species[101,102]. There is evidence that some forest

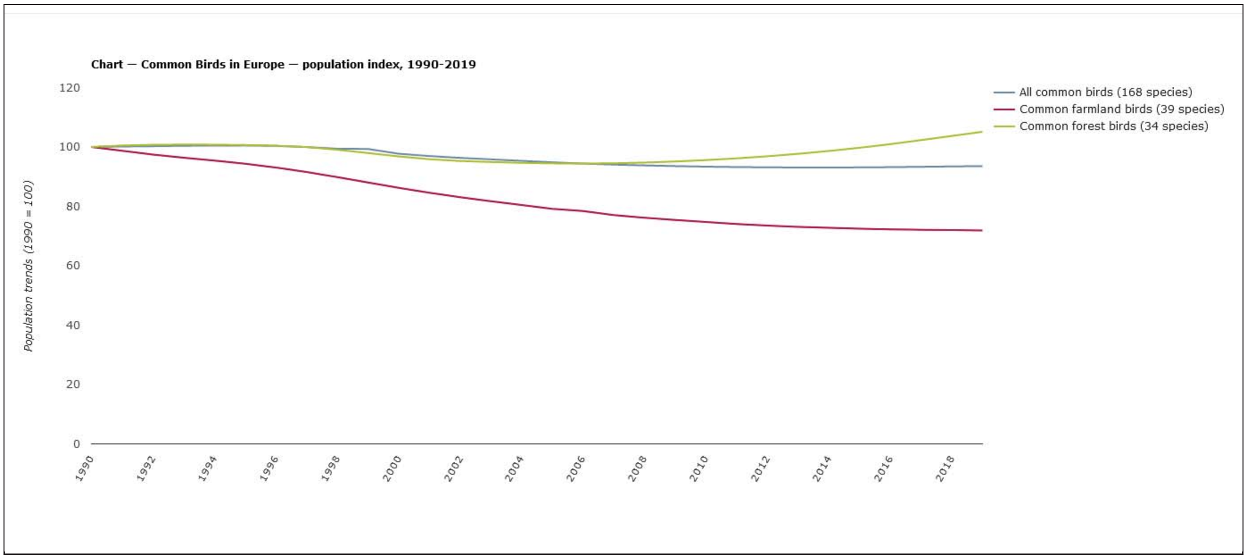
[85] Balestrieri, Rosario, et al. "A guild-based approach to assessing the influence of beech forest structure on bird communities." Forest Ecology and Management 356 (2015): 216-223.
[86] Czeszczewik, Dorota, et al. "Effects of forest management on bird assemblages in the Bialowieza Forest, Poland." iForest-Biogeosciences and Forestry 8.3 (2015): 377.
[87] Díaz, Iván A., et al. "Linking forest structure and composition: avian diversity in successional forests of Chiloé Island, Chile." Biological conservation 123.1 (2005): 91-101.
[88] Ludwig, Martin, et al. "Landscape-moderated bird nest predation in hedges and forest edges." Acta Oecologica 45 (2012): 50-56.
[89] Basile, Marco, et al. "Patchiness of forest landscape can predict species distribution better than abundance: the case of a forest-dwelling passerine, the short-toed treecreeper, in central Italy." PeerJ 4 (2016): e2398.
[90] Hofmeister, Jeňýk, et al. "Spatial distribution of bird communities in small forest fragments in central Europe in relation to distance to the forest edge, fragment size and type of forest." Forest Ecology and Management 401 (2017): 255-263.
[91] Koivula, Matti J., et al. "Breeding bird species diversity across gradients of land use from forest to agriculture in Europe." Ecography 41.8 (2018): 1331-1344.
[92] Roth, Roland R. "Spatial heterogeneity and bird species diversity." Ecology 57.4 (1976): 773-782.
[93] Uezu, Alexandre, and Jean Paul Metzger. "Vanishing bird species in the Atlantic Forest: relative importance of landscape configuration, forest structure and species characteristics." Biodiversity and Conservation 20.14 (2011): 3627-3643.
[94] Devictor, Vincent, Romain Julliard, and Frédéric Jiguet. "Distribution of specialist and generalist species along spatial gradients of habitat disturbance and fragmentation." Oikos 117.4 (2008): 507-514.
[95] Andren, Henrik, and Per Angelstam. "Elevated predation rates as an edge effect in habitat islands: experimental evidence." Ecology 69.2 (1988): 544-547.
[96] Donovan, Therese M., et al. "Variation in local‐ scale edge effects: mechanisms and landscape context." Ecology 78.7 (1997): 2064-2075.
[97] Borchtchevski, Vladimir G., et al. "Does fragmentation by logging reduce grouse reproductive success in boreal forests?." Wildlife biology 9.4 (2003): 275-282.
[98] Jasińska, Karolina D., et al. "Linking habitat composition, local population densities and traffic characteristics to spatial patterns of ungulate-train collisions." Journal of Applied Ecology 56.12 (2019): 2630-2640.
[99] https://www.ebcc.info/
[100] Filippi-Codaccioni, Ondine, et al. "Toward more concern for specialisation and less for species diversity in conserving farmland biodiversity." Biological Conservation 143.6 (2010): 1493-1500.
[101] Gregory, Richard D., et al. "Population trends of widespread woodland birds in Europe." Ibis 149 (2007): 78-97.

specialists, particularly birds associated with old-growth stands, have declined and are threatened by intensive forest use.

Indicators on common forest birds from PECBMS are used in many EU policy initiatives, some examples are in available on the EBCC website[103].

Between 1990 and 2019, there was a decrease of 14% in the index of common birds across the 25 EU Member States with bird population monitoring schemes. The common forest bird index decreased by 5% in the EU[104]

Figure III-8: Common birds in Europe – population index, 1990-2019. Source: EEA



Description:

This indicator shows trends in the abundance of common forest birds[105] across their European ranges over time. It is a composite index created from data of bird species characteristic for forest habitats in Europe.

Source:

The indicator is provided by the Pan-European Common Bird Monitoring Scheme[106], which is a joint initiative of EBCC and BirdLife International.

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102 Gregory, Richard D., et al. "An analysis of trends, uncertainty and species selection shows contrasting trends of widespread forest and farmland birds in Europe." Ecological Indicators 103 (2019): 676-687.

103 https://pecbms.info/use-of-the-results/policy/

104 EEA, Chart — Common Birds in Europe — population index, 1990-2019. https://www.eea.europa.eu/data-and-maps/daviz/common-birds-in-europe-population#tab-chart_1

105 The list of birds species in the Common forest bird indicator:
Accipiter nisus ; Anthus trivialis ; Bombycilla garrulus ; Bonasa bonasia ; Carduelis citrinella ; Certhia brachydactyla ; Certhia familiaris ; Coccothraustes coccothraustes ; Columba oenas; Cyanopica cyanus; Dryobates minor; Dryocopus martius; Emberiza rustica; Ficedula albicollis; Ficedula hypoleuca; Garrulus glandarius; Leiopicus medius; Lophophanes cristatus; Nucifraga caryocatactes; Periparus ater; Phoenicurus phoenicurus; Phylloscopus bonelli ; Phylloscopus collybita ; Phylloscopus sibilatrix ; Picus canus ; Poecile montanus ; Poecile palustris ; Pyrrhula pyrrhula ; Regulus ignicapilla ; Regulus regulus ; Sitta europaea ; Spinus spinus ; Tringa ochropus ; Turdus viscivorus.

106 PECBMS https://pecbms.info/

The main aim of PECBMS is to use common birds as indicators of the general state of nature using large-scale and long-term monitoring data on changes in breeding populations across Europe.

PECBMS has developed statistical methods to calculate supranational, multi-species indices using population data from national annual breeding bird surveys in Europe[107,108]. Skilled volunteers using standardized field methods undertake data collection where methods and survey designs differ slightly across countries. Survey plots tend to be widely distributed at a national level, covering many bird species and habitats with reasonable representation. National species' indices are calculated using log-linear regression, which allows for plot turnover. Supranational species' indices are constructed by combining the national species' indices weighted by the national population sizes of each species. Supranational, multi-species indicators are calculated by averaging the resulting indices.

These indices support EU biodiversity targets across national, regional, and European spatial scales[109,110], and can be used to monitor the effects of management practices on bird species[111,112].

Forest habitats differ across the European regions as well as the bird communities there. Therefore, the indicator is also produced at a regional (supranational) level and different regions show different trends of their respective common forest birds. It is recommended to use region/national specific species selection for the forest bird indicator to better reflect the differences between regions and countries.

To be noted, that a current work[113] is carried out to fine-tune the selection of species that will contribute to the indicator.

Time series:
A value of 100 is set for each species in the first year of the time series. The time-series covers the period 1980-2019, though it is usually assessed from 1990.

PECBMS produces European and EU indicators with 2-year delay. So, the 2021 update is based on data covering the period 1980–2019. Data for the current year are updated from the data provided by the MS in year N-2.

[107] Gregory, Richard D., et al. "Developing indicators for European birds." Philosophical Transactions of the Royal Society B: Biological Sciences 360.1454 (2005): 269-288.
[108] Devictor, Vincent, et al. "Differences in the climatic debts of birds and butterflies at a continental scale." Nature climate change 2.2 (2012): 121-124.
[109] EEA 2012
[110] Fraixedas, Sara, et al. "A state-of-the-art review on birds as indicators of biodiversity: Advances, challenges, and future directions." Ecological Indicators 118 (2020): 106728.
[111] Tisseuil, Clément, et al. "Strengthening the link between climate, hydrological and species distribution modeling to assess the impacts of climate change on freshwater biodiversity." Science of the total environment 424 (2012): 193-201.
[112] Gamero, Anna, et al. "Tracking progress toward EU biodiversity strategy targets: EU policy effects in preserving its common farmland birds." *Conservation Letters* 10.4 (2017): 395-402.
[113] quantifying species' association with and degree of specialization for different habitat types: technical and scientific support in relation to the delivery and development of wild bird indicators for the EU

However, the individual MS vary in national forest bird indicators production – some may publish the data until the current year already in the end of the given year. In near future, PECBMS aims to speed up the European indicators production, to 1-year delay.

Overall analysis of the indicators

A. Environmental impacts

Age structure - share of uneven-aged structure

Uneven-aged forests exhibit more structural diversity. In turn, structural diversity of forest is typically associated with higher levels of biodiversity, enhanced services and tree productivity, with research showing the positive effects of structural diversity on forest productivity and ecosystem dynamics[114].

The variety of stand strata allows the multiplication of habitats for a wide variety of species. It can be appreciated in a horizontal dimension (juxtaposition of homogeneous patches of vegetation) or vertical dimension (superimposition of vegetation strata of different sizes, also called "stratification").

Stratification is a crucial component of the habitat of forest species. The diversity of structures on a fine scale allows, on the one hand, the accommodation of a great diversity of species with varied requirements due to the juxtaposition and superimposition of different strata, and on the other hand, facilitates recolonization by species with low dispersal capacity, due to the proximity of similar strata.

Forest connectivity

Spatially explicit maps of forest connectivity are key elements for the assessment of forest biodiversity, habitat quality and ecosystem integrity.

- Forests and woody vegetation in other wooded land, thanks to their longevity, structural complexity and special microclimate, represent habitat for many plant and animal species. Often diversified vertical structure and plant species mixture form an environment for the survival of diverse animal species.
- Forests and woody vegetation formations form stabilizing landscape elements, especially in highly populated areas characterized by intensively managed anthropic landscape features with limited conditions for survival of many species.

The overall interest to manage land in a sustainable manner has led to the development of regional concept of SFM within MCPFE process[115]. Implementation of SFM is monitored by a

[114]Dănescu, Adrian, Axel T. Albrecht, and Jürgen Bauhus. "Structural diversity promotes productivity of mixed, uneven-aged forests in southwestern Germany." Oecologia 182.2 (2016): 319-333. https://link.springer.com/article/10.1007/s00442-016-3623-4

[115] FOREST EUROPE 2019. Pilot study: Forest Fragmentation Indicator, by Raši, R. & Schwarz, M., Liaison Unit Bratislava, Zvolen, 2019 https://foresteurope.org/wp-content/uploads/2016/08/Pilot-study-Fragmentation.pdf

set of regularly revised indicators for SFM, covering relevant issues of sustainability in forest management.

Moreover, locating and quantifying changes in forest connectivity allows for monitoring progress in policy directives (NRL, 8EAP, Green Deal, Biodiversity Strategy, Forest Strategy, 3 billion trees, SDG15 “Life on Land”) and improving forest ecosystem health by mitigating forest risks.

Tree cover density

Tree cover density is a synthetic indicator describing changes in the structure of forest ecosystems. Which in turn affect the delivery of key ecosystem services, including habitat for biodiversity, climate regulation, carbon storage and water supply, among other.

Continued tree cover loss over time will likely result in forest degradation and fragmentation. In addition, it is desirable that tree cover losses should be minor, or at least equal, than gains in the long term in order not to decrease the area covered by trees. Similarly, a large turnover of gain and losses will result in young forest stands unable to provide yet the full range of ecosystems services.

Consistent wall-to-wall information of tree cover density is useful for early detection of degradation trends. The baseline data of this indicator is updated every 3 years, which is a frequency higher than that of the information provided by National Forest Inventories (usually every five years).

In the environmental perspective:

- Increasing tree cover density in degraded or disturbed forest will result in improving overall ecological condition. Thus restabilising forest services and appropriate biodiversity levels.
- a healthy forest is one that is in a succession stage at which trees’ canopy is multi-layered and uneven-aged (see age –structure indicator); the forest is a combination of large living trees as well as decayed trees that provide a fundamental habitat for animals and micro-organisms[116]. These features are often observed in forest with high structural, functional and compositional diversity, that is, forest approaching an optimum ecological state.

The density of trees is a key trait of the structural configuration of forests. Tree cover density is associated with high levels of biomass, ecosystem productivity, soil protection, carbon sinks and other ecosystem functions. Maintaining appropriate levels of tree cover density is key for forest with a robust structural component, which can underpin functional and compositional traits at adequate levels. In contrast, a persistent reduction of tree cover density over long periods might be associated with overuse, tree defoliation and mortality, the effects of climate change-induced drought or other degrading processes.

[116] Kimmins, James Peter. "Forest ecology." *Fishes and forestry: Worldwide watershed interactions and management* (2004): 17-43.

Monitoring tree cover density periodically offers the possibility of tracking changes at local level, but also and more importantly, at forest and landscape level, where major degrading macro-processes can be detected using remote sensing technology.

Other references are available on tree cover density[117].

Dead wood

The volume of deadwood in intensively managed forests is under 10% of that in comparable types of natural forests[118]. Forest-dependent insects, mammals, non-vascular plants and breeding birds are heavily affected by an excessive removal of dead and old trees or the reduction of old-growth forests.

A meta study summarising the characteristics and results of 37 studies investigating threshold values of the occurrence or number of species in relation to dead-wood volume has been conducted on dead-wood threshold data from European forests and revealed 36 critical values with ranges of 10–80 m3/ ha for boreal and lowland forests and 10–150 m3 ha-1 for mixed-montane forests, with peak values at 20–30 m3 /ha for boreal coniferous forests, 30–40 m3/ ha for mixed montane forests, and 30–50 m3 /ha for lowland oak–beech forests.

Recommendation regarding dead wood threshold to make current wood-production practices in beech forests throughout Europe more conservation oriented (i.e., promoting biodiversity and ecosystem functioning): on the basis of studies' results , recommendations lead to increasing the amount of dead wood to >20 m3/ha; not removing dead wood of large diameter (50 cm) and allowing more dead wood in advanced stages of decomposition to develop and designating strict forest reserves, with their exceptionally high amounts of dead wood, that would serve as refuges for and sources of saproxylic habitat specialists.

Soil organic carbon in forest - SOC

Overall: the current levels of SOC in mineral soils are lowered (degraded) as a result of many forest operations/sylviculture. Mayer et al (2020)[119] showed that:

- Afforestation of former croplands increases soil C stocks, but stocks are unchanged or reduced in former grasslands and peatlands.
- Removal of biomass through harvesting, herbivory or removal of residue or fuelwood reduce soil C stocks, in accordance with the intensity of removal.
- Nitrogen addition through fertilization or inclusion of N-fixing plants consistently increases soil C stocks across a wide range of forest ecosystems.
- Tree species identity has a stronger impact on soil C stocks than tree species diversity.
- Stand density management and thinning have small effects on forest soil C stocks.

[117] Ibid 99

[118] Stokland, Jogeir N., Juha Siitonen, and Bengt Gunnar Jonsson. *Biodiversity in dead wood*. Cambridge university press, 2012.

[119] Mayer, Mathias, et al. "Tamm Review: Influence of forest management activities on soil organic carbon stocks: A knowledge synthesis." *Forest Ecology and Management* 466 (2020): 118127.

- Often artificially thick forest floors have been built. This soil carbon pool is very sensitive to climate change and other disturbances (e.g. fires).

Restorative forest management has the objective to transform current plantations towards nature-close, stable and resilient forests – with the effect that SOC in the mineral soil increases (increased root biomass and turnover in the mineral soils (less rooting in the forest floor), while decomposition occurs in the mineral soil rather than in the forest floor – leading to thinner litter layers thus less carbon stored in them (improved humus forms indicate improved soil biological activity).

The protective role of forest soils needs to be expanded to soils at risk of instability (steep shallow mountain soils, river plains, coastal soils and dunes, organic soils under agricultural management, but also peat protection (conservation function of forested wetlands).

Targeted and continued sustainable soil management practices can significantly help in achieving climate neutrality by increasing the carbon stocked in mineral soils. Achieving net-zero greenhouse gas emissions by 2050 relies also on carbon removals through the restoration and better management of soils to store the atmospheric CO2. Healthy forest soils will also make the EU more resilient to weather extremes and reduce its vulnerability to climate change (e.g. increased water retention reduces food peaks while mitigating drought conditions).

The banking and financial sector is increasingly interested in investing in those land owners who apply sustainable practices and increase soil carbon, as well as creating market-based incentives for carbon storage. There is evidence that carbon farming (agro-forestry and forestry) can contribute significantly to the EU's efforts to tackle climate change but also brings other co-benefits such as increased biodiversity and the preservation of ecosystems.

Given the crucial role of soil in the water cycle, it is also indispensable for climate adaptation. A high water retention capacity in soils reduces the effects of flood peaks and decreases the negative impact of droughts. Carbon content in soil is to a large extent a biological process so it is not surprising that higher levels of (retention is conditioned by soil texture). Increased soil carbon levels in mineral improves soil condition by supporting aggregate formation that in turn improves soil structure, a key factor that governs water and gas movement within soils as well as providing an improved habitat for soil organisms. In parallel, increased levels of organic matter provide the energy sources for soil-dwelling organisms, and thus underpinning the soil-food web, which in turn, is linked to higher soil biodiversity levels.

B. Socio-Economic Impacts

A short analysis of the different socio-economic impacts has been carried out for the following indicators:

Age structure - share of uneven-aged structure:
Changes in forest management practices oriented to increase the share of uneven-aged forests may have effects on wood production. For instance, more intense forest management approaches would have to face a reduction in the area of even-aged stands, which can influence forestry

decisions and wood production. This suggests in practice a shift from more intense forest management approaches to less intense approaches e.g. close-to-nature forestry, which often uses un-even aged stands in the wood production management.

An increased share of un-even aged stands would result in a richer structural diversity, which with time and appropriate management will result in forests with more compositional and functional diversity, hence in an improved forest condition. However, there might be a trade-off between wood production versus good ecological condition, richer biodiversity and other ecosystem services.

In sustainable forestry, forests should produce multiple ecosystem services for society, such as timber, carbon sequestration and biodiversity. Therefore, in the evaluation of forest management strategies, we have to consider the impacts of management on several ecosystem services. A recent study[120] compared the effects of five different forest management strategies on timber drain, carbon stocks, carbon balance and biodiversity indicators, while maximising economic revenues from timber production. The assessment was carried out in a boreal landscape of 43 000 ha over a 100-year calculation period and supports the finding that any-aged (forest management in which no explicit choice is made between even- and uneven-aged management) and continuous cover forestry is best in terms of carbon sequestration and biodiversity indicators. In general, management strategies that used thinning from above and that were not restricted to rotation forest management as the only option provided more ecosystem services and were also economically profitable.

A clear conclusion from this study is that more varied management strategies that include the combined use of continuous cover and rotation forestry have a greater potential to produce simultaneously multiple benefits from forests at the landscape level, while still being economically profitable. In this sense, it is important to diversify management strategies in order to satisfy the increasing and variable future demands for multiple forest use

Dead wood

The cost of deadwood enrichment strategy (and integrative management approach) management can be determined from reduced revenue and additional expenditures.

The case study of the Ebrach Forest[121] - Germany - shows that these approaches do not radically change overall economic viability, since many measures of benefit ecologically also economic benefits. Overall the Erbrach study shows that a forest deadwood enrichment strategy by only harvesting sawn wood (and to a minor degree industrial timber) and leaving the complete tree crowns on site can be economically efficient. This case study can serve as a good practice example for integrative forest management where biodiversity conservation, timber production, and many other ecosystem services are managed in an optimised way. Considering the scenarios of increasing pressure on wood resources in Europe because of increasing wood demand, it is

[120] Díaz-Yáñez, O., Pukkala, T., Packalen, P. and Peltola, H., 2019. Multifunctional comparison of different management strategies in boreal forests. Forestry: An International Journal of Forest Research

[121] U. Mergner1, D. Kraus - Ebrach – Learning from nature: Integrative forest management

crucial to ensure that quality and efficiency of biodiversity enhancement in forest management is equally given priority, and these studies show that this is economically feasible.

Furthermore, a further a more recent study conducted in Ebrach's forest showed that the Total Economic Value (TEV) provided by all ecosystem services far exceeds the income from timber[122]: on average, an annual profit of approximately € 1 million is generated from forest management. Around 67 €/ m³ is the average income from timber. This underlines the multi-benefit management of forests has even further economic potential.

Conclusions on indicators

The purpose has been to examine and justify what indicators that demonstrate the enhancement of biodiversity in forest ecosystems could be considered for inclusion in the legal proposal. To this end, a number of potential indicators were first identified and a set of criteria were developed to select the most promising. From the original broad set of indicators a set of six were identified as the most adequate. This was followed by an assessment of the environmental and socio-economic impacts that increases in some of these indicators would entail.

The indicators selected and analysed each constitute different ways of representing the enhancement of biodiversity in forests ecosystems. They focus on either on key indicator species (such as forest birds) or aspects of the habitats themselves (such as the age structure of a forest, or presence of deadwood) and are the most frequently used tool to monitor the status of biodiversity, changes to biodiversity, and the effects of management actions. In this way, together, the indicators provide complementary information on the presence of biodiversity in relation to the forest structural diversity, habitat provisioning, and forest matrix connectivity.

The increased ecological benefits also entail the improvement of the delivery of a range of forest ecosystem services, a number of which can contribute to direct economic benefits. An assessment by EUROSTAT of the value of ecosystem services of forest in good ecological condition indicates that the value of only four ecosystem services (carbon sequestration, flood control, water purification and nature-based recreation)[123] is 4.5 times the value of timber provision). Moreover, based on annually updated work from the Office for National Statistics (ONS), UK the annual value of woodland ecosystem services in England is estimated to be £1.6 billion in 2017, representing *50%* of the annual value for UK woodlands as a whole[124]. The ecosystem services included carbon sequestration, pollution removal, noise reduction and recreational and cultural services. To provide such services effectively forest ecosystems need to be in good health. Furthermore, some of the other studies in the previous section showed that showed that multiple-service benefit forest management is economically feasible, and in the future may have even more economic potential. Thus, increases in the values of the set of

[122] Stößel, Laura, et al. "Analysing wind and biomass electricity potential in rural Germany considering local demand in 15-minute intervals." *Wind Energy Science Discussions* (2019): 1-16.

[123] European Commission, Measuring what ecosystems do for us: new report on ecosystem services in the EU, 2021 https://ec.europa.eu/environment/news/measuring-what-ecosystems-do-us-new-report-ecosystem-services-eu-2021-06-25_en

[124] UK Office for National Statistics: Overall quantity and value of UK woodland https://www.ons.gov.uk/economy/environmentalaccounts/bulletins/woodlandnaturalcapitalaccountsuk/ecosystemservicesforenglandscotlandwalesandnorthernireland2020#overall-quantity-and-value-of-uk-woodland

indicators considered in this analysis would also would have the effect of providing a range of socio-economic benefits associated with these forest ecosystem services.

In summary, the indicators considered in this assessment, such as forest birds or dead wood or tree density, provide a robust set of indicators that describe biodiversity in forests ecosystems in a holistic and complementary manner. Overall, there is evidence to conclude that introducing an obligation for Member States to provide evidence of increasing trends for the set of indicators analysed, that describe enhancement of biodiversity, would provide overall benefits to the environment, society and the economy.

4. Agro-ecosystems

4.1 Scope

Agro-ecosystems include all grasslands and some other seminatural habitats that are usually grazed by livestock and/or used for other agricultural / silvi-cultural purposes, as well as all croplands including arable, vegetable, fruit and other permanent crops. These ecosystems are divided into the following:

- **Natural and semi-natural agricultural habitats (many of which are listed in Annex I of the Habitats Directive)**
  - Natural habitats: permanent grasslands, shrublands and other habitats that are extensively grazed, but are not dependent on grazing for maintenance and have not been significantly changed by livestock grazing or other human activities.
  - Semi-natural habitats: vegetation and associated species that have not been planted and are dominated by native species, but are the result of human activities, for example woodland clearance, grazing and burning. These include:
    - Grassland and shrubland pastures that are dependent on livestock grazing for their maintenance; and
    - Meadows that are dependent on mowing (usually for hay) for their maintenance, although they may also be grazed at some times of year.
- **Agriculturally improved grasslands and croplands**
  - Agriculturally improved grasslands, which have been modified to increase their agricultural productivity such as through drainage, use of artificial fertilizers, and ploughing and reseeding.
  - Cultivated croplands, including ploughed and sown artificial temporary grasslands which are often converted from permanent grasslands. Most cultivated and permanent croplands in Europe are currently intensively managed, but some extensive cereals (for example on poor soils, dry, saline or waterlogged areas, or in remote locations) and old traditionally managed orchards have semi-natural elements and are richer in biodiversity.

Natural and semi-natural agro-ecosystems include 35 Habitats Directive (HD) Annex I habitat types, hereafter referred to as HD Annex I agricultural habitats. These 35 HD Annex I agricultural habitat types cover close to **177 442 km^2** (**4.5 %** of the EU terrestrial area[125]); this excludes areas reported by Romania, which are known to be largely overestimated[126]. The area of natural and semi-natural agricultural habitats not covered by HD Annex I habitats is not known, as they have not been defined and mapped. According to Corine Land Cover data the total area of agro-ecosystems in the EU was 2 096 616 km^2 in 2018 (48 % of the EU terrestrial area). Whilst the Annex I data and Corine data are not directly comparable, they suggest that approximately **1.9 million km^2** are non-Annex I agricultural habitats. Although the exact

[125] Area of habitats calculated from the area reported by Member States as 'best estimate' or 'average of minimum/maximum'.
[126] The average total area of agri-habitats and grasslands habitats reported by Romania is 54 124 km^2.

proportion is not known, the vast majority comprises agriculturally improved grasslands and croplands.

This impact assessment also considers EU protected species that are associated with the agro-ecosystems. These include 123 bird species that breed or winter in grasslands and croplands, and 328 species listed in the HD Annexes II, IV or V, for which grasslands or croplands are a preferred habitat.

In addition, actions are considered for **agricultural areas in addition to those covered by the Annex I habitats types under the Habitats Directive**; see section 4.6.

A target on **rewetting drained organic soils/peatland under agricultural use (both grasslands and cropland)** is considered and analysed in the section on **soils**.

Detailed data on the geographical distribution, area (km²), conservation status and condition of agricultural habitat types of Annex I of the Habitats Directive in EU Member States is provided in Annex VIII-c.

4.2 Problem, current trends and ecosystem-specific baseline

Natural and semi-natural agro-ecosystems are of very high biodiversity importance in the EU for several reasons. Firstly, some extensive pastoral systems and traditional agroforestry systems are of high conservation and scientific interest as to some extent they mimic natural grassland ecosystems that were formerly present in some regions and maintained by wild native herbivores. Many semi-natural ecosystems and associated landscapes are also highly species rich. As a result of their high biodiversity value, and because many are now scarce and/or declining, many natural and semi-natural agricultural habitats in the EU are listed in HD Annex I, and a high proportion of associated species are listed in HD Annex II or Birds Directive Annex I. More than a quarter of habitats of European importance depend either fully or partially on extensive agriculture, including numerous species of flora and fauna[127], such as farmland birds. Increasingly, the EU's Common Agricultural Policy incentivises extensive farming practices, as illustrated by the CAP indicators related to agroforestry[128].

In addition to their fundamental role in providing food, and other products, some agro-ecosystems, especially grasslands and pastoral woodlands, are important for several other ecosystem services. Of these, carbon sequestration and storage and water retention (providing water supply and flood alleviation benefits) are the most important. Others are related to semi-natural landscapes that are of considerable cultural, historic and aesthetic value, as well as to the opportunities for recreation, sport, science and education.

[127] Halada, L., Evans, D., Romão, C., and Petersen, J.E. (2011). Which habitats of European importance depend on agricultural practices? Biodiversity and Conservation 20, 2365- 2378.

[128] CAP Result Indicator R.17: Afforested land: Area supported for afforestation, agroforestry and restoration, including breakdowns and Output Indicator O.14a: Number of hectares or number of other units under maintenance commitments for afforestation and agroforestry.

Now, HD Annex I agricultural semi-natural habitats, and associated species, are amongst the most threatened in the EU. Of these 35 habitat types, no dehesas or wood meadows were assessed as having a favourable conservation status in Member States' reports under Article 17 of the HD for the period 2013-2018. Only 8 % of assessments of agricultural heathlands and 11 % of grasslands assessments were reported as being in favourable conservation status. According to the Member States' reports on the condition (i.e. structure and function parameter) of their HD Annex I agricultural habitat types, 18 % of the habitats area was in not-good condition. However, the true area in not-good condition is uncertain, as 35 % of the total area of these habitats was reported as in 'unknown' (or not reported) condition. The true proportion of the area in a not-good condition is probably closer to the proportion of the area for which Member States reported on the condition of the habitat that had a not-good condition, which is 27 % [129]. The Article 17 reports have also revealed that most HD Annex I agricultural habitat types have declined in area over the twelve or so years up to 2018, despite over 43 % coverage within the Natura 2000 network. Not surprisingly, a high proportion of EU protected species that are dependent on HD Annex I agricultural habitats also has an unfavourable conservation status and declining trends. Furthermore, the trend in conservation status of the 35 Annex I agricultural habitats is showing that only 3% of the assessments have an improving trend and that 29% have a deteriorating one.

Whilst the extent of agriculturally improved grasslands and croplands is not declining, there is strong evidence that these habitats have a highly impoverished biodiversity. Monitoring studies also show that many species associated with agro-ecosystems are continuing to decline. For example, the Pan- European Common Bird Monitoring Scheme's common farmland bird index has documented an overall decline of 33 % between 1990 and 2017 at EU level.

The degradation of agro-ecosystems is also associated with soil carbon losses, soil erosion, soil compaction (causing water pollution, and accentuating floods), declines in pollinators and beneficial predators, and declines in landscape quality and public enjoyment of the countryside.

Two main pressures cause the degradation and associated declines in HD Annex I agricultural habitats: Land abandonment (sometimes followed by afforestation) and agricultural improvements and intensification, such as the ploughing of semi-natural grassland and heaths and conversion to improved grasslands. Some semi-natural grasslands have also been damaged because of eutrophication caused by the airborne deposition of nitrogen, mainly near areas with highly intensive livestock production. Within already agriculturally improved ecosystems, the main pressures are the result of past and ongoing agricultural intensification, specialisation and landscape simplification resulting in decreasing landscape features (hedgerows, tree lines, isolated trees, etc.). Other, non-agricultural pressures contributing to the degradation of agricultural habitats include urban expansion, invasive alien species, pollution from other sources than agriculture and climate change.

According to the review of evidence for the baseline assessment to 2030, there is little sign of change in most pressures (other than reductions in nitrogen pollution). Whilst the protection of

[129] 115 330 km^2 with a reported condition, of which 31 180 km^2 had a 'not-good' condition.

HD Annex I habitats is expected to improve within Natura 2000 sites, there is little to indicate that this will also happen outside Natura 2000 sites. Furthermore, EU protected species outside the Natura 2000 network remain highly vulnerable, especially in intensively managed farmland landscapes. Much will depend on improved implementation of the Nature Directives in conjunction with how the new CAP will be implemented by the Member States and whether the anticipated increases in biodiversity funding will focus on the most important and effective measures for HD Annex I habitats and protected species, including birds, in particular on tailored and targeted agri-environment interventions as well as effective eco-schemes.

Given these uncertainties, it is assumed under the baseline scenario to 2030 that the rates of loss of HD Annex I agricultural habitats and their degradation levels will not change significantly. Therefore, it is assumed that the loss of HD Annex I agricultural habitats will continue at 1.5 % per year and that in 2030 27 % of the HD Annex I agricultural habitat area will require restoration. Similarly, based on the evidence of pressures on agro-ecosystem species, a substantial proportion of the wider agro-ecosystems can be expected to continue to be degraded and requiring restoration.

4.3 Target options screened in/out

The following four broad objectives as a basis for targets setting are identified for agro-ecosystems, in order of priority in terms of their ability to provide biodiversity and ecosystem service benefits:

1. Maintain and restore HD Annex I agricultural habitats to good condition and ultimately favourable conservation status, and other natural and semi-natural habitats not listed in Annex I to good status.
2. Maintain and restore habitats for EU protected species that are predominantly associated with agro-ecosystems, including semi-natural habitats that are not HD Annex I agricultural habitats, and modified grasslands and croplands, such that they maintain and achieve a favourable / secure status.
3. Increase the proportion of agriculturally semi-improved and semi-natural habitats in the landscape, creating interconnected networks, buffering HD Annex I habitats, and aiming to restore some to HD Annex I habitats in the long-term.
4. Partially restore (i.e. enhance) agriculturally improved grasslands and croplands to increase their biodiversity beyond EU protected species and enhance ecosystem services, particularly in relation to climate mitigation and adaptation value.

Several options were considered for the achievement of these objectives, which are summarised together with the outcomes in Table IV-1. These were considered in the Biodiversity Strategy to 2030, including in relation to the target for **10 % coverage of landscape features** (e.g. including hedgerows and fallow) within farming landscapes. It was found that increasing the coverage of landscape features is a high priority, while recognising that the biodiversity value of landscape features is highly context specific and variable dependent on their quality. Basing the targets on HD Annex I agricultural habitats and EU protected species that are predominantly associated with agro-ecosystems is considered to be reliable way of presenting, achieving and measuring the desired outcomes. Such a target would also include the much-needed landscape features that are necessary to achieve improvements for the habitat types and species.

The most obvious aim of the target based on the EU protected species would be to achieve the sufficient habitats in terms of quantity and quality for the species concerned to reach favourable / secure status, as this would link directly to the objectives of the Birds and Habitats Directives, and its existing monitoring and reporting requirements. The target would complement the target based on HD Annex I habitats, as it would also cover the areas of semi-natural agricultural habitats not falling under HD Annex I definitions and standards.

There is also a strong argument for an additional complementary target because most of the HD listed species that are associated with agriculture are predominantly associated with HD Annex I habitats and other semi-natural habitats. Birds are much more widely distributed in agro-ecosystems, and restoration measures to secure their populations would provide wider benefits for agriculturally improved grasslands and croplands. Consequently, a target focused on restoring populations of common farmland birds that are typical of agriculturally improved grasslands and croplands would complement the overarching target for EU protected species, even though birds are already covered. The added value of the additional target would be that it would be more focussed on the established lists of common farmland species included in the Farmland Bird Index (FBI) at national level and a well-established and robust methodology that makes it ideally suited for target setting. A further advantage of adding a bird focused target for agriculturally improved grasslands and croplands is that birds are very good indicators of ecosystem condition as they are high in the food chain and occupy a range of ecological niches. Therefore, restoring their populations can be expected to contribute widely to restoring other species populations, as well as overall ecosystem quality and associated ecosystem services.

Two other options for targets were identified for further consideration: increasing semi-improved and semi-natural habitats in the landscape, and increasing old unploughed grasslands (permanent grassland) by halting ploughing and re-seeding of a proportion of agriculturally improved grasslands. The latter was selected as it is considered that it could provide significant biodiversity and ecosystem service benefits, whilst enabling continued sustainable agricultural production with limited economic costs and efficient monitoring and enforcement.

Table IV-1 Summary table screened target options

Target option	Screened in/out for assessment	Key reason(s) for screening in/out
1. Favourable conservation status of HD Annex I agricultural habitats	Included as primary goal of restoration target	This option provides a coherent measurable outcome target, which is considered coherent with environmental policy and feasible
2. Favourable conservation status of EU protected species predominantly associated with agro-ecosystems	Included	Provides a coherent measurable outcome target that supports and complements option1 and many EU protected species of agro-ecosystems
3. Increasing semi-improved and semi-natural vegetation in the farmland landscape	Included	Outcome focused and potentially measurable target that would complement options 1 and 2
4. Increasing landscape features	Not included as a	Impractical basis for setting SMART target suitable for a

in the farming landscape to a minimum coverage of 10 %	target as such but further considered in more general terms, and an indicator.	legally binding instrument as such, but to be considered further in a different formulation, such as an indicator.
5. Halting the ploughing and reseeding of agriculturally improved grasslands over a certain proportion of landscape	Included	Although not outcome focused, this would be a practical measure that would provide significant benefits, including in terms of decreasing GHG emissions at low cost that can be easily monitored and enforced

Based on the above considerations, the impact assessment considered the following targets.

HD Annex I agricultural habitats

A) Restore all HD Annex I agricultural habitats to good condition, with all necessary restoration measures completed on 30 % (or 15 %) of degraded areas by 2030, 60 % (or 40 %) by 2040 and 100 % by 2050.

B) Recreate 30 % (or 15 %) of additional habitat area required to achieve Favourable Conservation Status (FCS) of HD Annex I agricultural habitats by 2030, 60 % (or 40 %) by 2040 and 100 % by 2050.

For target A), the area of HD Annex I agricultural habitat requiring restoration is that projected to have a not-good condition in 2030 according to the baseline scenario, which is 27 % of the habitat area (i.e. 47 909 km^2). For target B, according to Member States information on 'favourable reference areas' for their HD Annex I agricultural habitats, at least 2 431 km^2 would need to be re-created to achieve their FCS. However, the exact area required is uncertain as a significant proportion of Member States have not estimated favourable reference areas.

EU protected species associated with agro-ecosystems

C) Restore and recreate agro-ecosystems as necessary to:

1) increase the populations of **common farmland birds** as measured by the common farmland bird index in each Member State.

Examples have shown that wildlife-friendly farming practices, such as cutting hedgerows and ditches just once every three years and the creation of insect-rich and seed-rich habitats, have the capacity to not only reverse the decline in farmland birds but to produce a major increase, as measured by the Farmland Bird Index[130].

Since the starting points of Member States are very different, there is a need to differentiate among those Member States with historically depleted populations of farmland birds and the others.

[130] E.g. Hope Farm in East Cambridgeshire: https://www.rspb.org.uk/our-work/conservation/conservation-and-sustainability/farming/hope-farm/bird-numbers/

In particular, the Member States with historically depleted populations of farmland birds are those where half or more species contributing to the national common farmland bird index has a negative long-term population trend. In Member States where information on long-term population trends is not available for some species, information on the European status of species is used.

The common bird monitoring data in Member States is not always available back to the 1980s. Thus, other sources of information have been used to fill the gaps. "Birds in Europe 2"[131] (BiE 2) and „Birds in Europe 3"[132] (BiE3) data sheets contain information on long-term trends (usually 1980 to 2012) of species in individual countries and information on the species European status. Birds in Europe data is the same reported under Article 12 of the Birds Directive. Trends (in broad categories decline, stable, increase, fluctuating) correlate with the trends obtained by the common bird monitoring schemes. As the common bird monitoring data is often unavailable back to the 1980s, the same applies to some countries and species for BiE data. In such a situation, the information on the species population status in Europe, particularly whether a species is depleted, can be used as an additional piece of information. Thus, the Member States are selected using the following procedure: a long-term trend from BiE is used solely in Member States where more than half of species contributing to the national FBI has long-term trend known. In this group of countries, those where half or more species in the national FBI has the long-term trend negative (decline) are selected in Group 1 (Member States with historically depleted populations of farmland birds). The rest, i.e. countries where less than half of the species in FBI has a negative long-term trend, is selected in Group 2 (Member States that do not have historically depleted populations of farmland birds). Again, only species with known information on long-term trends are used for this assessment.

In case when the majority of species contributing to a national FBI in a country has the BiE long-term trend unknown, additional criteria are used for the assessment: a species classified as 'depleted' in BiE3 in Europe. Thus, if half or more species in a Member States has a long-term trend declining, or those with the unknown national trend are classified as depleted in Europe, the country is selected in Group 1. The rest is selected in Group 2.

Group 1: Member States with historically depleted populations of farmland birds would be Czechia, Denmark, Estonia, Finland, France, Germany, Hungary, Italy, Luxembourg, Netherlands, and Spain.

Group 2: Member States that do not have historically depleted populations of farmland birds would be Austria, Belgium, Bulgaria, Croatia, Cyprus, Greece, Ireland, Latvia, Lithuania, Malta, Poland, Portugal, Romania, Slovakia, Slovenia, and Sweden.

The target would therefore read:

Each Member State shall increase the populations of farmland birds as measured by the common farmland bird index re-set at 100 at year X [=one year after the entry into force of this Regulation] to:

[131] Heath M., Borggreve C. and Peet N. 2000: European Bird Populations Estimates and Trends. BirdLife conservation series, no. 10. Cambridge, BirdLife International.

[132] Burfield I. J. and van Bommel F. (eds.) 2004: Birds in Europe Population Estimates, Trends and Conservation Status. BirdLife Conservation Series No 12. Cambridge, BirdLife International.

(a) 110 by 2030, 120 by 2040 and 130 by 2050, for Member States with historically depleted populations of farmland birds;

(b) 105 by 2030, 110 by 2040 and 115 by 2050, for Member States that do not have historically depleted populations of farmland birds.

2) restore and re-create agro ecosystems as necessary to achieve the favourable conservation status of **species that are listed in Annex II, IV and V of the Habitats Directive** as well as all birds predominantly associated with agro-ecosystems, with 30 % (or 15 %) of all necessary actions carried out by 2030 and 60 % (or 40 %) by 2040 and 100 % 2050.

Semi-natural vegetation

D) Restore and recreate agriculturally semi-improved and semi-natural grassland [to be defined by selected plant indicators] on agriculturally improved grasslands and croplands for general biodiversity and ecosystems services, to replace losses since [1990, 2000, 2010] with 30 % (or 15 %) of losses replaced by 2030, 60 % (or 40 %) by 2040 and 100 % by 2050.

Increasing landscape features

See section 4.6

Restoration of old unploughed grasslands from agriculturally improved grasslands

E) Restore and recreate unploughed / untilled grassland for general biodiversity and ecosystems services on modified grasslands and croplands, to replace losses since [1990, 2000, 2010] with 30 % (or 15 %) of losses replaced by 2030, 60 % (or 40 %) by 2040 and 100 % by 2050.

4.4 Impacts of assessed target options

The costs of restoration of agro-ecosystems were estimated by calculating the area of degraded ecosystems to be restored and re-created annually to meet each target and applying average per hectare capital costs for restoration and re-creation, and annual costs for maintenance mainly taken from Tucker et al. [133] The costs of restoration and re-creation include the capital costs of actions such as restoration grazing/mowing, scrub removal, reseeding, hydrological works, soil fertility reduction and wildfire control. Annual maintenance costs include grazing management; mowing; maintenance of hedges, ditches, and other features; creation and maintenance of field margins, winter stubbles, fallows and cover crops; management of farm inputs; and appropriate

[133] Tucker et al., (2013) Estimation of the financing needs to implement Target 2 of the EU Biodiversity Strategy. Report to the European Commission. Institute for European Environmental Policy, London. Available at: https://ec.europa.eu/environment/nature/biodiversity/comm2006/pdf/2020/Fin%20Target%202.pdf

cultivation, crop rotation and soil management practices. The required management will be undertaken largely by private landowners and land managers, in return for incentive payments, a large proportion of which include compensation for opportunity costs relating to land management (e.g. income forgone through reduced grazing, lower inputs and introduction of uncropped features on arable land). Maintenance costs were applied to the entire ecosystem area, since meeting the targets requires further degradation of ecosystems to be avoided.

Benefits estimates were based on an extensive review of literature of the value of benefits of agro-ecosystem restoration, which identified changes in per hectare values of ecosystem services for restored vs degraded ecosystems. The analysis applied estimates of the median per hectare value of carbon storage and sequestration values and total ecosystem service benefits of agro-ecosystem restoration derived from values obtained from more than 50 studies. Per hectare benefits estimates were applied to the area of ecosystem restored to give annual estimates of total benefits. Annual costs and benefits were estimated over the period 2022 -2070, recognising that, while restoration takes place to 2050, further maintenance costs continue beyond that date, while restored ecosystems continue to provide benefits into the future. Annual cost and benefit estimates were discounted, applying a 4% social discount rate, and summed to calculate their total present value. This enabled total net present value (benefits – costs) and benefit: cost ratios to be calculated.

The estimated costs of achieving good condition of HD Annex I agricultural habitats (target A) are summarised in Table IV-2. The costs are broadly based on the area of habitat that is in not-good condition or affected by specific pressures, multiplied by the costs of key measures to maintain the habitat and address pressures, thereby restoring the habitat, and to re-create habitat. The costs are additional to measures that are already in place. Also, to avoid double-counting, they do not include general supporting measures (e.g. creation of restoration plans), administration costs, or broad actions that apply to multiple ecosystems, such as the need to reduce nitrogen deposition below critical levels.

Table IV-2: Summary of projected costs (EUR) of achieving restoration targets for HD Annex I agricultural habitats in relation to current trends & expected 2030 baseline

Estimates do not include Romania as estimates of habitat extent are not available.

Targets 15 % and 40 %[134]

Period	% Full restoration	Maintenance costs	Restoration costs	Re-creation costs	Combined costs	Total over period
Average annual costs						
2022-2030	15 %	944 202 600	145 229 886	131 276 940	1 220 709 426	10 986 384 835

[134] Although the 2050 target aims to restore 100 % of the habitat, the 2050 cost estimation is for 90 % restoration as this is the maximum percentage that can be expected in practice. Furthermore, an extrapolation of current restoration costs would no longer provide reliable estimates in the range between 90 and 100 %.

2031-2040	40 %	952 554 600	217 844 829	125 331 678	1 295 731 107	12 957 311 071
2041-2050	90 %[135]	966 474 600	435 689 658	127 018 728	1 529 182 986	15 291 829 863
Cost over full period (29 years)						
2022-2050	90 %	27 688 115 400	7 842 413 849	3 704 996 520	**39 235 525 769**	

Targets: 30 % and 60 %

Period	% Full restoration	Maintenance costs	Restoration costs	Re-creation costs	Combined costs	Total over period
Average annual costs						
2022-2030	30 %	944 202 600	290 459 772	132 695 040	1 367 357 412	12 306 216 710
2031-2040	60 %	960 906 600	261 413 795	125 933 148	1 348 253 543	13 482 535 430
2041-2050	90 %[136]	977 610 600	261 413 795	125 933 148	1 364 957 543	13 649 575 430
Cost over full period (29 years)						
2022-2050	90 %	27 882 995 400	7 842 413 849	3 712 918 320	**39 438 327 569**	

Table IV-3 shows the projected costs of reversing the decline in common farmland birds (as included in the European farmland bird index) in each EU Member State, which includes key measures that would also contribute to reducing declines in pollinators and other farmland wildlife under target C. This is based on an adjusted extrapolation of the costs of a package of measures for birds, pollinators and other farmland wildlife in an agri-environment climate scheme in England. As this is the only study that has used detailed data from agri-environment schemes that have increased common farmland birds to quantify the area of habitat and scheme coverage needed to achieve farmland population increases, this has been used to estimate the costs for similar habitats and species in most EU countries. The per hectare unit costs of the package of measures were extrapolated according to the area of pasture and arable land in each country, and then adjusted to take account of differences in the trends in farmland bird populations and the costs of agri-environment measures. The estimates of the costs of target C for common farmland birds do not include Croatia, Italy, Portugal and Spain, due to their very different bird communities, and conservation requirements, which overlap more with those relating to HD Annex I agricultural habitats and BD Annex I bird species.

[135] Although the 2050 target aims to restore 100 % of the habitat, the 2050 cost estimation is for 90 % restoration as this is the maximum percentage that can be expected in practice. Furthermore, an extrapolation of current restoration costs would no longer provide reliable estimates in the range between 90 and 100 %. (See methodology section in SWD)
[136] Although the 2050 target aims to restore 100 % of the habitat, the 2050 cost estimation is for 90 % restoration as this is the maximum percentage that can be expected in practice. Furthermore, an extrapolation of current restoration costs would no longer provide reliable estimates in the range between 90 and 100 %. (See methodology section in SWD)

Table IV-3: Estimated annual costs of reversing declines of common farmland birds, and other key measures for wildlife in modified grasslands and croplands, as part of target C

	Pasture & heterogeneous land minus HNV land (km2)	Arable land minus HNV land (km2)	Min adjusted pasture & heterogeneous cost	Max adjusted pasture & heterogeneous cost	Min adjusted arable cost	Max adjusted arable cost	Min total cost	Max total cost
Total EU area	**316,123**	**805,134**	**96,119,467**	**170,057,519**	**497,024,782**	**753,553,702**	**593,144,249**	**923,611,220**

Min and max costs refer to the % coverage of the agricultural area with scheme agreements. Min pasture = 13 %, max = 23 %. Min arable = 31 %, max = 47 %. These are minimum and maximum estimates of the proportion of the landscape that need to be in schemes that provide 10 % of wildlife beneficial habitat (including agriculturally productive habitats) that would be required to increase the bird populations by 10 % by 2030. The minimum areas are where schemes focus on areas with high densities of the target species.

It would be expected that the achievement of favourable conservation status within HD Annex I agricultural habitats would also provide the required conditions for most associated EU protected species. Therefore, to avoid double counting, the habitat restoration costs for EU protected species were not estimated for HD Annex I agricultural habitats. Whilst some additional costs for species-specific measures would be expected, they would be a relatively small proportion of the total restoration costs (probably in the order of 10's of millions of euros). Relatively few HD Annex II, IV and V species are predominantly associated with agriculturally improved grasslands and croplands, and most of their restoration measures would be like those for birds and pollinators. Additional costs for these HD species would probably be relatively very low.

There was insufficient information available per unit area costs and area requiring restoration / re-creation to estimate the costs of restoring semi-improved and semi-natural vegetation (target D), and old unploughed grasslands (target E).

The costs of restoration action will be borne by farmers and land managers, who should in turn be compensated through agri-environment payments funded by taxpayers. Restoration actions will create employment and enhance incomes for farmers, farm workers and contractors.

Restoration of grasslands and agro-ecosystems will deliver substantial benefits for biodiversity, benefiting a wide range of European protected species. It will benefit society and the economy by enhancing the delivery of ecosystem services. These include provisioning services (especially by sustaining food production through sustainable agricultural practices), regulating services (climate, water quality, soil, flood management and pollination services) and cultural services (landscape, recreation and tourism, and benefits for non-visitors through knowledge that species and habitats are conserved). These services benefit the whole population, as well as specific sectors, especially agriculture, tourism and water sectors.

The ranges of per hectare values of benefits of restoration are summarised in Table I-5. The source studies give wide ranges of estimates for restoration benefits. Here we identify the median values for each type of ecosystem restoration measure. Based on the evidence available, the estimated median values for grassland restoration are €172/ha/yr for carbon sequestration and storage, and €2,313/ha/yr in total for all ecosystem service values, the latter including a wide range of provisioning (food and fibre), regulating (e.g. water quality, flood management, pollination, soil quality, erosion control, climate regulation) and cultural services (recreation, landscape, aesthetic values) as well as benefits for biodiversity itself.

Insufficient evidence was found to enable monetary estimation of the benefits of cessation of ploughing of grasslands, restoring semi-natural vegetation or reversal of the decline of farmland birds and other wildlife. However, because the key restoration measures for these are like those required for the restoration of HD Annex I agricultural habitats, it can be reliably expected that they would result in substantial increases in ecosystem services and their associated economic and wider benefits.

Table IV-4: Summary of Benefits Estimates from the restoration of HD Annex I agricultural habitats (targets A and B)

Ecosystem	Service valued	Range (EUR/ha/year)	Median estimate (EUR/ha/year)
HD Annex I agricultural habitats	Carbon sequestration	172	172
	Multiple ecosystem services	43 – 5 112	2 313
Favourable / secure status of EU protected species & reversal of farmland bird & biodiversity declines	No monetary estimates available.		
Increasing semi-improved and semi-natural vegetation	No monetary estimates available.		
Cessation of ploughing of grasslands	No monetary estimates available.		

Monetary estimates of the value of the benefits of ecosystem restoration have been made by multiplying the per hectare values in the table above by the area of ecosystems restored and re-created. The benefit: cost analysis estimates that the total ecosystem service benefits of restoring HD Annex I habitats outweigh the costs by a ratio of 9 to 1 (Table IV-5). The carbon sequestration benefits alone are estimated at 60 % -70 % of the overall costs.

Table IV-5: Benefits and costs of restoration of Annex I agricultural habitats (Present value, 2022-2070, MEUR)

	15 % /40 % /90 % target	30 % /60 % /90 % target
COSTS		
Maintenance	20 381	20 452
Restoration – full recovery	3 999	4 594
Re-creation	2 179	2 186
TOTAL (full recovery)	**26 559**	**27 732**

BENEFITS (full recovery)		
Carbon only	17 073	18 624
Total Ecosystem Services	229 589	250 451
Net Present Value (full recovery)		
Carbon only	-9 486	-10 159
Total Ecosystem Services	203 030	223 220
Benefit: Cost Ratio (full recovery)		
Carbon only	0.6	0.7
Total Ecosystem Services	8.6	9.2

4.5 Synthesis

Table IV-6 provides a summary of the analysis of options and conclusions in relation to the effectiveness, efficiency, coherence, and proportionality of each target. The overall conclusion is that there are strong arguments for legally binding targets for achieving favourable conservation status of HD Annex I agricultural habitats, and for EU protected species associated with all agro-ecosystems. Whilst both targets overlap, they also complement each other to some extent. In particular, the EU protected species target extends the coverage of restoration measures to all agro-ecosystems, thereby contributing to wider benefits across the countryside and related ecosystem services. This is particularly the case as it includes all birds, which act as indicators of overall ecosystem condition, and provide indirect protection for a wide range of species that are not listed in the annexes of the Habitats Directive. Therefore, there is a logical argument for including both targets.

The targets for re-creating semi-improved and semi-natural vegetation, and old unploughed grassland, from improved grassland and cropland, would probably trigger effective restoration measures that further complement and support the proposed targets of Annex I agricultural habitats and EU protected species. However, the further development of criteria for assessing and monitoring the status of semi-improved and semi-natural vegetation in the landscape beyond that of Annex I habitats would be required to implement this target effectively and robustly. Further evidence is also required on its potential cost effectiveness, as the re-creation of these habitats can be costly and constrained by important factors such as high fertility levels in agricultural soils. Whilst the feasibility of restoring old unploughed grasslands is high, further evidence is required on its cost effectiveness, and potential overlaps with other similar objectives in relation to soil quality and water resource management.

Table IV-6: Overview table assessing options on EU impact assessment criteria

	Annex I habitats	Measures for protected species	Increasing semi-improved and semi-natural vegetation	Restoring old unploughed grassland
Feasibility / effectiveness	High feasibility and potential for restoration and re-creation (for most habitats), and effective at increasing biodiversity and ecosystem services	Moderate to high feasibility in most Annex I habitats; variable in improved agricultural areas due to numerous species and diverse factors affecting them.	High feasibility and potential for re-creation; and increasing biodiversity and ecosystem services, especially semi-natural vegetation	High feasibility and high effectiveness in increasing soil biodiversity and carbon, and related ecosystem services; some benefits for wider biodiversity

Efficiency	Substantial benefits for biodiversity and ecosystem services. Carbon benefits alone are estimated at 60-70 % of total costs; total ecosystem service benefits are estimated to outweigh costs by a ratio of 9:1.	Substantial benefits for biodiversity and people, including environmental regulating and cultural services, cannot be estimated in monetary terms.	Insufficient evidence available to quantify, but expected to provide significant benefits.	Insufficient evidence available to quantify, but expected to provide significant benefits. May have high cost-effectiveness, for ecosystem service benefits, but further evidence required.
Coherence	Full coherence with EU environmental policies and climate goals. Potential to make significant contributions to climate mitigation, and climate adaptation. Overlaps with species target	Full coherence with EU environmental policies and climate goals. May indirectly contribute to climate adaptation and mitigation. Overlaps with Annex I target and targets for pollinators (separate IA).	Full coherence with EU environmental policies and climate goals. Potential to make significant contributions to climate mitigation, and climate adaptation. Overlaps with Annex I and species targets.	Full coherence with EU environmental policies and climate goals. Potential to make significant contributions to climate mitigation, and climate adaptation. Could overlap with soils targets (separate IA)
Proportionality	High due to the very high importance of the habitats for biodiversity and associated ecosystem services	High for declining EU protected species in HD Annex I habitats, moderate in improved grasslands and croplands	High for increasing semi-natural habitats, moderate for semi-improved	Probably high, due to expected relatively low opportunity costs – but needs further research
Conclusion	**Include as a target, with high priority**	**Include as a target, with high priority**	**Consider further, as a possible second stage target**	**Consider further as, a possible second stage target**

4.6 Agro-ecosystem indicators

General Introduction

Given the extensive evidence on the decline of biodiversity across many agro-ecosystems in the EU, options for action need to be considered for agricultural areas in addition to those covered by the Annex I habitats types under the Habitats Directive. Methods already exist to determine good condition of these habitat types and options for restoration targets for these were described in the previous sections. For habitat types or ecosystems not covered by the Habitats Directive, specific indicators can be used to provide evidence of enhancement of biodiversity.

This section therefore provides an assessment of introducing obligations for Member States to provide evidence of increasing trends for a set of indicators that describe enhancement of biodiversity in agroecosystems, in addition to those measures already described in previous sections for Annex I habitats. It should be noted that this assessment considers both the impacts that an indicator directly demonstrates (e.g. increase of butterfly populations per se) as well as the underlying costs and benefits of having healthier agro-ecosystems (as evidenced by having an increased butterfly populations).

Agroecosystems host some of the most species-rich habitats in the EU and it is estimated that roughly 50% of all species in Europe rely on agricultural habitats at least to some extent[137,138]. Healthy agroecosystems also provide safe, sustainable, nutritious and affordable food. However, the condition of agroecosystems has been suffering from long-term degradation and important biodiversity losses[139], while pressure levels are to a large degree unchanged or increasing (key drivers being climate change, land conversion, pollution and nutrient enrichment). As underlined in the Green Deal and the Biodiversity Strategy for 2030, the Union needs to improve the health and biodiversity of its agricultural lands.

Biodiversity losses are widespread and it is evident that efforts made so far need to be reinforced by restoration measures to be put into place in agricultural ecosystems in the EU, including in particular those not covered by the Annex I habitats types of the Habitats Directive. Therefore addressing the improvement in biodiversity even to some extent of these areas is clearly important, even if condition is not as yet defined. As mentioned in section 5.2, approximately **1.9 million km²** are non-Annex I agricultural habitats in the EU. Although the exact proportion is not known, the vast majority comprises agriculturally improved grasslands (i.e. pastures) and croplands.

For the initial stage in this analysis, a broad set of indicators were considered as a means of gauging the improvement of biodiversity in agroecosystems. Even though the methodology to define ecosystem condition for these ecosystems is not ready yet, evidence of an increasing trend in a set of indicators related to biodiversity would act as a proxy for improvement in biodiversity. This could thus constitute specific legal obligation of improvement of the indicators in the legal proposal.

The process of indicator selection is grounded on extensive work carried out over several years as part of the MAES[140] and the UNSEEA EA[141] standards that have been developing methodologies and indicators to assess the condition of all ecosystems. Part of these indicators concern agroecosystems condition (cropland, pasture, natural & semi-natural grassland), that are relevant, based on available data, repeatable through time, and ecologically meaningful in terms of ecosystem structure, function and composition. Moreover, these indicators have undergone various consultation processes based on scientific expertise, as well as including MS experts and stakeholders.

Based on the above, a broad number of potential indicators were first identified and a set of criteria were developed to select the most relevant indicators as potentially acting as good proxies for improvements in biodiversity state. In order to be operational in the short term, such indicators would have to satisfy a number of criteria, such as being based on data that are already available or will shortly be available in the EU. Therefore the criteria chosen for the purpose of the current evaluation of indicators were:

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[137] Halada, L., Evans, D., Romão, C., and Petersen, J.E. (2011). Which habitats of European importance depend on agricultural practices? Biodiversity and Conservation 20, 2365- 2378.
[138] Lomba1,et al, Back to the future: rethinking socioecological systems underlying high nature value farmlands. Frontiers in Ecology and the Environment, 2015.
[139] IPBES report in Europe and Asia, the ECA report on CAP and Biodiversity[Full References needed]
[140] Mapping and Assessment of Ecosystems and their Services - MAES - Environment - European Commission (europa.eu)
[141] Ecosystem Accounting | System of Environmental Economic Accounting

3. The indicator gives direct information about the state of biodiversity or the ecological quality of the ecosystem. Based on this, pressure indicators were excluded as often being indirect indicators of biodiversity.
4. The data are readily available or will shortly be available in the EU, and the data are reliable and updated periodically.

The indicators outlined below were evaluated against these criteria (see Table 1). Indicators need first to offer key information or proxy about the health and biodiversity quality of agroecosystems. Data availability and data robustness, in particular periodicity of updates and reliability, are also essential elements to consider. In particular indicators for which there are already obligations for reporting under other legislation (such as CAP or LULUCF), were considered as favourable elements in this respect.

The evaluation resulted in four indicators to be considered for the further analysis of impacts: **the grassland butterfly index, the share of agricultural land with landscape features, the organic carbon content in cropland mineral soils and the percentage of species and habitats of Community interest related to agriculture with stable or increasing trends**. Further information about these selected indicators is provided in the subsequent sections.

Table IV-7: Considered agroecosystem indicators

Indicator	Direct indicator of ecological/ biodiversity quality	Data availability	Periodicity of data updating	Reliability of data	Final assessment
Grassland butterfly index	Yes, grasslands butterflies are a very efficient proxy of grassland and ecosystem quality	Yes	Yes, available at EU level (16 MS covered)	Yes, CAP Impact indicator	Yes
Share of semi-natural eleme nts (landscap e features)	Provide benefits to biodiversity. Associated with management practices	Yes	Yes, every 3 years (LUCAS)	Yes, CAP Result and impact indicator	Yes
Organic carbon content in cropland mineral soils	Yes, strongly associated with key services like water holding capacity, resilience improvement, and is related to management practices	Yes	Yes, reported under LUCAS that provides data for Forest Europe. Every 5 years.	Yes, CAP Result and impact indicator	Yes
Enhanced biodiversity protection: species and habitats of community interest related to agriculture with stable or increasing	Yes, species and habitats of community interest are a very efficient proxy of ecosystem quality, mostly for protected area and extensive grassland	Yes	Yes, every 6 years	Yes, CAP impact indicator	Yes

trends					
Soil sealing (from land take)	No, Indirect measure of loss of habitat and even more indirect measure of ecological/biodiversity quality	Yes	Yes	Yes	No
Percentage of cropland and grassland covered by Natura 2000	No, Indirect measure of ecological/biodiversity quality	Yes	Yes	Yes, CAP Result indicator	No
Farmland bird index	Yes, but taken up in another target	Yes	Yes	Yes, CAP Impact indicator	No
Wild pollinators index	Yes, but no data available	No	No	No	No
Invasive alien species	No, Pressure indicator and not a direct measure of ecological/biodiversity quality	Yes	Yes	Yes, but covered in a separate legislation.	No
Soil biodiversity	Yes, Direct measure of ecological/biodiversity quality	No, data available only later in 2022	Yes	Yes, but limited in sample	No
Crop genetic diversity	No, insufficient measure of ecological/biodiversity quality	No	NA	No	No
Connectivity of semi-natural elements	No, insufficient measure of ecological/biodiversity quality	No	NA	No	No
Share of fallow land	No, insufficient measure of ecological/biodiversity quality	Yes	Yes	Yes, CAP Result and impact indicator	No
Crop diversity (spatial and temporal)	No, insufficient measure of ecological/biodiversity quality	Yes, to be developed	Yes	Yes, CAP Impact Indicator	No
Exceedances of critical loads for acidification	No, indirect measure of ecological/biodiversity quality	Yes	Yes	Yes	No
Exceedances of critical loads for	No, indirect measure of ecological/biodiversity quality	Yes	Yes	Yes	No

eutrophication					
Depth of the water table	No, indirect measure of ecological/biodiversity quality	No	NA	No	No
Soil compaction	No, indirect measure of ecological/biodiversity quality	No, only Partially	No	No	No
Organic soils no longer losing carbon	No, associated with land use change but indirect measure of ecological/biodiversity quality	No	No	No	No
Heavy metals in soil	No, indirect measure of ecological/biodiversity quality	Yes	No, only partially updated	No	No
Plastics in soil	No, indirect measure of ecological/biodiversity quality	No	No	No	No
Pesticides residues in soil	No, indirect measure of ecological/biodiversity quality	No – in preparation (2022)	No, partially	No	No
Veterinary antibiotics in soil	No, indirect measure of ecological/biodiversity quality	No	No	No	No
Acidification in soil	No, indirect measure of ecological/biodiversity quality	Yes	Yes	Yes	No
Soil salinisation	No, indirect measure of ecological/biodiversity quality	No	No	No	No
Gross nutrient balance	No, indirect measure of ecological/biodiversity quality	Yes	Yes	Yes, CAP Impact Indicator	No
Mineral fertilizer consumption (n)	No, Pressure indicator and not a direct measure of ecological/biodiversity quality	Yes	Yes	Yes, CAP Result indicator	No
Mineral fertilizer consumption (p)	No, Pressure indicator and not a direct measure of ecological/biodiversity quality	Yes	Yes	Yes, CAP Result indicator	No
Pesticide use and risk	No, Pressure indicator and not a direct measure of ecological/biodiversity quality	Yes	Yes	Yes, CAP Result and Impact Indicator	No
Water abstraction by agriculture	No, Pressure indicator and not a direct measure of ecological/biodiversity quality	No	No	Yes, CAP Result and Impact Indicator	No

Soil erosion	No, Indirect measure of ecological/biodiversity quality	Yes	Yes	Yes, CAP Result and Impact Indicator	No

Grassland Butterfly Index

Background

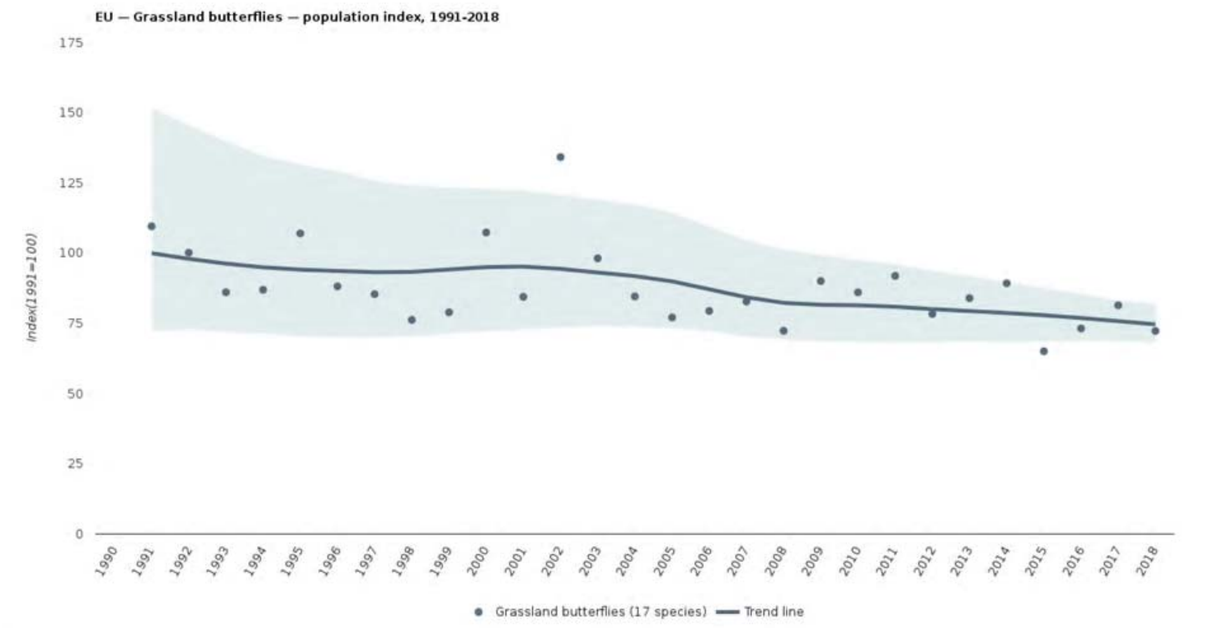
As the majority of grasslands in Europe requires active management by humans or sustainable grazing by livestock, butterflies also depend on the continuation of these activities. The main driver behind the decline of grassland butterflies is thought to be changes in rural land use. In some regions, grassland habitats have deteriorated due to agricultural intensification, while in other regions (such as more remote mountain areas) the main problem is land abandonment or afforestation. In both cases, the situation for butterflies is the same as their habitats become less suitable for breeding. When land use is intensified, host plants often disappear or the management becomes unsuitable for larval survival. In the case of abandonment, the grassland quickly becomes tall and rank, and is soon replaced by scrub and eventually woodland.

Large parts of Europe are used for agricultural purposes, and grasslands are a major land- cover type within these areas. For centuries, grasslands have formed an important part of the European landscape. Sustainably managed semi- natural grassland harbours a high biodiversity, especially of plants, butterflies and many other insect groups. Grasslands are the main habitat for many European butterflies. Out of 436 butterfly species in Europe for which information on habitat type is available, 382 (88 %) are on grasslands in at least one country in Europe, and for more than half of the species (280 species, 57 %) grassland is their main habitat. Grassland butterflies have undergone a huge overall decrease in numbers.

Between 1991 and 2018, the EU Butterfly Indicator for Grassland species showed a significant decline of 25% in the 17 EU countries with monitoring data. While the decline has slowed in the past few years, the grassland butterfly index still fell by 5% between 2013 and 2018. Moreover, [142]. The 2010 Red List of European butterflies listed 38 of the 482 European species (8%) as threatened and 44 species (10%) as near threatened (note that 47 species were not assessed) (van Swaay et al., 2020).

Figure IV-1 Grassland butterflies – population index, 1991-2018. Source: EEA

[142] Van Swaay, C. A. M., et al., 2020, Assessing butterflies in Europe — butterfly indicators 1990-2018: technical report, Butterfly Conservation Europe and ABLE/eBMS.



Notes:
Source: EEA, Butterfly Conservation Europe, European Butterfly Monitoring Scheme partnership, Assessing Butterflies in Europe (ABLE) project.

The shaded area represents the confidence limits.

Geographical coverage: Austria, Belgium, Czechia, Estonia, Finland, France, Germany, Hungary, Ireland, Latvia, Lithuania, Luxembourg, Netherlands, Romania, Spain, Slovenia, Sweden.

Thomas (2005)[143] argued that butterflies are good indicators of insects, which comprise the most species- rich group of animals in Europe. The trend in grassland butterflies is thus an indicator for the health of grassland ecosystems and their component biodiversity. Insects play a crucial role in pollination services and the health of the ecosystems on which they depend is important for Europe's future economic and social well- being.

Grasslands and their butterflies are highly dependent on activities such as grazing or mowing. Traditional forms of farming management, such as extensive livestock grazing and hay- making where fertiliser and pesticide use are minimal, provide an ideal environment for these butterflies. In recent decades, large areas of grassland have become abandoned, furthermore many villages in the European countryside have become abandoned for social and economic reasons. Following abandonment, some butterfly species flourish for a few years because of the lack of management, but thereafter scrub and trees invade and the grassland disappears, including its rich flora and butterfly fauna. Eventually, the vegetation reverts to scrubland and forest, eliminating grassland butterflies. In western Europe, farming has intensified rapidly and over the last 50 years and semi- natural grasslands have become greatly reduced in area. Related threats to grassland butterflies in Europe include fragmentation, the use of pesticides and climate change.

Details of the indicator

[143] Thomas, Jeremy A., et al. "Comparative losses of British butterflies, birds, and plants and the global extinction crisis." *Science* 303.5665 (2004): 1879-1881.

Butterflies are ideal biological indicators: they are well-documented, measurable, sensitive to environmental and climate change (what rapidly results in demographical responses due to their short generation time), occur in a wide range of habitat types but with highly characteristic species assemblages[144], are popular with the public because of their beauty, and represent many other insects as well as species of higher taxonomical level. For instance, Fleishman et al. (2005)[145] found that models explaining butterflies distributions in North America also explained birds distributions. Field monitoring is essential to assess changes in their abundance. Indicators based on butterfly monitoring data are valuable to understand the state of the environment and help evaluate policy and implementation.

Because butterflies require different resources along their phenology (i.e., food and nesting resources, host plants for their larvae) and are mobile organisms (some species are migratory). Trends in the abundance and distribution of their populations can inform not only about local conditions but also about changes in ecosystems at regional and EU level over time.

Another advantage of European grassland butterflies as biological indicators in the current policy context, is that they are highly sensitive to habitat loss/degradation, chemical pollution, and climate change[146], some of the main pressures on biodiversity that different European policies are trying to revert. In the case of European grasslands[147]. Thus, the relationship between the intensity of agricultural management and this taxon makes an indicator based on the population trends of these insects a good proxy for the structural and functional condition of these habitats.

The EU Grassland Butterfly Indicator is one of the indicators of the status of biodiversity in the European Union[148]. It is an indicator showing trends in abundance of populations of seventeen typical grassland butterfly species in different EU countries.

Based on the establishment of butterfly monitoring schemes in a number of European countries that collect annual data to a scientific standard over a wide geographical area, population trends of butterflies now represent an important source indicator[149]. In its last update up to 2018, more than 4000 transects covering 17 countries were used to assess the trends of these insects populations. The indicator is based on the fieldwork of trained professional and volunteer recorders, counting butterflies under standardised conditions with national coordinators collecting the data and performing quality control[150]. National population trends from the Butterfly Monitoring Schemes, are combined to form supra-national species trends. These trends

[144] Stefanescu, Constantí, Josep Peñuelas, and Iolanda Filella. "Butterflies highlight the conservation value of hay meadows highly threatened by land-use changes in a protected Mediterranean area." *Biological Conservation* 126.2 (2005): 234-246.

[145] Fleishman, Erica, et al. "Using indicator species to predict species richness of multiple taxonomic groups." *Conservation biology* 19.4 (2005): 1125-1137.

[146] Warren, Martin S., et al. "The decline of butterflies in Europe: Problems, significance, and possible solutions." *Proceedings of the National Academy of Sciences* 118.2 (2021).

[147] Bubová, T., Vrabec, V., Kulma, M., & Nowicki, P. (2015). Land management impacts on European butterflies of conservation concern: a review. *Journal of Insect Conservation*, *19*(5), 805-821.

[148] Van Swaay, C.A.M., et al. The EU Butterfly Indicator for Grassland species: 1990-2017. Technical report. 2019

[149] Brereton, T., van Swaay, C. H. R. I. S., & van Strien, A. R. C. O. (2009). Developing a butterfly indicator to assess changes in Europe's biodiversity. In *Conference proceedings of the European bird census council bird* (pp. 78-97).

[150] Van Swaay, C.A.M., et al. The EU Butterfly Indicator for Grassland species: 1990-2017. Technical report. 2019

per butterfly species are then combined into the indicator following the method described by Gregory et al. (2005)[151] for an equivalent bird index.

The Grassland Butterfly Indicator demonstrates how butterflies respond quickly to changes in the environment and how butterflies are thus a good ‘early warning’ indicator of changes in Europe’s biodiversity. The distribution of butterflies has been found to be a good predictor of areas of high biodiversity, species richness or habitat quality in many studies. In addition, butterflies are relatively easy to recognize and data on butterflies has been collected for many years and the method for monitoring butterflies is well described, extensively tested and scientifically sound[152].

Environmental impacts

Wild pollinator communities are indicators of ecosystem health and react quickly to environmental change. The main driver of their decline is the intensification of farming and changes in rural land use, resulting in habitat loss and degradation[153,154,155]. The loss of species-rich semi-natural grasslands has been particularly detrimental[156]. Moreover, agricultural intensification can entail high inputs of agrochemicals, including pesticides, which can dramatically reduce insect populations, including butterflies. Urban sprawl increases light pollution (i.e. artificial light at night), which is another major driver of insect decline[157]. Other drivers of population loss are invasive alien species and climate change[158].

Insects are a vital component of biodiversity because they comprise over half of the world’s terrestrial species and butterflies are an important part of such a contribution to global diversity and to ecosystems functioning providing pollination services. More than 90% of wild flowers rely upon these services for their reproduction[159,160] as well as 75% of crop species[161]. Therefore, as pollinators, butterflies also contribute to wild plant conservation and crop production also ensuring the survival of other animals such as birds in higher levels of the food web. This pollination service can be of particular importance for some plant species with long corolla tubes where only butterflies tongue lengths can reach the flower sexual organs and transfer pollen among individuals.

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[151] Gregory, Richard D., et al. "Developing indicators for European birds." *Philosophical Transactions of the Royal Society B: Biological Sciences* 360.1454 (2005): 269-288.

[152] Brereton, T., van Swaay, C. H. R. I. S., & van Strien, A. R. C. O. (2009). Developing a butterfly indicator to assess changes in Europe’s biodiversity. In *Conference proceedings of the European bird census council bird* (pp. 78-97).

[153] Sánchez-Bayoa, F. and Wyckhuys, K.A.G. Worldwide decline of the entomofauna: A review of its drivers. Biological Conservation (2019). DOI: 10.1016/j.biocon.2019.01.020

[154] Hallmann, C.A. et al. More than 75 percent decline over 27 years in total flying insect biomass in protected areas. PLoS One (2017). DOI: 10.1371/journal.pone.0185809

[155] Van Swaay, et al. Assessing Butterflies in Europe - Butterfly Indicators 1990-2018 Technical report. Butterfly Conservation Europe & ABLE/eBMS (www.butterfly-monitoring.net)

[156] Nilsson, S. G., Franzén, M. and Pettersson, L., 2013, 'Land-use changes, farm management and the decline of butterflies associated with semi-natural grasslands in southern Sweden', *Nature Conservation* 6, pp. 31–48

[157] Owens, A. C. S., Cochard, P. and Durrant, J., 2020, 'Light pollution is a driver of insect declines', *Biological Conservation* 241

[158] ibid 12.

[159] Costanza, Robert, et al. "The value of the world's ecosystem services and natural capital." *nature* 387.6630 (1997): 253-260.

[160] Ollerton, Jeff, Rachael Winfree, and Sam Tarrant. "How many flowering plants are pollinated by animals?." *Oikos* 120.3 (2011): 321-326.

[161] Bos, Merijn M., et al. "Caveats to quantifying ecosystem services: fruit abortion blurs benefits from crop pollination." *Ecological Applications* 17.6 (2007): 1841-1849.

84 % of the crops grown in Europe benefit at least partly from animal pollination[162], including fruits, vegetables, nuts, oil crops, pulses and legumes, crops grown for fibre or fuel or for animal food. Over 78 % of wild plants in the EU rely on pollinating insects[163], including many medicinal plants.

Grassland butterflies are an indicator of grassland condition. Natural and semi-natural grasslands are core components of High Nature. Extensive literature exists on the role of natural and semi-natural grasslands as ecosystem services providers[164] and in particular of regulating and cultural ecosystem services. Moreover, Bengtsson et al. (2019)[165] underline the fact that semi-natural grasslands in Europe should increase in area to meet the demand for the many services they could provide.

Socio-Economic Impacts

It is estimated that more than 150 (84%) of European crops are directly dependent upon insects for their pollination. Crop pollination by honeybees alone is estimated to be worth €4.25 billion per year in Europe. Dependence upon a single pollinator for crop production can be a risky strategy and many other pollinator species are known to provide excellent pollination services. Bumblebees, for instance, are important pollinators of several European crops and together with other non-honeybee pollinators are estimated to provide services worth more than €750 million per year[166].

Productivity, livestock carrying capacity and biodiversity are all strongly interrelated and high biodiversity and high economic yield are considered incompatible at higher levels of productivity. High levels of biodiversity seem to be confined to less productive conditions, with an inherently low carrying capacity for livestock and low marginal returns. These mathematical relationships are, however, an oversimplification[167]. In fact, plant species diversity contribute to more resilient agricultural systems, and farmers can benefit economically from this diversity as it contributes to more stable grassland-based production by increasing and stabilizing biomass yields[168].

In a 2017 study[169], authors explore the economic value of increasing biomass accumulation as local species richness increases in grassland habitats, demonstrating positive marginal value of species richness for carbon storage. The study is based on plant diversity, which is key to shape other biological communities composition. Relevance should be given to the fact that other ecosystem services are also sensitive to biodiversity loss.

[162] Williams, Ingrid H. "The dependence of crop production within the European Union on pollination by honey bees." *Agric. Zool. Rev.* 6 (1994): 229-257.
[163] Ibid 141
[164] Veen, P., et al, Grasslands in Europe of high nature value. KNNV Uitgeverli, 320 p. (2009)
[165] Bengtsson, J., et al, Grasslands—more important for ecosystem services than you might think, Ecosphere, 10 (2019).
[166] Borneck, R. and Merle, B. (1989) Essaie d'une evaluation de l'incidence économique de l'abeille pollinisatrice dans l'agriculture européenne. Apicata 24: 33-38.
[167] Hodgson, J. G., Montserrat-Martı, G., Tallowin, J., Thompson, K., Díaz, S., Cabido, M., ... & Zak, M. R. (2005). How much will it cost to save grassland diversity?. *Biological conservation*, *122*(2), 263-273.
[168] Schaub, S., Buchmann, N., Lüscher, A., & Finger, R. (2020). Economic benefits from plant species diversity in intensively managed grasslands. Ecological Economics, 168, 106488.
[169] Hungate, B. A., Barbier, E. B., Ando, A. W., Marks, S. P., Reich, P. B., Van Gestel, N., ... & Cardinale, B. J. (2017). The economic value of grassland species for carbon storage. Science Advances, 3(4), e1601880

As part of the reformed Common Agricultural Policy to be implemented under the period 2023-2027, the eco-schemes are a set of instruments designed to reward farmers for improved environmental and climate agricultural practices at their exploitations. These eco-schemes consist on financial support granted to farmers to compensate for additional costs and foregone income derived from the implementation of such practices. Eco-schemes can also represent economic incentives to perform the necessary improvements to manage the transition towards more sustainable food systems. They can therefore be used to get an indirect measure of the economic value of these environmental actions. Figures may vary among member states depending on their agricultural contexts so we provide some examples of proposed payments under eco-schemes targeting farmland management for improved environmental performance including grasslands. The examples are taken from draft strategic plans published by member states before their final approval.

Ireland, to promote traditional grassland farming practices at extensive animal stocking rates, proposes a yearly payment rate per hectare that ranges from a minimum of 66€ to a maximum of 131€. Payments vary depending on the eligible farmers partaking the eco-schemes that operates at national level.

Spain, proposes eco-schemes including different agricultural practices to increase carbon sink capacity and to improve biodiversity in grasslands. Yearly payments differ depending on the type of grassland ranging from 51.42€/ha to 62.16€/ha in humid pastures, and from 33.99€/ha to 41.09€/ha in dry pastures.

These figures provide case study illustrations of the socio-economic benefits of increased numbers of butterfly populations, either directly since butterflies act as pollinators or indirectly since higher butterfly populations indicate the presence of healthy grasslands and that provide even broader socio-economic benefits.

High diversity landscape features

Background information

The Biodiversity Strategy to 2030 pointed to the need to increase landscape features in agricultural areas, and underlined that there is an urgent need to bring back at least 10% of agricultural area under high-diversity landscape features. These areas include, buffer strips, rotational or non-rotational fallow land, hedges, non-productive trees, terrace walls, and ponds. They are important for biodiversity as they provide space for wild animals, plants, pollinators and natural pest regulators. They also help enhance carbon sequestration, prevent soil erosion and depletion, filter air and water, and support climate adaptation.

For the purposes of the Green Deal, High-diversity landscape features (HDLF) include A*gricultural Landscape Features* (ALF) and Land Lying Fallow (LLF). ALFs are (small) fragments of non-productive natural or semi-natural permanent vegetation. Further important subtypes of HDLF include L*and Lying Fallow* (LLF) established for biodiversity goals (with no productive functions), as well as the woody components of (arable) agroforestry systems. An indicator for ALF will be included among the context and impact indicators of the PMEF

(Performance Monitoring and Evaluation Framework) of the new CAP (Common Agricultural Policy), and information on LLF can be extracted from the relevant CAP data sets.

Recommendations to MSs for the preparation of the CAP Strategic Plan (2020, Annex I) identified reference values for the quantified Green Deal targets in the area of agriculture. As regards the 10% of agricultural area under high-diversity landscape features, the document used as indicator the share of agricultural area under high diversity landscape features (4.6% for EU-27). This value originated from Directorate General for Agriculture and Rural Development (based on EUROSTAT for land laying fallow and the Joint Research Centre based on LUCAS survey for estimation of landscape elements; the Recommendations added that these be taken with caution because of methodological caveats. It added that the Commission and the European Environmental Agency are developing a more robust indicator in the framework of the CAP post-2020 to ensure all elements defined in the EU 2030 Biodiversity Strategy are covered).

Details of the indicator

High-diversity landscape features are elements of permanent natural or semi-natural vegetation present in an agricultural context which provide ecosystem services and support for biodiversity. In order to do so, landscape features need to be subject to as little external disturbances as possible to provide safe habitats for various taxa, and therefore need to comply with the following conditions:

a) they cannot be under productive agricultural use (including grazing or fodder production), and
b) they should not receive fertilizer or pesticide treatment

Land lying fallow, productive trees part of arable land agroforestry systems and productive elements in non-productive hedges, can also be considered as high diversity landscape features, if they comply with criteria (a) and (b) above, and, in the case of the two types of productive elements mentioned in this paragraph, if harvests take place only at moments where it would not compromise high biodiversity levels.

This definition can be represented with two key component indicators of HDLF. These have different ecological characteristics, and they are also quite different from the perspective of management and policy (e.g. LLF responds much faster to policy changes). The two indicators are:

- A*gricultural Landscape Features* (ALF) : The new CAP includes indicators I.21 "*Share of agricultural land covered with landscape features*" (which is labelled also as a context indicator). This indicator will focus on agricultural LF (small non-productive LF embedded in agricultural land[170]), distinguishing four functionally different subtypes of ALF (woody, grassy, wet, and stony ALF). This indicator will rely on two key sources of raw information at the EU level, including the Copernicus Small Woody Feature (SWF)

[170] Czúcz B, Baruth B, Terres JM, Hagyó A, Gallego J, Angileri V, Nocita M, Perez Soba M, Koeble R, Paracchini ML: *Classification and quantification of Landscape Features across the EU: A brief review of existing definitions, typologies, and data sources for quantification*. Publications Office of the European Union, Luxembourg, 2022

layer and the LUCAS LF surveys (Land Use/Cover Area frame Survey, Landscape Features module). Copernicus SWF (available from 2015 (& 2018 coming soon)) is a wall-to-wall mapping product covering the EEA countries. It captures woody linear structures , such as hedgerows, scrubs or tree rows along field boundaries, riparian and roadside vegetation, patches of trees and scrub. The LUCAS LF module is a newly planned survey to provide a new data source on landscape features. It will be first launched in the next LUCAS survey (2022), which will provide a consistent overview of the main LF types relevant in Europe in a statistically representative sample. The relevant CAP indicators are listed under Annex I of Reg. (EU) 2021/2115[171].

- L*and Lying Fallow* (LLF): In contrast with ALF, which are typically situated in the (small) spaces adjacent to, between or within the agricultural parcels, LLF is a land use subtype of (the parcels themselves. LLF is actually a land use category similar to crop types, which is recorded in the GSAA (GeoSpatial Aid Application) systems of the MS implementing the CAP. Accordingly, it is possible to create an indicator for the *share of agricultural land lying fallow* based on the GSAA records.

Environmental impacts

The most important direct driver of biodiversity loss in the past 50 years has been land cover change, involving the loss and fragmentation of species habitats[172]. Therefore, introducing or preserving non-productive landscape features provides substantial benefits for biodiversity in agricultural landscapes. As a result, landscapes and habitats become more heterogeneous both in space and time, providing local environmental conditions and resources for a broader variety of species and along their entire phenological cycles (e.g. resources for overwintering, nesting, feeding, etc, in the case of animals). Habitat connectivity increases, enabling crossings between individuals of different populations as well as enabling, plant and animal populations to disperse and migrate across landscapes, which is of particular importance in the context of climate adaptation and genetic diversity. Increased populations of beneficial insects, spiders, and birds bring agronomic benefits through pollination or by controlling crop pests.

EU funded research found strong positive evidence that seminatural habitats in the agrarian matrix support pollinators and pest predators, based on a thorough review of available literature on the topic[173]. Field studies showed that insect pollination potential and pest predation increased on average by 10% and 13%, respectively, when landscape features share in agricultural land was increased from 6% to 26% (Figure IV-2)[174,175 176], increase carbon sequestration[177,178], soil

[171] Regulation (EU) 2021/2115 of the European Parliament and of the Council of 2 December 2021, OJ L 435, p.1, of 6.12.21; https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=OJ:L:2021:435:TOC

[172] Millennium Ecosystem Assessment (2005) Ecosystems and human well-being: biodiversity synthesis. World Resources Institute, Washington, DC.

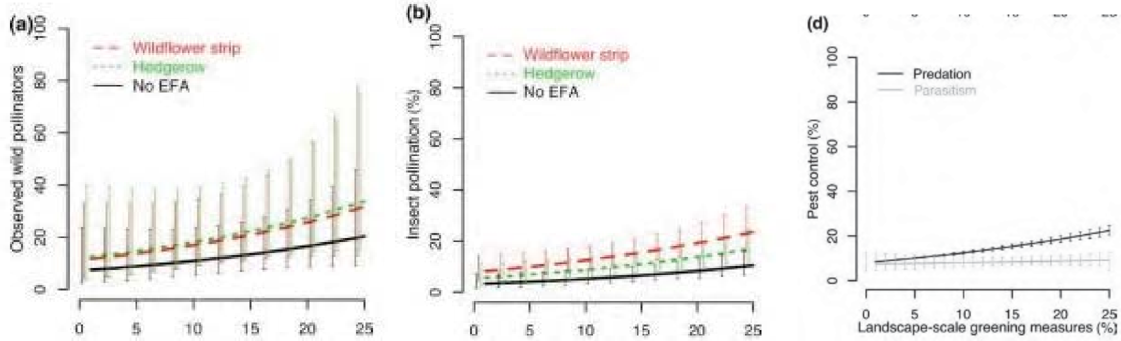
[173] Holland, J.M., Douma, J.C., Crowley, L., James, L., Kor, L., Stevenson, D., Smith, B.M. (2017) Semi-natural habitats support biological control, pollination and soil conservation in Europe: A review. Agronomy for Sustainable Development, 37:31.

[174] Sutter, L., Albrecht, M., & Jeanneret, P. (2018). Landscape greening and local creation of wildflower strips and hedgerows promote multiple ecosystem services. Journal of applied ecology, 55(2), 612-620

[175] Holland et al., 2017.

[176] Van Vooren, L., Reubens, B., Broekx, S., Reheul, D., & Verheyen, K. (2018). Assessing the impact of grassland management extensification in temperate areas on multiple ecosystem services and biodiversity. Agriculture, Ecosystems & Environment, 267, 201-212.

Figure IV-2 Effects of greening measures and adjacent Ecological Focus Areas (EFA) Source: Sutter et al, (2018).



(wildflower strip [red], hedgerow [green], and no EFA [black]) on (a) number of observed wild pollinator visits per plot (2 m2 , 10 min), (b) "local pollination potential" increase in seed set driven by insect pollination (%), (d) predation on pollen beetle (black) and pollen beetle parasitism (grey).

nutrients[179] and soil water retention[180] in their surroundings, as well as the water quality in nearby water streams[181], while they decrease nutrient leaching and soil erosion[182]. Such environmental outputs depend on the type of landscape feature. Moreover, a meta-analysis of 127 monitoring studies[183] revealed that the numbers of species of birds, insects, spiders and plants were significantly higher on set-aside land than on nearby control areas under conventional agriculture. The population densities of all four taxa were also higher on set-aside land. In this study set-aside is defined as "all or part of a field subjected to, for at least one growing season, low or no fertilizer or chemical inputs, low or no grazing or tillage, and mowing no earlier than late June, if at all, with vegetation either naturally regenerated or sown at the beginning with grass or wildflower mixtures".

Socio-Economic Impacts

In agricultural areas, an estimation of the costs for establishing and maintaining landscape features can be provided by looking at the premiums paid to farmer in the frame of CAP Pillar II. This then provides an estimation of the "willingness to pay" by the public sector to maintain such areas. In particular, Measure 10 of Rural Development Programs 2014-2022 supports the maintenance of landscape features on agricultural land, while Measure 4 supports non productive investments including the establishment of new landscape features. Similar measures are contained in the forthcoming CAP Strategic plans in the form of eco-schemes and Agri-

177 Drexler, S., Gensior, A. _& Don, A. (2021) Carbon sequestration in hedgerow biomass and soil in the temperate climate zone. Regional Environmental Change, 21(3), 74.

178 Zheng, Y.L., Wang, H.Y., Qin, Q.Q. & Wang, Y.G. (2020) Effect of plant hedgerows on agricultural non-point source pollution: a meta-analysis. Environmental Sciences and Pollution Research, 27(20), 24831-24847.

179 Wei, W., Chen, D., Wang, L.X., Daryanto, S., Chen, L.D., Yu, Y., Lu, Y.L., Sun, G. & Feng, T.J. (2016) Global synthesis of the classifications, distributions, benefits and issues of terracing. Earth-Science Reviews, 159, 388-403.

180 Zhang, X.Y., Liu, X.M., Zhang, M.H., Dahlgren, R.A., Eitzel, M. (2010) Review of vegetated buffers and a meta-analysis of their mitigation efficacy in reducing nonpoint source pollution. Journal of environmental quality, 39, 76-84.

181 Van Vooren, L., Reubens, B., Broekx, S., De Frenne, P., Nelissen, V., Pardon, P. & Verheyen, K. (2017) Ecosystem service delivery of agri-environment measures: a synthesis for hedgerows and grass strips on arable land. Agriculture, Ecosystems and Environment, 244 32-51.

182 Valkama, E., Usva, K., Saarinen, M. & Uusi-Kamppa, J. (2019) A meta-analysis on nitrogen retention by buffer zones. Journal of Environmental Quality, 48(2), 270-279.

183 Van Buskirk , J. and Willi , Y, Enhancement of farmland biodiversity within set-aside land. Conservation Biology 18 (4) : 987-994, (2004)

Environmental climate measures, provided they go beyond the baseline (GAEC 8, cfr Annex III of Regulation (EU) 2021/2115).

As a general rule, the amount of the financial support granted to farmers is determined to compensate for additional costs and foregone income: eco-schemes can also provide incentives. They therefore represent a good proxy of the cost that society as a whole is willing to pay for the establishment of these features and the enhancement of the benefits derived from a functioning landscape features network. Figures vary from country to country, in the following the most recent available information from some CAP Strategic Plans is reported:

Table IV-8 Ireland (AECM General)

Type of Landscape Feature	Unit	Amount
Grass margin on arable land (3 m width)	Linear meter (lm)	0.38 €/lm (=0.127 €/m^2)
Grass margin on grassland		
Plantation of new hedgerows	Linear metre	5.29 €/lm (≈ 1.76 – 2.65 €/m^2)
Planting Trees- Rows Groups or Parkland	Unit (tree)	6.21 €/tree
Riparian Buffer Zone adjacent to arable land	Hectare (ha)	1,242 €/ha (= 0.124 €/m^2)

In France, the basic Eco-Scheme supports the creation of Landscape features to cover up to 7% of UAA (level 1) at the rate of 60 €/ha UAA or up to 10% (level 2) at the rate of 82 €/ha UAA. Considering that the compulsory baseline value as for GAEC 8 is 4% of UAA covered by landscape features, this means that the cost paid is 1,367-2,000 €/ha or 0.137-0.2 €/m^2 of surface of landscape feature[184], very close to the Irish figures.

The Italian CAP SP has two specific Agri-Environmental climate measures for i) the creation and ii) maintenance of landscape features, including hedges, buffer strips, tree lines, woodlots, wet areas, riparian zones. Specific details on implementation will be subsequently defined at regional level but the maximum amount per ha of UAA for the two measures is 83.48 €/ha and 119.84 €/ha respectively, so final figures should be comparable to the French ones.

An EU analysis based on the CAPRI-model[185] suggests that an increase to 10% landscape features could reduce agricultural output by 2.1% and increase produces prices of crops and cattle by 2.2%. However, the study report acknowledges that it tends to overestimate the impact because it does not consider other influencing factors such as possible positive feedback loops (e.g. landscape features attracting pollinators which can increase agricultural yield) and policy measures supporting the transition. The same study also reports positive environmental impacts of increasing landscape features, e.g. reduction of harmful emissions.

[184] These figures refer to landscape features in general, for hedgerows in particular there is an additional bonus of 7 Euros/m^2 (top up).

[185] Supplementary material (provided by the author) to the study: Barreiro-Hurle, J., Bogonos, M., Himics, M., Hristov, J., Pérez-Domiguez, I., Sahoo, A., Salputra, G., Weiss, F., Baldoni, E., Elleby, C. Modelling environmental and climate ambition in the agricultural sector with the CAPRI model. Exploring the potential effects of selected Farm to Fork and Biodiversity strategies targets in the framework of the 2030 Climate targets and the post 2020 Common Agricultural Policy, EUR 30317 EN, Publications Office of the European Union, Luxembourg, 2021, ISBN 978-92-76-20889-1, doi:10.2760/98160, JRC121368.

In summary, increases of the in the landscape features indicator would directly provide direct evidence of improvements in biodiversity and environment. Based on the case examples provided a number of socio-economic benefits can be expected, including of how much society is willing to pay to ensure landscape features.

Soil organic carbon in cropland mineral soils

Background information

Soil organic carbon is the major component of soil organic matter. Organic matter in soil is essentially derived from residual plant and animal material, synthesised by microbes and decomposed under the influence of temperature, moisture and ambient soil conditions. The vast percentage of cropland soils in the EU are mineral soils. Mineral soils are defined by having an organic carbon content below 20%, although more generally it is below 5%.

Soil organic carbon (SOC) is a key indicator for soil health as it point to levels of biological, chemical and physical processes. These in turn underpin the delivery of all soil ecosystem services including carbon sequestration, soil fertility, water regulation, nutrient cycling and hazard risk mitigation. In terms of carbon sequestration, carbon stocks in EU-27 agricultural soils are estimated to be around 13,350 Mt C (or 48,950 Mt CO_2eq) in the topsoil (generally 0-30 cm).

A range of pressures threaten both organic and mineral soils driving their SOC content below critically low levels, including land management choices/changes, reclamation and drainage of organic soils, soil erosion, peat extraction, soil sealing, and climate change. Every year mineral soils under cropland are losing around 7.4 million tonnes of carbon, caused mainly by unsustainable farming practices. Soil restoration is urgently needed as soils provide the main foundation for life on Earth, both above and below ground, yet soil condition is deteriorating in the EU where around 60-70% of soils are estimated to be unhealthy[186].

Around 45 % of EU mineral soils have low or very low SOC and 1.5 % have extremely low SOC levels with lowest levels in Southern Europe[187,188] and arable soils[189,190,191,192]. Data from LUCAS Soil surveys shows that in particular cropland soils contain the lowest levels of organic

[186] https://ec.europa.eu/info/publications/caring-soil-caring-life_en

[187] Tanneberger, et al (2017) The peatland map of Europe. Mires and Peat No 19 (22), 1-17. (Online: http://www.mires-and-peat.net/pages/volumes/map19/map1922.php. Schils, R, Kuikman, P, Liski, J, Van Oijen, M, Smith, P, Webb, J, Alm, J, Somogyi, Z, Van der Akker, J, Billett, M, Emmett, B, Evans, C, Lindner, M, Palosuo, T, Bellamy, P, Jandl, R and Hiederer, R (2008) Review of Existing Information on the Interrelations between Soil and Climate Change (CLIMSOIL final report). Contract number 070307/2007/486157/SER/B1, European Commission, Brussels.

[188] Schils, et al (2008). Review of Existing Information on the Interrelations between Soil and Climate Change (CLIMSOIL final report). Contract number 070307/2007/486157/SER/B1, European Commission, Brussels.

[189] Stolte, J, et al (2015). Soil threats in Europe: status, methods, drivers and effects on ecosystem services. JRC Technical Reports, 978-92-79-54019, Joint Research Centre, European Commission.

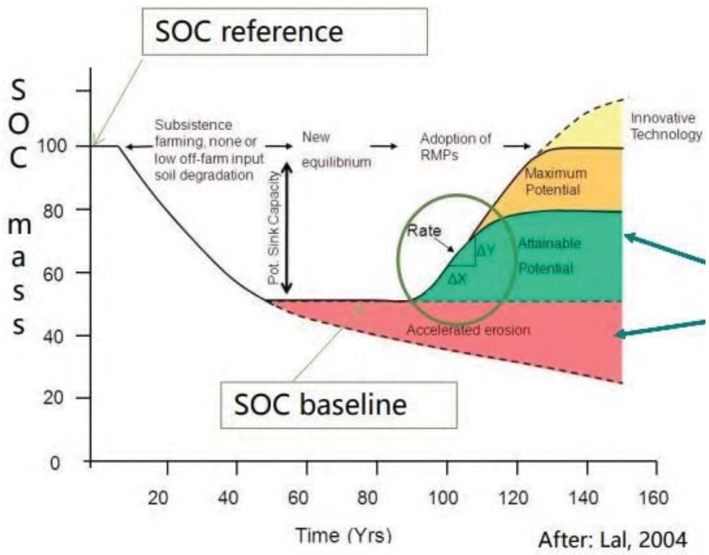
[190] Costantini, E., et al 2020. Local adaptation strategies to increase or maintain soil organic carbon content under arable farming in Europe: Inspirational ideas for setting operational groups within the European innovation partnership. Journal of Rural Studies, 79, pp.102-115.

[191] Maes et al (2020) Mapping and Assessment of Ecosystems and their Services: An EU wide ecosystem assessment in support of the EU biodiversity strategy. EUR 30161 EN, European Commission, Brussels.

[192] Jones, A, et al (2012) The State of Soil in Europe.

matter concentrations of any major land cover category[193]. Overall, EU SOC stocks in mineral soils have not changed significantly in the past decade. This is due to the plateauing of stocks towards a low steady state that is below optimal levels and reflects the significant loss of carbon stock in intensively managed arable soils. The current state mirrors a carbon input-output equilibrium where the rate of carbon inputs are matched by removals (e.g. harvest, mineralisation and erosion), echoing the consequences of continued long-term farming systems on soil condition.

Figure IV-3. Source: Lal, (2004)[194]



Despite this aggregate trend, key regional hotspots are experiencing notable SOC decreases in the Mediterranean and central-eastern Europe. Most areas at risk of critically low and decreasing SOC are on arable land, with decreases of 2.5 % in SOC concentrations reported in cropland from 2009-2015. Grasslands likely have an overall stable or slightly increasing SOC stocks. Trends in forest soil stocks are uncertain but generally acting as a sink. The largest SOC declines from 2009-2015, of 11 % on average[195] were reported for areas converted from grassland to cropland.

In the absence of additional legally binding soil restoration targets, the current mineral and organic soil degradation trends in the EU are assumed to continue to 2030: mineral soils will continue experiencing low SOC levels on 45% of EU area. Stable trends in aggregate SOC levels are expected to 2030 with some differences across regions and land-uses. Arable land will continue experiencing critically low SOC on 2.6% of it area with regional hotspots. Despite a likely overall equilibrium between SOC gains and losses, many agricultural soils maybe unable to provide fully their expected ecosystem services and declines will continue in high-risk arable

[193] Jones, A., Fernandez Ugalde, O. and Scarpa, S., LUCAS 2015 Topsoil Survey, EUR 30332 EN, Publications Office of the European Union, Luxembourg, 2020, ISBN 978-92-76-21080-1, doi:10.2760/616084, JRC121325.
[194] Lal, Rattan. "Soil carbon sequestration impacts on global climate change and food security." *science* 304.5677 (2004): 1623-1627.
[195] EUROSTAT, Eurostat regional yearbook — 2020 edition https://ec.europa.eu/eurostat/web/products-statistical-books/-/ks-ha-20-001

areas. Permanent grasslands will likely continue experiencing modest increases in SOC. The largest potential for SOC stock improvement is on degraded agricultural land as these areas are not saturated for SOC

Local carbon sequestration potentials vary across the EU as they depend on soil and climate variables. Practices which increase SOC stocks should be implemented following regional guidance adapted to local contexts[196]. The permanent conversion of arable land to grassland is particularly relevant as well as the maintenance of grassland and banning of ploughing on permanent grassland. Measures on arable land include improved crop rotations, residue management, cover cropping, agroforestry, and organic farming.

Details of the indicator

This indicator describes the amount (stock) of SOC: Soil organic carbon stocks in the topsoils of croplands (0-30 cm depth), expressed in tonnes or Mg per hectare. Soil organic carbon in mineral soil is the major component of soil organic matter, and is measured as the amount of organic carbon contained in soils.

Organic carbon content is derived through the laboratory analysis of a representative soil sample collected from the target depth and expressed as the gravimetric percentage of dry (105 °C)soil [g SOC kg-1]. Standard procedures for the determination of soil moisture are available. These include the dry combustion method, wet oxidation by dichromate ions, loss-on-ignition, spectroscopic techniques. Samples collected through the LUCAS survey are analysed following the ISO 10694:1995 Standard using the dry combustion method.

Data are available across Member States from LUCAS Soil[197] and JRC Biogeochemical modelling[198]. LUCAS data are field observations of cropland topsoils, which are collected every 3-4 years for all Member States. Data exist for 2009, 2015 and 2018. The next LUCAS sampling will take place in 2022 has been designed to provide statistically robust assessments of soil carbon stocks for croplands at NUTS 2 Level. Some Member States, such as France, have developed their own systems and data would then be reported by these national systems. As an action of the Soil Strategy, the JRC is collaborating with the EJP-Soil Project and others to develop a roadmap towards an integrated soil monitoring system for the EU, building on LUCAS and national or regional operational systems. It is hoped to be implemented for 2026. Through its WorldSoils Project, the European Space Agency is also investigating methods for monitoring SOC based on remote sensing data, large soil data archives and modelling techniques[199]

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[196] Lugato, Emanuele, et al. "Potential carbon sequestration of European arable soils estimated by modelling a comprehensive set of management practices." *Global change biology* 20.11 (2014): 3557-3567.

[197] Jones, A., Fernandez Ugalde, O. and Scarpa, S., LUCAS 2015 Topsoil Survey, EUR 30332 EN, Publications Office of the European Union, Luxembourg, 2020, ISBN 978-92-76-21080-1, doi:10.2760/616084, JRC121325 and Panagos, P., Ballabio, C., Scarpa, S., Borrelli, P., Lugato, E. and Montanarella, L., Soil related indicators to support agro-environmental policies, EUR 30090 EN, Publications Office of the European Union, Luxembourg, 2020, ISBN 978-92-76-15645-1, doi:10.2760/889067, JRC119220.

[198] Lugato et al. 2014. A new baseline of organic carbon stock in European agricultural soils using a modelling approachhttps://onlinelibrary.wiley.com/doi/abs/10.1111/gcb.12292

[199] WORLDSOILS Project Webiste (world-soils.com)

Robust evidence exists to show that land management and agricultural practices have an impact (both positive and negative on SOC stocks[200]). However, it should be noted that changes in SOC stocks are generally slow with significant change expected over a decade. Modelling approaches can be used to extrapolate changes at shorter time interval, however the general recommendation for soil (IPPC[201],FAO[202], Smith et al 2020[203]) is that in situ measures are needed to establish a baseline and provide independent estimates of large-scale SOC change on at least a decadal basis (or longer).

It is worth reflecting that SOC is a CAP Impact Indicator, used by the UNCCD methodology to define degraded land (SDG 15.3) and considered under the LULUCF Regulation. The approach used under LULUCF depends on changes in land use and land cover, and primarily uses modelling approaches.

In summary, this means that currently methods for measuring SOC are available across the EU MS, and that with time, these methods are likely to become more integrated and more accurate.

Environmental impacts

While there is a high level of interest in the potential of carbon sequestration in agricultural soils, farming practices that support soil carbon preservation and increased rates of sequestration generally enhance environmental quality through the provision of additional or enhanced benefits. These include an increase in infiltration, increased fertility and nutrient cycling, decreased wind and water erosion, reduced risk of compaction, enhanced water quality, decrease C emissions, impede pesticide movement and generally enhance environmental quality.

Mineral soils are defined by having an organic carbon content below 20%, although more generally it is below 5%. Every year mineral soils under cropland lose around 7.4 million tonnes of carbon, caused mainly by unsustainable farming practices. Carbon sequestration in mineral soils, while depending on soil type and climatic conditions, through targeted and continued sustainable management practices can significantly help in achieving climate neutrality by increasing the carbon stocked in mineral soils. Research shows that this is an effective emission mitigation method with significant potential to sequester between 11 to 38 MtCO2eq annually in Europe if a range of management practices, which have already been identified are applied on a larger scale in arable land[204] (see Fig. IV-3 below). Many of these practices are cost-effective. In this regards, achieving net-zero greenhouse gas emissions by 2050 relies also on carbon removals through the restoration and better management of soils to store the atmospheric CO2.

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[200] https://onlinelibrary.wiley.com/doi/abs/10.1111/gcb.12551

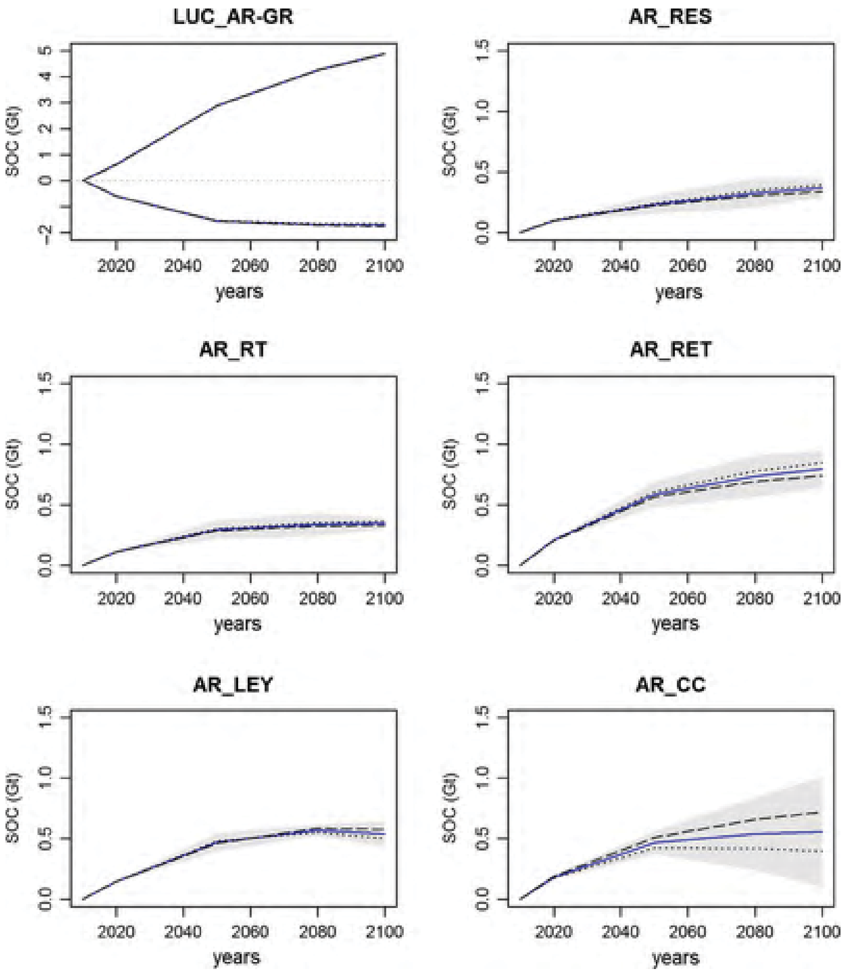
[201] The Intergovernmental Panel on Climate Change (IPCC), IPCC Good Practice Guidance for LULUCF, Cropland, 2003. https://www.ipcc-nggip.iges.or.jp/public/gpglulucf/gpglulucf_files/Chp3/Chp3_3_Cropland.pdf

[202] FAO, Measuring and modelling soil carbon stocks and stock changes in livestock production systems : Guidelines for assessment, 2019. https://www.fao.org/3/ca2934en/CA2934EN.pdf

[203] Smith, P., et al, How to measure, report and verify soil carbon change to realize the potential of soil carbon sequestration for atmospheric greenhouse gas removal, Global change biology, 2019. https://doi.org/10.1111/gcb.14815

[204] Lugato, E., et al, Potential carbon sequestration of European arable soils estimated by modelling a comprehensive set of management practices, Global Change Biology, Vol 20, Issue 11, 2014. https://onlinelibrary.wiley.com/doi/full/10.1111/gcb.12551

Figure IV-4 Trend of cumulated SOC change (Gt of C) at pan-EU level in relation to the different simulated agricultural management practices. Source: Lugato et al, 2014

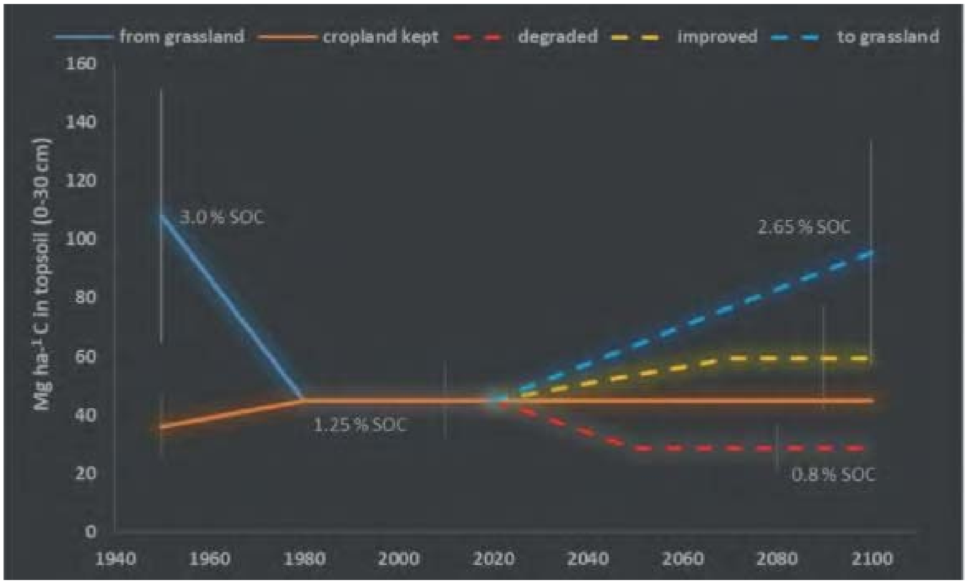


Thin and thick dotted lines correspond to contrasting climate change models. The blue line is the average, while the grey region delimited the 2σ confidence interval. Scenarios include Conversion from arable to grassland (AR_GR_LUC), Crop residue management (AR_RES), Reduced tillage (AR_RT), Ley in rotation (AR_LEY), Cover crops (AR_CC)..

Similar schematic scenarios for possible ranges of development in the soil organic carbon (SOC) stock in the topsoil (0-30 cm) with land management changes are evident in other studies. In the Fig. IV-5 below estimations are in t ha-¹ and calculated by typical initial SOC concentrations [%, mg 100 g] of a North German site, with standard deviations of 30 % and 40 % of the measured values in cropland and grassland samples, respectively and for a soil density of 1.2 g cm-3 (dry). Different reaction times of 30-100 years were assumed to reach a new equilibrium of SOC after land management changes. Improved management (carbon farming) might slowly improve levels back to the levels of grassland (blue dotted line) or somewhere in between (e.g., yellow dotted line)[205].

[205] Paulsen (ed.) (2020). Inventory of techniques for carbon sequestration in agricultural soils. Interreg Europe, Thünen Institute of Organic Farming. 20200313-cf-rapport.pdf (northsearegion.eu)

Figure IV-5 Development in the soil organic carbon (SOC) stock in the topsoil (0-30 cm) with land management changes. Source: Paulsen et al, 2020.



Increased soil carbon levels in mineral soils improves soil condition by supporting aggregate formation, which in turn improves soil structure, a key factor that governs water and gas movement within soils as well as providing an improved habitat for soil organisms. Given the crucial role of soil in the water cycle, this development is also indispensable for climate adaptation. Healthy cropland soils, with increased levels of SOC, will make the EU more resilient to weather extremes while reducing its vulnerability to climate change (e.g. increased water retention reduces flood peaks while mitigating drought conditions)[206,207].

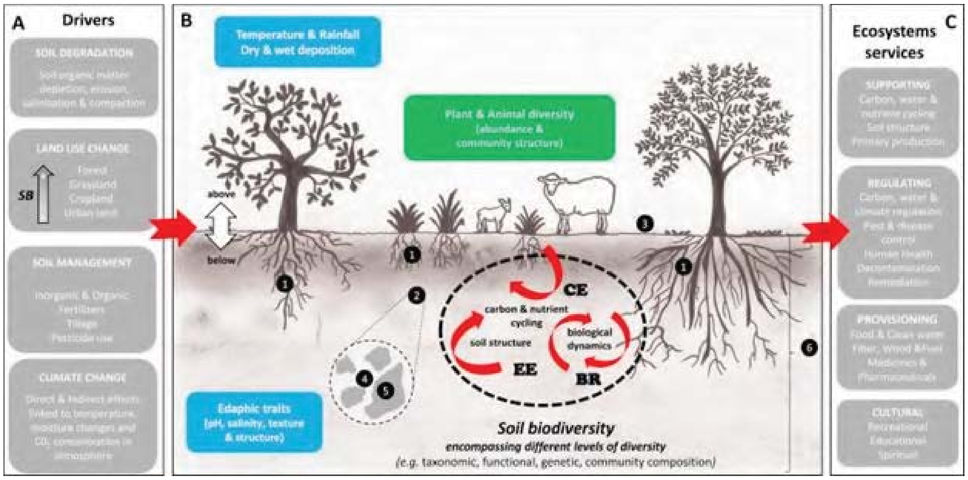
In parallel, increased levels of organic matter provide the energy sources for soil-dwelling organisms, and thus underpinning the soil-food web, which in turn, is linked to higher soil biodiversity levels. Soil organisms are the principal drivers of nutrient cycling while regulating the dynamics of soil organic matter, soil carbon sequestration and greenhouse gas emission[208].

[206] American University, What is Soil Carbon Sequestration? https://www.american.edu/sis/centers/carbon-removal/fact-sheet-soil-carbon-sequestration.cfm

[207] Á. Kertész, B. Madarász, Conservation Agriculture in Europe, International Soil and Water Conservation Research, Volume 2, Issue 1, 2014.https://www.sciencedirect.com/science/article/pii/S2095633915300162

[208] FAO, ITPS, GSBI, SCBD, and EC. 2020. State of knowledge of soil biodiversity – Status, challenges and potentialities, Summary for policymakers. Rome, FAO. https://www.fao.org/documents/card/en/c/cb1929en

Figure IV-6 Soil biodiversity overview. Source: Mujtar et al 2019[209].



The banking and financial sector is increasingly interested in investing in those farmers who apply sustainable practices and increase soil carbon, as well as creating market-based incentives for carbon storage[210].

There is evidence that carbon farming can contribute significantly to the EU's efforts to tackle climate change but also brings other co-benefits such as increased biodiversity and the preservation of ecosystems.

The revised Regulation on Land Use, Forestry and Agriculture (LULUCF) sets an overall EU target for carbon removals by natural sinks, equivalent to 310 million tonnes of CO2 emissions by 2030. National targets will require Member States to care for and expand their carbon sinks to meet this target. By 2035, the EU should aim to reach climate neutrality in the land use, forestry and agriculture sectors, including also agricultural non-CO2 emissions, such as those from fertiliser use and livestock.

Socio-Economic Impacts

Cost estimates from studies assessing the implementation of SOC conservation measures vary widely as studies follow different methodologies, include different soil management measures, and are based on regions with different pedo-climatic and socioeconomic contexts. Typically, values range from €100 to 1000 /ha/year with an average of around €280/ha/year.

[209] El Mujtar, V., et al, Role and management of soil biodiversity for food security and nutrition; where do we stand?, Global Food Security, Volume 20, 2019. https://www.sciencedirect.com/science/article/pii/S2211912418300300

[210] Rabobank, Soil health for stronger farms? We can measure that: Helping farmers better know their soil. https://www.rabobank.com/en/raboworld/articles/soil-health-for-stronger-farms-we-can-measure-that.html

Inaction on SOC decline costs the EU €3.4-5.6 billion every year[211]. Addressing SOC decline can avoid these large costs while delivering a range of additional on-site and off-site benefits. This target will deliver climate change mitigation benefits through increasing carbon sequestration in EU-27 agricultural land by 404 MtCO2eq by 2030 (equivalent to 0.31 tCO2eq/ha/year). Applying a carbon value of €100 per tCO2 equivalent, this would result in an economic benefit of around €40.4 billion from 2022-2030 and €31/ha/year. For specific measures, carbon stock increases range from 730 and 630 kgC/ha/year in the case of converting arable to grassland and implementing agroforestry practices respectively, to more modest increases between 15 and 30 kgC/ha/year in the case of grazing management, planting hedges, straw incorporation, and applying exogenous organic materials (EOMs).

Other considerations include biodiversity benefits by enhancing above and below ground habitat health, and increased crop yields, reduced erosion and increased water retention leading to increased resilience of agricultural production, natural hazard risk mitigation and food security. In addition, improved soil health that can benefit plant health and thus improve resilience towards droughts and increasing pests. These all lead to considerable climate adaptation benefits which may even outweigh the mitigation benefits of enhanced SOC[212,213]. In addition, measures can also reduce costs to farmers as they reduce input costs by, for example, reducing pesticide and fertilizer use.

Floods are the most common and most destructive natural disasters in Europe, resulting in a loss of life and significant economic damage. Over the past decades, the costs of floods have exhibited a rapid increase. Annual flood damage in the EU is currently estimated at €7.8 billion, affecting around 125,000 people, which could rise on the to €48 billion per year and 350,000 people by 2100 if nothing more is done to prepare[214]. There is increasing interest in the development of natural solutions to alleviate the impact of flood peaks. Increased water retention by agricultural soils is one of the options being considered with clear cost benefits[215].

There is a very high variation in estimated monetary benefits from SOC enhancement. A recent meta-review found soil protection measures deliver benefits ranging from 0 to 3440 €/ha/yr (average €93 €/ha/yr)[216]. Another study found overall on-site benefits from SOC conservation and enhancement on agroecosystems have been estimated at 2.1bn €/yr over 20 years in the EU-25. Carbon sequestration/preservation/farming activities can achieve several economic and environmental benefits in addition to climate change emission offsetting. Carbon farming programmes are by default long-term where annual costs will vary (e.g. schemes may call for a

[211] European Commission (2006a) Communication from the Commission to the Council, the European Parliament, the European Economic and Social Committee and the Committee of Regions – Impact Assessment of the Thematic Strategy on Soil Protection. SEC(2006)620 (http://ec.europa.eu/environment/archives/soil/pdf/SEC_2006_620.pdf)

[212] Powlson, D. S., A. P. Whitmore, K. W. T. Goulding (2011) Soil carbon sequestration to mitigate climate change: A critical re-examination to identify the true and the false. European Journal of Soil Science, vol. 62, no. 1, pp. 42–55.

[213] Amundson, R. and Biardeau, L. (2018) Opinion: Soil carbon sequestration is an elusive climate mitigation tool. Proceedings of the National Academy of Sciences of the United States of America, vol. 115, no. 46, pp. 11652–11656.

[214] https://www.science.org/content/article/europe-s-deadly-floods-leave-scientists-stunned

[215] https://www.arc2020.eu/flood-protection-lets-start-with-soil/

[216] Tepes, A, Galarraga, I, Markandya, A and Sánchez, M J S (2021) Costs and benefits of soil protection and sustainable land management practices in selected European countries: Towards multidisciplinary insights. Science of the Total Environment No 756, 143925.

commitment of 25 or more years, natural events such as floods, drought or fire may disrupt schemes while climate change may reduce sequestration rates). Sequestration is probably only viable for 30-50 years (depending on soil type and location) when equilibrium is reached. Payment schemes may then have to switch to preservation.

Concerns about the excessive costs of physically measuring soil carbon stores are increasingly less relevant given a decrease in laboratory testing prices, the increasing use of spectroscopy systems as alternatives to wet chemistry, and the proposed "Test your soil for free" initiative in the new EU Soil Strategy. These measures can also be supplemented by low-cost modelling approaches.

The opportunity cost of a permanent land-use change may be negative. Most solutions are available now, at low-cost, and technology and market changes may mean that other opportunities become much more profitable in the future. Soil carbon management lends itself well to both action and results-based payment schemes of the CAP and the recently announced carbon farming initiatives[217] as well as through the Living Labs and Lighthouse initiatives of the Soil Mission "A Soil Deal for Europe".

In summary, increases of the indicator of soil organic carbon in cropland mineral soils is related to management practices, and would directly provide direct evidence of improvements in biodiversity. Based on the case examples provided a number of socio-economic benefits, beyond carbon sequestration alone, would also be expected across the EU.

Species and habitats of community interest related to agriculture

Background information

Species and habitats of community interest related to agriculture are well documented and measured as part of the reporting obligations under the Habitats Directive. However, currently, only the grassland habitats category is the subject of specific focus, with specific figures available.

This indicator assesses the conservation status trends of those habitats and species of Community interest, i.e. listed in the relevant Habitats Directive annexes, that are considered to be strongly linked to agro-ecosystems. The work on this indicator has started after the publication of the CAP proposals in 2018 and is still in progress

Species and habitats of Community interest are those in danger of disappearance in their natural range, rare or endemic, or characteristic of one or more of the EU biogeographical regions; these species and habitats are listed in the annexes of the Habitats Directive.

The long-term existence of these habitats and species is strongly linked to the presence of certain extensive agricultural management practices; their conservation status is influenced by

[217] European Commission, Carbon Farming: https://ec.europa.eu/clima/eu-action/forests-and-agriculture/sustainable-carbon-cycles/carbon-farming_en

the management practices implemented, the intensity of land use, and by the conversion into or disruption by other land uses.

Lists that identify species and habitats protected under the Habitats Directive dependent on agro-ecosystems exists since many years. The species and habitat composition will vary between biogeographical regions and between Member States. The lists of species and habitats (one per Member State with indication of the relevant biogeographical regions) are being elaborated building on the guidance from the European Commission, also taking into account Halada et al. (2011)[218] and Roscher et al. (2015)[219]. The lists are to be validated by the Member States shortly. This indicator reduces the scope to species which are not birds, and to habitats and species strictly dependent on agriculture.

Details of the indicator

The unit of measurement is the percentage of assessments with a stable or improving conservation status trend. For both, species and habitats, the overall assessment of conservation trend is as follows: ‘improving +’, ‘deteriorating -’, ‘stable =’, ‘unknown x’.

The indicators is defined as:

Number of assessments that indicate an improving or stable trend /

Total number of assessments

The number of assessments depends on the total number of species and habitats, and on the number of biogeographical regions where they are represented (e.g. a species present in 2 biogeographic regions will have two assessments).

The data source is the reporting from Article 17 of the Habitats Directive, and it is reported to the European Environment Agency (EEA) by the Member States. The EEA would carry out the necessary calculations. The data collection level is foreseen to be applied at the level of the Member States (NUTS 0). Values are assessed at the biogeographical level of each Member State, in such a way that results can be aggregated at the level of the Member States and the EU. The frequency of the availability of the figure will follow article 17: current 2019 report due available (for 2013-2018), Next reports are due in 2025 (2019-2024) and 2031 (2025-2030).

Environmental impacts

For millennia farming has been a major contributor to biodiversity, thanks to the evolution diverse farming traditions which have resulted in the development of an intricate patchwork of semi-natural habitats across the landscape. This has, in turn, attracted a wide range of species of fauna and flora. Some are well known like the Hamster (Cricetus cricetus) and the European Ground Squirrel (Spermophilus citellus), but a myriad of other lesser known species, such as Dusky Blue Butterfly (Maculinea nausithous) and many orchid species have also made their

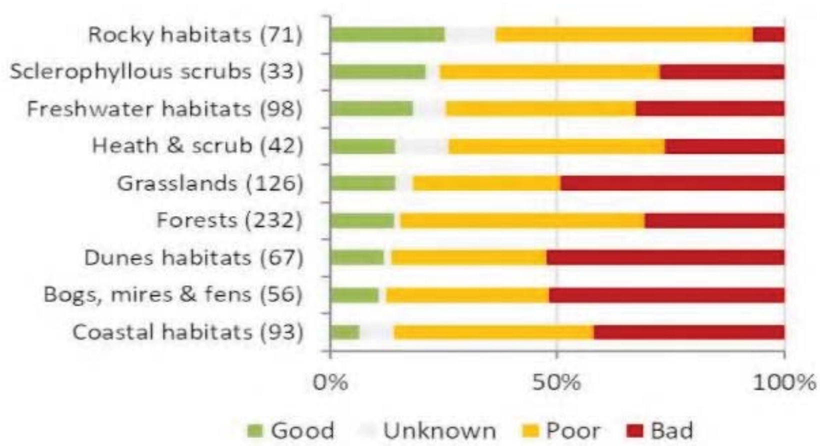
[218] Halada, L., Evans, D., Romão, C., and Petersen, J.E. (2011). Which habitats of European importance depend on agricultural practices? Biodiversity and Conservation 20, 2365- 2378.

[219] Roscher, Christiane; Weisser, Wolfgang W; Schulze, Ernst-Detlef (2015): Aboveground community and species-specific plant biomass from the Jena Experiment (Dominance Experiment, year 2004). PANGAEA.

home in these semi natural habitats. However, in the last 50 years, through the combined effects of farm intensification and land abandonment, farmland biodiversity has undergone a dramatic decline[220]. Such relatively rapid change in main agricultural management trends is a threat for a number of species and habitats that are now entirely dependent on locally tailored extensive farming systems and practices for their continued survival.

For habitats, the indicator covers for example alpine meadows and pastures, steppic plains, open heathland and wet grasslands. From the State of Nature report[221], Grasslands, which include some very species-rich habitats, are also among those with the highest proportion of 'bad status' assessments (49%). Grasslands that require active management are in a particularly bad state. For grassland habitats, mainly hay meadows , Molinia meadows and several types of semi-natural dry grasslands show a deteriorating conservation status trend, illustrating their dependence on extensive farming practices that are still in decline across the EU.

Figure IV-7 Conservation status of different habitats. Source: EEA, 2020.



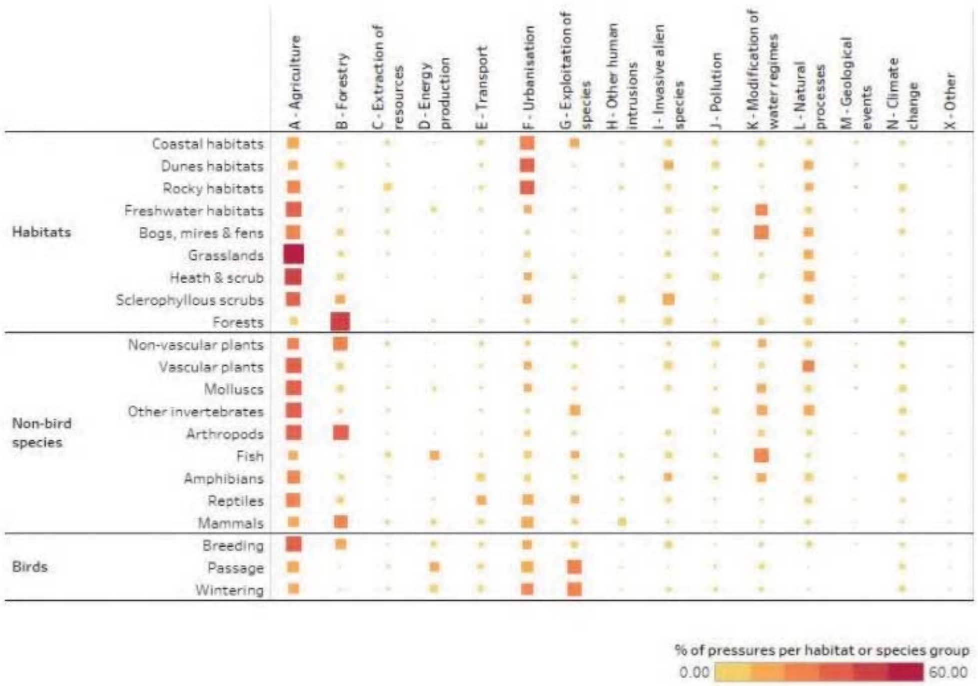
The most frequently reported pressures for both habitats and species stem from agriculture, which reflects the relative scale of agricultural land- use and changes in farming practices (intensification and abandonment of extensive agriculture). Extensive agricultural management creates and maintains semi-natural habitats with diverse fauna and flora. Since the 1950s, however, more intensive and specialised farming has contributed increasingly to ongoing biodiversity loss. Grasslands, freshwater habitats, heaths and scrubs, and bogs, mires and fens have been most severely affected. Semi-natural habitats depending on agriculture, such as grasslands, are particularly threatened and their conservation status is significantly worse than for other habitat types that do not depend on agriculture (45% are assessed as bad, as compared

[220] European Commission, Farming for Natura 2000: Guidance on how to support Natura 2000 farming systems to achieve conservation objectives, based on Member States good practice experiences, 2018. https://ec.europa.eu/environment/nature/natura2000/management/docs/FARMING%20FOR%20NATURA%202000-final%20guidance.pdf

[221] Report from the Commission to the European Parliament, the Council and the European Economic and Social Committee, The state of nature in the European Union Report on the status and trends in 2013 - 2018 of species and habitat types protected by the Birds and Habitats Directives, 2020. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2020:635:FIN

with 31% for other habitats). Compared to 2015, assessments of agricultural habitats show an overall deterioration in conservation status: good status decreased from 14% to 12% and bad status increased from 39% to 45%. Only 8% of agricultural habitats show an improving trend, whereas 45% are deteriorating. Many species of birds, reptiles, molluscs, amphibians, arthropods and vascular plants are also impacted and farmland biodiversity continuous to decline. Therefore evidence of increase of this indicator would provide evidence of direct benefit to biodiversity.

Figure IV-8 Distribution of level-1 pressure categories among habitats, non-bird species and birds. Source: EEA, 2020.



Socio-Economic Impacts

Most of the species and habitats covered by the indicator concern extensive farming well adapted to local conditions. These are mostly local small-scale farmers rather than large agri-businesses. However, they are far from being in the minority. Small scale farmers and extensive farming businesses still represent a significant proportion of the 14 million farmers in the EU. Some of these existing farming systems and practices are already compatible with conservation of the species and habitats. Although not as productive as the modern large scale farms, these farming systems are nevertheless a vital part of the socio-economic fabric of Europe’s rural areas and, as such, have an essential role to play socially, economically and environmentally within the EU.

They represent a substantial source of local employment and income, preventing rural depopulation and helping to keep rural communities alive. The report for DG ENV (BIO Intelligence Service 2011) estimated that Natura 2000 directly and indirectly supported some 1.3 million FTE jobs in the agricultural sector each year in the EU-27 during the period 2006-

2008222. They are a vital source of food and produce for many remote rural areas. And they play a major role in maintaining Europe's rich and diverse biodiversity. However, despite their socio-economic importance, the viability of extensively managed farming businesses has become increasingly precarious over the years. In many parts of the EU, farmers have been forced to abandon their land and go in search of alternative sources of income elsewhere, with devastating social and economic consequences for the rural areas concerned. Or they have further intensified their land, converting grassland to arable, increasing the livestock stocking rate, or increased fertilization. Over recent decades substantial areas of the EU have been affected by agricultural abandonment. There are also reasonable expectations that farmland abandonment in Europe, particularly of extensively grazed areas, will continue over the next decades.

These illustrations therefore point to the kinds of socio-economic benefits that can be expected when there is evidence of increase of the indicator of the Species and habitats of community interest related to agriculture.

Overall analysis of the indicators

The purpose has been to examine and justify which indicators that demonstrate the enhancement of biodiversity for agroecosystems could be considered for inclusion in the legal proposal. To this end, a broad number of potential indicators were first identified and a set of criteria were developed to select the most promising. From the original broad set of indicators a set of four were identified as the most adequate. This was followed by an assessment of the environmental and socio-economic impacts, that increases in these indicators would entail.

The indicators selected and analysed each constitute different ways of representing the enhancement of biodiversity in agroecosystems. They focus on either on key indicator species (such as butterflies) or aspects of the habitats themselves. A consideration of organic content in grassland and cropland soils is complemented by "above ground" aspects such as due to landscape features. This is further complemented by a consideration of those habitats or species that are in danger of disappearance. In this way, together, the indicators provide complementary information on the presence of biodiversity. Furthermore, increases in these indicators clearly provides evidence of improvement in trends in biodiversity as such as well as other environmental benefits.

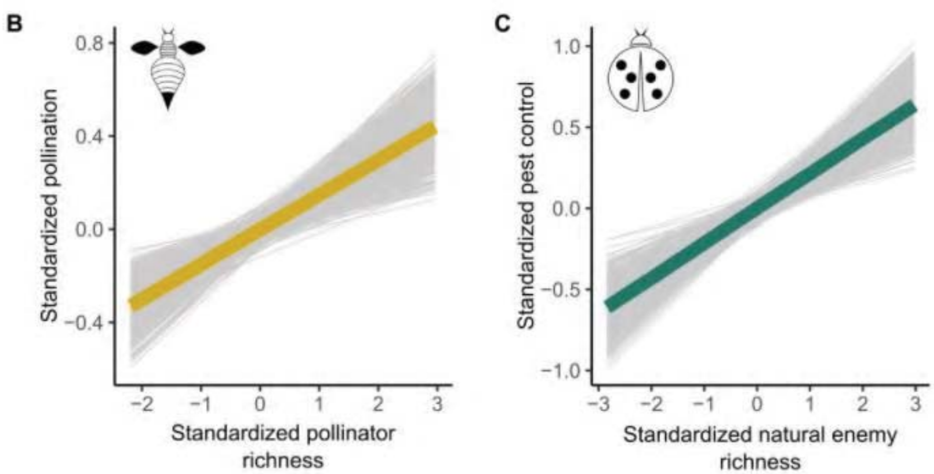
The evidence provided also shows that improvements in the set of indicators would also would reflect a range of socio-economic benefits. Associated administrative costs would be relatively small since each of these indicators are already well documented and monitored. Such socio-economic benefits are a reflection of the having increases in specific indicators species (such as butterflies) or evidence of good condition of aspects agro-ecosystems (such as specific agroecosystem habitats or soils).

[222] https://ec.europa.eu/environment/nature/natura2000/pdf/Natura2000_and_jobs_main%20report.pdf page 19

Together with other targets considered in this Impact Assessment such as on pollinators or farmland birds, this set provides a robust set of indicators and targets that describe biodiversity in agro-ecosystems in a holistic and complementary manner. These together offer a rich set of opportunities for ecosystem management that enhances biodiversity-rich agroecosystems that maintain ecological processes that affect the co-production of a range of ecosystems services and benefits top society[223].

This is also consistent with scientific findings of the broad and multiple ecosystem service benefits of species biodiversity in agro-ecosystems. As mentioned in previous sections, studies have found evidence that richness of service-providing organisms positively influenced agroecosystem ecosystem service delivery[224,225,226]. Figure IV-9 and IV-10 below illustrate the benefits of standardized pollinator and natural enemy richness on pollination and pest control, which are essential ecosystem services for crop production[227]. On the other hand, landscape simplification reduced both pollinator and natural enemies of pests, which had consequences for pollination and pest control and, in turn, decreased crop production.

Figure IV-9 (B) Global effect of pollinator richness on pollination (n = 821 fields of 52 studies). (C) Global effect of



natural enemy richness on pest control (n = 654 fields of 37 studies).

[223] Global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. https://doi.org/10.5281/zenodo.3831673. Chapter 2.3

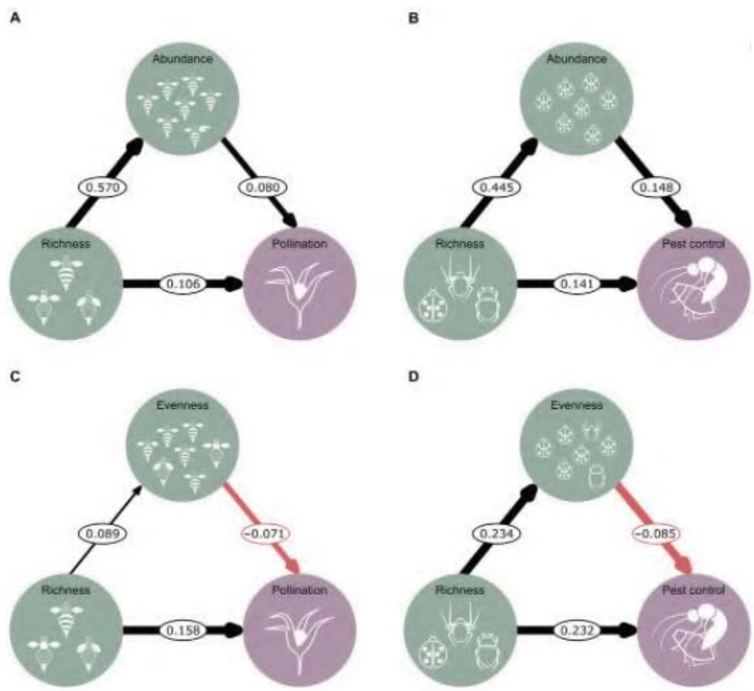
[224] Albrecht, M., et al (2020). The effectiveness of flower strips and hedgerows on pest control, pollination services and crop yield: A quantitative synthesis. Ecology Letters, 23(10), 1488– 1498.

[225] Marja R, Kleijn D, Tscharntke T, et al (2019) Effectiveness of agri-environmental management on pollinators is moderated more by ecological contrast than by landscape structure or land-use intensity. Ecol Lett 22:1493–1500. https://doi.org/10.1111/ele.13339

[226] England JR, O'Grady AP, Fleming A, et al (2020) Trees on farms to support natural capital: An evidence-based review for grazed dairy systems. Sci Total Environ 704:135345. https://doi.org/10.1016/j.scitotenv.2019.135345

[227] Da Silva, F., et al, Virtual pollination trade uncovers global dependence on biodiversity of developing countries, Science Advances, 7, 11, (2021).

Figure IV-10 Direct and indirect effects of pollinator and natural enemy richness on ecosystem services (pollination and pest control). Source: Dainese, Matteo, et al, 2019[228]



This overall points to the need for a number of *different aspects of biodiversity* (as evidenced by a set of different types of indicators) that need to improve *together in tandem* in order to optimise benefits, and is vital to sustain the flow of key agroecosystem benefits to society. Thus the set of indicators analysed here and targets considered in this Impact Assessment in particular on pollinators or farmland birds, provides a robust set of indicators and targets that can describe biodiversity enhancement in agro-ecosystems in a holistic and complementary manner.

Based on the evidence provided in these sections, one can conclude that introducing an obligation in the nature restoration law for Member States to provide evidence of increasing trends for the set of indicators analysed that describe enhancement of biodiversity, would provide overall important benefits to the environment, society and the economy.

[228] Dainese, Matteo, et al. "A global synthesis reveals biodiversity-mediated benefits for crop production." *Science advances* 5.10 (2019): eaax0121.

5. Steppe, heath, scrubland, dune and rocky habitats

5.1 Scope

This ecosystem impact assessment covers 62 types of steppe, heath, scrub, dune and rocky habitats listed in Annex I of the Habitats Directive (HD. These include 21 **steppe, heath and scrub habitat types** (excluding wet heaths and those dependent on agricultural management, which have been included respectively in the groups “wetlands” and “'agricultural habitats and grasslands”), which cover **80 894 km²** over the whole EU-27, yet this includes significantly overestimated data from Romania. Over the other 26 EU Member States the habitats cover 78 582 km^2 (2 % of the EU terrestrial area). These areas are mainly present in the Mediterranean region and most mountain ranges, including those of Fennoscandia. The Member States with the highest proportion of these habitats are Greece, Malta, Spain, Sweden and Austria. Although the 21 types of steppe, heath and scrub habitats listed in Annex I of the HD cover a large proportion of steppe, heath and scrub habitats, a substantial area of these habitats fall outside the Annex I definitions and standards. Scrub and/or herbaceous vegetation associations cover 163 270 km^2 according to Corine Land Cover estimates from 2018, whilst there are 114 777 km^2 of heathland, scrub and tundra based on the Ecosystems map[229]. This suggest that there are between about 34 000 and 82 000 km^2 which fall outside the Annex I definitions and standards, although some of this can be expected to be Annex I wet heath and dry heath not covered in this impact assessment.

This assessment also includes a group of 41 **'dune and rocky habitat types'**, comprising sea cliffs, beaches, and islets (8 types), coastal and inland dunes (21 types), and rocky habitats (12 types). These habitats are widely distributed across the EU particularly along coastlines, in mountain ranges, and inland sandy plains. In total they cover **65 135 km²** (excluding areas reported by Romania, which are known to be largely overestimated), which is 1.7% of the EU terrestrial area.

Due to differences in nomenclature and spatial resolution, it is not straightforward to compare the HD Annex I area data for dune and rocky habitats with Corine Land Cover (CLC) data. Nevertheless, the CLC category ‘Open spaces with little or no vegetation’, includes a similar set of habitats: beaches, dunes, sandy plains, bare rocks, sparsely vegetated areas and glaciers and permanent snow. The total CLC 2018 for these habitats was 62 554 km2, which indicates that a very high proportion of these types of sandy, rocky and icy habitats are covered by the list of HD Annex I habitat types.

Detailed data on the geographical distribution, area (km²), conservation status and condition of steppe, heath, scrubland, dune and rocky habitat types of Annex I of the Habitats Directive in EU Member States is provided in Annex VIII-d and -e.

5.2 Problem, current trends and ecosystem-specific baseline

Steppes, heathland and scrublands

[229] https://www.eea.europa.eu/themes/biodiversity/mapping-europes-ecosystems

Europe's steppes, heathlands and scrublands have declined by over 90 % since 1800s[230]. In recent decades, rates of loss have declined greatly (probably in part due to better protection), but declines continue. According to the baseline assessment for 2030, over the 2000 – 2018 period, net losses amounted to about 1.2 % (i.e. 0.07 % per year). It seems possible that some drivers of loss may increase, such as land take for housing and developments, abandonment and afforestation, but these may be counteracted by increased protection and funding for appropriate management. Member State data on threats to Annex I habitats and land cover flows all suggest that under existing measures, the extent of heath and shrublands ecosystems will continue to decline at similar rates as they have over recent decades. Therefore, the same rate of loss is assumed for this impact assessment, i.e. **loss in habitat area of 0.07 % per year**.

Member States' reports under Article 17 HD on the condition of the relevant habitat types indicate that at least 8.4 % of the 21 HD Annex I steppe, heath and scrub habitats area (excluding Romania) is in a not-good condition. 36.4 % of the area is reported as in 'unknown' (or not reported) condition. This means that as much as 44.8 % of the total area of these habitats could be in a poor condition if all the 'unknown' is assumed to be 'not-good'. This would be very unlikely, and therefore the true proportion of the area in a poor condition is probably closer to the proportion of the area for which Member States reported on the condition of the habitat that had a not-good condition, which is 13.2 % [231]. More than 10% of habitats assessments show deteriorating trends in condition, compared to improving trends in only 3% of assessments.

In addition, based on the data officially reported by Member States under Article 17 HD, it is estimated that a strict minimum of 400 km^2 would need to be re-created to achieve a 'favourable area'. Nonetheless, it is noted that the actual area that needs to be re-created is expected to be much higher since several Member States did not provide quantitative estimates of their 'favourable area'.

According to the same Member States reports, the top three groups of pressures affecting HD Annex I steppe, heath and scrub habitats are:

i. Conversion and land use change due to development of urban, industrial and leisure sites, from agriculture intensification, afforestation, and from building of roads and railroads.

ii. Habitat management with over 23 % of all pressures, which include inappropriate agricultural practices, such as intensive grazing or the abandonment of extensive grazing (73 %); or inappropriate forestry practices, such as burning, or the planting of non-native species (20 %).

iii. Invasive alien species and problematic species, many of them of EU concern.

[230] Maes et al. (2020) Mapping and Assessment of Ecosystems and their Services.
[231] 50 009 km^2 with a reported condition, of which 6 586 km^2 had a 'not-good' condition.

In addition to these, natural processes also are placing great pressures on these ecosystems, mainly originating from natural succession, which is often related to the lack of management of the concerned habitats.

The baseline assessment to 2030 also indicates that the main pressures affecting the condition of steppe, heath and shrub ecosystems are expected to continue. However, there is limited information on possible changes in the main drivers of pressures that could lead to increases in degradation or recovery. Some of the most important pressures such as land abandonment and large or intense fires are expected to increase, and be exacerbated by climate change, particularly in the Mediterranean region. Some pressures may also be countered to some extent by improved and wider management and restoration, especially within Natura 2000 sites. But this will also depend on many factors, including the outcome of the CAP reform, and whether sufficient funding will be directed to seminatural habitats such as scrubland and heathland by Member States. Given the uncertainties, it is assumed that degradation levels for HD Annex I steppe, heath and scrub habitats will not change under the baseline scenario to 2030, and therefore that 13.2 % (6 586 km^2) of the habitat area would require restoration.

Dune and rocky habitats

According to the EU Ecosystem Assessment[232], sparsely vegetated lands (which include bare or sparsely vegetated rock, lava, ice and snow of cliffs, screes, caves, volcanoes, glaciers and snow-fields, dunes, beaches and sand plains) can be reduced due to land take, such as for leisure and tourism. Climate change is also leading to the retreat of glaciers and snow-fields, and dunes and beaches are declining as a result of sea level rise and storms; although losses have been a small proportion of the habitat area until now. Overall land take trends have declined over the long- and short-term. The net effect of factors affecting sparsely vegetated lands has been an increase of 1.5 % between 2000 and 2018 (0.08 % per year), due to an increase in burnt areas. Future trends in the overall area of HD Annex I dune and rocky habitats are uncertain, but changes are likely to continue to affect a very small proportion of the habitat. In the absence of reliable information, **it is assumed that the overall area of HD Annex I dune and rocky habitats will remain approximately stable to 2030**.

The Member States' reports (based on Article 17 of the HD) for 2013-2018, indicate that at least 6 619 km^2 (10.2 %) of the 41 HD Annex I dune and rocky habitats area (excluding Romania) is in a not-good condition. However, a large proportion (43.7 %) of the area is reported as in 'unknown' (or not reported) condition. This means that as much as 55.9 % of the total area of these habitats could be in a poor condition. The more likely proportion of the area in a poor condition is the area for which Member States reported on the condition of the habitat that had a not-good condition, which is 18.05%, equating to 11 756 km^2.

In addition, it is estimated that a strict minimum of 355 km^2 of dune and rocky HD Annex I habitats would need to be re-created to achieve a 'favourable area'. This comprises 223 km^2 for coastal and inland dunes (particularly for priority habitat 'Pannonic inland dunes), 111 km^2 for

[232] Maes et al. (2020) Mapping and Assessment of Ecosystems and their Services.

rocky habitats and 22 km^2 for cliffs, beaches, and islets habitats. As for heaths, etc. the actual area that needs to be re-created is expected to be much higher since several Member States did not provide quantitative estimates of their 'favourable area'.

The Member States' Article 17 reports indicate that the top three groups of pressures affecting HD Annex I dune and rocky habitats are:

i. Sports, tourism and leisure activities (reported as a high pressure in 12% of assessments).
ii. Natural succession and agricultural abandonment (reported as a high pressure in 12% of assessments).
iii. Invasive alien species (reported as a high pressure in 11% of assessments).

All other pressures with high impacts were reported in less than 5% of assessments.

It is highly likely that all the main pressures affecting dune and rocky habitats will continue, but there is insufficient information available to reliably draw conclusions on future trends or quantify changes in pressures, or the overall condition of the habitats. It is therefore assumed that under the baseline scenario, the amount of habitat requiring restoration and re-creation would remain the same as current levels in 2030.

5.3 Target options screened in/out

As the rationale and context for restoration of these habitats is relatively straightforward and established, the following two related targets (with varying ambitions) are examined in this impact assessment, and no alternatives are considered.

A) Restore all HD Annex I steppe, heath, scrub, dune and rocky habitats to good condition, with all necessary restoration measures completed on 30 % (or 15 %) of degraded areas by 2030, 60 % (or 40 %) by 2040 and 100 % by 2050.

B) Recreate 30 % (or 15 %) of additional habitat area required to achieve Favourable Conservation Status of HD Annex I steppe, heath, scrub, dune and rocky habitats by 2030, 60 % (or 40 %) by 2040 and 100 % by 2050.

As a result of the high importance of steppe, heath,scrub, dune and rocky habitats for EU protected species, including birds, many of which are declining, it may be appropriate to have a related, but separate, target for EU protected species. The most obvious aim of the target would be linked to the achievement the favourable / secure status of the species concerned, as this would link directly to the objectives of the Birds and Habitats Directives. In particular, the target would concern the species' habitats restoration/recreation needs to achieve favourable / secure status of the species concerned, while other conservation action would be implemented under existing legislation.

Given the above rationale, the following complementary target for EU protected species that are predominantly associated with steppe, heath, scrub, dune and rocky habitats is considered in this impact assessment:

C) Restore and re-create steppe, heath, scrub, dune and rocky habitats as necessary to achieve the favourable conservation status of wild birds and species that are listed in Annex II, IV and V of the Habitats Directive and predominantly associated with steppe, heath and scrub habitats, with 30 % (or 15 %) of all necessary actions carried out by 2030 and 60 % (or 40 %) by 2040 and 100 % by 2050.

This target would complement the above targets based on Annex I habitats, as it would also cover the areas of steppe, heath, scrub, dune and rocky habitats not falling under Annex I definitions and standards, which are not negligible for steppes, heath and scrub habitats, as mentioned above.

5.4 Impacts of assessed target options

The costs of restorationwere estimated by calculating the area of degraded ecosystems to be restored and re-created annually to meet each target and applying average per hectare capital costs for restoration and re-creation, and annual costs for maintenance taken from Tucker et al.[233] The costs of restoration and re-creation include the capital costs of actions such as tree and scrub removal, invasive species control and vegetation re-establishment. Maintenance costs include low intensity grazing management. The per hectare costs of the dunes and rocky habitats group are only based on the costs of dunes, as data on the costs of other habitat types in the group are lacking. However, they are expected to be of similar or lower unit costs. For most habitats, the required management will be undertaken largely by private landowners and land managers, in return for incentive payments, a large proportion of which include compensation for opportunity costs relating to land management (e.g. income forgone through reduced grazing, or habitat creation on cropland). Maintenance costs were applied to the entire ecosystem area, since meeting the targets requires further degradation of ecosystems to be avoided. The costs of restoring caves, lava fields, and glaciers are not estimated as few specific management and restoration measures are feasible for these habitats. Instead they mainly require protection through regulation and/or general measures to reduce pressures, such as from water pollution and climate change.

Benefits estimates were based on an extensive review of literature of the value of benefits of these ecosystems, which identified changes in per hectare values of ecosystem services for restored vs degraded ecosystems. The analysis applied estimates of the median per hectare value of carbon storage and sequestration values and total ecosystem service benefits of ecosystem restoration derived from values obtained from 15 studies. Per hectare benefits estimates were applied to the area of ecosystem restored to give annual estimates of total benefits. Annual cost and benefit estimates were discounted, applying a 4% social discount rate, and summed to calculate their total present value. This enabled total net present value (benefits – costs) and benefit: cost ratios to be calculated.

[233] Tucker et al., (2013) Estimation of the financing needs to implement Target 2 of the EU Biodiversity Strategy. Report to the European Commission. Institute for European Environmental Policy, London. Available at: https://ec.europa.eu/environment/nature/biodiversity/comm2006/pdf/2020/Fin%20Target%202.pdf

The estimated costs of achieving good condition of HD Annex I steppe, heath, scrub, dune and rocky habitats are summarized in Table V-1. The costs are broadly based on the area of habitat that is in not-good condition or affected by specific pressures, multiplied by the costs of key measures to maintain the habitat, address the pressures thereby restoring the habitat, and re-creating habitat. The costs are additional to those associated with measures that are already in place (for example CAP measures). Also, to avoid double-counting, they do not include general supporting measures (e.g. creation of restoration plans), administration and monitoring costs, or broad actions that apply to multiple ecosystems, such as the need to reduce nitrogen deposition below critical levels.

Information on the costs of maintaining and restoring steppe, heath, scrub, dune and rocky habitats for EU protected species is insufficient to be able to calculate the costs of habitat restoration and re-creation necessary to achieve their favourable conservation status. Nevertheless, additional costs can be expected to be low for Annex I areas, as the achievement of favourable conservation status for habitats should also largely achieve the favourable conservation status of associated species.

Table V-1: Summary of projected costs (EUR) of achieving restoration targets for HD Annex I steppe, heath, scrub, dune and rocky habitats in relation to current trends & expected 2030 baseline

Targets 15 % and 40 %[234]

Period	% Full restoration	Maintenance costs	Restoration costs	Re-creation costs	Combined costs	Total over period
Average annual costs						
2022-2030	15 %	398 481 938	19 508 067	3 270 017	421 260 022	3 791 340 200
2031-2040	40 %	401 901 938	29 262 101	3 525 332	434 689 371	4 346 893 707
2041-2050	90 % [235]	407 601 938	58 524 202	4 667 557	470 793 697	4 707 936 969
Cost over full period (29 years)						
2022-2050	90 %	11 681 376 194	1 053 435 637	111 359 046	**12 846 170 877**	

Targets: 30 % and 60 %

[234] Although the 2050 target aims to restore 100 % of the habitat, the 2050 cost estimation is for 90 % restoration as this is the maximum percentage that can be expected in practice. Furthermore, an extrapolation of current restoration costs would no longer provide reliable estimates in the range between 90 and 100 %.

[235] Although the 2050 target aims to restore 100 % of the habitat, the 2050 cost estimation is for 90 % restoration as this is the maximum percentage that can be expected in practice. Furthermore an extrapolation of current restoration costs would no longer provide reliable estimates in the range between 90 and 100 %.

Period	% Full restoration	Maintenance costs	Restoration costs	Re-creation costs	Combined costs	Total over period
Average annual costs						
2022-2030	30 %	398 481 938	39 016 135	4 075 800	441 573 873	3 974 164 857
2031-2040	60 %	405 321 938	35 114 521	3 793 647	444 230 106	4 442 301 061
2041-2050	90 %	412 161 938	35 114 521	3 793 647	451 070 106	4 510 701 061
Cost over full period (29 years)						
2022-2050	90 %	11 761 176 194	1 053 435 637	112 555 146	**12 927 166 977**	

The costs of restoration will be incurred by landowners and land managers, who should in turn be compensated through incentive payments funded by the taxpayer. The funded restoration works will create employment and enhance incomes for land managers and contractors.

Restoration will deliver substantial benefits for biodiversity, society and the economy, through the delivery of enhanced ecosystem services. These include provisioning services (maintenance of sustainable grazing), regulating services (e.g. carbon storage and sequestration, coastal flood protection, wildfire prevention and erosion control) and cultural services (including landscape, recreation and tourism, as well as existence values). Beneficiaries will include society, as well as sectors such as farming and tourism.

Concerning the benefits associated to restoration, based on the evidence available, we estimate median values for steppe, heath and scrub restoration and re-creation of €348 ha/yr (carbon sequestration and storage) and €2 120 ha/yr (total ecosystem service values). These median values are taken from studies which give a wide range of benefits estimates, as summarised in the table below. Benefits for dune and rocky habitats were not assessed, due to time constraints.

Table V-2: Summary of Benefits Estimates from Ecosystem Restoration of steppe, heath and scrub habitats

Ecosystem	Service valued	Range (EUR ha/year)	Median estimate (EUR ha/year)
Heathland and scrubland	Carbon sequestration and storage	232 – 1 337	348
	Multiple ecosystem services	558 – 9 580	2 120

The value of the benefits has been estimated in monetary terms by multiplying the median values in Table V-2 by the areas of habitat restored and re-created. The benefits of restoring Annex I steppe, heath and scrub habitats are estimated to exceed the costs, even in a scenario where only carbon benefits alone are considered. Benefit cost ratios of meeting targets are estimated at 1.3-1.5:1 based on carbon benefits alone, and 7.9-9.2:1 if the total value of enhanced ecosystem services is considered.

Table V-3: Benefits and costs of restoration of steppe, heath and scrub habitats (present values[236], M EUR, 2022-2070)

Note: The cost-benefit analysis does not include costs and benefits for dune and rocky habitats, since time constraints did not allow for the assessments of benefits.

	15 % /40 % / 90 % Target	30 % /60 % / 90 % Target
COSTS		
Maintenance	2 777	2 799
Restoration	227	265
Re-creation	46	48
TOTAL (full recovery)	**3 051**	**3 111**
BENEFITS (full recovery)		
Carbon only	3 971	4 722
Total Ecosystem Services	24 191	28 768
Net Present Value (full recovery)		
Carbon only	920	1 611
Total Ecosystem Services	21 140	25 657
Benefit: Cost Ratio (full recovery)		
Carbon only	1.3	1.5
Total Ecosystem Services	7.9	9.2

5.5 Synthesis

Table V-4 provides a summary of the analysis of options and conclusions in relation to the effectiveness, efficiency, coherence, and proportionality of each target.

Table V-4: Overview table assessing options on EU impact assessment criteria

	Habitats Directive Annex I steppe, heath, scrub, dune and rocky habitats	EU protected species of steppe, heath, scrub, dune and rocky habitats
Feasibility / effectiveness	High feasibility and potential for restoration and re-creation (for most habitats), and effective at increasing biodiversity and ecosystem services	Uncertain due to limited information on restoration needs for the protected species associated with the habitat, but probably high feasibility.
Efficiency	Restoration delivers benefits for biodiversity and people, including a wide range of regulating, cultural and provisioning services. Benefits for carbon sequestration alone are estimated to exceed costs by a factor of 1.5:1. Total ecosystem service benefits are estimated to exceed costs by a factor of 8:1.	Insufficient evidence available to quantify, but expected to provide significant indirect benefits from the measures needed to restore the habitat (e.g. reducing large wildfires).
Coherence	Full coherence with EU environmental policies and climate goals. Potential to make significant contributions to climate mitigation, and climate adaptation. Overlaps with species target.	Full coherence with EU environmental policies and climate goals. May indirectly contribute to climate adaptation and mitigation. Overlaps with Annex I habitats target and with targets for pollinators (separate IA).

[236] For the purpose of making a cost-benefit analysis, values are presented in present values (i.e. with discount factor applied).

Proportionality	High due to high importance of the habitats for biodiversity and associated ecosystem services	Uncertain, due to unknown costs, but probably high because of the high importance of steppe, heath and scrub for EU protected species, including birds, many of which are declining
Conclusion	**Include as a target, with high priority**	**Include as a target, with high priority (even if quantified cost/benefit analysis could not be performed)**