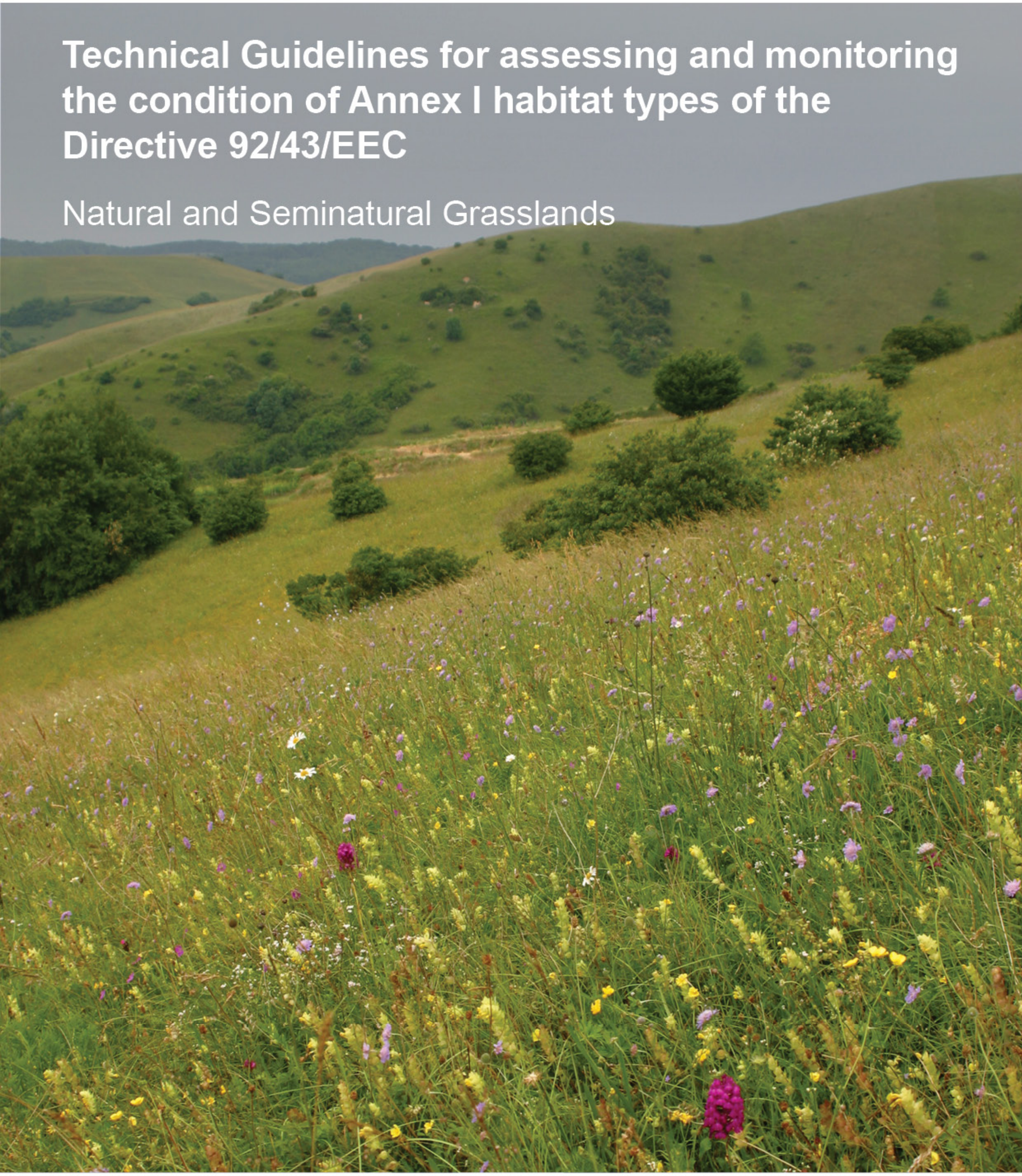
European Commission

Technical Guidelines for assessing and monitoring the condition of Annex I habitat types of the Directive 92/43/EEC

Natural and Seminatural Grasslands



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Technical Guidelines for assessing and monitoring the condition of Annex I habitat types of the Directive 92/43/EEC

Natural and Seminatural Grasslands

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Contents

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Glossary and definitions

Habitats

Natural habitats: are terrestrial or aquatic areas distinguished by geographic, abiotic and biotic features, whether entirely natural or semi-natural (Habitats Directive).

Habitat condition: is the quality of a natural or semi natural habitat in terms of its abiotic and biotic characteristics. Condition is assessed with respect to the habitat composition, structure and function. In the framework of conservation status assessment, condition corresponds to the parameter “structure and function”. The condition of a habitat asset is interpreted as the ensemble of multiple relevant characteristics, which are measured by sets of variables and indicators that in turn are used to compile the assessments.

Habitat characteristics: are the attributes of the habitat and its major abiotic and biotic components, including structure, processes, and functionality. They can be classified as abiotic (physical, chemical), biotic (compositional structural, functional) and landscape characteristics (based on the Ecosystems Condition Typology defined in the SEEA-EA; United Nations et al., 2021).

Species

Characteristic species: are species that characterise the habitat type, are used to define the habitat, and can include dominant and accompanying species.

Typical species: are species that indicate good condition of the habitat type concerned. Their conservation status is evaluated under the structure and function parameter. Usually, typical species are selected as indicators of good condition and provide complementary information to that provided by other variables that are used to measure compositional, structural and functional characteristics.

Variables

Condition variables: are quantitative metrics describing individual characteristics of a habitat asset. They are related to key characteristics of the habitat that can be measured, must have clear and unambiguous definition, measurement instructions and well-defined measurement units that indicate the quantity or quality they measure. In these guidelines, the following types of condition variables are included:

- **Essential variables:** describe essential characteristics of the habitat that reflect the habitat quality or condition. These variables are selected on the basis of their relevance, validity and reliability and should be assessed in all MSs following equivalent measurement procedures.
- **Recommended variables:** are optional, additional condition variables that may be measured when relevant and possible to gain further insight into the habitat condition, e.g. according to contextual factors; these are complementary to the essential variables, can improve the assessment and help understand or interpret the overall results.
- **Specific variables:** are condition variables that should be measured in some specific habitat types or habitat sub-groups; can thus be considered essential for those habitats, which need to be specified (e.g. salinity for saline grasslands, groundwater level for bog woodlands, etc.).

Descriptive or contextual variables: define environmental characteristics (e.g. climate, topography, lithology) that relate to the ecological requirements of the habitat, are useful to characterise the habitat in a specific location, for defining the relevant thresholds for the condition variables and for interpreting the results of the assessment. These variables, however, are not included in the aggregation of the measured variables to determine the condition of the habitat.

Reference levels and thresholds: are defined for the values of the variables (or ranges) that determine whether the habitat is in good condition or not. They are set considering the distance from the reference condition (good). The value of the reference level is used to re-scale a variable to derive an individual condition indicator.

Condition indicators: are rescaled versions of condition variables. Usually, they are rescaled between a lower level that corresponds to high habitat degradation and an upper level that corresponds to the state of a reference habitat in good condition.

Aggregation: is defined in this document as a rule to integrate and summarise the information obtained from the measured variables at different spatial scales, primarily at the local scale (sampling plot, monitoring station or site).

Abbreviations

EU**:** European Union

HD – Habitats Directive

IAS – Invasive Alien Species

MS: Member State

EU Member States acronyms:

Austria	(AT)	Estonia	(EE)	Italy	(IT)	Portugal	(PT)
Belgium	(BE)	Finland	(FI)	Latvia	(LV)	Romania	(RO)
Bulgaria	(BG)	France	(FR)	Lithuania	(LT)	Slovakia	(SK)
Croatia	(HR)	Germany	(DE)	Luxembourg	(LU)	Slovenia	(SI)
Cyprus	(CY)	Greece	(EL)	Malta	(MT)	Spain	(ES)
Czechia	(CZ)	Hungary	(HU)	Netherlands	(NL)	Sweden	(SE)
Denmark	(DK)	Ireland	(IE)	Poland	(PL)		

SEEA EA – System of Environmental Economic Accounting- Ecosystem Accounting

Executive summary

This document provides a comprehensive framework for assessing and monitoring the condition of Annex I grassland habitat types under Directive 92/43/EC, aiming to harmonize methodologies across EU Member States while respecting national practices and ecological specificities. The proposed methodology, grounded in national best practices and expert consultations, is not prescriptive but serves as a foundation for further harmonisation of methodologies applied across EU member states.

Grasslands, comprising dry, mesic, wet, alpine, and wooded grasslands, are defined by closed or semi-open herbaceous vegetation, hosting high biodiversity across Europe's landscapes. Some are natural, while many are secondary, shaped by traditional low-intensity management (grazing, haymaking). These guidelines classify grasslands to align with ecological functions rather than rigid categories, facilitating monitoring based on ecological features.

Assessment of grasslands condition (i.e. structure and functions) relies on a comprehensive set of abiotic (physical and chemical), biotic (compositional, structural and functional), and landscape variables:

- Abiotic physical variables include temperature, water regime and soil physical structure.
- Abiotic chemical variables include nutrient availability, organic matter, pH and salinity.
- Biotic compositional variables describe plant and animal species composition, including characteristic species and pollinators, which signal ecological health and habitat quality.
- Biotic structural variables include aboveground biomass, functional types (e.g., graminoids vs. forbs), cover of competitive, ruderal, alien species and shrub encroachment.
- Biotic functional variables include productivity, management intensity, disturbance regimes and litter accumulation, essential for habitat dynamics and resilience.
- Landscape variables include habitat area, connectivity, and heterogeneity, crucial for maintaining species populations and facilitating dispersal.

The document reviews methodologies of grassland monitoring from 21 EU countries, revealing variability in measured variables, metrics, and reference thresholds. While all countries monitor species composition, fewer measure abiotic or landscape variables systematically. The analysis identifies needs for harmonization across Member States, including a more consistent terminology and methods adapted to common monitoring goals. The variability in the methods currently applied by MSs complicates EU-level aggregation and comparison but reflects ecological and administrative diversity. To address the discrepancies detected, these guidelines propose the following:

- Standardizing core condition variables across Member States, with flexibility for habitat-specific variables based on ecological and biogeographical context.
- Establishing clear definitions, measurement instructions, and units for variables to ensure comparability.
- Using reference and threshold values linked to habitat quality and translating condition variables into condition indicators.
- Aggregating condition variables at local and biogeographical scales for EU reporting while retaining site-specific details.

- Promoting the use of existing open databases, remote sensing, and modelling to complement field data and improve cost-effectiveness.

The proposed guidelines are designed as a flexible tool to be tested, evaluated and adapted by national practitioners, ensuring feasibility within the diversity of European grassland types and management systems. We encourage collaboration between Member States, researchers, and conservation practitioners to refine and pilot the framework, enabling a coherent yet adaptable EU-wide approach to grassland habitat condition assessment.

1. Definition and ecological characterisation

1.1 Definition and interpretation of habitats covered

Grasslands are habitats with closed or semi-open vegetation dominated by herbaceous species, including graminoids (grasses, sedges and rushes) and forbs (non-graminoid herbs) (Squires et al., 2018). They also have bryophytes, lichens and fungi, which contribute to their species richness and diversity. Grasslands are also home to a high diversity of animals ranging from small insects and other invertebrates through birds and rodents to large herbivores. They are among the most diverse ecosystems in Europe and occupy about 17% of the EU area (Eurostat, 2018).

Some types of European grasslands are natural (primary). Such grasslands developed without human influence in areas not suitable for natural forest or shrublands, either due to low precipitation (dry grasslands; especially in the Steppic, Pannonian and partly also Mediterranean and Continental Biogeographical Regions) or low temperatures (alpine grasslands above the timberline; Alpine Biogeographical Region), usually in combination with natural grazing. However, most European grasslands are secondary, created and maintained by humans in the areas that would naturally evolve towards forest or scrub in the absence of large herbivores or management (Squires et al., 2018). These secondary grasslands have been used for livestock grazing (pastures) or haymaking (meadows). Under low-intensity management, which predominated in Europe until the mid-20th century, secondary grasslands were composed of a rich species pool of native plant species, often with a high percentage of non-graminoid herbs; such grasslands have been called semi-natural. As low-intensity management has been gradually replaced by intensive farming throughout Europe, large areas of semi-natural grasslands have disappeared due to abandonment or conversion into intensively managed grasslands with a reduced plant species richness and a dominance of graminoids (Squires et al., 2018). Many areas of species-rich, semi-natural grassland areas have only been preserved due to conservation management (Pärtel et al., 2005).

Wooded grasslands are human-made habitats that are transitional between open grasslands and forests. They have developed under the long-term influence of traditional management practices that keep scattered trees or shrubs in the grassland, including forest grazing and haymaking. The fine-scale mosaic of open and shaded patches increases the diversity of both plants and animals because it provides habitats for grassland species, forest species and species specialized to forest edges or semi-open landscapes (Bergmeier et al., 2010, Garbarino & Bergmeier 2014, Centeri et al., 2016, Le et al., 2025).

The Habitats Directive includes 32 habitat types of open grasslands and three habitat types of wooded grasslands. In addition, some forest habitat types may include grazed subtypes which can be regarded as wooded grasslands (see Bergmeier et al., 2010). Although the structure of open grasslands and wooded grasslands differs by the presence of a significant tree component in the latter, they are considered together in this document because the monitoring of the grassland component is very similar in both groups. Therefore, we define monitoring principles of the grassland component for both types and add specific principles that apply to the woody component in wooded grasslands. Nevertheless, we acknowledge that monitoring of specific species populations (e.g. insects and birds) may require different methods for open grasslands and wooded grasslands.

Annex I of the EU Habitats Directive and the Interpretation Manual (European Commission 2013) includes grasslands in the habitat group Natural and semi-natural grassland formations and divides them into five subgroups: (1) Natural grasslands, (2) Semi-natural dry grasslands and scrubland facies, (3) "Sclerophillous" [correctly: Sclerophyllous] grazed forests (dehesas), (4) Semi-natural tall-herb humid meadows, and (5) Mesophile grasslands. However, this division is problematic because several habitat types in the first group include secondary subtypes developed due to human influence, whereas several habitat types in the other groups (especially the second group) include subtypes that are primary, natural grasslands (Squires et al., 2018). Moreover, classification of wooded grasslands is inconsistent in Annex I of the Habitats Directive. The habitats 6310 Dehesas with evergreen Quercus spp. and 6530 Fennoscandian wooded meadows are classified into the group Natural and semi-natural grassland formations, but in different subgroups: the former to Sclerophyllous grazed forests (dehesas) (as the only habitat of this subgroup) and the latter to Mesophile grasslands. In contrast, the habitat 9070 Fennoscandian wooded pastures is included in the habitat group Forests. Therefore, we will use a more appropriate division of grasslands into dry, mesic, wet, alpine and wooded grasslands. The first four types are collective also referred to as open grasslands.

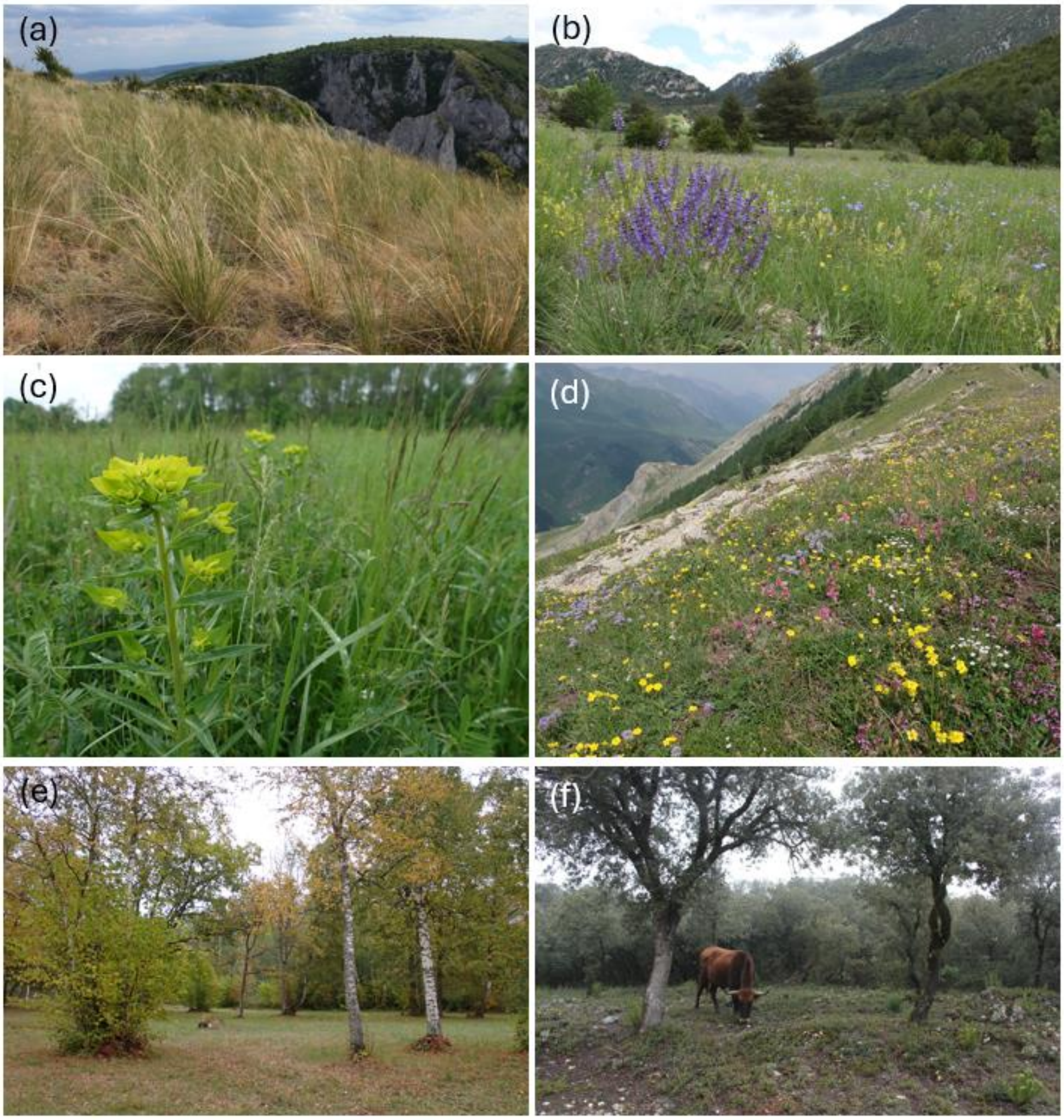
In addition to habitats included in the Habitats Directive's group Natural and semi-natural grassland formations, we also include here two habitat types of inland dune grasslands from the habitat group Coastal sand dunes and inland dunes (2330 Inland dunes with open Corynephorus and Agrostis grasslands and 2340 Pannonic inland dunes). Both of these habitats have sedimentary dynamics like coastal dune grasslands, but they occur on inland dunes, where they can be in contact with other types of grassland habitats. Therefore, grouping them with other inland grassland habitats makes more sense than grouping them with coastal habitats.

The habitat group Coastal sand dunes and inland dunes includes other habitats that physiognomically correspond to grasslands; however, as they occur exclusively on coastal dunes, they have various specifics in terms of monitoring. Consequently, we keep them separately. The group Coastal and halophytic habitats also includes some habitat types of grassland physiognomy, some of which occur inland (e.g. 1330 Atlantic salt meadows (*Glauco-Puccinellietalia maritimae*), 1340 Inland salt meadows and 1530 Pannonic salt steppes and salt marshes). We do not merge these habitats with grasslands here because all the halophytic habitats have several common features important to monitoring (e.g. salinity and occurrence of halophytes), and they are either transitional between grasslands and marshes or occur in a mosaic of grasslands and marshes.

In European habitat classifications, including the Habitats Directive, European Red List of Habitats (Janssen et al., 2016) and EUNIS Habitat Classification (Chytrý et al., 2020), grasslands do not include graminoid-dominated stands in areas where soil is constantly saturated with water; such habitats are classified as wetlands. Grasslands also do not include herbaceous stands developing in areas heavily disturbed by human activities, which are called man-made or anthropogenic habitats (Chytrý et al., 2020); these are usually not the subject of nature conservation.

Dry, mesic and wet grasslands, alpine grasslands, and wooded grasslands (Figure 1). A description of these grasslands is presented below. The correspondences between Annex I habitat types and EUNIS habitats is provided in Annex.

Figure 1. The main types of European grasslands



(a) dry grassland (pasture) with Stipa pulcherrima in Cheile Turzii, Transylvania; Romania, (b) mesic grassland (hay meadow) with Salvia pratensis in Sierra de Guara, Aragon, Spain; (c) wet grassland (hay meadow) with Euphorbia lucida near Břeclav, Czechia; (d) alpine grassland on limestone near Argentera, Maritime Alps, Italy; (e) hemiboreal wooded grassland, Laelatu, Estonia; (f) Mediterranean wooded grassland (dehesa), Sierra de las Nieves, Andalusia, Spain.

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Dry grasslands

Dry grasslands occur in areas with low annual precipitation (e.g., continental lowlands) or regular dry seasons (e.g., Mediterranean), combined with relatively warm summers. They can also occur on dry landforms such as rock outcrops or sand dunes in areas with intermediate precipitation. Poor moisture availability causes relatively low productivity in these grasslands and often an accumulation of humus in the topsoil due to reduced microbial activity in dry summer or frosty winter. Some of these grasslands are natural and exist independently of human management (continental steppe or rocky grasslands). However, most of them are secondary, dependent on grazing by domestic livestock or, to a smaller extent, mowing for hay (Janssen et al., 2016, Squires et al., 2018, Chytrý et al., 2020). An overview of dry grassland habitats listed in Annex I of the Habitats Directive is given in Table 1.

Table 1. Annex I habitats of dry grasslands

Code	Habitat name	Habitat description
2330	Inland dunes with open *Corynephorus* and *Agrostis* grasslands	open grasslands on acidic sand distributed mainly in sub-Atlantic Europe, typically species-poor, with a significant representation of annual herbs, bryophytes and fruticose lichens
2340*	Pannonic inland dunes	open grasslands on acidic sand dunes in the Pannonian Basin, with a significant representation of annual herbs, bryophytes and fruticose lichens
6110*	Rupicolous calcareous or basophilic grasslands of the *Alysso-Sedion albi*	small-scale pioneer vegetation on base-rich rock outcrops or shallow soil, dominated by short annual herbs, succulents and bryophytes
6120*	Xeric sand calcareous grasslands	open grasslands on base-rich sand
6130	Calaminarian grasslands of the *Violetalia calaminariae*	open grasslands on natural rock outcrops rich in heavy metals such as zinc and lead or spoil heaps around mines that contain high concentrations of these elements; these grasslands include plant species specialized in such habitats
6190	Rupicolous pannonic grasslands (*Stipo-Festucetalia pallentis*)	open rocky grasslands on steep limestone, dolomite or volcanic slopes of the mountains around the Pannonian Basin, dominated by perennial plant species
6210	Semi-natural dry grasslands and scrubland facies on calcareous substrates (*Festuco-Brometalia*) (*important orchid sites)	semi-dry, species-rich grasslands dominated by broad-leaved grasses and containing a large proportion of herbs
6220*	Pseudo-steppe with grasses and annuals of the *Thero-Brachypodietea*	open, short grasslands rich in annual plant species occurring in the Mediterranean lowlands
6240*	Sub-Pannonic steppic grasslands	dry grasslands of the Pannonian region dominated by tussock grasses, perennial herbs and chamaephytes
6250*	Pannonic loess steppic grasslands	semi-dry grasslands on deep soils over loess deposits in the Pannonian region
6260*	Pannonic sand steppes	steppe grasslands with perennial grasses, chamaephytes and therophytes occurring on inland sand dunes and sand plains in the Pannonian region
6280*	Nordic alvar and precambrian calcareous flatrocks	dry and semi-dry grasslands on flat sedimentary limestone covered with thin calcareous soils in the Baltic area
62A0	Eastern sub-Mediterranean dry grasslands (*Scorzoneretalia villosae*)	dry grasslands of the north-eastern Adriatic region which combine species of continental steppe, (sub-)Mediterranean species and Illyrian endemics
62B0*	Serpentinophilous grassland of Cyprus	dry grasslands with sparse plant cover and a significant representation of endemic plants on ultramafic rock outcrops in the mountain areas of Cyprus
62C0*	Ponto-Sarmatic steppes	dry grasslands dominated by perennial grasses and containing broadleaved herbs and chamaephytes that occur on the plains, plateaus and hills from Bulgaria through Romania, Moldova and Ukraine to the Southern Ural region in Russia

Asterisks indicate priority habitats

Mesic grasslands

Mesic grasslands occur in areas with intermediate annual precipitation and no significant seasonal droughts. They are confined to intermediate soils that are neither dry nor regularly flooded or waterlogged. Most of these grasslands are secondary, dependent on human management, in particular mowing for hay, livestock grazing, or a combination of both (Janssen et al., 2016, Squires et al., 2018, Chytrý et al., 2020). An overview of mesic grassland habitats listed in Annex I of the Habitats Directive is given in Table 2.

Table 2. Annex I habitats of mesic grasslands

Code	Habitat name	Habitat description
6180	Macaronesian mesophile grasslands	secondary grasslands occurring at the highest elevations of Macaronesian islands
6230*	Species-rich *Nardus* grasslands, on silicious substrates in mountain areas (and submountain areas in Continental Europe)	closed, mesic grasslands dominated by Nardus stricta on siliceous soils occurring from lowlands to montane regions.
6270*	Fennoscandian lowland species-rich dry to mesic grasslands	mesic grasslands developed under the long-term influence of grazing and mowing, occurring mainly on siliceous substrates in lowland parts of Fennoscandia
6510	Lowland hay meadows (*Alopecurus pratensis, Sanguisorba officinalis*)	species-rich, moderately fertilized hay meadows on mesic soils in lowland to submontane areas
6520	Mountain hay meadows	species-rich, moderately fertilized hay meadows on mesic soils in montane to subalpine areas of Western and Central Europe

Asterisks indicate priority habitats

Wet grasslands

Wet grasslands occur in stream floodplains or waterlogged depressions. Some types of wet grasslands are affected by a high ground water table occurring throughout the year. Other types are wet in some periods, especially winter and spring, and can even be flooded for a short period, and then dry in summer. Although some grasslands in floodplains are natural, developed at sites affected by erosion or accumulation processes or with woody vegetation disturbed by floods, most wet grasslands are secondary and used for hay-making or grazing (Janssen et al., 2016, Squires et al., 2018, Chytrý et al., 2020). An overview of wet grassland habitats listed in Annex I of the Habitats Directive is given in Table 3.

Table 3. Annex I habitats of wet grasslands

Code	Habitat name	Habitat description
6410	Molinia meadows on calcareous, peaty or clayey-silt-laden soils (*Molinion caeruleae*)	seasonally wet, extensively managed hay meadow on nutrient-poor soils, usually mown late in the year
6420	Mediterranean tall humid grasslands of the *Molinio-Holoschoenion*	humid grasslands with tall grasses and rushes in the Mediterranean and along the Black Sea coast
6430	Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels	tall-herb vegetation occurring on wet and nutrient-rich soils along water courses and at forest edges or canopy openings

Code	Habitat name	Habitat description
6440	Alluvial meadows of river valleys of the *Cnidion dubii*	alluvial meadows of lowland rivers in continental and subcontinental areas, usually flooded in spring and drying in summer, used for hay-making
6450	Northern boreal alluvial meadows	alluvial meadows dominated by grasses and sedges in the northern boreal zone, flooded in spring
6460	Peat grasslands of Troodos	wet grasslands dominated by *Calamagrostis epigejos* occurring in winter-inundated depressions in the Troodos Mountains of Cyprus
6540	Sub-Mediterranean grasslands of the *Molinio-Hordeion secalini*	extensive pastures and hay meadows in karst plains (poljes) in the Dinaric Mountains, which are wet in winter and spring and dry out in summer

Alpine grasslands

Alpine grasslands occur in high mountains above the timberline or around it. Most of them are natural grasslands developed at sites too cold for trees and shrubs. However, in many areas, alpine grasslands have been used as summer pastures for livestock, and their areas were extended by humans at the expense of forests (Janssen et al., 2016, Squires et al., 2018, Chytrý et al., 2020). An overview of alpine grassland habitats listed in Annex I of the Habitats Directive is given in Table 4.

Table 4. Annex I habitats of alpine grasslands

Code	Habitat name	Habitat description
6140	Siliceous Pyrenean *Festuca eskia* grasslands	subalpine and lower-alpine, mesic grasslands dominated by Festuca eskia, occurring on north-facing slopes and depressions in the Pyrenees
6150	Siliceous alpine and boreal grasslands	natural siliceous grasslands on mountains summits in the Alps, Carpathians, Scandinavia and other areas in the temperate and boreal regions of Europe
6160	Oro-Iberian *Festuca indigesta* grasslands	open grasslands dominated by Festuca indigesta and closely related species on the siliceous upper slopes and summits of the Mediterranean mountains on the Iberian Peninsula
6170	Alpine and subalpine calcareous grasslands	natural grasslands on calcareous bedrock in the subalpine and alpine belts of the Alps, Pyrenees, Apennines, Carpathians, Scandinavia and other mountain areas
62D0	Oro-Moesian acidophilous grasslands	natural siliceous grasslands on mountains summits in the central Balkan Peninsula

Wooded grasslands

Wooded grasslands are mosaic habitats with scattered trees and shrubs, which occur as solitary individuals or small groups. They are remnants of traditional multi-purpose management, which used an area for livestock grazing, hay-making, wood production and other economic activities. The fine-scale mosaic of open and shaded areas provides the habitat for rich communities of forest and grassland biota, including species dependent on forest-grassland ecotones (Bergmeier et al., 2010, Garbarino & Bergmeier 2014, Centeri et al., 2016, Le et al., 2025). An overview of wooded grassland habitats listed in Annex I of the Habitats Directive is given in Table 5.

Table 5. Annex I habitats of wooded grasslands

Code	Habitat name	Habitat description
6310	Dehesas with evergreen *Quercus* spp.	open woodland in the Mediterranean areas dominated by evergreen oaks, used as pasture land or cropland
6530*	Fennoscandian wooded meadows	open woodland in Fennoscandia dominated by broad-leaved deciduous trees, traditionally managed by a combination of hay-making, litter raking, livestock grazing and tree pollarding
9070	Fennoscandian wooded pastures	open woodland in Fennoscandia dominated by broad-leaved deciduous trees, spruce or pine and containing patches of grassland with a long continuity of grazing

Asterisks indicate priority habitats

6530. Fennoscandian wooded meadows in Laelatu, Estonia
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1.2 Environmental and ecological characterization and selection of variables to measure habitat condition

Grasslands occur under a broad range of climatic and edaphic conditions (Squires et al., 2018) and provide multiple ecosystem services (Bengtsson et al., 2019). The occurrence of primary grasslands depends on factors that prevent the development of forest, i.e. either moisture deficit, at least for a part of the year (dry grasslands; Wesche et al., 2016), low temperature and short growing season (alpine grasslands; Körner 2021) or highly dynamic natural processes such as sedimentation and sand drifting (sand grasslands; Riksen et al., 2006). The occurrence of secondary grasslands depends on regular disturbances of intermediate frequency and severity, which hinder the encroachment of trees and shrubs. These disturbances include grazing, especially by large herbivores such as domestic livestock or ungulates (Frank et al., 1998), mowing for hay (Bakker 1989; Janišová et al., 2023), and fire (either wildfire or intentional burning; Bond & Keeley 2005). Where disturbances are too infrequent or weak, grasslands may disappear due to the successional development of woody vegetation (Wieczorkowski & Lehmann 2022). In contrast, if disturbances are too frequent or too severe, grasslands can change into ruderal vegetation dominated by annual or short-living perennial plant species (Grime 1979).

These environmental factors determine the occurrence of grasslands in general, as opposed to other habitats. Nevertheless, the same factors can affect individual habitats in specific. For example, both decrease in soil moisture in wet grasslands and its increase in dry grasslands can decrease their habitat quality (Joyce et al., 2017, Klinkovská et al., 2024). An increase in temperature in alpine grasslands can lead to the spread of non-alpine species and the competitive exclusion of specialized alpine plants (Steinbauer et al., 2018). The absence or low frequency of management can result in the replacement of short grasslands with specialized plant species to tall grasslands and shrublands that are poor in insect-pollinated species (Sõber et al., 2024).

Other environmental factors also affect the condition of grassland habitats. For example, an increase in soil nutrients due to atmospheric deposition, fertilizer leaching from arable land or nutrient accumulation in the ecosystem due to the lack of management can result in the spread of nutrient-demanding, highly competitive plant species, which displace specialist species that are weak competitors (Staude et al., 2022). Relatively poorly known are the effects of controlled burning on grassland habitats (Valkó et al., 2014, Janišová et al., 2021). Landscape characteristics, namely the habitat patch size, habitat connectivity and habitat heterogeneity, are important for maintaining populations of habitat-specialized plants and animals, namely the habitat area, habitat connectivity and habitat heterogeneity (Krauss et al., 2004).

An overview of the ecological characteristics of grasslands and the corresponding variables that can be used to measure grassland habitat condition is given in Table 6. Their more detailed characteristics are described in the following text.

1.2.1 Abiotic characteristics

Physical state characteristics

Temperature. Grasslands can occur under the whole range of temperatures encountered in Europe (Mucina et al., 2016). However, there is a significant difference between the grasslands occurring in cold climates above the alpine timberline and the grasslands in warmer climates. The alpine and arctic grasslands are most impacted by climate change. Most of the alpine grassland habitats are natural because they occur in areas where low temperatures and short growing seasons limit the occurrence of trees and shrubs (Körner 2021). Consequently, they do not depend on management, natural disturbances or dry conditions. However, global warming is causing an upward migration of thermophilous species to higher elevations, thus changing the species composition and structure of alpine grasslands (Steinbauer et al., 2018). Therefore, increasing temperatures are decreasing the suitable range condition for alpine and arctic grasslands.

Water regime. Depending on water availability, grasslands are classified into dry, mesic and wet (Chytrý et al., 2020). Grasslands have different productivity (lowest in dry and highest in wet conditions) and different species composition under each of these moisture levels. Natural (primary) grasslands are more typical of dry conditions, which restrict the establishment and survival of trees and shrubs (e.g. steppe grasslands in the Steppic and Pannonic Biogeographical Region; Wesche et al., 2016). In contrast, semi-natural grasslands are more typical of mesic and wet conditions. However, these relationships are not absolute: many dry grasslands are secondary, and conversely, some mesic and wet grasslands are primary (Mucina et al., 2016). Rapid changes in water regime and associated changes in soil moisture are of particular importance for monitoring habitat condition, especially the draining of wet grasslands, which can destroy the habitat. Changes in moisture regime have the most pronounced effects on wet grasslands. In these grasslands, less moisture, which can be indicated and measured as a lower groundwater table or a shorter duration of regular floods, indicates a poor condition. Conversely, in dry grasslands, increasing moisture, e.g. due to litter accumulation, indicates declining habitat condition, sometimes called mesophyllization.

Physical soil properties. Physical properties of the soil influence the grassland community composition by regulating water availability. In general, shallow soils on slopes with hard bedrock retain less water than deeper soils on flat lands. Sandy or gravelly soils retain less water due to their better permeability than loamy soils. Clayey soil structure supports a regime of intermittent moisture. In moister periods, clay binds water, which is released slowly, and soil remains wet and muddy a long time after the last rain. In dry seasons, clayey soil becomes compacted, which prevents water absorption: rainwater is lost due to surface runoff, and the soil remains dry. The properties of different soils are summarized in the classification of soil types, with the FAO classification (IUSS Working Group WRB 2014) accepted as an international standard. However, soil physical structure can also be affected by disturbances such as trampling, the passage of heavy machinery or earthworks, which can significantly alter soil properties and ecosystem functioning.

Chemical state characteristics

Soil nutrient availability. The supply of nutrients, particularly nitrogen and phosphorus, influences grassland productivity, species composition and community structure. Plant-available nutrients originate partly from natural sources, which include fixation from the atmosphere by microorganisms that developed symbiosis with some groups of vascular plants (nitrogen) and weathering of bedrock (phosphorus) (Barker & Pilbeam 2015). A large part of nutrients in the current landscape also originates from anthropogenic sources, such as atmospheric deposition of nitrogen compounds (ammonium from agricultural sources and oxidized nitrogen from fossil fuel combustion) and leaching of fertilizers from arable land (nitrogen, phosphorus, potassium) (Stevens et al., 2011). Nutrients from both natural and anthropogenic sources are redistributed across the landscape by natural processes such as soil erosion, movement of water down slopes and catchments and dust transport by wind.

Vegetation ecologists often refer to oligotrophic, mesotrophic and eutrophic grasslands, with regard to the nutrient availability and trophic levels of different grassland types, though there is no consensus on the exact delimitation of these categories. These terms are rather used as ordinal classes for comparing the trophic levels of different grassland types. In general, most dry and alpine grasslands are considered oligotrophic to mesotrophic, whereas most mesic and wet grasslands are considered mesotrophic to eutrophic (Mucina et al., 2016, Chytrý et al., 2020). Oligotrophic grasslands have lower productivity, which is usually coupled with high species richness of plant communities. In contrast, eutrophic grasslands are highly productive, which usually results in the dominance of a single, highly competitive plant species, which may locally outcompete many other species (Grime 1979). Therefore, eutrophic grasslands are often monodominant and species-poor. Changes in soil nutrient availability, especially eutrophication due to atmospheric nitrogen deposition or leaching of fertilizers from arable land can result in significant changes in habitat species composition.

Soil organic matter. Grassland soils are globally significant carbon stock, which contributes to the mitigation of global warming (Dondini et al., 2023). The concentration of soil organic matter (i.e. organic carbon compounds) depends on climate, bedrock and management. It tends to be highest in wet and cool areas, where moisture supports primary productivity, and low temperatures reduce mineralization rates (Dondini et al., 2023). Grassland management can both increase and decrease the concentration of soil organic matter (Conant et al., 2001). The carbon-to-nitrogen (C/N) ratio is used as a proxy for the decomposition rate of organic carbon; in general, high values of the C/N ratio indicate slower decomposition in grassland soils (Blanco et al., 2023)

Soil pH. Grasslands occur under a broad range of pH, which depends on the chemistry of bedrock. Grasslands are broadly divided into acidic (on siliceous bedrock or leached soil) and base-rich (on calcareous bedrock) (Mucina et al., 2016, Chytrý et al., 2020). In non-saline soils, pH usually depends on calcium concentration or calcium carbonate content. Soil reaction can decrease because of atmospheric deposition (acidification; Stevens et al., 2010) or increase after liming (Holland et al., 2018).

Soil salinity. Saline grasslands occur on soils with a high concentration of soluble salts such as chlorides, carbonates and sulphates of sodium, potassium, calcium and magnesium (Pätsch et al., 2024). Salinity is usually measured as the electric conductivity of soil solution, which is a proxy for the concentration of different salt ions. Salinity can decrease due to the artificial draining of naturally saline soils (Bromberg Gedan et al., 2009, Danihelka et al., 2022) or increase close to roads due to the use of salt for winter de-icing (Łuczak et al., 2021).

1.2.2 Biotic characteristics

Compositional state characteristics

Plant species composition and typical species. Grassland flora is very diverse, and different grassland types are characterized by specific combinations of species (Chytrý et al., 2020). Grassland habitats are defined largely by their typical composition and presence of characteristic and typical species (see typical species below). However, these combinations can vary according to local abiotic conditions, the site history, including traditional management practices, and partly depend on the biogeographical history of the broader region, including past species migrations, speciations and extinctions. Therefore, species composition and sets of typical (or diagnostic, indicator, characteristic) species can vary among European regions even within the same habitat type.

Plant species richness. Temperate grasslands are the most species-rich plant communities at the local scale globally (Wilson et al., 2012). Thus, the number of vascular plant species per unit area is a key characteristic. However, local species richness is less important for biodiversity conservation than the number of ecologically specialized or rare species. A species-poor grassland community with specialized species can be more valuable than a species-rich community consisting of widespread generalists (Padullés Cubino et al., 2022).

Animal species. Some groups of specialized animals are also important indicators of habitat quality or specific microhabitat characteristics in grasslands. Among invertebrates, there is traditionally a strong focus on using indicators from specific taxonomic groups, in particular Orthoptera, Hymenoptera, Coleoptera and Lepidoptera, and less frequently Hemiptera and Araneae. Among soil fauna, the most frequently studied groups are Collembola and Araneae

(Gomes Borges et al., 2021). The selection of these specific taxa is given by the availability of specialists, a good level of knowledge about them, and relatively easy monitoring compared to other invertebrate groups. However, especially in the orders Diptera, Hymenoptera and Coleoptera, as well as in some groups of Lepidoptera, many highly adapted species are typical for grasslands and should be taken into account as typical species. Molluscs are also an important component of grassland habitats. Vertebrates, especially birds and mammals, are less often used as habitat quality indicators for grasslands because they are more mobile and move between different habitat types. For example, there is evidence that several species of farmland birds require the presence of both grasslands and arable land in the landscape (Robinson et al., 2001). Like plants, animals can also be used as either positive indicators of habitat quality (e.g. rare or Red-List species) or negative indicators (e.g. invasive species).

Pollinator species. Pollinators (including bees, butterflies, hoverflies and other insect groups) are essential for the reproduction of many wild plants, which maintains plant diversity and ecosystem structure in European habitats. They are sensitive to environmental changes (habitat loss, pesticides, climate change), making them effective bioindicators for the condition and trends of habitats. They are also directly linked to food production and biodiversity maintenance. Pollinators are declining in abundance and diversity, signalling ecosystem imbalance (Potts et al., 2010). Recent studies have shown that grassland habitat types appear to be of outstanding importance for all kinds of pollinating insects (Kudrnovsky et al., 2020). Monitoring them can help early detection of degradation in habitats before plant communities visibly decline.

Structural state characteristics

Plant aboveground biomass. Aboveground biomass depends on primary productivity (see Functional state characteristics below) and biomass removal by grazing or mowing. It varies considerably during the season (Michaud et al., 2012, Fischer et al., 2023). Therefore, it is usually measured when it is highest. An increase in the aboveground biomass in a nutrient-limited (oligotrophic) or temperature-limited (alpine or arctic) grassland can indicate a negative change in habitat condition. In contrast, a decrease in the aboveground biomass in a highly productive grassland can indicate a moisture deficit and consequent deterioration of the habitat conditions. In general, changes in biomass can be used as early-warning indicators of habitat change, which can continue with the loss of specialist species and biodiversity decline (Weber et al., 2018). It can be monitored either on site by clipping and weighing dry biomass or by measuring compressed sward height by a raising plate meter (Murphy et al., 2021) or by analyzing indices derived from remote-sensing data that correlate with biomass, for example, the Normalized Difference Vegetation Index (NDVI; Pettorelli et al., 2005).

Plant functional types. The main plant functional types in grasslands are graminoids and forbs. The ratio of these two functional types reflects the abiotic site conditions and management. For example, graminoids can increase their cover relative to perennial forbs in some grassland types due to the absence of grazing or mowing (Csergő et al., 2013). Another parameter of the functional structure is the annual-to-perennial plant ratio: an increase in this ratio, either due to an elevated mortality of perennials or an increasing cover of annuals, can indicate either stronger (more frequent or more severe) disturbance or the effect of drought (Stampfli et al., 2018). Dwarf shrubs also naturally occur in some grasslands. If management ceases, the cover of dwarf shrubs can increase and the grassland changes into heathland or another shrubby habitat types (Palaj et al., 2024). Some grasslands, especially on wet or acidic soils, contain a significant layer of bryophytes or lichens (Chytrý et al., 2020), which is a defining characteristic.

Dominance of competitive native herbs and dwarf shrubs. The abandonment of secondary grasslands often results in increasing dominance of a highly competitive plant species that occurs naturally in the community but cannot dominate it if the grassland is grazed or mown. This process, which is the first sign of secondary succession, results in the decline of competitively weaker species (Czarniecka-Wiera et al., 2019).

Cover of insect-pollinated plants. To maintain the diversity and abundance of pollinators, it is essential that grassland habitats contain a significant proportion of insect-pollinated (entomophilous) plant species. Different plant species flower in different parts of the growing season, supporting different groups of pollinators. Nevertheless, most of these plants, except for some ephemeral annuals and geophytes, can be recorded by monitoring at the peak of the growing season, even if they may be in a non-flowering phenological phase. Information on whether they are insect-pollinated can be obtained from botanical databases (e.g. Klotz et al., 2002).

Cover of ruderal plant species. When a grassland community is affected by an unusual, severe disturbance, which creates gaps in the herb layer and exposes bare soil, these gaps can be colonized by ruderal plants, i.e. fast-growing species adapted to spreading quickly to disturbed areas (Grime 1979). This happens particularly when severe disturbance is combined with nutrient input. Ruderal species change the structure of the community, resulting in the loss of grassland characteristics and the development of ruderal vegetation. However, if regular grazing or cutting continues, herbaceous vegetation with ruderal species can slowly change into non-ruderal grassland (Török et al., 2008, Sojneková & Chytrý 2015).

Cover of alien plant species. Some grassland sites are affected by the establishment of alien (non-native) plant species, which is one of the processes of global environmental change (Axmanová et al., 2021). Most often, these species spread after disturbance or the addition of limiting resources such as nutrients or water. If an alien plant species invades a grassland community and increases its cover, it can outcompete some of the native species, which leads to a change in community structure, a decrease in native species richness, and a decline in habitat quality (Hejda et al., 2009). On the other hand, proper management actions can remove the dominant alien species and restore a grassland plant community (Świerszcz et al., 2024).

Cover of trees and shrubs. Solitary individuals and trees or shrubs often occur in grasslands, and their occurrence is often beneficial to biodiversity, especially in the case of old native trees. In wooded grasslands, they are the defining feature of the habitat (Bergmeier et al., 2010). However, abandonment of secondary grasslands and wooded grasslands may trigger the successional processes of shrub and tree encroachment, which ultimately leads to the decline of these habitats and their associated biodiversity (Michielsen et al., 2017).

Density of veteran trees. Old trees with hollows and dead branches are called veteran or habitat trees (Bütler et al., 2013). They also include old pollarded trees. These trees are essential habitats for many species of vertebrates, invertebrates, fungi, bryophytes and lichens. Although their presence is essential for assessing the condition of wooded grasslands, solitary veteran trees can also occur in other grassland types and contribute to their higher nature value. However, in non-wooded grasslands, the presence of veteran trees is not essential for assessing good habitat condition.

Presence of dead wood (relevant for wooded grasslands). Dead wood is an essential microhabitat for the maintenance of the biodiversity of saproxylic insects and other invertebrates, fungi, bryophytes and lichens (Lachat et al., 2013).

Functional state characteristics

Primary productivity. Grasslands are highly variable in their primary productivity, which increases with temperature, moisture, nutrient availability and elevated levels of atmospheric CO_2 (Andresen et al., 2018). Plant species richness in grasslands shows a unimodal dependence on productivity: it is low at low productivity levels, high at medium productivity levels and low at high productivity levels, in the latter case because of the increasing dominance of highly competitive herbaceous species, which outcompete weaker competitors (Grime 1979).

Management. Grassland management varies from high intensity through low intensity to abandonment. A high-intensity management with frequent biomass removal (overgrazing or cutting more than three times a year) and significant input of nutrients can cause a decline of many plant species and the creation of species-poor grassland (Plantureux et al., 2005). Seeding of specific cultivars of grasses (e.g. Lolium sp., Festuca sp.) or legumes (e.g. Trifolium sp., *Medicago* sp.) can lead to outcompeting native herbs. Overgrazing can open bare soil, cause erosion and trigger the spread of ruderal or alien plant species, thus significantly changing the grassland species composition. Abandonment of secondary grasslands can also cause a decline in plant species richness, especially in mesotrophic and eutrophic grasslands, due to the increasing dominance of a few tall herbs or woody plants that outcompete shorter, competitively weaker species (Czarniecka-Wiera et al., 2019). In line with the intermediate disturbance hypothesis (Huston 1979), the most species-rich grasslands develop in places with extensive management. There are two main management practices used in traditional farming systems: **livestock grazing** and **mowing** for hay. In general, grazing promotes the spread of unpalatable (poisonous, spiny) species or species with a concentration of aboveground biomass near the soil surface (e.g. rosette-forming herbs), whereas mowing is less selective (Tälle et al., 2016). Since grazing and hay-making have become economically non-profitable in some areas, the current conservation management sometimes uses mulching, i.e. cutting biomass into small pieces that are left in the grassland area (Doležal et al., 2011, Gaisler et al., 2013, Caboň et al., 2021)

Disturbance. Grasslands are adapted to disturbances of intermediate frequency and severity, which remove a large part of the aboveground plant biomass but do not kill the plants (Grime 1979). The most typical disturbance types include grazing, mainly by livestock but also by wild animals, and mowing for hay (Tälle et al., 2016). However, some grasslands are also influenced by irregular and infrequent disturbances such as soil disturbance and subsequent erosion (Wiesmair et al., 2017), fire (Valkó et al., 2014) and, in some types of alpine grasslands, avalanches (Rixen et al., 2007). These infrequent disturbances are important for the removal of trees and shrubs and the maintenance of grassland areas.

Litter accumulation. Accumulation of plant litter depends on the management. Large litter accumulation indicates that the community has not been recently grazed, mown or burned. Long-term litter accumulation at productive sites decreases plant community species richness because no patches of bare ground remain available for germination and seedling establishment (Ruprecht 2012, Kelemen et al., 2013).

Regeneration of native woody plants (relevant for wooded grasslands). Natural regeneration of native trees and shrubs is essential for the long-term sustainability of wooded grasslands. In grazed areas, trees often regenerate in patches where access to livestock is limited due to the presence of thorny shrubs or fences (Vera 2000). Regeneration declines in overgrazed areas. However, for the maintenance of wooded grasslands, regeneration must be controlled to prevent overgrowing of open areas and successional development from wooded grassland to closed forest.

1.2.3 Landscape characteristics

Habitat area. The area occupied by individual grassland patches is important for the maintenance of populations of rare and habitat-specialized species. According to the theory of island biogeography (MacArthur & Wilson 1967), grassland specialists are more prone to extinction in small than in large grassland patches. Therefore, grassland areas that have recently reduced in size or were fragmented into smaller sub-areas due to land-use change (urbanization, conversion to arable land, afforestation) can suffer biodiversity loss (Krauss et al., 2010).

Habitat connectivity. To maintain high species diversity, grassland patches (and small patches in particular) must be connected to the regional grassland metacommunity (Leibold et al., 2004). This metacommunity consists of grassland patches distributed across the landscape in a way that allows species to disperse from one to another. If a species becomes locally extinct in a specific grassland patch, its population can be restored naturally through immigration from other grassland patches in the regional metacommunity. However, these processes only work if specialized grassland species can successfully disperse across the unsuitable habitats that form the landscape matrix, either passively (e.g. by wind or with grazing animals that move across the landscape) or actively (animals).

Habitat heterogeneity within grassland areas. Grassland areas that contain small patches of woodlands or scrub, lines of trees, hedges or small wetlands usually have higher biodiversity than uniform grasslands. Small patches of natural or semi-natural non-grassland habitats contain robust populations of species that can reproduce well in such habitats and increase the diversity of grasslands through the spatial mass effect (Shmida & Wilson 1985, Leibold et al., 2004). Presence of specific microhabitats is also important, for example, small patches of bare soil for ground-nesting wild bees or the presence of ant hills for myrmecophilous or ant-eating animal species.

Oro-Iberian *Festuca indigesta* grasslands (6160), Calamorro de San Benito, Spain
© Milan Chytrý

Table 6. Framework for the ecological characterization and selection of variables to measure grassland habitat condition

Ecological characteristics	Types	Description	Examples of variables
Abiotic characteristics	Physical state characteristics	Temperature of air and soil, including mean and extreme values and seasonal oscillations.	Temperature (mean, minimum, maximum) Temperature indicator values (community mean)
		Water regime, including the degree of water saturation, groundwater table depth and their seasonal variation, including the length of drought periods (if any) and duration of floods (if any).	Soil water table depth (minimum, maximum) Duration of flood Moisture indicator values (community mean)
		Physical soil properties, especially those that determine soil water-holding capacity, such as soil depth and the proportion of gravel, sand, silt and clay.	Soil depth Soil structure (gravely, sandy, loamy, clayey) Disturbance to the soil physical structure
	Chemical state characteristics	Soil nutrient availability, especially nitrogen and phosphorus (including its changes, i.e. mainly eutrophication). Soil organic matter, i.e. concentration of undecomposed remnants of plant and other organisms.	C/N (organic carbon/total nutrients) ratio in soil Nutrient indicator values (community mean) Atmospheric nitrogen deposition Soil organic carbon
		Soil pH, i.e. negative logarithm of hydrogen ion concentration in soil solution (including its changes, i.e. mainly acidification)	Soil pH Reaction indicator values (community mean)
		Soil salinity, i.e. concentration of chlorides, carbonates and sulphates of sodium, potassium, calcium and magnesium in soil solution	Soil electrical conductivity Salinity indicator values (community mean)
Biotic characteristics	Compositional state characteristics	Plant species composition and typical species occurring in local plant and animal communities.	Plant species composition Number of habitat-specialist plant species, butterflies and moths)
		Plant species richness, i.e. the number of species occurring in local plant and animal communities.	Total vascular plant species richness
		Animal species composition and typical species, i.e. occurrence or abundance of selected animal groups that are easy to survey and are good indicators of habitat condition.	Presence of selected animal species
		Pollinator species abundance and richness, i.e. representation of the main pollinator groups.	Abundance and richness of the four main pollinator groups (wild bees, hoverflies

Ecological characteristics	Types	Description	Examples of variables
	Structural state characteristics	Plant aboveground biomass, i.e. the weight of dry plant tissues, which correlates with vegetation cover and height. Cover of insect-pollinated plants, i.e. quantity of plant species that can serve as a source of nectar or pollen for insects	Herb-layer cover Herb-layer height Normalized Difference Vegetation Index (NDVI)
		Plant functional types such as herbaceous vs. woody plants, annual vs. perennial herbs or graminoid vs. non-graminoid herbs and their relative representations.	Relative cover of annual and perennial plants
		Dominance of competitive native herbs and dwarf shrubs, i.e. a prevalence of species that can locally outcompete other species	Relative cover of herbs and dwarf shrubs Cover of competitive native herbs and dwarf shrubs
		Cover of ruderal plant species, i.e. quantity of species adapted to strong or frequent disturbances (usually indicators of negative human impact)	Cover of ruderal plant species
		Cover of alien plant species, i.e. quantity of species introduced to the area from other geographical regions due to human activities.	Cover of alien plant species
		Cover of trees and shrubs, i.e. vertical projection of woody plant canopies in percentages.	Cover of trees and shrubs
		Cover of insect-pollinated plants, i.e. quantity of plant species that can serve as a source of nectar or pollen for insects.	Cover of insect-pollinated plants
		Density of veteran trees, i.e. number of individuals per unit area of old native trees that occur as solitary individuals in non-wooded grasslands or with higher density in wooded grasslands.	Density of veteran trees per unit area
		* Presence of dead wood (relevant for wooded grasslands), i.e. decaying logs, branches and standing dead tree individuals.	Dead wood quantity per unit area
	Functional state characteristics	Primary productivity, i.e. the production of green biomass per unit of time.	Density of livestock units Density of excrements of large herbivores Maximum annual harvest of hay Forage quality
		Management, especially the intensity and frequency of grazing and mowing.	Mowing frequency
		Disturbance other than grazing and mowing either natural or	Frequency and severity of natural disturbances

Ecological characteristics	Types	Description	Examples of variables
		anthropogenic, e.g. soil disturbance, fire and avalanches.	Frequency and severity of human caused disturbances
		Litter accumulation, i.e. the accumulation of dead plant material.	Litter cover Litter thickness Cover of standing dead biomass in winter
		* Regeneration of native woody plants (relevant for wooded grasslands), i.e. recruitment of trees and shrubs.	Density of tree and shrub seedlings and saplings
Landscape characteristics		Habitat area is the area occupied by individual grassland patches of the same habitat Habitat connectivity is the degree of connectedness of individual grassland patches with the regional grassland metacommunity Habitat heterogeneity within grassland areas considers the presence and quantity of patches of woodlands or scrub, lines of trees, hedges or small wetlands within grassland areas.	Area of habitat patches Presence of solitary trees in a grassland area Presence of small woodland or scrub patches in a grassland area Presence of wetland patches in a grassland area Buffering capacity to fertilizer and pesticide input (habitat contact with arable land)

1.3 Selection of typical species for condition assessment

Typical species of the habitat are used to assess the habitat conservation status. The Habitats Directive uses the term ‘typical species’, but it does not give a definition, and little guidance has been provided on how to use the typical species in this assessment for use in reporting.

For a habitat type to be considered and being at favourable conservation status, the Habitats Directive requires that both its structure functions and its ‘typical species’ are in a favourable status (Art. 1(e)). This would suggest that the assessment of typical species could be carried out separately and complement the assessment of structure and function. In this regard, the selection of typical species should be as robust and appropriate as possible.

According to the analysis of national methodologies available for the assessment of habitat structure and function, some MSs assess the typical species separately, while others seem to include the typical species in the assessment of compositional characteristics.

All MSs have communicated a list of typical species for each habitat type, although usually they have not provided any justification or rationale for their selection. The variability of the selection of typical species by MSs seems to indicate that they have different interpretations on the concept of typical species. Mostly plants are proposed as typical species (> 90% of the selected species) and in many cases dominant or characteristic species are included. However, species from other taxonomic groups are also considered (e.g., lichens, insects, birds, mammals…).

It has long been clear from the reports provided by the MSs that they interpreted the typical species differently, meaning that the lists produced have probably had limited value. Therefore, the consideration of "typical species" in the assessment of the habitat conservation status still needs to be discussed and clarified.

Recommendations for the selection of typical species

According to the guidelines for reporting under Article 17 (European Commission, DG Environment, 2023), typical species should be species which occur regularly at a high frequency (constancy) in a habitat type or at least in a major subtype or variant of a habitat type. Typical species should include species that are reliable indicators of good habitat quality, e.g. by indicating the presence of a wider group of species with specific habitat requirements. They should include species sensitive to changes in the condition of the habitat (early warning indicator species). Typical species may be drawn from any taxonomic group. In addition to vascular plants, which are most often selected, consideration should also be given to bryophytes, lichens, fungi, vertebrates and invertebrates (particularly insect taxa and guilds such as pollinators). The guidelines also state that dominant species may not be a good choice for monitoring typical species, as they do not provide any additional information on structure and functions (being usually assessed as part of the habitat composition and structure).

Typical species should be distinguished from characteristic species, which are used to identify the habitat type according to the Interpretation Manual of EU habitats (where a formal list of characteristic species is provided for each habitat). They can vary across the habitat range. The set of typical species for a habitat type should consider the ecological diversity (all subtypes) of the habitat across its range. Typical species do not need to be exclusive of one habitat type; some typical species could be shared by more than one habitat.

It can be useful to consider key functional groups for the selection of typical species, taking into account the habitat's ecology, the role of typical species as bioindicators (e.g. pollinators, dispersers, decomposers, trophic and symbiotic relationships, etc.) and their sensitivity to changes. Table 2 provides an illustrative list of species' groups that can be used as indicators to assess grassland habitats.

Following the concepts used in the EUNIS Habitat Classification (Chytrý et al., 2020), typical species can belong to one or more of the following groups:

Diagnostic species (= habitat specialists). These species occur in the target habitat but are rare or absent in other habitats. Their lists for each habitat type are found in national and regional habitat manuals.

Constant species. These are species that frequently occur in the target habitat but are also found in other habitats. Consequently, they are not habitat specialists, although they commonly occur in the habitat. However, they are often mixed with habitat specialists (diagnostic species) in habitat manuals.

Within grasslands, groups of typical species differ among individual habitat types, although there is a considerable overlap in species considered typical of two or more habitat types. In general, typical plant species of grasslands include grasses and forbs, largely perennial species and, to a small extent, especially in dry grasslands, also annual species. In some specific grassland habitats, typical species can also include dwarf shrubs, bryophytes, lichens and fungi. Typical species from various animal groups, especially well-studied groups of invertebrates, such as butterflies, grasshoppers, ground beetles, hymenopterans, dipterans and oribatid mites, can also be used in addition to plant species.

An important group of species are indicators of changing habitat conditions because their monitoring is fast, inexpensive and non-destructive. Ellenberg indicator values for vascular plants (Ellenberg et al., 1991), which have been recently extended to datasets covering a large part of the European flora (Dengler et al., 2023, Tichý et al., 2023), provide species-level indicator values for light, temperature, moisture, soil reaction, nutrients and salinity.

Further, Midolo et al., (2023) defined indicator values for disturbance frequency and disturbance intensity, grazing pressure, mowing frequency and soil disturbance. Each of these indicator values can be used to identify species that are spreading in a habitat but have untypical (either too low or too high) values for that habitat. Alternatively, mean values across all the species in a given habitat or at a given site can be calculated at time t1 and repeatedly at time t2. In grasslands, the following main trends in indicator values should be mainly monitored:

- Decreasing light values can indicate a lack of management, overgrowing, increased sward density or woody tree encroachment.
- Increasing temperature values can indicate global warming, especially in (sub)alpine and (sub)arctic grasslands.
- Decreasing moisture values in wet grasslands can indicate changes in the local hydrological regime or effects of climate-dependent droughts.
- Decreasing soil reaction value can indicate acidification, e.g. due to atmospheric pollution
- Increasing nutrient value can indicate eutrophication due to fertilizer application related to grassland management intensification, atmospheric nutrient deposition, leaching of fertilizers from arable land or nutrient accumulation in the grassland ecosystem after abandonment.
- Decreasing salinity value in saline grasslands can indicate a change in hydrological regime or grazing abandonment that results in the loss of salt ions from the upper soil layers.
- Decreasing values for disturbance frequency, grazing pressure or mowing frequency can indicate a lack of proper management or abandonment.
- Increasing values for grazing pressure can indicate overgrazing.
- Increasing values for disturbance intensity or soil disturbance can indicate a strong anthropogenic disturbance.

Trees and shrubs in wooded grassland

A condition assessment in wooded grasslands requires, in addition to the above-mentioned species groups, a separate assessment of native trees and shrubs, including their species composition, cover, height, age structure, distribution pattern and regeneration.

Boloria eunomia © Frank Vassen

Table 7. Examples of species groups that can be used to select typical species for grassland habitats, as indicators of good habitat quality

Species group	Indicator value and sensitivity to changes
Bryophytes	Bryophytes in grasslands are indicators of various environmental conditions, including air and water quality, climate change and habitat quality. They are sensitive to pollutants, changes in moisture levels, and temperature fluctuations.
Lichens	Lichens in grasslands are often indicators of air quality, particularly for sulfur dioxide (SO_2). They are also sensitive to other pollutants and environmental changes, including nitrogen deposition and habitat disturbances.
Orchid species	Orchids in grasslands often indicate a healthy, species-rich, and relatively undisturbed habitat, particularly those with low nutrient levels. They can be sensitive to management intensification, and changes or pressures in their surroundings.
Birds	Grassland birds are indicators of overall grassland habitat quality. Their presence, abundance, and diversity reflect the health and integrity of the grassland ecosystem. Specific bird species can be used to assess the impact of management practices or human disturbance. Grassland birds in the EU are experiencing significant population declines due to habitat loss and degradation caused by agricultural intensification and other land-use changes. These birds, including species like the Great bustard, Little bustard, and Montagu's harrier, rely on open landscapes and are particularly vulnerable to changes in vegetation cover and insect availability.
Butterflies	Butterflies are excellent indicators of grassland habitat quality. Specifically, the European Grassland Butterfly Indicator, based on the population trends of 17 butterfly species, is used to assess biodiversity in Europe. Declines in butterfly populations can signal broader issues with grassland condition, including habitat degradation and loss of plant diversity. Butterflies are highly sensitive to habitat changes, including vegetation structure, food plant availability, and climate. Some butterfly species are highly specialized to particular grassland types, making them valuable indicators of specific habitat conditions. Many grassland butterflies are important pollinators, and their decline can negatively impact plant reproduction and ecosystem functioning. Butterfly populations can be monitored using standardized methods, making them relatively easy to track over time.
Small mammals	Small mammals in grasslands can be useful indicators of the overall health of grasslands and the impact of agricultural practices, reflecting changes in vegetation, soil quality, and disturbance levels. Their sensitivity to changes in vegetation height, density, and species composition directly influence small mammal populations. For example, some species prefer tall grasses for cover and nesting, while others thrive in more open areas. Soil characteristics like organic matter content and moisture affect the availability of food and shelter for small mammals. Changes in water availability due to drainage or flooding can significantly impact small mammal communities. Both natural disturbances (like fire and grazing) and human-caused disturbances (like agriculture or urbanization) can alter small mammal populations. Small mammals can provide an early indication of habitat degradation before more severe impacts are observed in other species.
Reptiles	Reptiles in grasslands are indicators of good habitat quality. Their presence, abundance, and diversity are influenced by factors like grazing intensity, vegetation structure, and habitat fragmentation. Due to their limited mobility and specific habitat requirements, reptiles are sensitive to habitat changes. Reptile abundance and diversity can be impacted by grazing intensity; excessive grazing can reduce their populations due to habitat loss and reduced prey availability. The structure of the vegetation (e.g., grass height, cover, and diversity) plays a crucial role in reptile habitat. Reptiles may prefer certain vegetation structures for foraging, nesting, and shelter. Habitat fragmentation can isolate reptile populations and reduce their ability to move between suitable areas, impacting their long-term survival. Reptiles are also sensitive to pesticides.

2. Analysis of existing methodologies for the assessment and monitoring of habitat condition

2.1 Variables used, metrics, measurement methods and existing data sources

This guidance has been informed by methodologies for the assessment of grassland habitats that were collected from 21 EU member states. Most MSs have developed common methodologies for all grassland habitats (or for grassland and other habitats, or broad groups of related grassland habitats), although some national methodologies contain specific variables used for individual habitat types (e.g., Belgium - Flanders, Oosterlynck et al., 2020; France, Maciejewski et al., 2015; Italy, Angelini et al., 2016; Poland, Mróz 2010–2015, Germany, BfN 2017).

Member states are in many cases measuring the same habitat characteristics, but they use different variables, and the methods are not directly comparable. National methodologies have defined variables using partly identical and partly different concepts and terminology. Metrics, measurement methods, reference values and thresholds are precisely defined in some countries but less so in others. Exact measurements such as pH, electrical conductivity and other soil properties are used in some countries (e.g. Spain, Goñi et al., 2019), while in most countries, only estimations based on observations and rough categories are used.

This guidance interprets the variables used in each country and matches them to the concepts and terms we defined in the framework for the ecological characterization of grassland habitats (Table 1) in the previous section. The results are summarized in Table 8.

Most variables in Table 8 are defined broadly and include other, more narrowly defined variables. For example, while some habitat manuals define grazing intensity, others only define a broad variable for management, which includes grazing along with mowing and possibly also some other management practices.

It is important to note that we did not match some variables defined in general terms that necessarily involve a large degree of subjectivity in the assessment, for example, degradation or naturalness (e.g. Czechia, Lustyk 2023; Hungary, Horváth et al., 2021; Poland, Mróz et al., 2010–2015). We also did not match variables that do not describe habitat conditions but rather suggest conservation or restoration actions, such as future prospects or restoration needs (e.g. Poland, Mróz et al., 2010–2015).

The analysis shows that most methodologies focus on compositional and structural biotic variables. Some of the physical abiotic state variables and functional biotic variables are also often used. In contrast, chemical abiotic state variables and landscape variables are used rarely.

Table 8. Variables measured for grassland habitats (including wooded grasslands) in 21 Member States according to the national methodologies

For some member states, more than one methodology was considered

Variable category	Variable group	AT	BE	BG	CZ	DE	DK	ES	FR	GR	HR	HU	IE	IT	LT	LV	NL	PL	RO	SE	SI	SK
Abiotic, physical state	Temperature																					
	Water regime	X	X				X			X		X		X		X	X		X			
	Physical soil properties	X	X			X	X	X		X		X	X	X			X		X	X		
Abiotic, chemical state	Soil nutrient availability		X				X	X									X					
	Soil organic matter							X														
	Soil pH		X				X	X									X					
	Soil salinity	X	X					X														
Biotic, compositional	Plant species composition and typical species	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
	Plant species richness							X		X		X	X					X				X
	Animal species		X						X	X		X		X		X				X		
Biotic, structural	Plant above-ground biomass		X	X		X	X	X				X		X				X	X	X		
	Plant functional types		X	X		X				X			X		X			X				
	Dominance of competitive native herbs & dwarf shrubs		X						X	X			X		X	X		X	X			
	Cover of ruderal plant species	X	X	X		X		X	X	X		X		X				X	X			X
	Cover of alien plant species	X	X	X		X			X			X	X	X	X	X		X	X			X
	Cover of trees and shrubs		X	X		X		X	X	X			X		X	X		X	X	X		X
	Density of veteran trees*		X												X	X				X		
	Presence of dead wood*																					
Biotic, functional	Primary productivity																					
	Management				X		X	X		X		X		X	X	X		X	X			X
	Disturbance				X		X	X	X	X		X	X	X		X	X	X	X			X
	Litter accumulation		X									X	X			X		X				
	Regeneration of native woody plants*														X							
Landscape	Habitat area	X										X		X				X	X	X		X
	Habitat connectivity			X								X		X	X		X	X				
	Habitat heterogeneity within grassland areas		X			X									X			X				X

* Relevant for wooded grasslands

The basic characteristic of habitat measured in all national methodologies is the plant species composition or representation of typical plant species. Other frequently recorded characteristics are:

- Cover of trees or shrubs (13 countries)
- Disturbance (13 countries)
- Physical soil properties (at least the cover of bare soil; 12 countries)
- Cover of ruderal plant species (12 countries)
- Cover of alien plant species (12 countries)
- Management (11 countries)
- Plant aboveground biomass (10 countries)
- Water regime (9 countries)
- Dominance of competitive native herbs and dwarf shrubs (8 countries)

All the identified variables are relevant for both open and wooded grasslands. Mediterranean dehesas (habitat type 6310) are analysed in a group of grassland habitats in the Spanish methodology (Goñi et al., 2019) and separately in the Italian methodology (Angelini et al., 2016), but the latter does not list any variables specific to dehesas other than those studied in meadows. The northern wooded grasslands (habitat types 6530 and 9070) are analysed in the Latvian and Lithuanian methodologies (DAP 2023, Gamtos tyrimų centras 2015). In the Latvian methodology, these two habitats are assessed jointly with the habitat 5130 Juniperus communis formations on heaths or calcareous grasslands, whereas in the Lithuanian methodology, the former is assessed according to the same criteria as grassland habitats and the latter according to the same criteria as forest habitats, which correspond to the classification in Annex I of the Habitats Directive but disregards the common features of these habitats. Consequently, there is a lack of information on specific variables measured in wooded grasslands. The Latvian methodology (DAP 2023) is most relevant, providing a comprehensive list of the following structural and functional biotic variables of wooded grasslands assessed by visual inspection:

- Open area without trees or shrubs (proportion of area, %)
- Area with grassland vegetation (proportion of area, %)
- Total area under canopies (characteristic trees and secondary trees together; proportion of area, %)
- Area under canopies of secondary trees or shrubs (proportion of area, %)
- Trees characteristic of the habitat are from various age groups (yes/no)
- Species of trees characteristic of the habitat in the 1st layer (presence/absence)
- Species from the 2nd layer and undergrowth characteristic of the habitat (presence/absence)
- Old wide-canopy trees in the 1st layer (alive or dead; number per ha, four-point scale)
- Dead trees (standing or fallen) from the ancient wooded meadow landscape in the second layer and undergrowth (number per ha, four-point scale)
- Dead trees and stumps >50 cm (number per ha, four-point scale)
- Logs > 50 cm diameter (number per ha, four-point scale)
- Living trees > 50 cm diameter (number per ha, four-point scale)
- Trees > 50cm with hollows (number per ha, four-point scale)

- Trunks of alive trees with damage from livestock (number per ha, four-point scale)
- Trees and bushes shaped by livestock browsing (number per ha, four-point scale)
- Tree stands where characteristic features of grassland appear due to grazing (number per ha, four-point scale)
- Invasive and expansive plant species (ten-point scale)
- Layer of trees and shrubs with the lower part of the canopy eaten by livestock (proportion of area, %)
- Openings in forest or shrubs created by grazing (presence/absence)
- Appropriate hydrological conditions for a particular habitat (proportion of area, %)
- Recent cutting of secondary trees and shrubs (proportion of area, %)
- Area with tree stands that is being grazed (proportion of area, %)
- Open area that is being grazed (proportion of area, %)
- Open area that is being mown (proportion of area, %)
- Area with tree stands which is being mown (proportion of area, %)
- Area where restoration of the hydrological regime is necessary (proportion of area, %)
- Area where reintroduction of continuous management is necessary (proportion of area, %)
- Area where secondary trees and shrubs need to be cut (proportion of area, %)

Some variables relevant to wooded grasslands are also monitored in open grasslands, particularly the presence of solitary (in some cases veteran) trees (e.g. Denmark, Fredshavn et al., 2022; Wallonia, Couvreur et al., 2021).

We observed that none of the member states monitors temperature within habitats, the presence of dead wood and primary productivity, although the latter is often approximated by the plant aboveground biomass (including cover estimates).

In the following text we compare the main habitat characteristics defined in Section 1.2 with variables used in national methodologies:

Abiotic characteristics

In general, abiotic characteristics are assessed in different ways, including direct measurements (e.g. laboratory analyses of soil samples), expert judgement based on field observations (e.g. modified hydrology) or bioindication (e.g. cover of plant indicators of eutrophication).

Physical state characteristics

Temperature. Monitoring of temperature is not specifically mentioned in any national methodology. Only one methodology (Spain, Goñi et al., 2019) mentions the use of temperature indicator values for species instead of temperature measurement. This reflects the fact that temperature monitoring is a standard part of the climatic measurements, which can be interpolated to sites of individual habitats. Microclimate related to habitats and specific sites can also be characterized based on remote sensing (Zellweger et al., 2019). Nevertheless, near-surface and soil temperatures can follow specific patterns that are relevant for habitat conditions, as done by an increasing number of temperature monitoring programmes within specific habitats for scientific purposes (Lembrechts et al., 2020). In this context, it is surprising that the spread of warm-demanding species is not monitored in alpine grasslands because this indicates a decline in habitat quality (Steinbauer et al., 2018).

Water regime. Most national methodologies use visual assessment of changing local hydrological conditions (mainly drainage), reflecting that a change in water regime can cause a decline in habitat quality, particularly if wet grassland is getting drier or dry grassland is changing towards mesic conditions. Two methodologies measure the groundwater level (Italy, Angelini et al., 2016; the Netherlands; BIJ12 2024). Some methodologies use plant indicators of increasing or decreasing moisture (Flanders, Oosterlynck et al., 2020; Sweden, Toräng et al., 2022).

Physical soil properties. Two methodologies measure soil depth (thickness) and collect soil samples (Denmark, Fredshavn et al., 2022; Spain, Goñi et al., 2019). One methodology also measures soil texture as a percentage of soil particles of different sizes, soil bulk density and soil compaction using a penetrometer (Spain, Goñi et al., 2019). Romanian methodology (Trif et al., 2015) determines the soil type. In most cases, these measurements describe soil variables that are long-term, stable and do not change in the absence of a strong disturbance.

Chemical state characteristics

Soil nutrient availability. In most countries where eutrophication is monitored, the assessment is based on the presence and abundance of plant indicators (nutrient-demanding species). In fewer countries, it is based on precise chemical analyses (Denmark, Fredshavn et al., 2022; Spain, Goñi et al., 2019). An increasing input of nutrients is considered an indicator of declining habitat quality.

Soil organic matter. Soil organic matter is only determined from soil samples in Spain (Goñi et al., 2019). The Flemish methodology (Oosterlynck et al., 2020) does not measure soil organic matter explicitly; however, it measures the soil C/N ratio, which is a proxy for decomposition, and includes the soil organic carbon measurement.

Soil pH. In three countries, monitoring includes measurements of soil pH (Denmark, Fredshavn et al., 2022; the Netherlands, BIJ12 2024; Spain, Goñi et al., 2019). Flemish methodology (Oosterlynck et al., 2020) also assesses the cover of plant indicators of acidification for a specific habitat type. The purpose of this monitoring is to assess the potential effects of acidification, which can lead to a decline in plant community species richness.

Soil salinity. Soil salinity is monitored as the electrical conductivity of groundwater in Spain (Goñi et al., 2019). Any deviation from the salinity range that is typical of a particular habitat can indicate a decline in habitat quality.

Biotic characteristics

Biotic variables mainly rely on vascular plants, whereas bryophytes, lichens and animals are assessed in only a few countries, always in combination with the assessment of vascular plants. The most probable reason is the low availability of specialists in groups other than vascular plants.

Compositional state characteristics

Plant species composition and typical species. Vascular plant species composition and the occurrence of typical species of vascular plants are the most common variables in national methodologies. They are used in all the 21 methodologies studied. Some methodologies record total species composition at specific sites, while others only record typical species.

Several methodologies also require recording of rare species. In general, the presence of typical and rare/endangered species is considered an indication of good habitat quality.

Plant species richness. The total species richness of vascular plants is explicitly mentioned in some methodologies (Hungary, Horváth et al., 2021; Ireland, Martin et al., 2018; Poland, Mróz 2010–2015; Spain, Goñi et al., 2019). Some other methodologies include it implicitly in recording the total species composition, which can be directly used to extract information on total species richness. However, the change in species richness does not translate directly into an assessment of habitat quality. On the one hand, a decrease in species richness in a species-rich grassland can be considered an indication of declining habitat quality. On the other hand, an increase in species richness in a specialized, species-poor grassland due to eutrophication or warming can also be a sign of a negative trend.

Animal species. Although the protection of Annex I habitats should ensure the protection of both plant and animal species, only five countries explicitly monitor selected groups of animal species. Among them, the most popular group are birds, which are monitored in four countries (Flanders, Delescaille et al., 2020-2021; Greece, Dimopoulos et al., 2018; Italy, Angelini et al., 2016; Sweden, Haglund & Vik 2010). Other methodologies include monitoring of selected, well-known groups of insects, particularly butterflies (France, Maciejewski et al., 2015), beetles (France, Maciejewski et al., 2015), and orthopterans (Flanders, Delescaille et al., 2020-2021). The French methodology (Maciejewski et al., 2015) also explicitly mentions monitoring of coprophagous insects (beetles and dipterans). The Latvian methodology (DAP 2023) monitors anthills and molehills, which are considered a measure of disturbance in grassland stands. The Hungarian methodology (Horváth et al., 2021) requires recording the presence of the animals and the degree of their effect on habitat quality, including anthills, molehills, fox holes, wild boar burrows, droppings or hoofprints.

Structural state characteristics

Plant aboveground biomass. Many national methodologies measure the cover of each plant species or cover of specific species groups (e.g. habitat-typical, ruderal or alien species). Some methodologies measure the herb-layer height (Denmark, Fredshavn et al., 2022; Ireland, Perrin et al., 2014, Martin et al., 2018; Italy, Angelini et al., 2016; Spain, Goñi et al., 2019). An increase or decrease in biomass can be interpreted as an indication of negative changes in abiotic habitat characteristics, namely, moisture and nutrient availability.

Plant functional types. National methodologies contain various variables to measure the functional structure of vegetation. These include relative proportions of graminoids and forbs (e.g. Flanders, Oosterlynck et al., 2020; Germany, BfN 2017; Greece, Dimopoulos et al., 2018; Ireland, Martin et al., 2018), annual and perennial plants (Bulgaria, MOEW 2023; Greece, Dimopoulos et al., 2018), total cover of bryophytes and lichens (Bulgaria, MOEW 2023; Czechia, Vydrová & Lustyk 2014; Flanders, Oosterlynck et al., 2020; Ireland, Perrin et al., 2014, Martin et al., 2018; Lithuania, Gamtos tyrimų centras 2015; Poland, Świerkosz & Szczęśniak 2018; Spain, Goñi et al., 2019), herb-layer cover (most methodologies) and herb-layer height (Denmark, Fredshavn et al., 2022; Ireland, Perrin et al., 2014, Martin et al., 2018; Italy, Angelini et al., 2016; Spain, Goñi et al., 2019). Each grassland habitat is characterized by the presence and relative proportions of individual plant functional types, and the absence or low proportion of the characteristic functional types is considered as an indicator of negative trends.

Dominance of competitive native herbs and dwarf shrubs. This variable is used in several national methodologies. Grassland habitat condition declines if these species increase their cover and start to dominate the plant community.

Cover of ruderal plant species. This variable is used in several national methodologies, though in some of them, it is not explicitly distinguished from the presence of ruderal species. An increasing cover of ruderal species is considered a sign of grassland habitat degradation.

Cover of alien plant species. This variable is used in several national methodologies, though in some of them, it is not explicitly distinguished from the presence of alien plant species. An increasing cover of alien species is considered a sign of grassland habitat degradation.

Cover of trees and shrubs. This is the second most frequently used variable to assess grassland habitats in national methodologies. In open grasslands, an increasing cover of woody plants is considered to indicate successional processes and the decline of grassland habitat quality.

Density of veteran trees. The density of veteran trees (alive or dead, including old pollarded trees) typical of ancient wooded grasslands is assessed in the specific methodologies for wooded grasslands but also in other grasslands (e.g. Sweden, Haglund & Vik 2010). The presence of veteran trees is considered a sign of good habitat quality.

Presence of dead wood (relevant for wooded grasslands). The presence and amount of dead wood are not mentioned in grassland methodologies, although it is relevant for wooded grasslands, where it indicates good habitat quality, especially for heterotrophic organisms, bryophytes and lichens.

Functional state characteristics

Primary productivity. No national methodology assesses productivity. However, many methodologies measure species cover and some (Denmark, Fredshavn et al., 2022; Ireland, Perrin et al., 2014, Martin et al., 2018; Italy, Angelini et al., 2016; Spain, Goñi et al., 2019) measure the height of the herb layer, which can be used as proxies for productivity. An increase or decrease in productivity, most typically due to changing moisture or nutrient availability, indicates a deviation from normal habitat condition and a possible trend of decline in habitat quality.

Management. Most national methodologies record the presence or intensity of grazing, including overgrazing or grazing cessation, which is judged from direct observation of grazing animals or of various signs of grazing (excrements, grazed forms of woody plants, paths created by grazers etc.). Simple ordinal scales for estimating grazing intensity are used in some countries (e.g. Lithuania uses four categories of grazing intensity: 0 – none, 1 – non-intensive, 2 – medium, 3 – intensive; Gamtos tyrimų centras 2015). Mowing is also recorded in several national methodologies, usually based on direct observations. It is often merged into one broader management variable that includes grazing and mowing, and optionally some other management measures such as burning (e.g. Latvia, DAP 2023). It is assessed whether the management contributes to the maintenance of typical species composition and structure of the given habitat type (it does not if it has too low or too high intensity or uses an inappropriate management practice). In some cases, grazing and mowing are assessed through the occurrence of grazing and mowing indicator plants (e.g., France, Maciejewski et al., 2015).

Disturbance. Several national methodologies assess soil disturbance, mostly as the presence of bare ground caused by the disturbance. Other methodologies assess disturbance through biotic indicators, namely the cover of ruderal species (e.g. Austria, Ellmauer et al., 2020; Germany, GfN 2017), or evidence of the disturbance in general. In most cases, disturbance is considered a negative factor; however, in some grasslands that require open structure, disturbance is essential. Some methodologies use the term disturbance for processes that are not disturbances according to the predominant usage in ecology (Grime 1979); for example, modified hydrology in Austrian methodology (Ellmauer et al., 2020) and eutrophication in Flemish methodology (Oosterlynck et al., 2020) are considered disturbances.

Litter accumulation. This variable is used in several national methodologies and measured either as litter cover or litter thickness. A significant litter accumulation can indicate a lack of management and declining habitat quality.

Regeneration of native woody plants (relevant for wooded grasslands). No national methodology specifically assesses the regeneration of woody plants in wooded grasslands. However, the lack of natural regeneration is a potential threat to the long-term persistence of this habitat.

Landscape characteristics

Landscape characteristics are not part of the grassland habitat assessment in several countries. However, most countries do monitor at least one landscape characteristic.

Habitat area. Habitat area is assessed in several national methodologies, usually as the size of each habitat patch (e.g. Austria, Ellmauer et al., 2005; Hungary, Horváth et al., 2021; Italy, Angelini et al., 2016; Poland, Mróz 2010–2015; Romania, Trif et al., 2015; Sweden, Haglund & Vik 2010). Some methodologies specifically require and assessment of the degree of habitat area decline or fragmentation since the last mapping (e.g. Poland, Mróz 2010). Small or declining habitat area is considered a negative factor because of the risk of extinction debt due to habitat island effects.

Habitat connectivity. Some national methodologies record the distance to the nearest patches of the same habitat or the identity of habitats in the surroundings (e.g. Hungary, Horváth et al., 2021, Italy, Angelini et al., 2016). Some methodologies measure this by visual assessment in the field (e.g. Poland, Mróz 2010–2015), while others conduct GIS analyses (e.g. Angelini et al., 2016; the Netherlands, BIJ12 2024). Some methodologies (e.g. Bulgaria, MOEW 2023) record recent habitat fragmentation due to anthropogenic activities. Habitat patches connected to other patches are considered better than isolated, unconnected habitat patches.

Habitat heterogeneity within grassland areas. This characteristic is not assessed in most national methodologies. The Wallonian methodology (Couvreur et al., 2021) records the presence of other small-scale habitats within the matrix of the prevailing habitat. The Polish methodology (Mróz 2010–2015) records spatial habitat mosaics. In some methodologies, the relative proportion of the target habitat is measured (e.g. in Poland, habitat area is measured as percentage representation along sampling transects, Mróz 2010–2015; in Slovakia, it is measured in percentages of the locality area, Šeffer & Lasák 2022). Most other methodologies record the cover of trees and shrubs, but it is mostly used as an indication of succession rather than an indicator of desired habitat heterogeneity. In general, heterogeneous landscapes are assumed to increase habitat quality.

2.2 Definition of ranges and thresholds to obtain condition indicators

Ranges and thresholds are provided in some national methodologies but not in others. Some countries report that there is not yet enough information to set the thresholds or that the thresholds are under development. Some countries use various ordinal scales for some variables that do not directly translate to the categories of good or bad conditions. Other countries use very broadly defined concepts, such as habitat degradation, instead of referring to clearly defined, unequivocally measurable variables.

Overall, the establishment of ranges and thresholds for grasslands is not enough documented. Expert judgement, rather than precise measurements, is used in most cases, even where the nature of the variable is quantitative. A large part of the information is derived from vascular plant species composition, including the information on abiotic variables. Moreover, there are considerable differences among the MSs in the ranges and thresholds considered, even for the same habitat type.

Abiotic characteristics

Physical state characteristics

Reference levels for physical state characteristics are, in most cases, not given or unexplained. Some countries report a lack of sufficient data to set reference levels.

Temperature. No national methodology measures temperature, although global warming can significantly influence grassland habitats, especially in alpine areas (Steinbauer et al., 2018).

Water regime. In some national methodologies, moisture is estimated on an ordinal scale by expert judgement, especially with reference to artificial drainage (from no drainage to complete drainage; e.g. Austria, Ellmauer et al., 2005) or through the cover of plant indicators of wet conditions. In Flanders, the average groundwater level is measured in centimeters.

Physical soil properties. No information on ranges or thresholds is available in national methodologies.

Chemical state characteristics

The only two countries/regions that report ranges of measured values for chemical characteristics in grasslands are Flanders (Van Calster et al., 2020) and the Netherlands (BIJ12 2024). The former defines favourable ranges for different grassland habitats on the scales representing different soil and atmospheric chemical variables. The latter defines thresholds for dividing the scales into three categories: High, Middle and Low. Other countries assess soil properties through bioindication using vascular plants.

Soil nutrient availability. Flemish and Dutch methodologies (Van Calster et al., 2020, BIJ12 2024) use the data on annual nitrogen deposition to define thresholds for individual grassland habitat types. The Flemish methodology also considers soil nitrogen and phosphorus concentration and their ratios to other elements, resulting in different ranges and thresholds for different habitats. In other countries, the cover of plant indicators of eutrophication is usually used to assess nutrient availability; in such cases, a cover of these species below 10% cover is usually considered as the upper threshold for good condition.

Soil organic matter. The Spanish methodology (Goñi et al., 2019), which is the only one that measures the soil organic matter, states that there is still not enough information to give threshold values for this set of variables.

Soil pH. Soil pH measured from soil solution is considered in some national methodologies, but ranges or thresholds are not defined, except for Flanders (Van Calster et al., 2020). Definitions of favourable ranges could only be established after a detailed study of soils associated with each habitat type because pH varies greatly between habitat types. Van Calster et al., (2020) show that the favourable ranges of pH for a single habitat type can differ depending on the subtype (phytosociological association), data source and measurement methods.

Soil salinity. The conductivity of soil, as a proxy for salinity, is measured in Spain (Goñi et al., 2019). However, no thresholds have been defined.

Biotic characteristics

Compositional state characteristics

Plant species composition and typical species. Several national methodologies are consistent in setting three levels corresponding to high, middle and low numbers of habitat-typical species. Vascular plant species are used for this purpose. Typical species are selected for each habitat type separately by expert judgement. The lists of typical species can differ between countries for the same habitat type, partly due to expert bias, and partly due to biogeographically determined differences in species composition. The threshold numbers of species for classification into the three categories are, in most cases, also determined based on expert judgement. In the Slovak methodology (Šeffer & Lasák 2022), the ranges of the three categories are set to be equal. In addition to the number of typical species, some countries also assess the percentage of cover of typical species, most often with three levels that differ by habitat type. Although the cover is a structural rather than compositional variable, in the case of typical species, these are closely related.

Species richness. The total number of plant species is rarely used in national methodologies, however, in some cases, a high number of species is considered an indicator of good habitat quality. For example, habitat 6230* is considered to have a good condition if it contains more than 25 species according to the Irish methodology (Perrin et al., 2014).

Animal species. Animal species are understood as a complementary criterion in most national methodologies where they are considered. Only the French methodology (Maciejewski et al., 2015) provides thresholds for determining habitat conditions based on animals. It uses criteria that can be easily used by non-specialists, e.g. considering colours of butterflies instead of species identities (no butterflies or only white: unfavourable/bad; at least 5 orange/brown butterflies: unfavourable/inadequate; white individuals, orange/brown ones (>5), blue ones (>5), and white with black dots (>5): favourable). However, these indicators are not always measured by the field surveyors (M. Mistarz, pers. commun., 2024).

Structural state characteristics

Plant aboveground biomass. Some national methodologies set thresholds for total aboveground biomass (measured as percentage cover) for specific habitats, usually using three categories. For example, the Polish methodology (Mróz 2010–2015) sets thresholds of 75% and 50% for habitat 6170 and 25% and 10% for rocky grasslands, with higher values indicating better condition.

Plant functional types. Different measures (percentage covers or ratios) are used in some national methodologies depending on the characteristic features of individual habitats. These include, for example, the cover of bryophytes, the cover of non-grass species, the annual/perennial ratio or the forb/graminoid ratio. These quantitative measures are simplified into two or three categories, using various thresholds set by experts for individual habitat types. In some cases with three categories, the middle range can indicate the best conditions. For example, habitat 6230* is considered in good condition in Ireland if the graminoid ratio is 20-90% (Perrin et al., 2014).

Dominance of competitive native herbs and dwarf shrubs. Some countries use this indicator, which estimates the cover of competitive native herbs or dwarf shrubs (excluding typical species) in percentages and converts them into two or three categories. For example, the Flemish methodology uses a 50% threshold (Oosterlynck et al., 2020), while the French methodology (Maciejewski et al., 2015) uses two thresholds of 1/3 and 2/3.

Cover of ruderal plant species. Two or three levels based on percentage cover are used in some countries, with thresholds varying by country and habitat type.

Cover of alien plant species. Two or three levels based on percentage cover are used in some countries. The level for good condition is usually either 0 or 1%. The second level in the systems with three levels ranges between 1 and 30%.

Cover of trees and shrubs. For open grassland habitats, two or three levels of tree and shrub covers based on ranges on the percentage scales are defined in most countries. The threshold for good/favourable condition varies by country and habitat from 0 to 30%. In the Slovak methodology (Šeffer & Lasák 2022), the range is split based on equal intervals into three categories (good, inadequate, bad).

Density of veteran trees. The number of trees per hectare is counted. In Latvia (DAP 2023), a four-point scale is used for the number of dead trees from ancient wooded meadows per hectare: 0 - no trees, 1-5 trees, 6-10 trees, >10 trees.

Presence of dead wood (relevant for wooded grasslands). There is limited information on the deadwood assessment in wooded grasslands. However, Danish methodology (Fredshavn et al., 2022) records deadwood even in open grasslands, focusing on deadwood of a minimum length of 2 m and a minimum diameter of 20 cm within the 15 m circle. In addition, this methodology records the presence of 25 indicator species of wood-dwelling fungi, mosses and lichens.

Functional state characteristics

Some methodologies do not provide thresholds. The French methodology (Maciejewski et al., 2015) uses some variables to define thresholds for condition, and other variables to define positive or negative bonus points to improve the assessment. The Hungarian methodology (Horváth et al., 2021) also uses a scoring system with positive and negative scores for the occurrence of individual plant species typical or untypical of the habitat. The Irish methodology (Perrin et al., 2014, Martin et al., 2018) also considers that habitat areas in good condition should not contain more than 10% of negative indicator species individually or more than 20% collectively.

Primary productivity. No national methodology is assessing primary productivity.

Management. Management is assessed either by observation of management actions or based on plant indicators. Observations of management actions are usually simplified into three categories (regular, irregular, no management). Plant indicators of grazing or mowing are assessed based on their cover, which is converted into three categories based on expert-defined thresholds. For example, a >40% cover of grazing or mowing plant indicators indicates a good condition for managed grasslands in the French methodology (Maciejewski et al., 2015), while <20% cover of such species indicates an unfavourable/bad condition.

Disturbance. Several national methodologies assess soil disturbance due to erosion as the percentage of bare soil. Percentages are then converted to two or three categories. There seems to be an agreement that good condition is indicated by less than 10% of soil surface affected by erosion.

Litter accumulation. Litter accumulation is measured as either litter thickness (e.g. Poland, Mróz 2010–2015) or litter cover (e.g. Ireland, Perrin et al., 2014, Martin et al., 2018). The measured values are converted into two or three categories. For example, a thickness of 2 cm and a cover of 25% (or 20%, depending on habitat type) are the thresholds for good condition in the Polish and Irish methodologies, respectively.

Regeneration of native woody plants (relevant for wooded grasslands). This information is largely lacking in the national methodologies.

Landscape characteristics

Habitat area. The national methodologies mostly assess the degree of decline in habitat area rather than the absolute area, using two or three categories, of which the best category includes an increase, stability or, in some cases, a slight decrease (e.g. by 1% in Romania; Trif et al., 2015). In contrast, the Austrian methodology (Ellmauer et al., 2005) uses four levels based on absolute area with thresholds of 1 ha, 0.1 ha and 0.01 ha, where more than 1 ha is considered as optimal while 0.01 is considered as a minimum.

Habitat connectivity. The assessment of habitat connectivity is highly variable among national methodologies, though in most cases, the assessment results in three categories. For example, the Hungarian methodology (Horváth et al., 2021) uses a scoring system assessing the distance to the nearest habitat patch of the same type with thresholds of 100 and 500 m. Bulgarian and Polish methodologies (MOEW 2023, Mróz 2010–2015) focus on habitat fragmentation, e.g. the presence of new fragmented anthropogenic structures that occupy up to 1%, 1-10% or >10% of the habitat area in Bulgaria and patch sizes, specific for different habitats, with thresholds from 0 to 0.2 ha in Poland. The Dutch methodology (BIJ12 2024) is based on a GIS analysis involving connectivity and distance, resulting in three categories with threshold values ranging from 1 to 150 ha, depending on the habitat type.

Habitat heterogeneity within grassland areas. This variable is only used in a few countries and is based on different methods and thresholds. For example, the Polish methodology (Mróz 2010–2015) uses an expert-based assessment combining the change of the original habitat mosaic with an estimation of heterogeneity, including the categories preserved spatial and structural mosaic, altered spatial and structural mosaic, lack of spatial and structural mosaic, and homogenization.

2.3 Aggregation methods at local scale

Aggregation at the local scale summarizes different condition indicators to obtain an overall condition assessment for a given habitat at a given location. The location is defined either as a monitoring plot or a habitat patch (polygon), i.e. a contiguous area covered by the target vegetation type. The data for the assessment are collected by surveying the entire area or by sampling in plots or transects. For example, the French methodology (Maciejewski et al., 2015) considers several options:

- Full survey of the entire habitat patch. This is recommended for very small habitat patches or poorly represented habitats at the Natura 2000 site scale.
- Plot sampling. This is conducted in large habitat patches, in which a full survey would be very time-consuming. Plots can be selected at random or using a systematic design.
- Transect sampling. This is also recommended for large habitat patches. A transect line is chosen that crosses the habitat patch and divides it into thirds. Each third is assessed separately, and the information from the three thirds is averaged.

Aggregation consists of merging information from the assessments of various abiotic and biotic (and in some cases also landscape) quality indicators. The method chosen to aggregate these individual assessments into an overall evaluation can greatly influence the outcome. There are several types of aggregation methods (Borja et al., 2014, Langhans et al., 2014), of which the most used are:

- One-out-all-out method, which postulates that all variables must achieve good condition. This aggregation method follows the precautionary principle; however, it often results in overly negative assessments by considering only the element with the worst condition. This method can be used for both quantitative and categorical data.
- Conditional rules, which define that a specific proportion of the variables must achieve a good condition. This method can be used for both quantitative and categorical data.
- Averaging approach, which allows a single poor-quality element to be balanced out by several elements in good condition. This approach can be applied to quantitative data and uses either non-weighted or weighted averaging. The non-weighted averaging assumes that all variables are of equal importance, which is often not the case in condition assessment. In contrast, the weighted averaging assigns different weights to different variables, but the problem is the arbitrary nature of the weights.
- Majority-rule approach is a variant of the averaging approach for categorical data.
- Scoring, which uses the sum of weighted scores. This approach requires assigning different weights to different elements, which includes arbitrary decisions that influence the outcome of the aggregation.

Descriptions of the aggregation methods at the local scale are available for most countries. However, aggregation algorithms are still under development for Czechia and Latvia, while information is missing for Croatia, the Netherlands and Slovenia. In most countries where these methods are described, they are common to all habitats or non-forest terrestrial habitats.

Here we describe the application of different local aggregation rules using examples from some countries, for which the local aggregation methods have been described with a sufficient level of detail:

The Austrian methodology (Ellmauer et al., 2005) uses a combination of the majority-rule approach with the one-out-all-out method. Three groups of variables (species composition, habitat quality and structure, disturbance indicators) are combined, each with three categories (A, B, C). These are then combined using the following rules:

A = AAA, AAB
B = ABC, ABB, AAC, BBB, BBC
C = ACC, BCC, CCC

However, if species composition = C, the whole score = C. This is an example of the application of the one-out-all-out rule in an otherwise majority-rule approach.

The German methodology (LANA 2001) uses the majority rule approach. First, it assesses the status of each of three criteria: (1) Indicators of typical habitat structures: A = excellent development, B = good development, C = moderate to average development; (2) Habitat typical species inventory: A = present, B = mostly present, C = only partly present; (3) Disturbance indicators: A = insignificant, B = moderate, C = heavy. Second, these criteria are combined in the same way as in the Austrian methodology, except for applying the one-out-all-out method.:

A = AAA, AAB

B = ABB, ABC, AAC, ABC, BBB, BBC

C = ACC, BCC, CCC

The Hungarian methodology (Horváth et al., 2021) uses a scoring system. The condition of a single sampled habitat plot is determined based on 16 main variables, using 30 tables. The tables are partly textual and partly metric and are used to assign + or – scores to each variable. An aggregated score is made based on the scores given to each variable. The positive and negative scores of the indicator variables are summed up separately, getting a positive total score (max. +75 points) and a negative total score (max. -75 points). The rating algorithm then rates the habitat patch with the given positive and negative total scores. The algorithm assigns a 'favourable' category to the habitat if the positive and negative total scores are greater than a given threshold, and a 'poor' category if the positive and negative total scores are each less than a given threshold. In all other cases, the final rating is 'unsatisfactory'. Three classes of the condition exist (good, non-satisfactory and bad, with the thresholds >40, 30-40 and <30 summarized scores). The thresholds are arbitrary and defined based on the unpublished (inter) assessment of thousands of plots.

The Slovak methodology (Šeffer & Lasák 2022) combines the averaging approach with multivariate statistics. The aggregation of variables is conducted using the ordination of monitoring records in multi-dimensional space, where each axis represents the assessed variables (typical/indicator species, vertical structure, change of area, influences/management, future prospects). Then the shift of the monitoring record in multidimensional space is interpreted according to the score change on individual axes. The evaluation is based on the Euclidean distance of the evaluated site from the best-quality record. Thresholds are defined for four categories based on equal intervals: A = excellent, B = good, C = poor, and D = bad condition based on distances from the best monitoring records.

The Spanish methodology (Goñi et al., 2019) uses a scoring system. It uses four groups of variables: (1) physical structure, (2) vegetation structure, (3) floristic composition and (4) grazing effects. The scoring system allows each variable to be assigned scores (0, 5, 10), based on criteria defined in a table. This table only indicates qualitative criteria, since there is insufficient data to establish quantitative threshold values. The variables or indicators are distributed in different 'blocks'. The scores of the variables of a block are added up and divided by the maximum score of the block (= the sum of the maximum scores of all the variables). The value of the block is then multiplied by the weight of the block in the total value. Although the same weight is given to each block by default, weights can be given based on experience if necessary. Finally, all the values obtained in the different blocks are added to give a final value whose maximum is 100, which is contrasted with a classification of values between 0 and 100.

2.4 Aggregation methods at biogeographical scale

Habitat conditions aggregated at the local level must be further aggregated over large spatial scales. The spatial units for aggregation are the biogeographical regions of Europe or their corresponding areas within countries. This aggregation at the biogeographical level involves compiling data from various sites within a particular biogeographical region to deliver a comprehensive view of the habitat condition.

Most countries follow the current recommendation for Art. 17 reporting on the aggregation of the assessment of local condition to obtain an overall assessment at the biogeographical scale. This recommendation postulates that "if 90% of habitat area is considered as in ‘good’ condition, then the status of ‘structure and functions’ parameter is ‘favourable’. If more than 25% of the habitat area is reported as ‘not in good condition’, then the ‘structure and functions’ parameter is ‘unfavourable-bad’".

However, some countries do not provide information on aggregation at the biogeographical scale or declare that they are in the process of developing aggregation methods. Other countries use specific, locally developed methods. For example, the Lithuanian methodology (Gamtos tyrimų centras 2015) uses a multivariate approach applied to all monitoring sites, employing numerical classification methods such as k-means clustering and ordination methods such as principal components analysis (PCA). In the Dutch methodology (BIJ12 2024), the conservation degree of each habitat type is evaluated for each Special Area of Conservation (SAC) and the conservation degree of each habitat type is then aggregated according to their area percentage across all SACs. Ireland (Martin et al., 2018) is testing a method based on the assessment of indicators instead of the analysis of plot-based data; this method aggregates information from multiple monitoring plots directly at a biogeographical scale without combining all the relevant criteria of the single sample plots to a conservation degree.

2.5 Selection of localities

Descriptions of how localities for assessment and monitoring are selected are only available for some countries. They differ in the method of selection of monitoring plots, number of plots per habitat, total number of monitoring plots per country, minimum size of the habitat patch for establishing a monitoring plot and whether monitoring is conducted only within the Special Areas of Conservation (SAC) or both within and outside these areas. Some countries only monitor within SACs, but this does not comply with the prerequisites for Art. 17 reporting, which should consider all the habitat occurrences in the biogeographical region, both inside and outside SACs.

There are two main methods of monitoring plot selection – preferential and random stratified (Michalcová et al., 2011, Alessi et al., 2023):

Preferential selection is based on expert knowledge. Habitat experts select monitoring plots based on their subjective judgement, trying to find a representative set of plots that cover the geographic range of the habitat within the country and its internal variation in environmental conditions and species composition. A major problem of preferential selection is its bias towards high-quality examples of each habitat. Consequently, the monitoring is positively biased towards detecting a decline in habitat quality because best-quality plots will tend to either remain stable or decrease in quality but not increase in quality.

Random stratified selection is conducted using GIS, based on habitat or land-cover maps and geographic grids. Monitoring plots are selected by generating random coordinates within strata defined as specific combinations of habitats and grid cells, which ensures that monitoring plots for each habitat are selected in different areas. Different countries use grid cells of different sizes. The random stratified selection is not biased towards detecting negative trends like the preferential selection, but it may not include the best examples of individual habitats, which should have the highest conservation priority and be subject to specific monitoring. Therefore, random stratified selection complemented with additional preferentially selected monitoring plots might be an optimal solution. However, the analysis must differentiate between which plots were selected randomly within strata, and which were selected preferentially.

Another parameter that is highly variable among countries (and not reported by some countries) is the total number of monitoring plots or localities and the minimum number of monitoring plots/localities per habitat. Also, the relationship between the number of monitoring plots and habitat area within the country is not unified. In some cases, the number of monitoring plots per habitat is positively proportional to the habitat area in the country, but this is not the case in some countries or information is not given.

- Austrian methodology (Ellmauer et al., 2020) uses 100 grid squares of 1 x 1 km for each combination of the biogeographical region and the occurrence of the target habitat. Within each mapped habitat area, one to four plots of 20-50 m2 are identified in relatively homogeneous and representative areas of the habitats and fixed using geographical coordinates.
- Czech methodology (Vydrová & Lustyk 2014) uses a set of plots with a representative or characteristic occurrence of the target habitat that were selected by experts.
- Flemish methodology (Oosterlynck et al., 2020) draws a random sample from all known occurrences of the habitat. The number of plots per habitat is a function of the total area of the habitat and a desired minimum detectable difference of 10%. This number ranges from 36 to nearly 500.
- Hungarian methodology (Horváth et al., 2021) determines the number of the necessary plots using several factors such as distribution, rarity, importance in nature conservation, and the role of Hungary in the preservation of the corresponding habitat. The necessary numbers of plots per habitat in the country are defined by national park directorates (6110: 5 plots in 1 directorate, 6190: 54 plots in 7 directorates, 6210: 60 plots in 7 directorates, etc.
- Irish methodology (Perrin et al., 2014) selects survey sites from a comprehensive list of sites identified as candidates for the habitat monitoring network. These sites have been prioritised using the following criteria: (1) area, (2) number of habitats, (3) number of Annex I habitats that are Qualifying Interests (for SACs only), (4) representativity of the Qualifying Interests (for SACs only), (5) proportion of site composed of the habitats, (6) presence of habitat features that are either rare or particularly important in an international context.
- Latvian methodology (DAP 2023) selects monitoring localities based on the following steps: (1) For each habitat type, the list of sites to be surveyed includes all sites with entries A and B in the Natura SDF for this habitat type; (2) For the habitat types for which A and B together account for at least 20% of the total number of sites, all those sites shall be monitored; when A + B < 10 sites, C sites should be selected randomly to add the required number of sites (at least 10); (3) For the habitat types where C sites > 80%, the C sites to be visited shall be selected by randomly selecting 20% of all C sites. Each habitat type

should have at least 10 sites. If the total number is less than 10, all sites should be visited, irrespective of whether they are A, B or C; (4) It is checked that there are no Natura 2000 sites left outside the list that would not have been visited even once; (5) It is analyzed which habitats occur in these remaining sites. All habitats that are already well-represented in more than 20 sites included in the monitoring plan are removed. For the remaining habitat types, one to three habitat types are included to be monitored for each site.

- Polish methodology (various authors) uses expert choice for more widespread habitats or monitors all known localities for rare habitats.
- Romanian methodology (Trif et al., 2015) uses at least 6 plots per habitat distributed both within and outside protected areas.
- Slovak methodology (Saxa et al., 2015) selects the number of permanent monitoring localities for a particular habitat type to be correlated with the number of known sites. It varies from four for rare habitats to more than 700 for widespread habitats.
- Spanish methodology (Busqué et al., 2019) uses a set of criteria including statistical significance, extent and distribution pattern of the habitat type, representation in the Natura 2000 network, threat status, structure and function, whether the localities can be considered reference ecosystems, ecological significance and national uniqueness, ecological diversity, existing information, distance to other monitoring points, and accessibility and representativeness of the localities.

2.6 General monitoring and sampling methods

Most countries use sample plots, though sampling along transects is also used (e.g. France; Maciejewski et al., 2015; Spain, Goñi et al., 2019, Poland, various authors), while permanent monitoring localities (habitat patches) are used as a monitoring units in Slovakia (Saxa et al., 2015). Countries differ in sampling methods used, especially in the following variables:

Sample plot size and shape. The areas and shapes of sample plots differ among countries. For open habitats, the most common plot size seems to be 25 m^2, but also plots smaller than 1 m^2 or larger than 100 m^2 are used. In some countries, different plot sizes are used for different open habitats. Squares or circles are usually the basic shapes, while rectangles can be used in narrow, elongated habitat patches. Here we provide some examples from individual national methodologies:

- Austria (Ellmauer et al., 2020): Circles of 20-50 m^2. In narrow habitat patches, other shapes than circles can be used.
- Flanders (Oosterlynck et al., 2020): Squares of 9 m^2 for vegetation relevés and circles of 18 m radius around each square for the assessment of larger structural parameters such as the cover of woody species.
- Czechia (Vydrová & Lustyk 2014): Squares of 25 m^2.
- France (Maciejewski et al., 2015): Plots of 5 x 5 m^2, 10 x 10 m^2 or 15 x 15 m^2, or transects.
- Spain (Goñi et al., 2019): Plots of 10 x 10 m^2 or 5 x 25 m^2. Alternatively, permanent transects within sampling stations of 1 ha are used instead of plots.

- Hungary (Horváth et al., 2021): Six plots of 0.5 x 0.5 m^2 located in sampling areas of 400 m^2. The sampling areas should be preferably squares, but their shape can be modified depending on the shape and morphology of the site.
- Latvia (DAP 2023): Transects of 50 m are used for sampling habitat patches smaller than 1 ha and transects of 100 m are used for sampling habitat patches of a size between 1 and 5 ha. Vegetation is studied in two vegetation plots in each habitat patch (each of a size of 25m^2 with one subplot of 1 m^2, where species richness is counted), one subjectively chosen in the place with the best habitat quality, and one chosen at random.
- Poland (various authors): Fixed transects of 200 x 10 m with vegetation plots sampled at the beginning, in the middle and at the end of each transect.
- Romania (Trif et al., 2015): Plots of 1 x 1 m, 1 x 10 m, 5 x 5 m and 10 x 10 m.
- Slovakia (Saxa et al., 2015): Permanent monitoring localities of 0.1-5 ha, where the data are collected along a zigzag transect line.

Plot fixing. Little information is available on the procedure of fixing the plot location, whether with permanent marking (e.g. nails or magnets), regular GPS or differential GPS with centimetre accuracy.

Field sampling. In all countries with available information, monitoring is conducted in the field. The basic procedure is plot recording of plant species composition with abundance information, i.e. collecting Braun-Blanquet-type relevés or a similar approach. There are differences in recording abundances using scales such as the Braun-Blanquet scale (e.g. Bulgaria, MOEW 2013) or in percentages (e.g. Czechia, Vydrová & Lustyk 2014). There are also differences in considering or disregarding bryophytes and lichens. Several national methodologies mention the requirement of taking a photograph of the habitat (e.g. Austria, Ellmauer et al., 2020; Bulgaria, MOEW 2013). Only two countries specifically mention the collection of soil samples for laboratory analyses. (Denmark, Fredshavn et al., 2022; Spain, Goñi et al., 2019).

Timing of sampling. Monitoring is normally conducted during spring or summer. There are differences among countries that reflect differences in climate (earlier times of the season tend to be used in southern Europe) and also within countries, depending on the phenological optimum of individual habitats. Some national methodologies (e.g. Spain, Goñi et al., 2019) define specific sampling times for individual habitats. Sampling time also depends on management: for example, the Hungarian methodology (Horváth et al., 2021) requires that mown grasslands are sampled before mowing.

Monitoring frequency. Most countries use the six-year monitoring frequency, which is required by Article 17 reporting. Some countries use longer periods of up to 12 years (e.g. Lithuania, Gamtos tyrimų centras 2015), at least for some habitats. The Danish methodology (Fredshavn et al., 2022) contains tables that define different intervals for different habitats. The Hungarian methodology (Horváth et al., 2021) recommends a standard resurvey period of six years, however, the frequency is longer for some habitat types because of the lack of capacity (K. Bata, pers. comm.).

2.7 Other relevant methodologies

Remote sensing. Ground-based surveys used in the national monitoring schemes can be combined with satellite data, especially using the Sentinel-2 satellite data available since 2015 at spatial resolutions from 10 to 60 m. While the ground-based data provide information on species composition and other local, biotic and abiotic variables, satellite data provide information on the changing extent of individual habitats. Several case studies in different regions and habitats have demonstrated that identification of Natura 2000 habitats from satellite data is possible (Rapinel et al., 2020, Čahojová et al., 2022, Jarocińska et al., 2023), and machine-learning methods for automatic segmentation of satellite images into habitat types are becoming available (Mikula et al., 2023). Unlike ground-based monitoring, earth observation missions run independently of habitat monitoring programmes, data are freely available, and with appropriate methods, habitat changes can be analyzed for the past periods or periods between a specific time in the past and the present. For the period before the start of the Sentinel-2 mission (2015), Landsat data (with a coarser resolution of 30 to 60 m) can be used.

Beyond satellite remote sensing, other methods of remote sensing can significantly enhance habitat monitoring. **Unmanned aerial vehicles (UAVs),** or drones, provide high-resolution imagery (often sub-meter) that can capture fine-scale habitat features, enabling detailed analyses of vegetation structure, species distribution, and even microhabitat conditions (Anderson & Gaston, 2013). UAVs are particularly useful for monitoring inaccessible or sensitive areas without disturbing the habitat. Additionally, airborne or handheld LiDAR (Light Detection and Ranging) can map habitat structures in three dimensions, offering valuable data on canopy height, forest density, and understory characteristics that are crucial for understanding habitat dynamics and biodiversity (Lefsky et al., 2002).

Complementary data sources, such as **hyperspectral sensors**, can further refine habitat classification and condition assessments by detecting subtle spectral differences in vegetation health and composition (Ustin et al., 2004). Combining these remote sensing techniques with ground-based surveys can provide a comprehensive understanding of habitat dynamics at multiple scales. For instance, UAVs and LiDAR can bridge the gap between the localized data from ground surveys and the broader-scale insights from satellite imagery.

European vegetation resurvey data. The recent launch of the ReSurveyEurope database (Knollová et al., 2024), which collects data from repeated vegetation surveys and monitoring all over Europe, provides opportunities for assessing long-term habitat change that goes deeper in time than the current monitoring schemes. This is important for assessing whether the current trends of habitat change are part of longer trends, fluctuations or trend reversals. The ReSurveyEurope data also provide information from the EU countries where Natura 2000 monitoring data are not yet available and from non-EU countries such as the UK and Switzerland, which can be important for comparing with habitat trends recorded in the EU.

European plant indicator values. Habitat monitoring can be complemented by using datasets with indicator values for European vascular plants that have recently become available. Dengler et al., (2023) and Tichý et al., (2023) published indicator values for light, temperature, moisture, soil reaction, nutrients and salinity (the latter only in Tichý et al., 2023), and Midolo et al., (2023) published indicator values for disturbance severity, disturbance frequency, mowing frequency, grazing pressure and soil disturbance. Each plant species has been assigned a value for each of these variables on an ordinal scale. These values can be averaged across all species occurring at a site and used for comparing data from two surveys conducted at different times. The use of these new European datasets can contribute to the standardization of habitat assessment across countries. A combined dataset of Ellenberg-type indicator values and disturbance indicator values is available at https://floraveg.eu/download/.

Threshold establishment by expert elicitation. The analysis of European methodologies shows that thresholds of individual variables are predominantly set arbitrarily, based on undocumented judgement and opinion. Dorrough et al., (2020) demonstrated an alternative approach of establishing thresholds based on simple floristic indicators and combining the judgement of multiple experts through hierarchical modelling. Similar approaches deserve a wider application in the process of habitat condition assessment.

2.8 Conclusions

EU Member States have developed and used their own methodologies to evaluate habitat conditions. We have analyzed methodologies from 21 member states, including more than one methodology for each Member State. In some countries, there are different methodologies for parts of the country (e.g. Wallonia and Flanders in Belgium). In other countries, there are specific methodologies for different habitats, often prepared by different authors (e.g. in Germany and Poland). We have not identified any attempts at harmonizing methodologies between neighbouring countries or countries belonging to the same biogeographical regions.

Despite common characteristics, the variables assessed in individual countries and their thresholds or ranges vary considerably. There is a general agreement on using vascular plant species composition and the representation of typical species of vascular plants. These characteristics are used in each of the 21 member states for each habitat type, although the specific methods of how they are assessed vary. Other commonly used variables mainly represent structural biotic conditions (e.g. the cover of woody plants, ruderal and alien plant species), functional biotic conditions (e.g. disturbance and management) and physical abiotic conditions (e.g. physical soil properties and water regime). Most national methodologies pay relatively little attention to chemical abiotic conditions and landscape characteristics. In the assessment of biotic conditions, focus is dominantly put on vascular plants, whereas other taxa (bryophytes, lichens, fungi, animals) are either used as auxiliary information or not monitored at all.

Regarding wooded grasslands, a specific methodology is only described for Latvia and Sweden (DAP 2023, Naturvårdsverket 2010). In principle, wooded grasslands can be assessed using the same monitoring methodology as open grasslands, but some variables related to the woody component must be added, e.g. the characteristics of crown cover, the density of undergrowth, amount of deadwood, regeneration of woody plants, and counts of hollow, veteran or pollarded trees, as described in the Latvian and Swedish examples.

Most variables in national methodologies are estimated by experts in the field rather than exactly measured. Categories are often used instead of quantitative variables. Moreover, quantitative variables are often converted to categories, most often three categories representing favourable, unfavourable/inadequate and unfavourable/bad condition (e.g. Austria and Germany).

Aggregation at the local scale is also conducted using different methods in different countries. Aggregation methods are mainly based on binary or ordinal categories, although quantitative variables are used as well. The aggregations are conducted using several broad methods, including the one-out-all-out method, conditional rules, the averaging approach, the majority-rule approach or scoring systems. Various combinations of these broad methods are also used.

Aggregation at the biogeographical scale is rather unified across member states due to the EU recommendation on the Article 17 reporting.

In most countries, field monitoring is based on vegetation plots but transects or permanent monitoring localities (whole patches of a specific habitat, such as in Slovakia) are used as well. These plots are selected either preferentially by experts or based on random-stratified sampling plans prepared using the habitat distribution maps in GIS. The number of plots differs among countries, but in most cases, it is proportional to the area or the number of localities of each habitat. Plots are mostly squares, but circles are used in some countries, and elongated shapes are allowed in narrow habitat patches. Plot sizes are standardized within the countries, although some national methodologies allow several plot sizes. There is no standardization between countries, but most plot sizes used are between 1 and 100 m^2, and the most frequent plot sizes tend to be around 25 m^2. The recording interval is six years in most countries to align with the reporting period according to Article 17. However, this period is extended to 12 years in some countries.

Overall, national methodologies for assessing and monitoring habitat condition are far from being standardized among the EU member states. This lack of standardization can result in different assessments of the same habitat change in different countries. Consequently, increasing the level of standardisation would be highly desirable.

Habitat monitoring can also benefit from using new technologies and new resources. Remote sensing, such as the use of data from Sentinel-2 satellites, cannot replace field observations, but it can complement them by analyzing primary productivity, soil moisture, surface temperature and other characteristics that are difficult to monitor in situ. LiDAR technology can be extremely useful to monitor changes in vegetation structure. New datasets of indicator values for European plants can help assess the changes in underlying drivers from the changes in species composition, and the new database ReSurveyEurope can complement the data from monitoring programmes with longer time series, which can help separate short-term fluctuations from long-term trends.

6230 * Species-rich *Nardus* grasslands, on siliceous substrates in mountain areas (and submountain areas in Continental Europe) © Milan Chytrý

3 Guidance for the harmonisation of methodologies for assessment and monitoring of habitat condition

3.1 Selection of condition variables, metrics and measurement methods

The harmonization of condition variables used for monitoring across the EU Member States needs to follow these principles:

- the monitored variables must have an explicit relationship with the main environmental and ecological characteristics of grassland habitats
- the variables must be sensitive to natural threats or human pressures that affect the condition.
- the variables should be suitable for measuring over long time periods to ensure that they detect changes in habitat condition
- the variables should already be in use in several countries so that the previous data collected in the national monitoring programmes can be used
- a difference should be made between essential and recommended variables
- the essential variables should be relatively easy and cheap to measure, though optional variables can be added that are more time-consuming or more costly
- international training programmes for habitat monitoring staff should be designed to standardize the details of habitat monitoring.

The proposed condition variables for habitat monitoring at the EU level are classified into three categories:

- **Essential variables**. These variables should be measured in all grassland habitats and in all the EU Member States. They include the variables that are essential for monitoring the main habitat characteristics that determine their condition and, at the same time, are relatively easy to measure. Most of these variables have already been measured in some way in several EU Member States.
- **Recommended variables**. These variables can be measured in grassland habitats if there are sufficient resources in terms of time of monitoring staff and availability of a sufficient number of automatic sensors (e.g. for temperature or soil moisture measurements).
- **Specific variables**. These variables are only relevant for some grassland habitats, e.g. groundwater level for wet grasslands and the age structure of the tree layer for wooded grasslands. In these habitats, they can be either essential or recommended.

In addition to the proposed condition variables, it seems advisable to measure other variables that describe relevant environmental features (e.g. climate, topography, lithology). These contextual variables are useful for the habitat characterisation, to define thresholds for the condition variables and to interpret the results of the assessment. The information for these variables can be obtained from existing data sources, e.g. meteorological stations can provide information on temperatures and precipitation, data on topography and lithology can be obtained from maps, etc. These variables are not integrated in the aggregation to determine the overall condition but can be very useful and necessary also in the context of climate change and should therefore be considered in the monitoring of grassland habitats at the appropriate scale.

Having these principles in mind, we propose a set of condition variables presented in Table 9, divided into abiotic, biotic and landscape variables. We excluded the following variables related to the ecological characteristics of grasslands identified in Section 1:

- Physical soil properties, such as soil depth and the proportion of gravel, sand, silt and clay; these properties are important determinants of plant species composition and vegetation structure of different areas in the landscape, but they depend mainly on bedrock and topographic position. Consequently, they tend to remain stable in time and are of limited importance for monitoring.
- Primary productivity is difficult to measure by ground survey, requiring several visits in different parts of the growing season. However, it can be approximated by the biomass of undisturbed vegetation at the peak of the growing season. Biomass can be measured using indices derived from remote sensing data, such as NDVI (Rouse et al., 1973).

Regarding abiotic variables, we define many of them as recommended because they have high demands for resources (automatic data loggers, chemical soil analyses), which are not available in all the national monitoring programmes. In this regard, we also recommend the use of bioindication under biotic characteristics, namely, calculations of mean indicator values for vascular plants. Indicator values have some disadvantages compared to direct measurements of abiotic factors, for example, the dependence on species composition, which can be influenced by factors other than the abiotic variable of interest (Zelený 2018). However, they also have several advantages. For example, measurements of soil moisture or groundwater level depend on weather conditions in the period shortly before sampling, whereas mean indicator values reflect local conditions and prevailing values over several months or years.

6520 - Mountain hay meadows © Milan Chytrý

Table 9. A proposal for a standardised set of variables for assessing grassland habitat condition in the EU

Variables	Application	Metrics, units	Examples of measurement procedures
1. Abiotic characteristics			
1.1 Physical state characteristics			
Topsoil temperature	Recommended (relevant for alpine grasslands)	°C	Automatic data loggers, located 5 cm below the ground surface, measuring temperature once per hour.
Soil moisture	Recommended (most relevant for wet grasslands)	m^3 of water / m^3 of soil	Automatic data loggers, located 5 cm below the ground surface, measuring moisture once per hour.
Groundwater level	Recommended (wet grasslands)	cm	Automatic data loggers, measuring groundwater level once per day. Alternatively, plungers can be used to measure water depth in vertical plastic pipes, but this requires a person to measure it; in such a case, the measurement interval can be once per month or once per two months.
Soil disturbance	Essential	%	Visual estimation of the percentage of surface area with recently disturbed soil surface due to human or animal activities. Natural erosion that is not directly caused by humans or animals is not considered.
1.2 Chemical state characteristics			
Soil C/N ratio	Essential	ratio	Soil samples are taken from the upper mineral soil horizon at 5 cm belowground at five systematically placed points in a monitoring plot. These samples are mixed and analyzed for soil organic carbon using a TOC analyzer and total nitrogen using the Kjehldahl method. A ratio is calculated from the values obtained.
Soil organic carbon –	Recommended (most relevant for wet grasslands transitional to fens)	% (percentage in soil's total dry weight)	Sampled as a part of sampling for Soil C/N ratio, see above.
Soil phosphorus	Recommended	% (percentage in soil's total dry weight)	Soil samples are taken from the upper mineral soil horizon at 5 cm belowground at five systematically placed points in a monitoring plot. These samples are mixed and analyzed for plant-available phosphorus using the Mehlich III extract and a spectrophotometer.
Soil pH	Essential	negative logarithm of the hydrogen ion concentration	Soil samples are taken from the upper mineral soil horizon at 5 cm belowground at five systematically placed points in a monitoring plot. These samples are mixed and analyzed for pH in distilled water solution using a pH-meter.

Variables	Application	Metrics, units	Examples of measurement procedures
Soil electrical conductivity	Specific (only for saline grasslands)	μS/cm	Soil samples are taken from the upper mineral soil horizon at 5 cm belowground at five systematically placed points in a monitoring plot. These samples are mixed and analyzed for electrical conductivity in distilled water solution using a conductivity meter.
2. Biotic characteristics			
2.1 Compositional			
Characteristic vascular plant species	Essential	count	The number of vascular plant species found in the monitoring plots that are considered characteristic of the given habitat type in the given country/region, according to a reference list.
Plant species that indicate habitat degradation	Essential	count	The number of vascular plant species found in the monitoring plots that are considered indicators of bad habitat condition (e.g. ruderal, nitrophilous, alien species or native expansive species) in the given country or region.
Unweighted mean of indicator values for light, temperature, moisture, nutrients, reaction and salinity	Recommended	real number	Mean indicator values for the plant found in the monitoring plot. Use of national or regional indicator values is preferable for the countries or regions where they exist. European indicator values (Tichý et al., 2003) can be used in other areas.
Bryophyte and lichen composition	Recommended (mainly relevant for dry and alpine grasslands)	count	The number of species of ground-dwelling bryophytes and lichens found in the monitoring plot that are considered characteristic of the given habitat type in the given country/region, according to a reference list
Characteristic animal species	Essential	count	A list of observed or detected (e.g. through signs, traces, camera traps or acoustic monitoring) animal species that are characteristic of the habitat according to a reference list for the given country or region, including butterflies, other insects, birds, small mammals, reptiles or other relevant groups.
Pollinator species	Essential	count	Abundance and richness of the four main pollinator groups (wild bees, hoverflies, butterflies and moths) monitored following the EU Pollinator Monitoring Scheme (EU-PoMS).
2.2 Structural			
Herb-layer height	Essential	cm	The height of the herb layer at the peak seasonal biomass. It can be measured either by a ruler or a tape. In such a case, the top of the higher herb-layer level should be measured, excluding isolated tall plants that overtop this level. Alternatively, compressed vegetation height can be measured by a rising plate meter; in that case, it is essential that the whole monitoring programme in the country uses exactly the same type of rising plate meter.
Total cover of the herb layer	Essential	%	Visual estimation or image analysis in the monitoring plot.

Variables	Application	Metrics, units	Examples of measurement procedures
Total cover of bryophytes	Recommended (mainly relevant for dry and alpine grasslands)	%	Visual estimation in the monitoring plot.
Total cover of lichens	Recommended (mainly relevant for dry and alpine grasslands)	%	Visual estimation in the monitoring plot.
Total cover of competitively strong native herbs and dwarf shrubs	Essential	%	Visual estimation or image analysis in the monitoring plot; a list of these species must be defined for each habitat and each country.
Total cover of ruderal plant species	Essential	%	Visual estimation or image analysis in the monitoring plot; a list of these species must be defined for each habitat and each country.
Total cover of alien species (neophytes)	Essential	%	Visual estimation or image analysis in the monitoring plot; the definition of neophytes follows the standard list for the country or region.
Graminoid/forb cover ratio	Recommended	fraction	A ratio of the total cover of graminoids (Poaceae, Cyperaceae and Juncaceae) to the total cover of other herbs, based on the visual estimation or image analysis in the monitoring plot.
Total cover of shrubs	Specific for wooded grasslands, recommended for other grassland habitats	%	Visual estimation of percentage cover in a 1 ha area around the monitoring plot or in the whole habitat patch if smaller than 1 ha.
Total cover of trees	Specific for wooded grasslands, recommended for other grassland habitats	%	Visual estimation of percentage cover in a 1 ha area around the monitoring plot or in the whole habitat patch if smaller than 1 ha.
Density of living veteran trees	Specific for wooded grasslands, recommended for other grassland habitats	count	Number of veteran trees per hectare, estimated in a 1 ha area around the monitoring plot. Alternatively, especially in habitat patches smaller than 1 ha, veteran trees can be counted in areas of other sizes than 1 ha and recalculated to 1 ha.
Density of standing dead trees	Specific for wooded grasslands, recommended for other grassland habitats	count	Number of dead trees standing per hectare, estimated in a 1 ha area around the monitoring plot. Alternatively, especially in habitat patches smaller than 1 ha, standing dead trees can be counted in areas of other sizes than 1 ha and recalculated to 1 ha.
Age structure of the tree layer	Specific (wooded grasslands)	categories	Visual estimation in the habitat patch around the monitoring plot (two categories: even-aged, uneven-aged).

Variables	Application	Metrics, units	Examples of measurement procedures
Amount of dead wood	Specific (wooded grasslands)	count	Number of dead wood pieces larger than 2 m per hectare, estimated in a 1 ha area around the monitoring plot. Alternatively, especially in habitat patches smaller than 1 ha, dead wood pieces can be counted in areas of other sizes than 1 ha and recalculated to 1 ha.
2.1 Functional			
Litter accumulation	Essential	%	Visual estimation of the monitoring plot area covered, with optionally added information on mean litter thickness or quantity of standing dead biomass in winter.
Regeneration of native woody plants	Specific (wooded grasslands)	categories	Visual estimation in the habitat patch around the monitoring plots (three categories: good regeneration, limited regeneration, no regeneration).
Succession in the habitat patch	Essential	%	The percentage area within the grassland patch in which the grassland habitat has been changed to other habitats (tall grassland or tall herbaceous vegetation, scrub or forest) due to recent successional processes, estimated in situ with the help of aerial photographs.
Litter accumulation	Essential	%	Visual estimation of the monitoring plot area covered, with optionally added information on mean litter thickness or quantity of standing dead biomass in winter.
Regeneration of native woody plants	Specific (wooded grasslands)	categories	Visual estimation in the habitat patch around the monitoring plots (three categories: good regeneration, limited regeneration, no regeneration).
Succession in the habitat patch	Essential	%	The percentage area within the grassland patch in which the grassland habitat has been changed to other habitats (tall grassland or tall herbaceous vegetation, scrub or forest) due to recent successional processes, estimated in situ with the help of aerial photographs.
3. Landscape characteristics			
Patch size	Essential	ha	The size of the habitat patch, estimated in situ with the help of aerial photographs.
Habitat fragmentation	Recommended	% of area change and distance in m	The percentage change (positive or negative) in the habitat patch area and in the distance between habitat patches since the last sampling, estimated in situ with the help of aerial photographs.
Heterogeneity in the habitat patch	Recommended	%	The percentage area within the grassland patch occupied by small patches of natural or semi-natural forest (groups of trees), scrub, wetlands, water bodies and sparse vegetation, estimated in situ for each of these broad habitat types with the help of aerial photographs.
Anthropogenic disturbance in the habitat patch	Recommended	%	The percentage area within the grassland patch occupied by small patches of anthropogenic structures (e.g. houses) or areas recently disturbed due to human activities, estimated in situ with the help of aerial photographs.

3.2 Guidelines for the establishment of reference and threshold values, and obtaining condition indicators for the variables measured

The measured values of the condition variables need to be compared with reference values and critical thresholds to assess the condition of each variable. A reference level is the value of a variable under reference conditions, against which it is meaningful to compare past, present or future measurements. The difference between a variable's measured value and its reference level represents its distance from the reference condition.

Reference levels should be defined consistently across different variables within a given ecosystem type, and for the same variable across different ecosystem types. This ensures that derived indicators are compatible and comparable, and that their aggregation is ecologically meaningful (United Nations, 2021).

Reference levels are typically defined with upper and lower values reflecting the endpoints of a condition variable's range, which can then be used in re-scaling. For instance, the highest value may represent a natural state, while the lowest value may represent a degraded state where ecosystem processes fall below the threshold required to maintain function (Keith et al., 2013, in United Nations, 2021). For example, pH values in freshwater ecosystems clearly indicate whether biological life can be sustained, while soil nutrient enrichment beyond a certain threshold can lead to the loss of sensitive species.

Establishing reference values and thresholds is essential for determining whether habitats are in good condition or have become degraded. Reference values represent the desired state of an ecosystem, typically reflecting intact or minimally disturbed conditions. These values serve as benchmarks for assessing habitat condition.

These guidelines do not aim to prescribe specific threshold values. Rather, they outline the main approaches and provide guidance for establishing reference values that support the determination of good or not-good condition, while accounting for the ecological variability of habitats across their range.

With regard to the variables, the harmonisation of reference values and thresholds should consider a set of common requirements:

- For a given habitat, the final assessment of its condition and trend over time – based on the reference values and thresholds of the variables characterising the habitat – should be equivalent across MSs, after accounting for the contextual factors specific to each MS (e.g., climate).
- Thresholds, limits, and reference values should be tested using sufficiently robust datasets that represent the full range of habitat conditions, from degraded to high-quality sites.
- Thresholds must account for the natural variability of habitats across their range. Consequently, different threshold or reference values for the same habitat type may be appropriate in different MSs or in different regions within a single MS.
- Establishing reference values requires information external to the evaluated site, which can provide insight into the condition of the habitat and be translated into variable values that characterise that condition.
- Reference values should meet the criteria of validity (ecological relevance), robustness (reliability), transparency, and applicability (Czúcz et al., 2021, Jakobsson et al., 2020).
- Each MS should provide a clear, justified, and comprehensible description of the methodology used to establish threshold and reference values for each variable.

- The methodologies should be designed for regular evaluation and improvement, based on the best available scientific knowledge. Any modifications made – and their implications for past monitoring data – must be communicated transparently.
- A reference library and indicator thresholds should be developed for different habitat types across regions, taking into account their ecological characteristics and natural variability.
- Joint training or guidance on setting threshold and reference values should be offered to experts from the different MSs in order to achieve ensure harmonised approaches.

Several approaches have been recognised for estimating reference values to assess habitat condition (Stoddard et al., 2006, Jakobsson et al., 2020, Keith et al., 2020). These can be broadly synthesised into six categories: (1) absolute biophysical boundaries, (2) comparison to reference empirical cases - i.e., areas or communities considered to be in good condition, (3) comparison to undisturbed cases, (4) modelling and extrapolation of variable-condition relationships, (5) statistical assessments, and (6) expert judgement.

All approaches should be grounded in scientific literature. Methods that use values from a single baseline year as a reference for good condition are not recommended, as the selected year may not reflect favourable conditions, and historical data may be unreliable or incomplete (Jakobsson et al., 2020). The use of historical period (e.g., pre-industrial) as a reference state, as proposed by Stoddard et al., (2006) and Keith (2020), aligns with the baseline approach but also overlaps with comparisons to undisturbed cases (see below). If conditions during a specific baseline year are well documented as favourable, they may be useful for trend analyses. Likewise, where historical pristine conditions are clearly documented, they may serve as valid reference states under the undisturbed comparison approach.

Absolute biophysical boundaries

These refer to situations in which observed values of variables exceed the physical and chemical limits (e.g., pH, bare soil cover, critical loads for eutrophication or acidification) or biotic limits (e.g., presence of alien species) that define the habitat. When such limits are exceeded, the habitat cannot be in good condition (Jakobsson et al., 2020). These thresholds therefore indicate negative impacts on the favourable condition of the habitat.

- Advantages: This approach provides robust and transparent criteria that are clearly linked to the ecological integrity of the habitat.
- Disadvantages: It is applicable to a limited number of variables, typically those with direct negative impacts on habitat condition.

Comparison to empirical cases considered to be in good condition

This approach is based on identifying areas or communities considered to be in good condition (Stoddard et al., 2006, Jakobsson et al., 2020, Keith et al., 2020). These serve as reference cases from which the reference values can be derived. Therefore, their careful selection – and the availability of a sufficient number of such cases – is essential for ensuring the reliability of the reference value estimates (Soranno et al., 2011). While this method may appear straightforward, it is often limited by the scarcity of suitable sites, especially in landscapes that have been historically modified.

- Advantages: Providing that sufficient data from high-quality cases are available, this approach offers empirical validity and reliability by directly linking variable values to habitat condition.
- Disadvantages: Methodological challenges arise due to the difficulty of identifying a sufficient number of suitable reference sites in historically altered environments.

Comparison to cases with a natural disturbance regime

This approach is closely related to the previous one, based on the assumption that most human-induced disturbances reduce habitat quality. This assumption is generally valid in human-modified landscapes and can be linked to historical reference conditions when human pressures were less pronounced (Stoddard 2006). However, disturbances that are part of a natural disturbance regime may actually indicate naturalness and thus good habitat condition. In fact, a certain level of disturbance can be beneficial, supporting microhabitat formation, enhancing biodiversity, and promoting regeneration of habitat-characteristic species (Keith et al., 2020).

Historical reference criteria may include the absence of human intervention or management, as found in "primary" forests (sensu Sabatini et al., 2017), and are often directly connected to climax communities such as old-growth or primeval forests (Wirth et al., 2009, Burrascano et al., 2013, Buchwald 2005), which are typically assumed to be in good condition. However, in regions with long-standing anthropogenic pressure, it may be difficult to identify unaltered or naturally disturbed habitats for certain types (Keith et al., 2020). Additionally, defining the undisturbed state based on a relatively short time period may overlook disturbance legacies that persist over longer timescales (Alfaro-Sánchez et al., 2019).

- Advantages: This approach provides transparent and empirically grounded criteria for defining reference conditions and can benefit from large-scale information on disturbance and land-use history.
- Disadvantages: The assumption that any disturbance reduces habitat quality may not always be valid. Moreover, identifying sufficient undisturbed or naturally disturbed reference areas can be challenging for some habitat types.

Modelling the relationships between variables and condition

This approach assumes a relationship between variable values and habitat condition. When determining threshold and reference values, models that describe these relationships share a conceptual basis with methodologies based on dose-response curves. Such models assume that certain cases of good condition correlate with specific levels of a condition variable.

The advantage of modelling is that it allows reference values to be inferred where empirical examples of good condition or undisturbed condition are lacking. In these situations, information from known empirical examples can be extrapolated to other contexts, such as locations along a climatic gradient.

Various modelling procedures are available. Functional relationships – linear, saturated, or humped – can be applied (Stoddard et al., 2006, Jakobsson et al., 2020). For instance, deadwood volume in pristine forests can be modelled along productivity gradients to establish reference values in climatic conditions where unaltered forests no longer exist (Jakobsson et al., 2020). Correlative climate niche models can also be used to estimate the suitability of species sets (i.e., variables that characterise the habitat) at different points along the climatic gradient (Jakobsson et al., 2020).

Although these approaches offer a functional basis for establishing reference values, they involve several assumptions that often require expert judgement. It is also possible to create models in which condition is inferred from variables other than the condition variable itself – for example, biodiversity-related condition variables may be inferred from pollution levels. However, this approach should be used with caution to avoid tautological inferences involving variables that reflect pressures.

- Advantages: Modelling approaches are flexible, transparent, and encompass a variety of procedures based on functional relationships between variables and condition (validity), drawing on scientific knowledge from multiple disciplines. Can also be applied to obtain reference values when empirical examples of good or undisturbed condition are lacking.
- Disadvantages: The information available to build models is often insufficient or unreliable for many variables. Outputs are highly sensitive to the chosen modelling procedure and underlying assumptions, and expert judgement is ultimately required at multiple stages of the modelling process.

Statistical assessments

This approach is based on quantitative data from databases, such as habitat inventories, which report the distribution of variables within a given habitat. It assumes that higher values of certain variables correspond to good condition when a positive relationship exists, and vice versa. For such variables, high percentile values or confidence intervals (e.g., 95%, Jakobsson et al., 2020), or differences from the maximum observed values (Storch et al., 2018), may be used.

For variables with a negative impact on habitat condition, low (e.g., 5%) or minimum values are applied, while for variables that show a hump-shaped (non-linear) relationship with condition – peaking at intermediate values (e.g., gap occurrence, browsing) – a combination of high and low percentiles may be used.

This approach is particularly suited to variables obtainable from forest inventories (Storch 2018, Pescador et al., 2022), and is useful when empirical examples of good condition are lacking. However, it may provide limited insight into the state of habitats that are in poor condition throughout the entire assessed territory. In other words, this approach is not directly based on reference situations of good condition, but on statistical inferences subject to the constraints of the sampling used to build the reference database.

- Advantages: This approach can be applied with reasonable ease by users with statistical training. It is transparent, replicable, and minimally subjective.
- Disadvantages: The existence of appropriate, quantitative datasets representing the reference state is essential for this method. Its reliability depends on the distribution of condition classes (from bad to good) in the dataset and on how well this distribution corresponds to empirical situations of good condition. As a result, it may lead to under- or overestimation of good condition and may be less reliable for habitats that are poorly represented in the dataset.

Expert judgement

Setting of reference values and thresholds based on expert judgement is common practice, particularly where other sources of information are lacking – for instance, in certain non-abundant habitats where experts have developed empirical knowledge of habitat condition. However, this approach is often criticised for its limited transparency, and the level of expertise may be insufficient in some cases. For this reason, it is sometimes considered a last-resort option for many variables.

Nonetheless, for certain variables – such as assemblages of characteristic species, successional stages, the presence of microhabitats, or regeneration characteristics – expert judgement may be appropriate for establishing thresholds and reference values. In other cases, it can also serve as a complement to other approaches.

In all situations, it is advisable to apply expert judgement through protocols based on consensus and consultation with multiple experts of comparable experience. This should include clear procedures (e.g., standardised questionnaires) and transparent documentation of how conclusions were reached (Stoddard et al., 2006). A further limitation is the lack of available experts for certain habitats, which can hamper the correct application of this approach.

- Advantages: This approach is easy to apply and is commonly used.
- Disadvantages: It entails a high degree of subjectivity and low transparency, which limits replicability and reliability. Its use may also be constrained by the scarcity of suitable experts for particular habitats and Member States.

Table 10 provides an overview of the approaches used to establish thresholds and reference values for the proposed condition variables intended for harmonisation. These approaches are drawn from methodologies applied by Member States and documented in the literature. Given the uncertainties involved in setting reference levels, a combination of approaches is generally recommended to improve reliability. The approaches described are not mutually exclusive, and are often applied in combination. For example, expert judgement is typically required when defining reference cases for good condition or when making modelling decisions about the relationship between variables and condition. Similarly, modelling-based approaches can complement those based on empirical cases of good or undisturbed condition and may also be integrated with statistical methods.

Habitat condition assessments are based on determining whether the variables used indicate good or not good condition. However, it is common practice to define more than two categories for each variable – e.g., good, medium, and bad – as observed in the analysis of methodologies used by MSs. The criteria for assigning these condition categories vary depending on the characteristics of each variable. For example, categorical variables may involve thresholds such as “no alien species allowed”, while quantitative variables may follow linear or non-linear relationships with condition (Jakobsson et al., 2020).

This classification of variable values – whether quantitative or categorical – into condition categories (e.g., good and not good; or good, medium and bad) corresponds to the scaling process needed for joint evaluation through aggregation procedures, as described in the following section. Condition categories can be translated into numerical values (e.g., good = 2, medium = 1, bad = 0|. Alternatively, where quantitative values for the variables are available, these can be directly standardised for use in aggregation.

In habitat condition assessments, each characteristic and its associated variable is likely to be measured in a different unit. Owing to the different metrics and magnitudes used for the variables that characterise habitats, the values obtained from their measurement require some form of standardisation – e.g., through re-scaling – in order to build indicators that combine multiple variables. These values are normalised using reference levels and reference conditions, allowing comparison across variables. Measurement values are thus scaled in relation to their reference levels, thereby normalised to a common scale and aligned direction of change. They can then be combined to form a composite index or used to obtain an overall condition result through appropriate aggregation approaches (see further details in Section 3.3. on Aggregation).

Thresholds, limits and reference values must be tested against sufficiently broad data sets, covering the full range of habitat conditions – from degraded to high-quality examples.

Table 10. Approaches for establishing thresholds and reference values for the proposed variables characterizing grassland habitats

Variable	Biophysical boundaries	Comparison to good conditions	Comparison to naturally disturbed cases	Modelling	Statistical assessment	Expert judgement
1. Abiotic characteristics						
1.1 Physical						
Topsoil temperature						
Soil moisture						
Groundwater level						
Soil disturbance						
1.2 Chemical						
Soil C/N ratio						
Soil phosphorus						
Soil pH						
Soil electrical conductivity						
2. Biotic characteristics						
2.1 Compositional						
A list of characteristic vascular plant species						
A list of vascular plant species that indicate habitat degradation						
Full vascular plant composition						

Variable	Biophysical boundaries	Comparison to good conditions	Comparison to naturally disturbed cases	Modelling	Statistical assessment	Expert judgement
Unweighted mean of indicator values for light, temperature, moisture, nutrients, reaction and salinity						
A list of habitat-specialized bryophyte and macrolichen species						
Bryophyte and lichen composition						
A list of characteristic animal species						
2.2 Structural						
Herb-layer height						
Total cover of the herb layer						
Total cover of bryophytes						
Total cover of lichens						
Total cover of competitively strong native herbs and dwarf shrubs						
Total cover of ruderal plant species						
Total cover of neophytes						
Graminoid/forb cover ratio						
Total cover of shrubs / trees (plot level)						
Total cover of shrubs / trees (patch level)						

Variable	Biophysical boundaries	Comparison to good conditions	Comparison to naturally disturbed cases	Modelling	Statistical assessment	Expert judgement
Density of living veteran trees						
Density of standing dead trees						
Age structure of the tree layer						
Amount of dead wood						
2.3 Functional						
Livestock grazing						
Mowing						
Burning						
Litter accumulation						
Regeneration of native woody plants						
3. Landscape characteristics						
Habitat area						
Habitat fragmentation						
Habitat heterogeneity in the habitat patch						
Athropogenic disturbance in the habitat patch						
Succession in the habitat patch						

The colour intensity indicates the priority of the approach, with dark being the highest priority

3.3 Guidelines for the aggregation of variables at the local level

Ecological assessments require the integration of physical, chemical, and biological quality elements. The choice of aggregation method for combining these partial assessments into an overall evaluation has been widely discussed within the scientific community, as it can significantly influence the final outcome. Various approaches can be used to integrate the values of measured variables into an overall index reflecting the condition of habitat types at the local scale (e.g., monitoring plot, station, or site).

Applying appropriate aggregation approaches is essential for categorising condition at the local scale as good or not good, since the proportions of habitat type area in good/not good condition is the key information needed for evaluating the conservation status of structure and functions at the biogeographical level.

3.3.1 Overview of aggregation methods

Based on the literature (e.g., Langhans et al., 2014, Borja et al., 2014), two main aggregation approaches can be distinguished: the one-out, all-out rule (minimum aggregation) and additive aggregation (e.g., addition, arithmetic mean, geometric mean).

Further information on aggregation approaches and methods is provided below.

Minimum aggregation, or the one-out, all-out rule

For the minimum aggregation, the aggregated value is calculated as the minimum of the values of the measured variables.

The one-out, all-out (OOAO) rule has been recommended for assessing ecological status under the Water Framework Directive (CIS, 2003). The principle behind this minimum aggregation method is that a water body cannot be classified as having good ecological status if any of the measured quality elements fail to meet the required threshold. This is considered a precautionary and rigorous approach, but it has also been criticised for potentially underestimating the true overall status.

A precautionary OOAO approach is also used in the aggregation of parameters when assessing conservation status under the Habitats Directives, the IUCN Red List of Species and the IUCN Red List of Ecosystems.

Conditional rules

Conditional rules require that a certain proportion of variables meet their respective thresholds in order for the overall assessment to achieve a good condition rating. For example, the overall status may be considered as not good when a specific number of variables fail to meet their thresholds.

Simple additive methods and averaging approaches

Simple additive methods calculate an aggregated value as the sum of the n values of the variables.

Averaging approaches are among the most commonly used methods for aggregating indicators. These include straightforward calculations such as the arithmetic mean, weighted average, median, or combinations thereof, to produce an overall assessment value.

Weighting

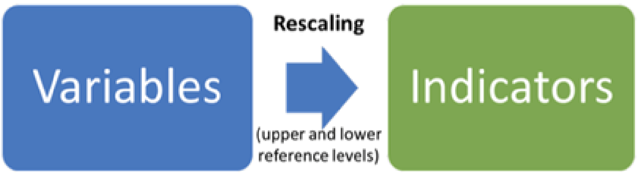
Differential weighting of indicators may be applied when calculating sums, means, or medians. The choice of weighting system should reflect the relative importance of each indicator in determining the overall condition of the ecosystem. Ideally, the approach should be supported by a clear scientific rationale and informed by input from ecologists with expertise in the relevant ecosystem types.

However, a robust basis for assigning weights is not always available. In such cases, weighting often relies on expert judgment, which can be subjective, as expert opinions may differ considerably.

Normalization of variables' values (rescaling)

In the assessment of habitat condition, each characteristic and associated variable is likely to involve the use of different measurement units. To ensure comparability, the measured values of variables are often normalised to a common scale (e.g., 0 to 1 or 0 to 100). This involves rescaling the raw data based on reference values or thresholds that define the boundary between good and not good condition for each variable. By rescaling the condition variables, indicators are standardised to the same scale, making it possible to aggregate them into condition indices that reflect the overall condition at a given plot or location.

Figure 2. Example of deriving condition indicators by rescaling the values obtained for variables, based on upper and lower reference levels



$$\textit{Condition indicator} = \frac{(V-VL)}{(VH-VL)} \quad \text{[Equation 1]}$$

Where:

- V is the measured/observed value of the variable,
- VH is the high condition value for the variable (upper reference level),
- VL is the low condition value (lower reference level).

Source: Vallecillo et al., (2022)

3.3.2 Proposal for the aggregation of measured variables

A quantitative aggregation method should be applied to integrate all essential and specific variables measured to assess the habitat condition. The method should be applied consistently across the habitat range in order to obtain comparable results. The main steps for aggregation are described below.

Step 1 – Normalisation of the variables

The quantitative values obtained for each variable should be normalised by rescaling based on reference values (as described above). The value of each variable will be thus in the range from 0 to 1.

Step 2 – Aggregation of normalised variables

The aggregated value is then calculated by the aggregation of the normalised values of the variables. For the sake of simplicity, and considering the difficulties to suggest a more complex method or index, we describe here a preliminary proposal for aggregation based on the arithmetic mean with normalisation of the values obtained for each of the measured variables, which could be used to determine the habitat condition at the local scale, as summarised in the following equation:

$$Local\ condition = \sum_{1}^{n} v_i/\mathrm{n}$$

Where n is the number of variables, v_i the rescaled value of the corresponding variable (between 0 and 1). The aggregated value would range between 0 and 1.

An alternative method would be to use the weighted average, in which the weight of each variable should be decided, justified and agreed upon for each habitat type by all the MSs that would apply the method. This method can be formulated with the following equation:

$$Local\ condition = \sum_{1}^{n} v_i * w_i/\mathrm{n}$$

Where n is the number of variables, v_i the rescaled value of the corresponding variable (between 0 and 1) and w_i the corresponding weight, with $\sum w_i = 1$. The aggregated value would range between 0 and 1.

This second method, however, presents some difficulties when assigning weights to the variables, which must be based on a proper evaluation of their importance and influence on the habitat condition, based on a robust scientific knowledge. It also requires reaching a consensus on the weights assigned to the variables measured for each type of habitat, among all the countries that must assess its condition. This is a crucial aspect to obtain comparable results in the assessments carried out by all the Member States.

Step 3 – Identify the threshold to determine good/not good condition at the local scale

Finally, a threshold must be applied to the aggregated value to distinguish between good and not good overall condition. This is a crucial step and, wherever possible, this threshold should be established based on empirical data from reference localities in good condition and from localities showing a degraded state. Where such reference localities are not fully available, modelling to obtain such thresholds could be applied.

3.4 Guidelines for aggregation at the biogeographical region scale

The aggregation on the biogeographical region scale is based on the proportion of the habitat area in good and not good condition. It follows the Article 17 reporting guidelines, which require that if more than 25% of the habitat area is reported in not good condition, then the structure and functions parameter is 'unfavourable-bad'. However, numerical thresholds for 'favourable' or 'unfavourable-inadequate' are not defined.

It was agreed between the European Commission and the Member States to use a threshold of 90% of the habitat type area in 'good' condition to consider the structure and functions parameter ‘favourable’. If a Member State uses a different threshold value, this should be noted and explained. This threshold value could vary according to the rarity/commonness of the habitat type, e.g. closer to 100% for rare habitat types with a restricted area.

To assure reliable results of the aggregation on the biogeographical scale, it is essential to base the estimation of the habitat areas in good vs. not good condition on a representative dataset that includes sufficient numbers of samples from each habitat type.

3.5 Guidelines on general sampling methods and protocols

Habitat condition monitoring should be conducted in a network of permanent monitoring plots in individual habitat types. These plots should be located in visually homogeneous patches of grassland vegetation. They should be either squares or circles. The advantage of squares is that they can be easily delineated using a string fixed in four corners. The advantage of circles is that they can be permanently fixed using a single marker in the centre; however, the delineation of the plot during sampling is less practical. In narrow habitat patches, plot shape can be adjusted to rectangles.

The most common plot sizes used for sampling European grasslands are 25 m^2 or 10 m^2, although 1 m^2 or 100 m^2 plots and other sizes within this range are also used (Chytrý & Otýpková 2003). The European Dry Grassland Group uses a sampling protocol with nested plots of multiple sizes, including 1 cm^2, 10 cm^2, 100 cm^2, 1000 cm^2, 1 m^2, 10 m^2 and 100 m^2 (Dengler et al., 2016); however, it would be time-consuming to sample each site using so many plot sizes in habitat monitoring programmes.

A plot size of 10 m^2 seems to be the most appropriate choice for new monitoring schemes because this size or similar sizes are often used. For the already existing schemes, established plot sizes should not change. If standardization across plots with different sizes is needed, nested sampling can be used with one plot size corresponding to the initial sampling and the other plot size corresponding to the required unified sampling size.

All vascular plant species rooted in the plot should be recorded, and the cover of each species in vertical projection should be estimated. Visual estimations can be conducted either in percentages, using values of 0.01%, 0.1%, 0.5% and integers, or using the specialized cover-abundance scales such as the Braun-Blanquet scale (Westhoff & van der Maarel 1973). The total cover of species groups listed above as variables of biotic state characteristics should also be recorded. A photograph of the plot at the time of sampling should be taken. Automatic procedures of image analysis can also be used to estimate vegetation cover from vertically directed photographs. However, unless drones are used, this is only feasible for small plots such as 1 m^2.

If soil variables are measured, soil samples should be taken from four places, each at a randomly selected place along each side of the quadrat, just outside the plot to prevent disturbance inside the plot. These samples should be mixed and used for laboratory analyses. pH and electrical conductivity should be measured in a solution of soil and distilled water (ratio 2 : 5) after 24 hours with a pH-meter and conductivity-meter. Total nitrogen should be determined by the Kjeldahl method, phosphorus content after Mehlich III extraction using spectrophotometry, and total organic carbon by a TOC analyzer.

Field work should be done in spring or summer, in the period when most plant species are visible and/or when vegetation has the highest biomass. In mown grassland, it should be conducted before the first mowing. However, monitoring of animal species requires several visits during the year. More than one visit during the year (e.g. one in early spring and one in late spring/summer) can also improve the quality of plant monitoring, especially in habitats that harbour seasonally dynamic plant communities (e.g. Vymazalová et al., 2012; Fischer et al., 2023).

Plots should be fixed by markers such as metal sticks or magnets to be located by metal detectors or magnet detectors. The geographic coordinates of their centre should be measured using a GPS. Alternatively, plots can be located using a differential GPS with centimetre accuracy; in such a case, geographic coordinates should be recorded in each corner.

In wooded grasslands, two plots should be established in the same habitat patch:

- Smaller plot (e.g. 10 m^2) located in open areas with grassland vegetation and sampled in the same way as in open grasslands
- Larger plot (e.g. 100 or 400 m^2) plot located in an area with a higher density of trees and occurrence of forest herbs in the herb layer. In this plot, species of the tree, shrub and herb layers should be recorded separately.

Some variables that describe the tree and shrub components in grassland areas and landscape variables must be monitored in the patch (habitat polygon) around the monitoring plot. The characteristics of the woody component should be estimated in an area of approximately 1 ha around the monitoring plot. The count variables, such as the number of veteran trees or large deadwood particles, should be recalculated to density within a 1 ha area. The landscape characteristics should be estimated at the level of the whole habitat patch, based on in situ observations combined with information from aerial photographs.

The default frequency of sampling of abiotic habitat characteristics and plant communities should be six years, corresponding to the Article 17 reporting period. If the analysis of repeated records shows that no significant change has occurred in a specific habitat or site over the period of six years, the sampling interval can be extended up to 12 years. In contrast, if a habitat or a locality undergoes rapid changes in local conditions and species composition, the sampling frequency can be set to a shorter interval than six years. However, for proper assessment of typical plant species, more repeated visits are necessary (e.g. several times a year in two subsequent years of the six-year period).

3.6 Selecting monitoring localities and sampling design

The selection of sampling localities – along with the sample size (number of plots) and power – is essential to ensure that the results of assessment and monitoring are representative for each habitat type at the biogeographical scale.

Identifying and selecting localities for sampling requires a systematic approach to ensure that the chosen sites provide comprehensive and representative data on habitat condition within the biogeographical region. Sampling localities should reflect the full range of habitat diversity, as well as environmental gradients, including variations in elevation, soil types, and climate. Moreover, sites should be selected both inside and outside protected areas. This requires a sound understanding of the distribution and variability of each habitat across its range, including the identification of ecotypes or subtypes, where relevant. The main criteria for selecting monitoring localities are summarised below.

- Ecological variability: Localities must represent the full range of ecological diversity and variability within the habitat type. Selection should include different ecotypes or subtypes, successional stages, and reflect key environmental gradients such as altitude, soil type, moisture levels, geomorphological features, and topography.

- Spatial coverage: Adequate spatial coverage is essential to capture habitat heterogeneity. Localities should be selected across the full geographical range of the habitat type within the region, ensuring they are well distributed and represent a significant proportion of the habitat's total occupied area.
- Degree of conservation and exposure to pressures and threats: The selection of monitoring localities should include areas with varying degrees of conservation and degradation, in order to capture the full range of habitat condition across its distribution. This includes both well-conserved areas with minimal human impact, and areas affected by degradation and subject to different pressures. To reflect the diversity of pressures acting on the habitat, localities should span a range of intensity levels – from low to high – and account for different sources of disturbance, such as urbanisation, agriculture, and climate change.
- Presence inside and outside Natura 2000 sites: The assessment and monitoring of habitat conservation status must be carried out both inside and outside Natura 2000 sites. This requires selecting localities – and an appropriate number of plots – that reflect the proportion to the habitat's distribution within and outside the Natura 2000 network.
- Habitat fragmentation at landscape scale: Localities should be selected based on landscape metrics such as patch size and connectivity. Including both isolated and well-connected sites allows for the assessment of fragmentation effects on habitat condition. Understanding these patterns is essential for developing strategies to mitigate the negative impacts of habitat fragmentation.
- Lack of information: Including areas where data are lacking contributes to building a more comprehensive dataset. Selecting localities in historically under-sampled regions ensures a more balanced and complete understanding of habitat condition across its range. This helps to address data gaps and supports more informed conservation planning.
- Accessibility and practicality: Monitoring localities should be accessible for regular field visits, taking into account logistical factors such as distance from roads and ease of access. Practical considerations also include the safety of field personnel and the feasibility of transporting equipment to and from the site.
- Historical data and existing monitoring sites: Making use of existing monitoring sites with historical data can strengthen the understanding of long-term trends and changes in habitat condition. Such sites provide valuable baselines for comparison and support more robust trend analyses over time.

Sample size

Once sampling localities have been identified for each habitat type, the minimum number of plots per locality – and across the biogeographical region – must be calculated to balance sampling effort with the need for representative data.

The size of the sample influences two statistical properties: 1) the precision of the estimates and 2) the power of the assessment to draw meaningful conclusions. The number of plots must be statistically sufficient to detect changes and trends with the desired level of confidence. Appropriate statistical methods should be applied to determine an adequate sample size.

Considering the heterogeneity of habitat types, it is highly recommended to consult a sampling statistician when determining sample size – that is, the minimum number of plots required to ensure representativity and statistical significance.

Some **key elements for ensuring statistical representation** of habitat condition in the sample are summarised below:

Sample size and distribution:

- The number of localities/transects etc. should be sufficient to provide a statistically robust sample size. This ensures that the data collected can be generalized to the entire habitat type within the region.
- Statistical methods such as stratified random sampling are often used to ensure that all habitat subtypes and environmental gradients are adequately represented.

Sampling design:

- Within each sampling area or locality, multiple plots are established to collect detailed data on benthos, infauna, mobile species and other ecological indicators. The distribution and number of sampling stations depend on the variability and size of the habitat patch. Sampling areas (plots, transects) are laid out considering the existing main ecological gradients, e.g., exposure to waves/currents/tides, depth, sediment characteristics.

Replication and randomization:

- Replication of sampling units within each locality and randomization of sampling plots location help to reduce bias and increase the reliability of the data.
- Randomized plot locations ensure that the sampling captures the natural variability within the habitat.

3.7 Use of available data sources, open data bases, new technologies and modelling

Remote-sensing techniques can be used for habitat mapping and monitoring different variables that characterize habitat condition, in particular, water regime, vegetation biomass, encroachment of trees and shrubs, habitat area and habitat fragmentation.

- **Grassland habitat mapping**. The main challenge is the development of algorithms that can identify grassland habitat types from satellite images. Although there have been significant recent technological advances in this field (e.g. Mikula et al., 2023), extensive calibration with ground-truthed data is still necessary to achieve reliable accuracy for grasslands. Once these technical issues are resolved, remote-sensing techniques should be able to document changes in habitat area and fragmentation. In addition, information on mowing and grazing cycles can be obtained from temporal satellite image series.

- **Soil moisture estimation from satellite data uses the interaction of microwave radiation with water molecules in the soil.** Microwave sensors, both passive and active, are employed for this purpose (Kerr et al., 2012). Passive microwave sensors measure the natural microwave radiation emitted from the Earth's surface. The amount of radiation emitted is influenced by soil moisture content. Active microwave sensors transmit microwave pulses and measure the backscattered signal. The strength of the backscattered signal is also affected by soil moisture.

- **Vegetation productivity, cover and succession**. There are several vegetation indices based on the satellite data (Xue & Su 2017), e.g. the Normalized Difference Vegetation Index (NDVI), which is sensitive to chlorophyll content and widely used for vegetation monitoring, or the Enhanced Vegetation Index (EVI), which is less sensitive to atmospheric effects and soil background and is often preferred in areas with dense vegetation. Many studies have shown strong correlations between these vegetation indices and aboveground biomass. By monitoring changes in the values of vegetation indices, changes in biomass and, consequently, primary productivity can be inferred. These indices can also detect successional changes. As succession progresses, species composition changes, and unique spectral signatures of different species can be captured by various vegetation indices.

New European datasets of plant indicator values (Dengler et al., 2023, Tichý et al., 2023) make it possible to complement or replace difficult and problematic measurements of temperature, moisture and nutrients by mean indicator values for these factors. These values can also be used to estimate soil reaction and salinity, although these two properties can be measured relatively easily from soil samples. Although these values are ordinal and based on expert judgement, they provide robust estimates of trends in habitat change. When analyzing the change in mean indicator values between two sampling times, permutation tests developed specifically for this purpose (Zelený 2018) must be used to avoid biased p-values.

The monitoring of Annex I grassland habitats can also highly profit from a number of current initiatives aimed at vegetation monitoring:

- **EU Biodiversity Observation Coordination Centre** (EBOCC) is a pilot for establishing a centralized hub to coordinate monitoring efforts across Europe. The pilot builds on the results of an EU wide research Project, the Europa Biodiversity Observation Network (EuropaBON: https://europabon.org/). This project assessed the specific needs of users and policymakers regarding biodiversity monitoring and conducted a comprehensive review of existing monitoring programmes, including long-term ecosystem studies, remote sensing initiatives, and citizen science projects. EuropaBON developed an EU-wide framework for monitoring biodiversity and ecosystems with a priority list of Essential Biodiversity Variables (EBV) to be monitored, and the workflow for harmonisation and integration of observations using data infrastructures and models to provide EBV datasets and indicators. The pilot centre will test this framework and help establish a systematic collection of high-quality data on biodiversity that is harmonized and interoperable. It will address the needs for better biodiversity monitoring in support of Member State bodies responsible for the implementation of the Nature Restoration Regulation and the Birds and Habitats Directives.
- **European Long Term Ecological Research Network** (eLTER: https://elter-ri.eu/) is a research infrastructure designed to facilitate groundbreaking research and generate novel insights into the combined effects of climate change, biodiversity loss, soil degradation, pollution, and unsustainable resource use on terrestrial, freshwater, and transitional water ecosystems. At its core is DEIMS-SDR, a dynamic database that compiles information from a vast array of long-term ecosystem research sites worldwide. This comprehensive repository includes site-specific details such as location, ecosystem types, research facilities, measured parameters, and research focus, as well as data on associated researchers and networks.
- **EU Grassland Watch** (https://ec.europa.eu/eu-grassland-watch/) provides grassland information in 3689 Natura 2000 sites in 27 EU Member States based on satellite data. Covering the period from 1994 until the present, the information in this portal exploits Landsat and, since 2016, Copernicus Sentinel 1 and 2 images. Users can explore grassland cover changes in specific land parcels, Natura 2000 sites or at regional scales. At present, the portal covers Natura 2000 sites that were previously mapped in the frame of the Copernicus Land Monitoring Service.

- **MOTIVATE project** (https://www.biodiversa.eu/2024/04/15/motivate/) aims at substantially improving the quality of reporting on the conservation status of the EU's terrestrial habitats by combining so-far untapped data with remote sensing, modelling and extrapolation methods. This will improve the standardization of reporting and support national conservation agencies and decision-makers. MOTIVATE (2024-2027) integrates expertise and techniques from different knowledge domains, namely vegetation science, biodiversity modelling, remote sensing and human geography. At its core is the community-owned database of vegetation plot time series, ReSurveyEurope, integrating on-the-ground data with ongoing monitoring under the Habitats Directive. These data will be used to produce both habitat- and species-specific assessments of plant biodiversity status and trends, and to develop workflows for upscaling these results using remote sensing, and for attributing drivers to the observed changes based on biodiversity modelling. In addition, MOTIVATE will establish pipelines to collect additional vegetation-plot time series in the future and invest in capacity-building to secure the involvement of future generations in the continued sampling of time series. Knowledge exchange among multiple stakeholders will help in understanding how biodiversity data can be integrated with broader public perceptions. This will improve how decision-makers put monitoring data into practice.
- **ReSurveyEurope database** (Knollová et al., 2024; https://euroveg.org/resurvey/) has assembled existing vegetation resurvey datasets across Europe. Version 1.0 of ReSurveyEurope contained 283,135 observations (i.e., individual surveys of each plot) from 79,190 plots sampled in 449 independent resurvey projects. Of these, 62,139 (78%) were permanent plots, that is, marked in situ or located with GPS, which allows for high spatial accuracy in resurvey. The remaining 17,051 (22%) plots were from studies in which plots from the initial survey could not be exactly relocated. Four data sets, which together account for 28,470 (36%) plots, provide only presence/absence information on plant species, while the remaining 50,720 (64%) plots contain abundance information (e.g., percentage cover or cover-abundance classes such as variants of the Braun-Blanquet scale). The oldest plots were sampled in 1911 in the Swiss Alps, while most plots were sampled between 1950 and the present. Although such datasets are not available for all habitats in all regions, in many cases, they do exist and can provide a long-term perspective on historical changes and establish whether the recent change detected in Annex I habitat monitoring is a continuation of a long-term trend or a deviation from this trend.
- **GLORIA network** (Pauli et al., 2015; https://www.gloria.ac.at/home) is a Global Observation Research Initiative in Alpine Environments. It operates a worldwide long-term observation network with permanent plot sites in alpine environments. Nevertheless, it is particularly relevant for monitoring European alpine grasslands as it started in the European Alps and established monitoring plots in alpine grasslands on mountain summits across most European high-mountain ranges. Vegetation and temperature data collected at the GLORIA sites are used to discern trends in species diversity, composition, abundance, and temperature, and to assess and predict losses in biodiversity in alpine ecosystems, which are under accelerating climate change pressures. The basic focus is on vegetation and vascular plants, but where experts and funding are available, other organism groups such as bryophytes, lichens, and different vertebrate and arthropod groups are included.

4 Guidelines to assess fragmentation at appropriate scales

Habitat fragmentation is a process of division of a large and contiguous habitat into smaller, isolated habitat patches (Fahrig 2003). Although habitat fragmentation can occur naturally, recent human impact on natural ecosystems has triggered fragmentation processes that threaten habitat-specialized species.

Habitat fragmentation should be assessed using Geographic Information Systems (GIS) based on satellite data, aerial photographs or maps from ground-based habitat mapping. Any of these data sources must contain boundaries of all habitat patches on the national scale.

The metrics used for the assessment of fragmentation can be divided into three groups (Hargis et al., 1998, Wang et al., 2014):

- **Patch-level metrics** measure characteristics of individual habitat patches. Common patch-level metrics include:
  - Patch area: The total size of the patch.
  - Patch perimeter: The length of the patch boundary.
  - Edge density: The length of the patch edge per unit area.
  - Shape index: Compares the patch perimeter to the perimeter of a circle with the same area. A higher value indicates a more complex shape.
  - Fractal dimension: Measures the complexity of the patch boundary.
- **Class-level metrics** assess fragmentation at the landscape level. They provide a broader perspective on habitat fragmentation by considering the overall distribution and configuration of habitat patches within a landscape. They include:
  - Landscape shape index: Measures the complexity of the landscape configuration. Higher values indicate a more complex and fragmented landscape.
  - Fractal dimension: Quantifies the complexity of the landscape pattern. Higher values suggest a more irregular and fragmented landscape.
  - Patch density: The number of patches per unit area. Higher density indicates greater fragmentation.
  - Patch size distribution: Describes the distribution of patch sizes within the landscape. This information can reveal whether there are a few large patches or many small ones.
  - Edge density: The total length of edges per unit area. Higher values indicate a more fragmented landscape with increased edge effects.
- **Connectivity metrics** evaluate the degree of connectivity between habitat patches. They include:
  - Mean patch isolation: The average distance between patches. Higher values indicate greater isolation.
  - Connectivity index: Measures the degree of connectivity between patches. Higher values suggest better connectivity.

Habitat fragmentation can be assessed statically to characterize fragmentation at a specific point in time or dynamically by comparing fragmentation indices based on past data with the same indices based on the current data.

5 Next steps to address future needs

This document provides an analysis of the methodologies used for grassland habitat monitoring in the EU Member States and compares them with the main ecological characteristics of grasslands, evaluating how well these approaches align with the requirements for effective habitat monitoring. Building upon this comparison, it proposes a common methodology for the harmonisation of habitat monitoring across the EU to improve consistency, data quality, and comparability across Member States.

Although the proposed methodology is grounded in extensive information compiled from national habitat monitoring manuals, published data, and discussions with numerous experts across Europe, it is not intended to be prescriptive. Rather, its application should be tested for further refinement. National experts and practitioners actively engaged in habitat monitoring should test and assess the proposed methodology in order to properly evaluate its feasibility, appropriateness and adaptability to diverse ecological, administrative and logistical contexts of different EU Member States.

Based on practical experience and iterative evaluation, national and international experts should collaborate to refine and develop common methods, particularly for setting ecologically meaningful thresholds for habitat condition and for the aggregation and interpretation of monitoring results at multiple scales.

In addition to efforts directed at standardizing Annex I habitat monitoring across EU Member States, it is crucial to take additional steps to improve workflows and foster interoperability between different European initiatives focused on habitat monitoring and the study of habitat changes. These initiatives include, but are not limited to, EuropaBON, eLTER, EU Grassland Watch, MOTIVATE, ReSurveyEurope, and GLORIA. While these initiatives and projects operate with different specific aims and utilize different types of data collected under varying methodologies, the complete standardization of their activities is neither practical nor desirable, as it could compromise the flexibility required to address their respective objectives. However, there is significant value in fostering closer collaboration between these initiatives, particularly in standardizing elements and workflows that are compatible and beneficial to the goals of these projects. Moreover, establishing systematic, secure, and efficient workflows for sharing relevant datasets and metadata among these initiatives will be essential for improving data availability and reusability, facilitating integrated analyses across initiatives, and ensuring that efforts to monitor and assess habitat changes across Europe are coherent and complementary.

Further research and technological development will also be needed to enhance habitat monitoring practices using innovative and emerging technologies, thereby increasing the accuracy, efficiency, and spatial-temporal resolution of monitoring activities. The most promising avenues for future research and implementation include:

- The integration of Artificial Intelligence (AI) and Machine Learning techniques with remote sensing data to develop advanced algorithms for automated habitat mapping, habitat change detection, and species identification from high-resolution satellite and aerial imagery (e.g., Mikula et al., 2023).
- The expanded use of Unmanned Aerial Vehicles (UAVs), Terrestrial Laser Scanners, and multi-sensor systems to collect high-resolution spatial and temporal data on vegetation structure, soil properties, and microtopography, providing critical information that complements traditional field-based monitoring approaches (de Castro et al., 2021).

- Automated, AI-assisted image analysis for the assessment of plant species cover within survey plots, using standardized photographic data as an alternative or complement to person-based visual estimations conducted in the field, thereby reducing observer bias and increasing the consistency of cover assessments (Yu & Guo, 2021).
- Systematic utilization of temporal series of satellite data for the assessment of biomass development dynamics, mowing cycles, grazing regimes, and the detection of land-use changes impacting grassland habitats, providing essential information for adaptive management and early warning of degradation processes.
- The deployment of advanced sensor networks capable of collecting real-time data on key environmental parameters, including air and soil temperature, humidity, and soil moisture, to better understand microclimatic variations and their impact on habitat condition and dynamics (e.g., Lembrechts et al., 2020).
- Advancements in environmental DNA (eDNA) extraction and analysis techniques to allow for more accurate, efficient, and cost-effective biodiversity assessments based on eDNA sampling, which will enhance the monitoring of previously underrepresented taxa, such as invertebrates, fungi, and bacteria, thus improving the overall comprehensiveness of biodiversity monitoring efforts in grassland habitats (e.g., Větrovský et al., 2023).

Collectively, these actions will support the development of a more unified, effective, and technologically advanced approach to grassland habitat monitoring across the EU, ensuring that monitoring activities are aligned with ecological requirements while also remaining practical for implementation by Member States. By fostering collaboration between projects, refining methodologies through practitioner feedback, and adopting innovative technologies, it will be possible to advance the quality and utility of habitat monitoring to support biodiversity conservation and sustainable land management across European grasslands.

6430 - Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels
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Annex - Correspondences between Annex I habitats and EUNIS habitats

Dry grasslands

Code	Annex I habitat name	Corresponding EUNIS habitat(s)
2330	Inland dunes with open *Corynephorus* and *Agrostis* grasslands	**R1P** - Oceanic to subcontinental inland sand grassland on dry acid and neutral soils **R1Q** - Inland sanddrift and dune with siliceous grassland
2340*	Pannonic inland dunes	**R1Q** - Inland sanddrift and dune with siliceous grassland
6110*	Rupicolous calcareous or basophilic grasslands of the *Alysso-Sedion albi*	**R13** - Cryptogam- and annual-dominated vegetation on calcareous and ultramafic rock outcrops
6120*	Xeric sand calcareous grasslands	**R1P** - Oceanic to subcontinental inland sand grassland on dry acid and neutral soils
6130	Calaminarian grasslands of the Violetalia calaminariae	**R1S** - Heavy-metal grassland in Western and Central Europe
6190	Rupicolous pannonic grasslands (Stipo-Festucetalia pallentis)	**R16** - Perennial rocky grassland of Central and South-Eastern Europe
6210	Semi-natural dry grasslands and scrubland facies on calcareous substrates (*Festuco-Brometalia*) (*important orchid sites)	**R14** - Perennial rocky grassland of the Italian Peninsula **R18** - Perennial rocky calcareous grassland of subatlantic-submediterranean Europe **R1A** - Semi-dry perennial calcareous grassland (meadow steppe)
6220*	Pseudo-steppe with grasses and annuals of the *Thero-Brachypodietea*	**R1D** - Mediterranean closely grazed dry grassland **R1E** - Mediterranean tall perennial dry grassland **R1F** - Mediterranean annual-rich dry grassland **R1R** - Mediterranean to Atlantic open, dry, acid and neutral grassland
6240*	Sub-Pannonic steppic grasslands	**N35** - Mediterranean and Black Sea soft sea cliff **R1A** - Semi-dry perennial calcareous grassland (meadow steppe) **R1B** - Continental dry grassland (true steppe)
6250*	Pannonic loess steppic grasslands	**R1A** - Semi-dry perennial calcareous grassland (meadow steppe) **R1B** - Continental dry grassland (true steppe)
6260*	Pannonic sand steppes	**R11** - Pannonian and Pontic sandy steppe
6280*	Nordic alvar and precambrian calcareous flatrocks	**R13** - Cryptogam- and annual-dominated vegetation on calcareous and ultramafic rock outcrops **R1A** - Semi-dry perennial calcareous grassland (meadow steppe)
62A0	Eastern sub-Mediterranean dry grasslands (*Scorzoneretalia villosae*)	**R16** - Perennial rocky grassland of Central and South-Eastern Europe **R19** - Dry steppic submediterranean pasture of the Amphi-Adriatic region **R1A** - Semi-dry perennial calcareous grassland (meadow steppe)
62B0*	Serpentinophilous grassland of Cyprus	**U29** - Eastern Mediterranean base-rich scree
62C0*	Ponto-Sarmatic steppes	**R1A** - Semi-dry perennial calcareous grassland (meadow steppe) **R1B** - Continental dry grassland (true steppe)

Mesic grasslands

Code	Annex I habitat name	Corresponding EUNIS habitat(s)
6180	Macaronesian mesophile grasslands	**R1T** - Azorean open, dry, acid to neutral grassland
6230*	Species-rich *Nardus* grasslands, on silicious substrates in mountain areas (and submountain areas in Continental Europe)	**R1K** - Balkan and Anatolian oromediterranean dry grassland **R1M** - Lowland to montane, dry to mesic grassland usually dominated by Nardus stricta **R43** - Temperate acidophilous alpine grassland
6270*	Fennoscandian lowland species-rich dry to mesic grasslands	**R1A** - Semi-dry perennial calcareous grassland (meadow steppe) **R1P** - Oceanic to subcontinental inland sand grassland on dry acid and neutral soils **R21** - Mesic permanent pasture of lowlands and mountains **R22** - Low and medium altitude hay meadow
6510	Lowland hay meadows (*Alopecurus pratensis, Sanguisorba officinalis*)	**R22** - Low and medium altitude hay meadow **R35** - Moist or wet mesotrophic to eutrophic hay meadow
6520	Mountain hay meadows	**R23** - Mountain hay meadow

Wet grasslands

Code	Annex I habitat name	Corresponding EUNIS habitat(s)
6410	Molinia meadows on calcareous, peaty or clayey-silt-laden soils (*Molinion caeruleae*)	**R37** - Temperate and boreal moist or wet oligotrophic grassland
6420	Mediterranean tall humid grasslands of the *Molinio-Holoschoenion*	**N1J** - Mediterranean and Black Sea moist and wet dune slack **R31** - Mediterranean tall humid inland grassland
6430	Hydrophilous tall herb fringe communities of plains and of the montane to alpine levels	**R55** - Lowland moist or wet tall-herb and fern fringe **R56** - Montane to subalpine moist or wet tall-herb and fern fringe
6440	Alluvial meadows of river valleys of the *Cnidion dubii*	**R35** - Moist or wet mesotrophic to eutrophic hay meadow
6450	Northern boreal alluvial meadows	**R35** - Moist or wet mesotrophic to eutrophic hay meadow
6460	Peat grasslands of Troodos	**R31** - Mediterranean tall humid inland grassland
6540	Sub-Mediterranean grasslands of the *Molinio-Hordeion secalini*	**R34** - Submediterranean moist meadow

Alpine grasslands

Code	Annex I habitat name	Corresponding EUNIS habitat(s)
6140	Siliceous Pyrenean *Festuca eskia* grasslands	**R43** - Temperate acidophilous alpine grassland
6150	Siliceous alpine and boreal grasslands	**R41** - Snow-bed vegetation **R42** - Boreal and arctic acidophilous alpine grassland **R43** - Temperate acidophilous alpine grassland
6160	Oro-Iberian *Festuca indigesta* grasslands	**R1G** - Iberian oromediterranean siliceous dry grassland **R1N** - Open Iberian supramediterranean dry acid and neutral grassland
6170	Alpine and subalpine calcareous grasslands	**R1H** - Iberian oromediterranean basiphilous dry grassland **R41** - Snow-bed vegetation **R44** - Arctic-alpine calcareous grassland

		R45 - Alpine and subalpine calcareous grassland of the Balkans and Apennines
62D0	Oro-Moesian acidophilous grasslands	**R43** - Temperate acidophilous alpine grassland

Wooded grasslands

Code	Annex I habitat name	Corresponding EUNIS habitat(s)
6310	Dehesas with evergreen *Quercus* spp.	**R73** - Mediterranean wooded pasture and meadow
6530*	Fennoscandian wooded meadows	**R72** - Hemiboreal and boreal wooded pasture and meadow
9070	Fennoscandian wooded pastures	**R72** - Hemiboreal and boreal wooded pasture and meadow

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