

REPORT

FloraVeg.EU – An online database of European vegetation, habitats and flora

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Abstract

This article describes FloraVeg.EU, a new online database with open-access information on European vegetation units (phytosociological syntaxa), vegetated habitats, and plant taxa. It consists of three modules. (1) The *Vegetation* module includes 149 phytosociological classes, 378 orders and 1305 alliances of an updated version of the EuroVegChecklist modified based on the decisions of the European Vegetation Classification Committee. Vegetation units dominated by vascular plants are characterized by country-based distribution maps and data on the dominant life forms, phenology, soil properties, relationships to vegetation regions, elevational vegetation belts and azonal habitats, successional status, and degree of naturalness. A list of diagnostic taxa is also provided for each class. (2) The *Habitats* module includes vascular-plant-dominated terrestrial, freshwater, and marine habitat types from the first to the third or fourth highest hierarchical levels of the EUNIS classification. Of these, 249 vegetated habitats are characterized by a brief description, a point-based distribution map, diagnostic, constant, and dominant taxa, and a list of the corresponding alliances. (3) The *Species* module provides information on 37 characteristics of European vascular plant species and some infrageneric or infraspecific taxa, including functional

For affiliations refer to page 9.

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traits (habitus and growth type, leaf, flower, fruit and seed traits, and trophic mode), taxon origin (native vs alien), and ecological information (environmental relationships, Ellenberg-type indicator values, disturbance indicator values, and relationships to vegetation units and habitat types). Values for at least three variables are available for 36,404 species. Individual taxa, vegetation units, and habitats in these three modules are illustrated by more than 34,000 photographs. The *Download* section of FloraVeg.EU provides open-access data sets in a spreadsheet format that can be used for analyses. FloraVeg.EU is a new resource with easily accessible data that can be used for research in vegetation science, ecology, and biogeography, as well as for education and conservation applications.

KEYWORDS

database, EUNIS, Europe, habitat type, indicator values, phytosociology, plant traits, syntaxon, vascular plant, vegetation classification, vegetation unit

1 | INTRODUCTION

In this era of unprecedented environmental challenges and rapid biodiversity loss (IPBES, 2019), the comprehensive documentation of biodiversity at the level of species and their habitats becomes paramount. Online botanical databases have emerged as invaluable tools in this pursuit, supporting scientific research, conservation efforts, and public awareness. Most botanical databases focus on species, specifically on their taxonomy, nomenclature, and distribution (e.g., POWO, <https://powo.science.kew.org>; World Flora Online, <https://www.worldfloraonline.org>; GBIF, <https://www.gbif.org>), traits (e.g., TRY, Kattge et al., 2020; GIFT, Weigelt et al., 2020), and occurrences of alien species (e.g., GloNAF, <https://glonaf.org>; van Kleunen et al., 2019).

In Europe, the main comprehensive source of updated information on plant taxonomy and country-based distributions is the Euro+Med PlantBase (Euro+Med, 2024). In addition, there are several online databases of national or regional floras with detailed and critically revised information, e.g., for the British Isles (Plant Atlas 2020, <https://plantatlas2020.org>), Croatia (Flora Croatica Database, <https://hirc.botanic.hr/fcd>; Nikolić et al., 2001), the Czech Republic (Pladias, <https://pladias.cz>; Chytrý, Danihelka, et al., 2021), France (Tela Botanica, <https://www.tela-botanica.org>), Germany (FloraWeb, <https://www.flora-web.de>), Greece (Flora of Greece Web, <https://portal.cybertaxonomy.org/flora-greece/intro>), Hungary (PADAPT, <https://padapt.eu>; Sonkoly et al., 2023), Italy (Portal to the Flora of Italy, <https://dryades.units.it/floritaly>), Spain (Anthos, <http://www.anthos.es>), and Switzerland (InfoFlora, <https://www.infoflora.ch>).

In contrast to the abundant online databases of plant species, detailed information on vegetation units and habitat types is scarce, although such resources are highly important for both research and conservation (e.g., the EU Habitats Directive, 92/43/EEC) or nature restoration (e.g., the EU Regulation on nature restoration, 2024/1991). More elaborated online databases of vegetation units based on phytosociological classification have been developed

at the national level, in particular for the Czech Republic (Pladias, <https://pladias.cz/en/vegetation>; according to Chytrý, 2007–2013), Germany (FloraWeb, <https://www.floraweb.de/lebensgemeinschaften/gesellschaften.html>; according to Rennwald, 2000), Italy (Vegetation Prodrome of Italy, <https://www.prodromo-vegetazione-italia.org>; Biondi et al., 2014), Spain (SIVIM, <http://www.sivim.info/sivi>; Font et al., 2010), and Ukraine (<https://geobot.org.ua/syntaxonomy>). Examples of national online databases of habitats are from Switzerland (TypoCH, <https://www.infoflora.ch/de/lebensraeume>; according to Delarze et al., 2016), Norway (Artsdatabanken, <https://artsdatabanken.no/rodlisefornaturtyper>), and Ukraine (<https://geobot.org.ua/biotope>; according to Kuzemko et al., 2018). At the international scale, information on vegetation units of Europe and the world is provided by the eVeg database (<https://www.e-veg.net/en/homepage>). However, classification in this database follows the principles of integrated synusial phytosociology (Gillet & Julve, 2018), in which forest tree and herb layers are classified separately using independent classification schemes. This approach has not been adopted by most European vegetation scientists, and it is also not reflected in current habitat classification schemes.

The European Vegetation Survey Working Group (hereafter EVS Group) of the International Association for Vegetation Science (IAVS) made major efforts toward classifying and cataloguing biodiversity at the level of vegetation units and habitat types across Europe. First, Mucina et al. (2016) compiled the so-called EuroVegChecklist, a three-level hierarchical classification system of European vegetation classes, orders, and alliances, and Preislerová et al. (2022, 2024) prepared distribution maps and a data set of standardized structural, ecological, and biogeographical attributes for the EuroVegChecklist alliances dominated by vascular plants. Second, Chytrý et al. (2020) revised the terrestrial part of the EUNIS Habitat Classification and prepared a characteristic species combination and a distribution map for each vegetated habitat type at the third hierarchical level of this continental-scale classification system, which is governed and used by the European Environment Agency.

The EuroVegChecklist and the EUNIS Habitat Classification, with their accompanying resources such as species lists and distribution maps, contain crucial information for European nature conservation (Rodwell et al., 2018) and are increasingly used in biodiversity research. Therefore, it is important to make them easily accessible in open-access online databases, which contain not only the published versions but also recent and future updates of these resources.

For these purposes, we developed a new online database, FloraVeg.EU, which is described in this article. The acronym *FloraVeg* reflects that the classifications of both vegetation and habitats in this database are based on floristic composition. For a better understanding of species diversity, ecology, and function of each vegetation unit or habitat type, the database also contains data on ecological and biogeographical characteristics of European plant species and links between species and vegetation units or habitat types in which they occur. This is reflected in the structure of the database, which consists of three interconnected modules called *Vegetation*, *Habitats* and *Species* (Figure 1).

2 | THE GEOGRAPHICAL SCOPE OF FloraVeg.EU

The geographical scope of FloraVeg.EU is Europe with eastern borders on the Ural Mountains and the Ural River, including Iceland and the Arctic archipelagos of Europe. Cyprus and the Macaronesian archipelagos belonging to Portugal or Spain are also included. Thus, the domain code *EU* in the database name refers both to the European Union and the entire European continent.

The inclusion of other adjacent territories varies, depending on their coverage in source data sets. The *Vegetation* module also includes Greenland, while the *Habitats* module also includes the Asian part of Turkey (Anatolia). The Caucasian countries (Georgia, Armenia, and Azerbaijan) are included in the *Habitats* module and the maps of vegetation units in the *Vegetation* module, although the representation of their vegetation diversity is incomplete because they were not covered by the EuroVegChecklist (Mucina et al., 2016). The taxon data set in the *Species* module follows the geographical delimitation of the Euro+Med PlantBase (Euro+Med, 2024), that is, Europe, the Macaronesian archipelagos except for Cabo Verde, the Caucasian countries, all the African and Near East countries that border the Mediterranean Sea, and Jordan.

3 | THE MODULES OF FloraVeg.EU

3.1 | The *Vegetation* module

The *Vegetation* module (<https://floraveg.eu/vegetation>) is the core part of FloraVeg.EU, which serves as the official platform for presenting the standard European vegetation classification governed by the EVS Group. The basis of this classification is the published

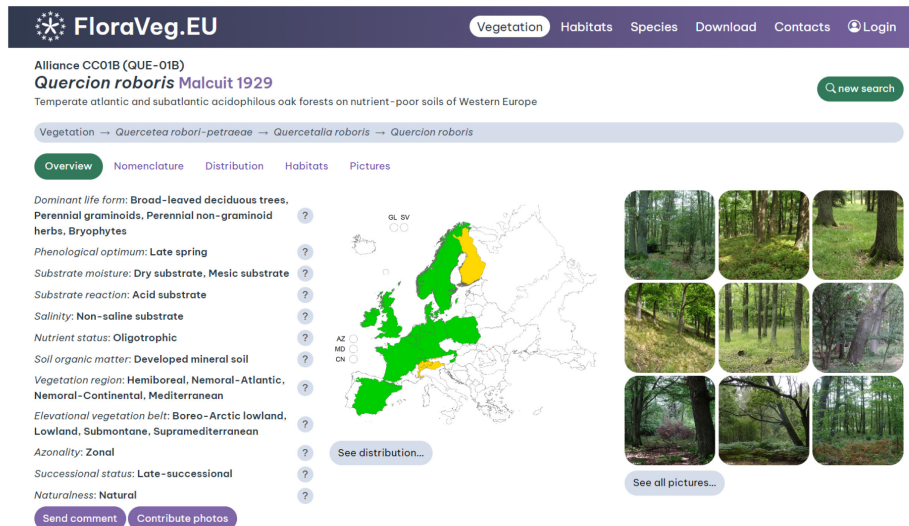
version of the EuroVegChecklist (Mucina et al., 2016), whose updates are published in the FloraVeg.EU *Vegetation* module. This classification follows the principles of Braun-Blanquet's syntaxonomy (Westhoff & van der Maarel, 1978; Dengler et al., 2008). Other systems of vegetation classification are not considered in FloraVeg.EU because they do not receive wide acceptance in most European countries.

Following the EuroVegChecklist, three formal hierarchical levels of vegetation classification are used in FloraVeg.EU: class, order, and alliance. In contrast, units of secondary ranks (subclass, suborder, suballiance, and subassociation) and associations are not considered. The focus is on vegetation units dominated by vascular plants (EVC1 in Mucina et al., 2016). Vegetation units dominated by bryophytes, lichens, and algae (EVC2 and EVC3 in Mucina et al., 2016) are included, but information about them is limited compared to the units dominated by vascular plants.

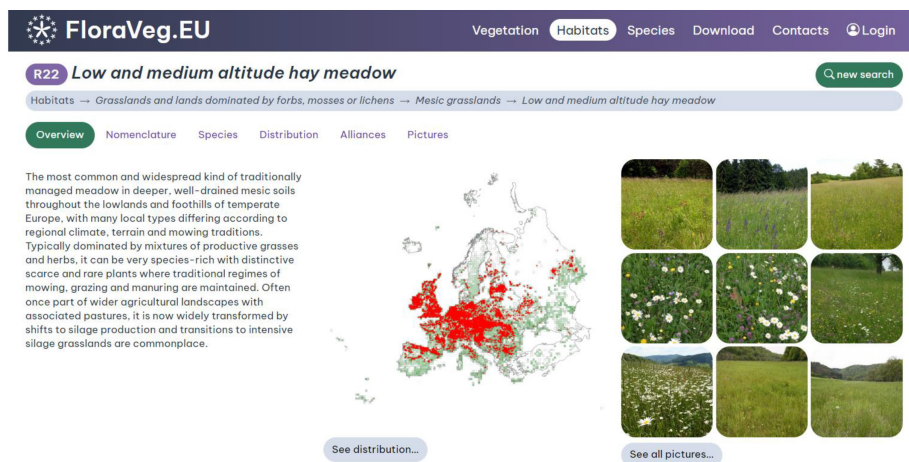
The information about each vegetation unit contains (1) its brief description taken from the EuroVegChecklist, in some cases with minor corrections; (2) information on its nomenclature, containing the accepted name in the current version of FloraVeg.EU, the name and the synonyms from the EuroVegChecklist, and remarks on syntaxonomy and nomenclature from the EuroVegChecklist, as well as remarks added later by various experts; (3) distribution maps, for alliances taken from Preislerová et al. (2022), and for orders and classes created by merging the alliance maps; (4) photographs of typical stands. The information on classes (but not orders and alliances) also includes (5) the list of diagnostic taxa as provided by the EuroVegChecklist, with a few corrections, and (6) a bibliography with a selection of the most important phytosociological studies on each class, also from the EuroVegChecklist. The information on alliances (but not orders and classes) also contains (7) a set of standardized attributes describing the structure, ecology, and biogeography of each alliance according to Preislerová et al. (2024). These attributes are the dominant life form, phenological optimum, substrate moisture, substrate reaction, salinity, nutrient status, soil organic matter, vegetation region, elevational vegetation belt, azonality, successional status, and naturalness (see Preislerová et al., 2024 for descriptions).

The standard European vegetation classification provided by the EVS Group is subject to updates based on published scientific studies and evaluation of their results by experts. For this purpose, the EVS Group established the European Vegetation Classification Committee in 2017 (Biurrun & Willner, 2020; <https://euroveg.org/evc-committee>). Proposals of changes in the EuroVegChecklist classification (Mucina et al., 2016) can be submitted to this Committee, which evaluates if they are supported by scientific evidence. When a proposal is accepted, vegetation units can be renamed, added, removed, split, merged or moved to another higher syntaxon in the FloraVeg.EU database. After each change, a new numbered version of the EuroVegChecklist is created, which can be downloaded from the FloraVeg.EU website. The updated version is then presented dynamically on the web pages of the *Vegetation* module, which show, in the *Nomenclature* section, both the accepted name in the current version of the classification and

(a) Vegetation



(b) Habitats



(c) Species

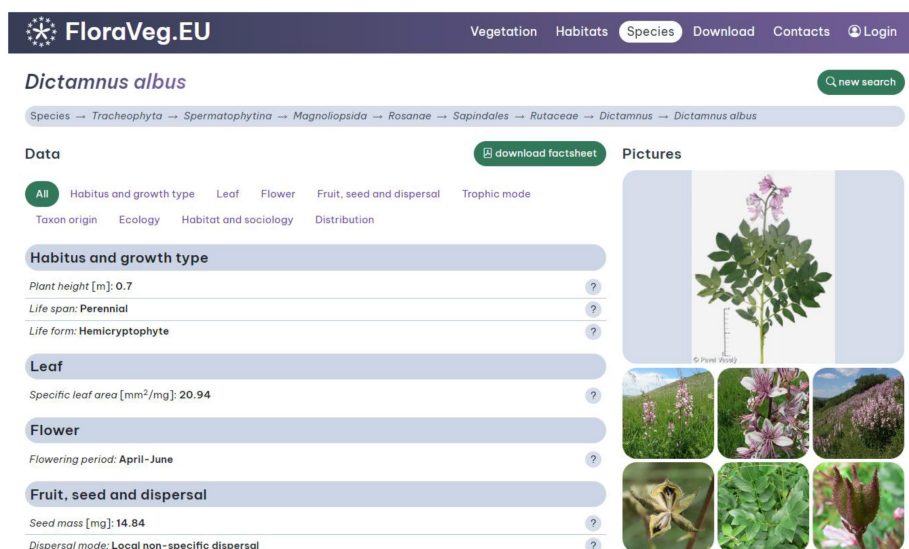


FIGURE 1 Screenshots of the three main modules of the FloraVeg.EU database: Vegetation (top), Habitats (middle), and Species (bottom).

the name used in the original version of EuroVegChecklist (Mucina et al., 2016). Comments on minor errors and inconsistencies can be sent to the website administrator using a form accessible through the Comment button on the page of each vegetation unit. It is important to note that the names of vegetation units accepted in the EuroVegChecklist (Mucina et al., 2016) follow the third edition of the International Code of Phytosociological Nomenclature (Weber et al., 2000), and some of them do not comply with the rules of the fourth edition (Theurillat et al., 2021). However, any revisions of syntaxon names contained in FloraVeg.EU follow the fourth edition.

The basic version of FloraVeg.EU, corresponding to the EuroVegChecklist, contained a total of 1296 alliances, of which 1106 were dominated by vascular plants (note that for the latter, Mucina et al., 2016 reported 1108 alliances and Preislerová et al., 2022 reported 1105 alliances due to some inconsistencies in the database). These alliances were grouped into 377 (300 dominated by vascular plants) orders and 149 (109) classes. The most recent version 3 of the EuroVegChecklist was published in June 2024. It includes new alliances and changes in the concepts and names of some orders and alliances as approved by the European Vegetation Classification Committee based on the proposals by Marcenò et al. (2018, 2024), Bonari et al. (2021), and Jiroušek et al. (2022). It also includes corrections of formal errors and typos from the EuroVegChecklist. After these changes, version 3 contains 1305 alliances (1115 dominated by vascular plants), 378 (301) orders and 149 (109) classes.

Besides the scientific context, we made efforts to collect representative photographs of individual vegetation units from different locations. These photographs are an important part of FloraVeg.EU because they greatly help non-specialists to understand individual vegetation units. Although other databases also collect vegetation photographs and present them online (e.g., Fleri et al., 2021), our database is the only one on the continental scale that assigns vegetation photographs to units of a formal vegetation classification system with standardized names. Vegetation photographs were contributed by 93 specialists in vegetation classification from different parts of Europe. By 1 June 2024, FloraVeg.EU contained 4699 photographs of 476 alliances, and we are working, partly with the help of external contributors, on filling the gaps.

3.2 | The *Habitats* module

The *Habitats* module (<https://floraveg.eu/habitat>) presents vascular-plant-dominated terrestrial, freshwater, and marine habitats of the EUNIS Habitat Classification. This classification was initiated and has been governed by the European Environment Agency (EEA), and it has been extensively revised and complemented with standardized information by the EVS Group (Chytrý et al., 2020). The official version is published on the EEA website (<https://www.eea.europa.eu/en/datahub/datahubitem-view/123d0c9a-a6fa-4f2d-b887-5d8e5>

468faed). Although this website contains various data sets, it is poorly structured and specific information is difficult to find. Therefore, based on an informal agreement with EEA, we provide up-to-date, comprehensive data on vascular-plant-dominated habitats of EUNIS in FloraVeg.EU.

The EUNIS Habitat Classification is a hierarchical system, and FloraVeg.EU contains its three highest levels (or four highest levels in the case of marine habitats), which were recently revised (Chytrý et al., 2020). In the habitat group of inland waters, the revised classification is based on abiotic features such as water body type, elevation, and water chemistry but not on vegetation. Each habitat type defined in this way can include a mosaic of several distinct types of aquatic and wetland vegetation. Therefore, to maintain the link to aquatic habitats defined through plant community types (such as those listed in Annex I of the EU Habitats Directive), we have added the group “P3 Aquatic plant communities”, which is, however, not an official part of the EUNIS classification. Constructed, industrial, and other artificial habitats with no vegetation, as well as habitat complexes defined in the EUNIS classification are not included in FloraVeg.EU. However, for comprehensiveness, we included natural terrestrial habitats with no vegetation in the group “U Inland habitats with no or little soil and mostly with sparse vegetation”.

On 1 June 2024, the *Habitats* module comprised nine habitat groups (first level of the EUNIS classification), subdivided into 45 habitat types at the second level, 322 types at the third level, 11 types (all in the marine habitat group) at the fourth level, and eight types of aquatic plant communities. Of the habitat types at the third or fourth level, 249 types had lists of diagnostic, constant, and dominant taxa (Chytrý et al., 2020) and a point distribution map based on vegetation-plot data from the European Vegetation Archive (Chytrý et al., 2016) classified using the latest version of the classification expert system EUNIS-ESy (Chytrý, Tichý, et al., 2021; <https://doi.org/10.5281/zenodo.4812736>). Habitats for which this information is missing could not be classified based on vegetation-plot data. The habitats on the third or fourth levels also have information on the corresponding habitat type(s) in the European Red List of Habitats (Janssen et al., 2016) and a list of corresponding alliances of the EuroVegChecklist. Habitat types are also documented by photographs that are automatically retrieved from the *Vegetation* module based on the corresponding alliances, while the results of this automatic procedure are adjusted manually in cases of alliances that correspond to more than one habitat type.

The content of the *Habitats* module is subject to changes, which are based partly on changes in the EUNIS classification system made by the EEA, and partly on the improvements of the EUNIS-ESy expert system and the availability of new data in the European Vegetation Archive. The data sets with numbered updated versions of the classification of vegetated habitats of the EUNIS classification are published in the Zenodo repository (Chytrý, Tichý, et al., 2021), and each new version is then presented at FloraVeg.EU with version information.

3.3 | The Species module

The *Species* module (<https://floraveg.eu/taxon>) contains data on functional traits (functional characteristics that can be measured on single individuals; Pérez-Harguindeguy et al., 2013) and ecological and biogeographical characteristics of plant taxa (mainly species but also informal species aggregates and some infrageneric or infraspecific taxa such as sections or subspecies). The module is currently limited to vascular plants. It contains a comprehensive list of European native and alien plant taxa growing in the wild, with the addition of several taxa of cultivated plants.

On 1 June 2024, FloraVeg.EU contained 37 plant traits and other characteristics. The database contained 36,404 species (other taxa and aggregates not included in this count) with at least three characteristics. A list of the characteristics is given in Table 1, and their detailed descriptions with respective data sources can be found in Appendix S1.

The taxonomic concepts and nomenclature of plant taxa follow the Euro+Med PlantBase (Euro+Med, 2024) and are regularly updated following the updates of this database. However, some taxa occurring in European vegetation and habitats but not included in Euro+Med had to be added. On 1 February 2024, there were 2429 additions (Appendix S2), which included (1) 684 hybrids that are relatively often recorded in the field (e.g., *Medicago* × *varia* and *Populus* × *canadensis*), because Euro+Med has included only a few hybrids up to date; (2) 230 species aggregates frequently recorded in vegetation surveys but not defined in Euro+Med (e.g., *Aconitum napellus* aggr.); (3) 341 newly described taxa, not distinguished in Euro+Med but with regional and ecological significance, especially from marginal parts of Europe (e.g., *Adenocarpus complicatus* subsp. *bivonae* (C.Presl) Peruzzi); (4) 129 taxa added or moved to another genus to increase taxonomic consistency of the taxon list, namely autonymic subspecies missing in Euro+Med (e.g., *Leucanthemum ircutianum* includes several subspecies in Euro+Med but *L. ircutianum* subsp. *ircutianum* is missing); (5) 1045 alien taxa recently spreading in Europe (e.g., *Akebia quinata*), which is the largest group and is continuously updated. The taxonomy and nomenclature of these added taxa largely follow the Plants of the World Online (<https://powo.science.kew.org>), except for a few cases where their concepts are inconsistent with those used in Euro+Med.

Bryophytes, lichens, and algae are listed in descriptions of some vegetation units or habitat types in FloraVeg.EU, but the *Species* module itself does not include these groups. The taxonomic concepts and nomenclature of bryophytes in FloraVeg.EU follow the Euro+Med PlantBase (Euro+Med, 2024) and those of lichens and algae follow the names used by Mucina et al. (2016) and Chytrý et al. (2020).

Data on traits and other characteristics of vascular plants were partly prepared as entirely new data sets with published documentation and partly compiled from various sources, critically revised and harmonized. The main source of compiled data was existing European databases, most notably BiolFlor (Klotz et al., 2002), LEDA

(Kleyer et al., 2008), Baseflor (French flora database; Julve, 2020), Flora d'Italia (Guarino & La Rosa, 2019), Pladias Database of the Czech Flora and Vegetation (Chytrý, Danihelka, et al., 2021), Hungarian Flora Database (Horváth et al., 1995), Ukrainian Plant Trait Database (Vynokurov et al., 2024), BROT (Tavşanoğlu & Pausas, 2018), and Greek Flora database (<https://www.greekflora.gr>). Further data were extracted from the Flora of Romania (Săvulescu, 1952–1976), which is not available in electronic format but covers an area of Europe with rich flora and sparse trait data. Individual source databases were matched to taxon concepts and names of Euro+Med. Values of taxon characteristics were checked for outliers and improbable values, especially when values given for the same taxon in different databases were considerably different. These values were corrected based on the literature or expert knowledge. Then, the values from different databases were aggregated to receive a single value for Europe by taking the mean, minimum, maximum or multiple categories, depending on the variable type. Some missing values, especially for taxa commonly occurring in European vegetation plots, were added by targeted search in different sources. Data sets on plant dispersal modes and dispersal distance classes were compiled specifically for FloraVeg.EU (Lososová et al., 2023). Indicator values were also prepared as new data sets for FloraVeg.EU (Midolo et al., 2023; Tichý et al., 2023). Data on habitats and sociology were adopted from the EuroVegChecklist (Mucina et al., 2016; taxon assignment to vegetation classes based on expert knowledge) and resources related to the EUNIS Habitat Classification (Chytrý et al., 2020; taxon assignment to habitat types based on a statistical analysis of European vegetation plots). Data on species' relationships to continentality were taken from Berg et al. (2017).

The values of taxon characteristics in the database are automatically transferred across levels of taxonomic hierarchy according to the rules developed for the Pladias database (Chytrý, Danihelka, et al., 2021: pp. 10–11). The transfer from a hierarchically higher to a lower taxon (e.g., species to subspecies) is only applied if there is a single lower taxon within the higher taxon. The transfer in the opposite direction is also applied if there are two or more lower taxa; the values of these taxa are combined following specific rules for each plant characteristic (see Chytrý, Danihelka, et al., 2021 for details).

The FloraVeg.EU website also shows photographs of plant taxa if available. On 1 June 2024, the database contained 29,779 photographs of 4233 plant taxa. Most photographs were taken from the Pladias Database of the Czech Flora and Vegetation (Chytrý, Danihelka, et al., 2021) and the Flora d'Italia database (Guarino & La Rosa, 2019). Before uploading to FloraVeg.EU, each photograph is checked by a curator for technical quality and, in most cases, for correct taxonomic identification. The photographer's name with a copyright symbol is printed at the bottom left corner of the image. Compared to massive collections of plant pictures from citizen science projects such as iNaturalist (<https://www.inaturalist.org>) or Pl@ntNet (Joly et al., 2016), curation leads to fewer photographs; however, they are selected to show high-quality, representative pictures of different plant organs.

TABLE 1 An overview of taxon characteristics included in the *Species* module of FloraVeg.EU.

Taxon characteristic	Author or reference	No. of species	Unit	Data type
Habitus and growth type				
Plant height	Axmanová	8922	m	interval_avg
Life span	Dřevojan, Čeplová, Štěpánková, Vynokurov, Borovyk, Axmanová	13,942	-	enum_nominal
Life form	Dřevojan, Čeplová, Štěpánková, Vynokurov, Borovyk, Axmanová	15,961	-	enum_nominal
Spinescence	Axmanová	692	-	Boolean
Leaf				
Leaf type (woody plants only)	Axmanová	610	-	enum_nominal
Leaf phenology (woody plants only)	Axmanová	704	-	enum_nominal
Specific leaf area	Axmanová	3141	mm ² /g	interval_avg
Flower				
Flowering period	Axmanová	8587	month	month
Fruit, seed and dispersal				
Seed mass	Axmanová	6920	-	interval_avg
Dispersal mode	Lososová et al. (2023)	13,025	-	enum_nominal
Dispersal distance class	Lososová et al. (2023)	10,099	-	integer
Trophic mode				
Parasitism and mycoheterotrophy	Těšitel, Těšitelová, Fahs, Blažek, Knotková, Axmanová	36,404	-	enum_nominal
Carnivory	Axmanová	36,404	-	Boolean
Symbiotic nitrogen fixation	Fahs, Blažek, Těšitel, Axmanová	36,404	-	enum_nominal
Taxon origin				
Origin in Europe	Axmanová	13,136	-	enum_nominal
Ecology				
<i>Environmental relationships</i>				
Substrate humidity relationship	Axmanová, Čeplová, Tichý, Chytrý	7420	-	enum_nominal
Substrate reaction relationship	Axmanová, Čeplová, Tichý, Chytrý	6074	-	enum_nominal
Nutrient relationship	Axmanová, Čeplová, Tichý, Chytrý	6126	-	enum_nominal
Salinity relationship	Axmanová, Čeplová, Tichý, Chytrý	6799	-	enum_nominal
<i>Ellenberg-type indicator values</i>				
Light indicator value	Tichý et al. (2023)	7995	-	real
Temperature indicator value	Tichý et al. (2023)	7251	-	real
Moisture indicator value	Tichý et al. (2023)	7873	-	real
Reaction indicator value	Tichý et al. (2023)	7130	-	real
Nutrient indicator value	Tichý et al. (2023)	7041	-	real
Salinity indicator value	Tichý et al. (2023)	7330	-	real
<i>Disturbance indicator values</i>				
Disturbance frequency	Midolo et al. (2023)	6265	-	real
Disturbance frequency (herb layer)	Midolo et al. (2023)	6265	-	real
Disturbance severity	Midolo et al. (2023)	6265	-	real
Disturbance severity (herb layer)	Midolo et al. (2023)	6265	-	real
Mowing frequency	Midolo et al. (2023)	6265	-	real
Grazing pressure	Midolo et al. (2023)	6265	-	real
Soil disturbance	Midolo et al. (2023)	6265	-	real

(Continues)

TABLE 1 (Continued)

Taxon characteristic	Author or reference	No. of species	Unit	Data type
Habitat and sociology				
Diagnostic species of phytosociological classes	Mucina et al. (2016)	9442	–	enum_syntaxons
Diagnostic species of EUNIS habitats	Chytrý et al. (2020)	3501	–	enum_nominal
Constant species of EUNIS habitats	Chytrý et al. (2020)	2400	–	enum_nominal
Dominant species of EUNIS habitats	Chytrý et al. (2020)	591	–	enum_nominal
Occurrence in broad habitats	Axmanová, Čeplová, Chytrý	12,321	–	enum_nominal
Distribution				
Continentality	Berg et al. (2017)	1866	–	integer
Continentality amplitude	Berg et al. (2017)	2425	–	integer

Note: Author names are given in data compilations prepared specifically for FloraVeg.EU, while references are given for data from published sources. No. of species refers to the number of species (excluding other taxa) for which a value of each characteristic is available. Measurement units are given for quantitative variables. Data types are described in Chytrý, Danihelka, et al. (2021: pp. 9–10) and Novotný et al. (2022): Boolean: logical values true/false; enum_nominal: multistate categorical variable with unsorted categories; integer: whole numbers; real: decimal numbers; interval_avg: interval with the mean; month: integer from 1 to 12; enum_syntaxons: list of vegetation units.

4 | DOWNLOAD SECTION

The *Download* section of FloraVeg.EU provides individual data sets on vegetation units, habitat types and plant taxa in a spreadsheet format that can be used for analyses. Fixed versions with different release dates are also available for regularly updated data sets.

5 | TECHNICAL SPECIFICATIONS

FloraVeg.EU uses the database structure developed for the Pladias Database of the Czech Flora and Vegetation, described in detail by Novotný et al. (2022). The data are stored in a PostgreSQL relational database. The public interface was created using the Nette framework (PHP), while the interface for data management is based on the Play! framework (Java/Scala). All elements are based entirely on open-source software. The database is hosted on two Linux-based servers running in streaming replication at the Institute of Botany of the Czech Academy of Sciences.

6 | DISCUSSION

FloraVeg.EU is an entirely new online resource of information on European vegetation, vegetated habitats, and flora. It has several unique features compared to other databases.

First, it contains an official presentation of an up-to-date version of the standard phytosociological classification of European vegetation, which is governed by the IAVS Working Group European Vegetation Survey. It is based on the published classification of EuroVegChecklist (Mucina et al., 2016) but reflects and presents updates approved by the European Vegetation Classification Committee (Biurrun & Willner, 2020), using fixed versions.

Second, unlike several national or regional databases, FloraVeg.EU covers the whole European continent and some adjacent areas. To our knowledge, there are currently only two other botanical databases with similar geographical extent. The eVeg database presents information on European vegetation but is defined as a “database of French vegetation extended to Europe” (quoted from the database homepage, <https://www.e-veg.net/en/homepage>), which does not present a consensus view of international experts and uses an uncommon approach of integrated synusial phytosociology (Gillet & Julve, 2018). The Euro+Med PlantBase presents critically revised and constantly updated information on European flora, but it focuses on taxonomy, nomenclature, and distribution, whereas FloraVeg.EU focuses on the ecological characteristics of individual taxa, using the Euro+Med data as a taxonomic backbone.

Third, FloraVeg.EU links data on vegetation (Mucina et al., 2016 and further updates) with data on habitats (EUNIS Habitat Classification; Chytrý et al., 2020 and further updates) and various data on plant species. These links help experts from different backgrounds (phytosociology vs nature conservation) understand the relationships between vegetation classification and habitat classification. They also help users understand the plant composition of individual vegetation or habitat types or, conversely, the relationships of individual plant taxa to these types.

Fourth, the database contains several new data sets of plant traits covering large proportions of the taxa of European flora. Although extensive data on plant traits are available in the TRY database (Kattge et al., 2020), this database is a collection of individual data sets, and raw data retrieved from TRY require harmonization and checking, both in terms of the consistency of taxonomy/nomenclature and reliability of individual trait measurements. Moreover, some trait data on European species in TRY originate from outside Europe, where the trait values can differ, especially in introduced species. In contrast, the FloraVeg.EU database contains trait data from several reliable European sources, most of which were compiled by respected professional botanists and carefully harmonized

and checked using expert knowledge. Therefore, we consider these trait data reliable and promptly usable.

Fifth, FloraVeg.EU contains biogeographical and ecological characteristics of the taxa of the European flora, which usually only exist at the national level but are rarely harmonized internationally because national schemes differ in approaches and categories used. Notably, FloraVeg.EU contains a new, extensively revised list of plant species alien to Europe, removing errors in earlier compilations (DAISIE, 2009; van Kleunen et al., 2019; Euro+Med, 2024). It also contains data on the affinities of plant taxa to individual vegetation or habitat types at the European scale, which have not been available before the EuroVegChecklist (Mucina et al., 2016) and the expert system classification of EUNIS habitats (Chytrý et al., 2020) were published. Another new feature is a harmonized list of indicator values of European plant species (Midolo et al., 2023; Tichý et al., 2023).

These features make FloraVeg.EU a key resource for European vegetation scientists, nature conservationists, restoration ecologists and ecologically oriented botanists. On the one hand, it provides extensive data sets that can be downloaded and used for scientific analyses. On the other hand, it can serve non-experts, students and amateur naturalists who need specific information about individual vegetation units, habitats, or species.

We aim to extend the resources contained in FloraVeg.EU in the future. In the *Vegetation* module, we plan to improve the data on the attributes and distributions of alliances and update the classification based on the decisions of the European Vegetation Classification Committee. In the *Habitats* module, we plan to update the habitat classification based on the decisions made by the EEA and improve the characterizations of habitat types based on the refinements of the EUNIS-ESy expert system and new data in the EVA database. In the *Species* module, we plan to add new plant characteristics and complete missing values in characteristics already included in the database. We also plan to update the species list continuously, especially by adding newly described taxa and alien taxa introduced to Europe (those escaping into the wild). We cooperate with the Euro+Med PlantBase (Euro+Med, 2024), regularly checking their accepted species list and providing feedback from our database. For all the modules, we continuously collect and upload representative photographs of vegetation units (via the upload page <https://flora.veg.eu/vegetation/contribution>), habitat types, and plant taxa. We welcome feedback from the database users on potential errors and inconsistencies in the data and any suggestions for improving the database.

AUTHOR CONTRIBUTIONS

The FloraVeg.EU database is a joint product of the IAVS Working Group European Vegetation Survey and Vegetation Science Group at Masaryk University, Brno. Milan Chytrý conceived of the idea, secured funding, coordinated the database project and the *Habitats* module and wrote the article. Stephan Hennekens, Zdenka Preislerová and Milan Chytrý prepared the *Vegetation* module, which made use of earlier work coordinated by Ladislav Mucina. Wolfgang

Willner, Idoia Biurrun, Zdenka Preislerová and Milan Chytrý coordinated the updates of the *Vegetation* module. Irena Axmanová coordinated the *Species* module. Marcela Řezníčková technically edited the whole database. Petr Novotný did database programming and Tomáš Kebert prepared the website design. Dana Holubová, Corrado Marcenò, Riccardo Guarino and Milan Chytrý coordinated the collection of photographs. Irena Axmanová, Zdeňka Lososová, Gabriele Midolo and Lubomír Tichý led the preparation of individual data sets for the *Species* module. Petr Blažek, Dariia Borovyk, Natálie Čeplová, Pavel Dřevojan, Nina Fahs, Riccardo Guarino, Behlül Güler, Veronika Kalusová, Ilona Knollová, Kateřina Knotková, Petra Štěpánková, Jakub Těšitel, Tamara Těšitelová and Denys Vynokurov contributed to the preparation of individual data sets for the *Species* module. Eckhard von Raab-Straube provided the Euro+Med PlantBase. Jiří Danihelka contributed to the interpretation of plant taxonomy and nomenclature. Dana Holubová, Milan Chytrý, Zdenka Preislerová, Gianmaria Bonari, Denys Davydov, Riccardo Guarino, Richard Hrivnák, Veronika Kalníková, Veronika Kalusová, Dragan Koljanin, Javier Loidi, Zdeňka Lososová, Corrado Marcenò, Djordjije Milanović, Pavel Novák, Kamila Reczyńska, Joop Schaminée and Krzysztof Świerkosz provided significant numbers of photographs. Fabio Attorre, Idoia Biurrun, Anna Kuzemko and Joop Schaminée contributed ideas on developing FloraVeg.EU as an official platform of the EVS Group. All the authors commented on the manuscript.

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DATA AVAILABILITY STATEMENT

The FloraVeg.EU database and its data sets are freely available at <https://floraveg.eu/>.

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Appendix S1. Description of plant characteristics in the *Species* module of the FloraVeg.EU database.

Appendix S2. Taxa included in the *Species* module of the FloraVeg.EU database but absent in the Euro+Med PlantBase.

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SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.