



VEGETATION DATA PROCESSING AND ANALYSIS IN THE LIGHT OF THE EUROPEAN VEGETATION SURVEY

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ABSTRACT – The processing and analysis of collected field data is one of the key activities in vegetation research and as such a key topic of the European Vegetation Survey (EVS). The handling of vegetation data plays a vital role in achieving the goals that were set in the early years of the newborn organization, including the development of compatible software and the encouragement of national programs with the compilation of an overview of European plant communities (Rodwell et al., 1995). The national programs should result in national vegetation databases, that ultimately could be brought together in one central European vegetation database. How the major goals of the European Vegetation Survey were dealt with during the last forty years of vegetation research, is the topic of this article. The overview will be completed with some examples of how the results are applied in European nature policy and preceded by some historic and general concepts. The handling of vegetation data can be divided into an analytic and a synthetic phase, the first one dealing with the collection of data in the field, the second one with the processing of collected data behind the desk. The plot observation (vegetation relevé) can be seen as the basic document in the entire operation, whereas ordination and classification are principal techniques to reveal the interplay of plant species in nature, based on differences in how vegetation can be looked at, differences that strongly influenced the development of vegetation research in diverse parts of the world.

KEYWORDS: VEGETATION DATA ANALYSIS, FIELD DATA COLLECTION, VEGETATION RESEARCH

PLOT OBSERVATIONS

In the *Einleitung* to his classic textbook *Pflanzensoziologie* (1928), Braun-Blanquet entitled the plant community as a ‘striking social entity’ (expressing the prevailing environmental and phytogeographic conditions) and, in the following description of the phytosociological methodology, the plant association as the central unit of the systematic arrangement of communities (Flahault & Schröter, 1910). Just as knowing the name of a species is essential for physiological studies on plants, the plant community is a basic entity for allowing generalisations and comparisons in ecological research. Fundamental for the analysis of

vegetation is the plot description, the so-called vegetation relevé (Fig. 1).

This fundamental position was clearly underlined by Dierschke in his handbook, published in 1994 under the same title as the classic publication of Braun-Blanquet: ‘*Aufnahmen bilden die wesentliche Grundlage pflanzensoziologischer Arbeit. Von ihrer Qualität und ihrem Informationsgehalt hängt das Ergebnis aller weiteren Auswertungen ab*’ (Dierschke, 1994). Since the early days of vegetation research, worldwide hundreds of thousands of such relevés have been made. In a first overview of vegetation plot-data and databases in 2009, it was estimated that there must be more than 4,300,000 of such records throughout Europe (Schaminée et al., 2009).

Ges. Artenreicher Buchenwald ca. 100 Jahre alt			Dat. 11.5.86		Nr. 96	
Ort Göttinger Wald ca. 1 km w Kackensrode			Bearb. Dierschke			
Standort/Bem. Muschelkalkplateau, leicht mullig. Braunerde - Rendzina mit geringer Aufl.-Anlage.			TK L 4526 Duderstadt			
			R 357213		H 571010	
Geschlossener Hallenwald Anemone - Aspekt			Höhe 410 m		15x20 m ²	
			Exp. W		Incl. 2-3°	
			T ₁ T ₂ S H M Laub			
			85 5 1 95 1 90			
			30 10 4			
T ₁	5	Fagus sylvatica	1	Fraxinus excelsior		
T ₂	1	Carpinus betulus				
S	1	Fagus sylvatica				
H	3	Anemone nemorosa	+	Polygonatum verticillatum		
	1	Anemone ranuncul.	+	Dentaria bulbifera		
	2,3	Mercurialis perennis	1	Lilium martagon		
	2	Aarum europaeum	+	Geranium robertianum		
	1	Hostelmus europaeus	1°	Allium ursinum		
	1	Milium effusum	+	Ranunculus auricomus		
	1	Helica uniflora	+	Luzula pilosa		
	1	Primula elatior	+	Viola reichenbachiana		
	+	Carex sylvatica	2	Fraxinus excelsior		
	+	Hepatica nobilis	1	Acer pseudoplatanus		
	1	Galium odoratum	1	Acer platanoides		
	1	Lactuca vernus	1	Fagus sylvatica		
	1	Oxalis acetosella	+	Cystopteris spec.		
	1	Dryopteris filix-mas	+	Acer campestre		
	1,3	Lamium galebold.	(+)	Anem. maculatum		
M	1	Polygonatum nult.	(+)	Daphne mezereum		
	+	Atrichum undulatum				

k 4.34.13 Strandweide voor Laarzen

horizontaal aan overstroming door de zee bevoogdheid terrein dat als veld herweide gebruikt wordt. Bodems kleiachtig silt met kumus.

Glyc. ma.	5.4
Suaeda	2.2
Salic. R.	1.1
Spergularia ma.	x 1
Art. T. Ch. pl.	x 1
Str. lat.	x 1
Glaux	x 1
Plant. C.	x 1

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Figure 1. Two examples of a vegetation relevé, the first one made by W.C. de Leeuw in 1927 in the Netherlands, the second one made in 1986 by Hartmut Dierschke in Germany. De Leeuw has been a key person in the history of European vegetation research: together with Braun-Blanquet, he set up and financed the Station International Géobotanique Méditerranéenne et Alpine (SIGMA) in Montpellier. The relevé, made in a saltmarsh at the borders of the former Zuiderzee, is the oldest know plot description in the Netherlands. The vegetation is dominated by *Puccinellia maritima* (= *Glyceria maritima*), with *Suaeda maritima* and *Salicornia europaea* as the main companions. Dierschke, one of the founding fathers of the European Vegetation Survey, has contributed a lot to the syntaxonomy of European vegetation, with a focus on forests. The relevé represents a beech forest near his hometown Göttingen, dominated by *Fagus sylvatica*, with species like *Carex sylvatica*, *Hepatica nobilis* and *Galium odoratum* in the herb layer.

Clements versus Gleason

Since the early days of vegetation research, the processing and analysis of vegetation data has been strongly influenced by seemingly contradictory traditions, based upon the conflicting ideas of two leading plant researchers, Henry Gleason and Frederic Clements. Their debate was fueled by the contrasting views on how plants grow together in nature. Gleason (1882-1975) addressed the individualistic behavior of plants and stood at the basis of what is called the Anglo-American tradition. He served at the universities of Illinois, Chicago and Michigan, before being appointed at the New York Botanical Garden in The Bronx, where he worked for the rest of his career. According to Gleason, plants

just form loose assemblages without much interaction. Spatial and temporal changes in vegetation are gradual, in line with existing gradients in the landscape and slow or steady succession. Clements (1874-1945) hold a belief in an organismic approach, reflecting the view that plant communities are complex organisms that grow, rise and die. He was a professor of botany at the University of Nebraska. According to Clements, individual plants strongly influence each other, leading to cohesive assemblages with a predictable species composition and well-defined structure. His approach stood at the basis of the Central-European tradition. For the development of methodologic techniques, one may state that the view of Gleason has evolved in ordination techniques, whereas the view of Clements

is reflected by the classification of plant communities. Ordination, derived from the German word *Ordnung* and firstly used in vegetation science by the Soviet ecologist Ramenski (1930), can be defined by the arrangement or ranking of objects in a one- or multi-dimensional space. In our research, these objects can be species, vegetation relevés or groups of relevés. As it is impossible to display all variations within one figure, several complementary ordination diagrams will be calculated, each representing a two-dimensional space with the projection of all points in a single plane with perpendicular axes. The diagrams provide insight into the environmental conditions of the plant communities under research, based on the arrangement of the individual species or (groups of) relevés. As an example, an ordination diagram is shown in Fig. 2, showing the mutual position of all plant communities in the Netherlands.

Classification is focused on the assignment of objects (relevés) to clusters based on their mutual similarity, using species composition (presence and abundance) as input. Especially in Europe, hundreds of such studies have been performed during the last century, ranging from single nature reserves to entire countries. Here, the landscape is – over long periods of time – strongly defined by traditional land use. Until the 1970's, the resulting classification schemes were based on handmade vegetation tables, but nowadays the analyses are done by applying a wide range of software applications or even Artificial Intelligence. TWINSpan (Two-Way Indicator SPecies ANalysis) was one of the first methods developed, and still widely applied (Hill, 1979). An example of a – handmade – classification table is shown in Fig. 3, taken from the classic study of Sandro Pignatti on the halophytic vegetation of the Lagune of Venice (1966).

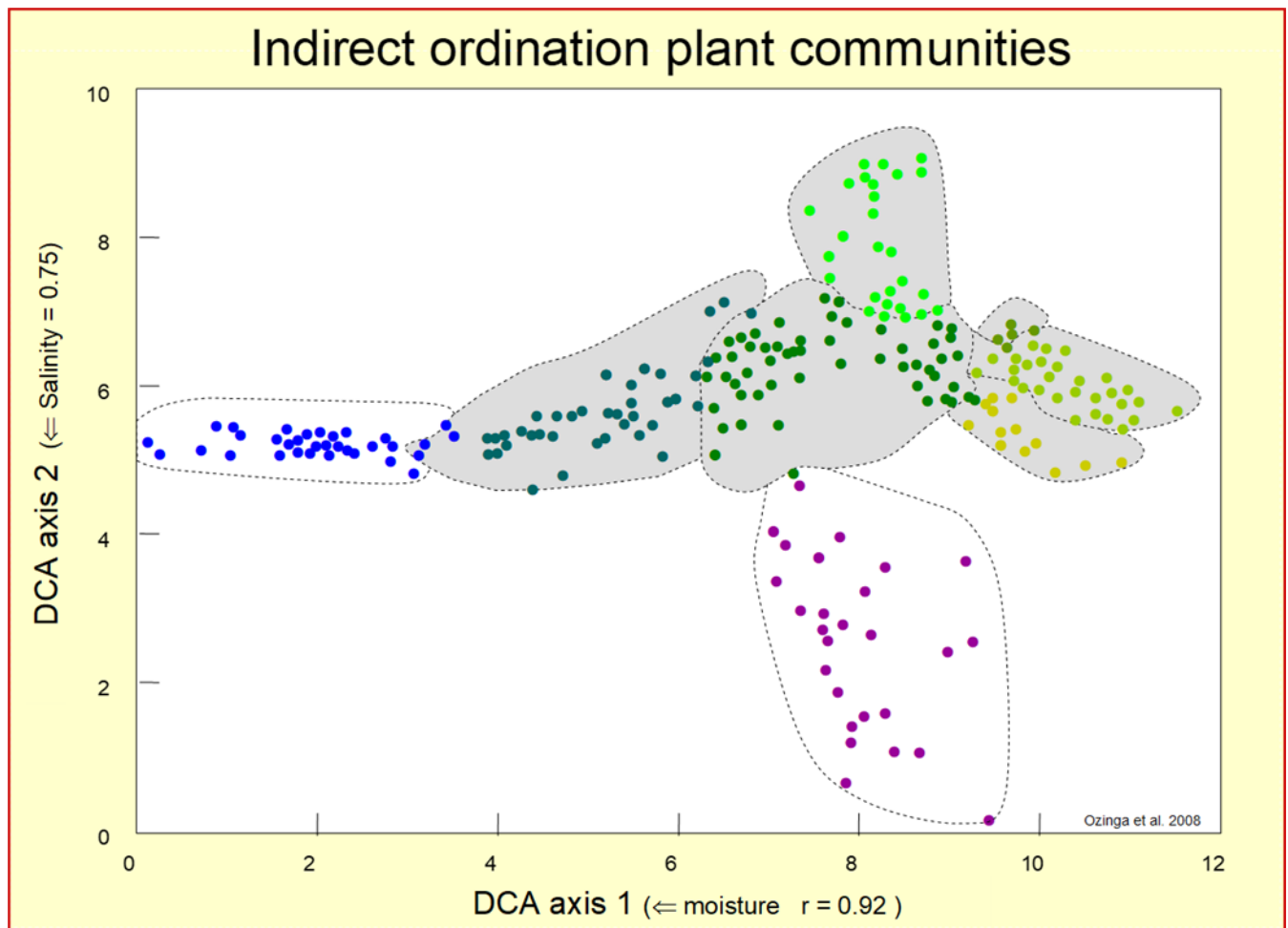


Figure 2. Ordination diagram showing the position of Dutch plant communities along the first two axes of the diagram. The analysis, solely based on the floristic composition of the plant communities without any additional ecological data, clearly reveals some environmental characteristics. The aquatic communities, as an example, are positioned at the left side of the diagram, whereas the saline communities are depicted in the lower part of the ordination. The forest communities are found at the top of the diagram; they become visible in another diagram showing the first and third axis.

TAB. 6. - SUAEDETUM MARITIMAE-KOCHIETUM

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	Presenza rel. 1-18	19
SPECIE CARATTERISTICHE																				
<i>Suaeda maritima</i> var. <i>procumbens</i>	1.1	2.2	4.4	4.4	4.5	4.3	4.3	5.5	5.5	5.5	5.5	5.5	5.5	4.4	5.5	5.5	5.5	5.5	18	3.2
<i>Kochia hirsuta</i>	.	.	.	.	.	.	.	+	1.1	.	.	.	.	.	.	.	.	.	2	.
SPECIE CARATT. DELLA ALLEANZA																				
<i>Puccinellia distans</i>	.	.	.	.	.	.	.	+	.	1.2	1.1	+	.	+	+	+	.	+	8	.
<i>Salsola soda</i>	.	.	.	.	+	.	+	.	.	.	.	.	.	.	.	.	.	.	2	.
<i>Spergularia marginata</i>	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	1	+
<i>Pholurus incurvus</i>	.	.	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	1	.
SPECIE CARATT. DELLA CLASSE																				
<i>Aster tripolium</i>	.	.	.	.	.	2.1	+	+	1.1	+	.	.	+	+	.	1.1	.	+	13	1.2
<i>Salicornia herbacea</i> (stricta)	+	+	2.1	.	.	4.3	4.3	.	.	.	+.2	+	+	+	+	1	+	8	+	.
<i>Obione portulacoides</i>	.	.	.	.	.	.	+	+	.	+	.	.	.	.	1.0	.	+.0	6	+	.
<i>Limonium vulgare</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.
<i>Inula crithmoides</i>	.	.	.	.	.	+	.	.	.	.	+	.	.	.	.	.	.	.	1	+
<i>Salicornia fruticosa</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	4.5
<i>Puccinellia palustris</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.
COMPAGNE																				
<i>Atriplex triangulare</i>	+	+	+	+	+	.	.	1.1	.	.	.	.	.	.	(+)	.	1.2	1.2	8	.
<i>Atriplex tataricum</i>	.	.	.	.	+	.	.	+	.	.	.	.	.	.	.	.	+.0	.	2	.
<i>Agropyrum litorale</i>	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.	1	.
<i>Phragmites communis</i>	.	.	.	.	+	.	.	.	.	.	.	.	.	.	.	.	.	.	.	.

Figure 3. Classification table of the Suaedetum maritimae-Kochietum in the Lagoon of Venice (Pignatti, 1966). The association is represented by two variants, each dominated by one of the name-giving species. Pignatti classified this association in the Puccinellio-Salicornietea, which – according to the EuroVegChecklist – belongs to the Salicornietea fruticosae, a class of Mediterranean and thermo-atlantic perennial saltmarsh herblands and scrub (Mucina et al., 2016). The perennial *Salicornia fruticosa*, however, is only present – with low abundance – in one relevé, whereas the annual *Salicornia herbacea* is found in almost all relevés, sometimes with high abundance.

EUROPEAN VEGETATION SURVEY

The idea of a European network for vegetation research was discussed at a meeting at the University of Lancaster in the autumn of 1991, and the first meeting of the aimed platform took place in Rome in March 1992, in the *orto botanico* in Trastevere, the same place where we celebrated the legacy of Sandro Pignatti in 2025. The goals of the European Vegetation Survey are elucidated in an article in the *Journal of Vegetation Science* (Rodwell et al., 1995). At that time, already 25 countries were represented in our European network and committed to reach the goals that were formulated. Additional plans for the further future were outlined, most notably the production of a book *The Vegetation of Europe*. There are still dreams to be dreamed! The fact that the initiative to launch a European network of phytosociologists took place in the United Kingdom might be surprising, but it is in line with historic developments.

In November 1989, the fall of the Berlin Wall started the destruction of the Iron Curtain between western and eastern Europe, and in the same period the “brown blanket” between Britain and the continent was torn into pieces. At that time, national vegetation programmes were running in countries like Austria (Mucina et al., 1993) and the Netherlands (Schaminée et al., 1995-1998; Stortelder et al., 1999), building on old and long traditions. In the United Kingdom, this was quite another story, without hardly any tradition in vegetation classification, being part of the Anglo-American tradition. Here, John Rodwell and his Unit of Vegetation Science carried out the *National Vegetation Classification*, not only resulting in a series of five books (Rodwell et al., 1990-1995), but also creating a national vegetation database, compatible software and nation-wide application of the classification system. The first volume appeared in 1991, celebrated at the memorable meeting in Lancaster. John Rodwell invited Stephan Hennekens to support him in the digital world, speaking about crossing borders.

They together shaped the Darwin Initiative and organised workshops to initiate related projects and programs in eastern Europe, which became a great success.

COMPATIBLE SOFTWARE

By the start of the European Vegetation Survey in 1992, the development of compatible software was an important topic. As mentioned before, up to then, vegetation tables had to be made by hand (Fig. 4).

In the Netherlands, at that time, for the processing of phytosociological data, the computer software package TURBOVEG was established by Stephan Hennekens to support the national vegetation classification. The first version of the package was launched in 1992, after which TURBOVEG2 became available for a wider public in 1998 (Schaminée & Hennekens, 1995; Hennekens & Schaminée, 2001). This package comprised an ‘easy-to-use database management system’ and was installed – within a couple of years – in more than 25 countries throughout Europe and overseas. The databank to be managed could be divided into several databases which might consist of up to 100,000 relevés each. The program provided methods for input, import, selection, analysis and export of relevés. In 1994, Turboveg was accepted as the standard computer package for the European Vegetation Survey. Currently, a new version of the package (TURBOVEG3) is available, offering more and new possibilities (Fig. 5).

For editing, classification and analysis of phytosociological tables, the computer program JUICE was designed by Lubomír Tichý at Masaryk University in Brno (Tichý,

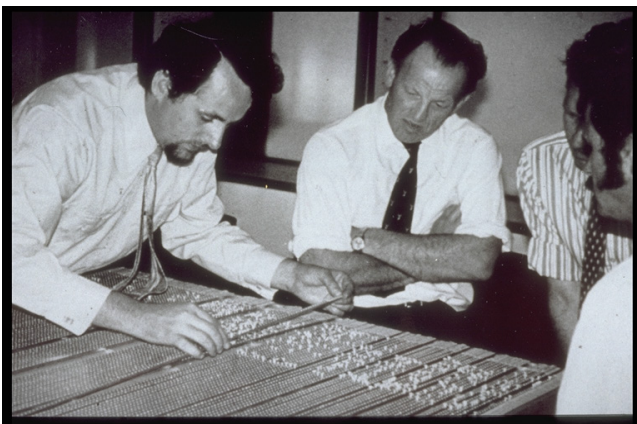


Figure 4. To facilitate the construction of vegetation tables, Marinus Werger (left on the picture) developed the so-called Table board at the Department of Professor Westhoff at the University of Nijmegen, with which columns and rows could be re-ordered using a switch.

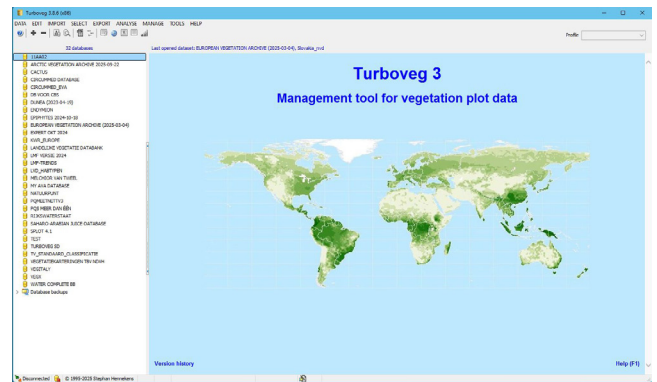


Figure 5. The first prototype of TURBOVEG3 was in 1914. In this tool, all data is stored in a single SQL-based file, instead of being stored in hundreds of individual dBase III+ files. The SQL database is based on a robust model, capable of handling many different sources with different database structures. As far as European plot observations are concerned, TURBOVEG3 supports multiple taxonomies, allowing data analysis at European level. The tool has a sophisticated built-in GIS, supporting many different input formats and almost any coordinate system, and comprehensive methods to query the data, including spatial constraints. Turboveg3 databases are Unicode based, accepting any character sets (e.g. Chinese, Arabic and Russian).

2002). This program allows users to perform many functions for easy manipulation of table and header data, using classification methods like COCKTAIL (Bruehlheide 1995, 2000) and the already mentioned TWINSPLAN (Hill, 1997). Such functions include the analysis of fidelity measures and average Ellenberg indicator values, the preparation of synoptic tables, automatic sorting of relevé tables, and export of table data into other applications like word processors, spreadsheet programs or mapping packages. The program is optimized for use in association with TURBOVEG. Currently, the maximum capacity can handle more than 1 million relevés in a single table (Fig. 6).

Another tool that could be provided with the availability of large vegetation datasets and syntaxonomic overviews are so-called *Expert systems*, that assign individual vegetation plots to already established classification systems. Examples at national level are developed in Czech Republic (Chytrý et al., 2007-2013) and the Netherlands (Janssen et al., 2023). EUNIS-ESy is an example at European level (Chytrý et al., 2020). Such systems are based on formal definitions, written in an editable script and stored as a text file. The computer program that runs the expert system evaluates all the plots of a vegetation database and checks for each of them whether it meets the conditions of one or more of the formal definitions in this script. If a plot matches a definition of one habitat type or plant community, it is assigned to it. In the case of EUNIS-ESy, formal definitions are developed for 248 habitat types of the EUNIS Habitat Classification (see further on). The expert system currently classifies 1,891,168

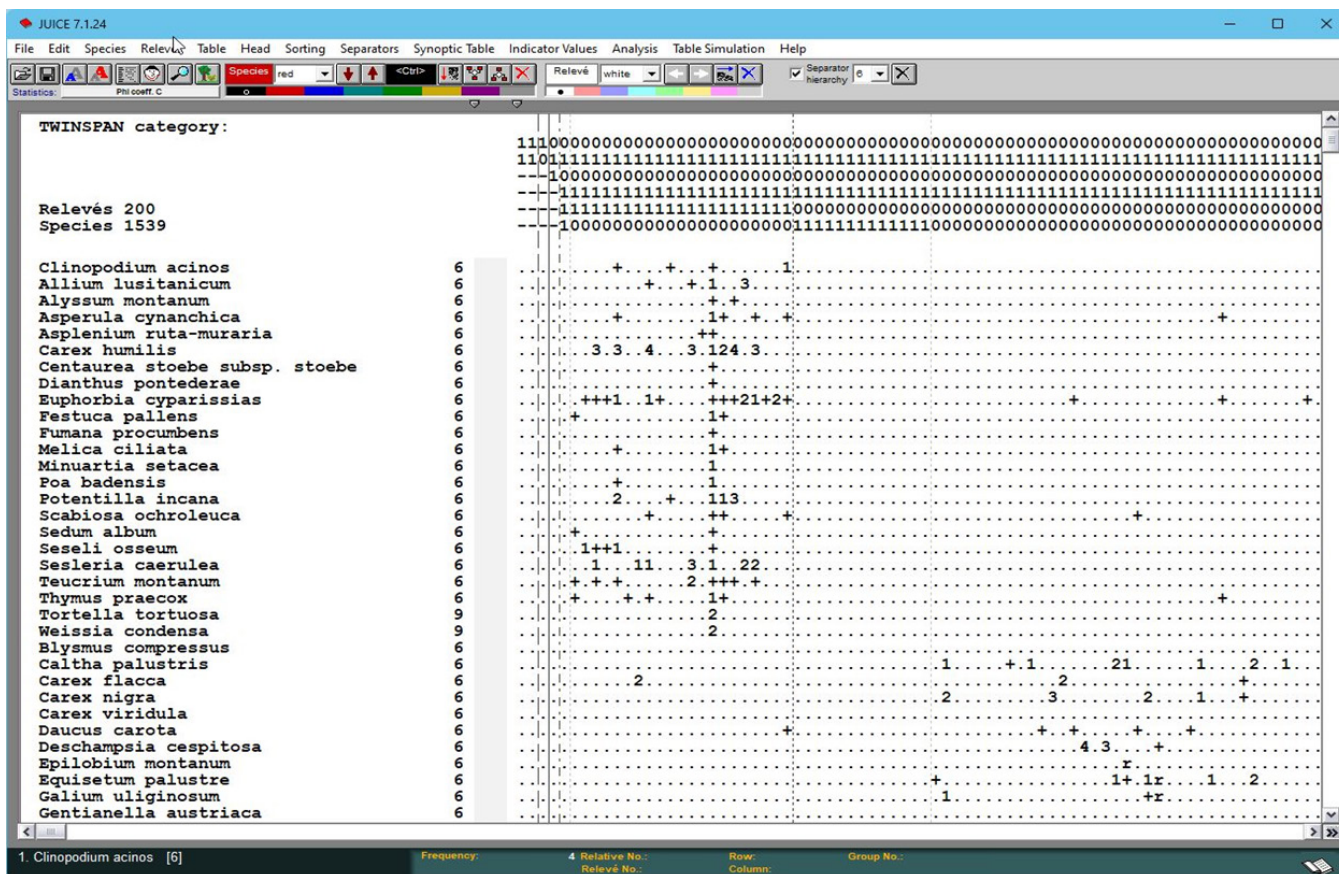


Figure 6. For the sorting of vegetation tables, the computer program JUICE has been developed by Lubomír Tichý at Masaryk University in Brno. Shown is a fragment of an unsorted table, containing 200 relevés and 1,539 species. The ordering of relevés (columns) and species (rows) can be performed by hand or by applying diverse analytical tools.

vegetation plots to one of these habitat types; 612,870 plots remain unclassified or are classified as more than one habitat type. Vegetation research is a living field of study, and the development of new methods and software applications is continuously in progress. Multiple data analysis packages are currently available for statistical software such as *R*, and the new possibilities offered by Artificial Intelligence are increasingly being utilized.

EUROPEAN OVERVIEW OF SYNTAXA

As a major milestone of the European Vegetation Survey, the EuroVegChecklist was published in 2016 as a special issue of *Applied Vegetation Science*, under the leadership of Ladislav Mucina (Mucina et al., 2016). The checklist handles a hierarchical floristic classification system of vascular plant, bryophyte, lichen, and algal communities, comprising – regarding vascular plant communities – 109 classes, 300

orders and 1,108 alliances. The paper indeed features a critical account of European syntaxa and synthesizes more than hundred years of classification effort by European phytosociologists. While working on the syntaxonomic systems of the EuroVegChecklist, the authors aimed to enhance the nomenclatural stability in a decisive way by checking thousands of names for nomenclatural correctness. No classification overview will be final, but the presented schemes provide an important baseline for future development and revision of European syntaxonomy. But this milestone too has its history and precursor. To develop a more coherent picture of vegetation across the whole of Europe, Sandro Pignatti invited a small team to gather for a couple of days at his office in the Roman *orto botanico* to compile such an overview, based on available literature and expert knowledge. This resulted in *The Diversity of European Vegetation*, published by the Dutch government (Rodwell et al., 2002), featuring 80 classes, 233 orders and 928 alliances (Fig. 6). Some years before, Mucina (1997) published a conspectus of vegetation classes in Europe, with – for each class – a brief ecological description and a list of the most important diagnostic species.

VEGETATION DATABASES

Vegetation plot data offer the basis for classifying and describing plant communities, but as unique documents of co-occurrences of plant species at a certain place at a certain moment, they offer much wider application, ranging from exploring vegetation-environment relationships to monitoring vegetation changes over time (Dengler et al., 2012). In line with this, numerous national and regional databases have been assembled over time, leading to the initiative of the European Vegetation Survey to set up a centralized database of European vegetation plots, called the European Vegetation Archive (EVA). The archive is under development since 2012 and first made available for use in research projects in 2014 (Chytrý et al., 2016). It stores copies of individual national and regional databases – or parts of these – on a single software platform.

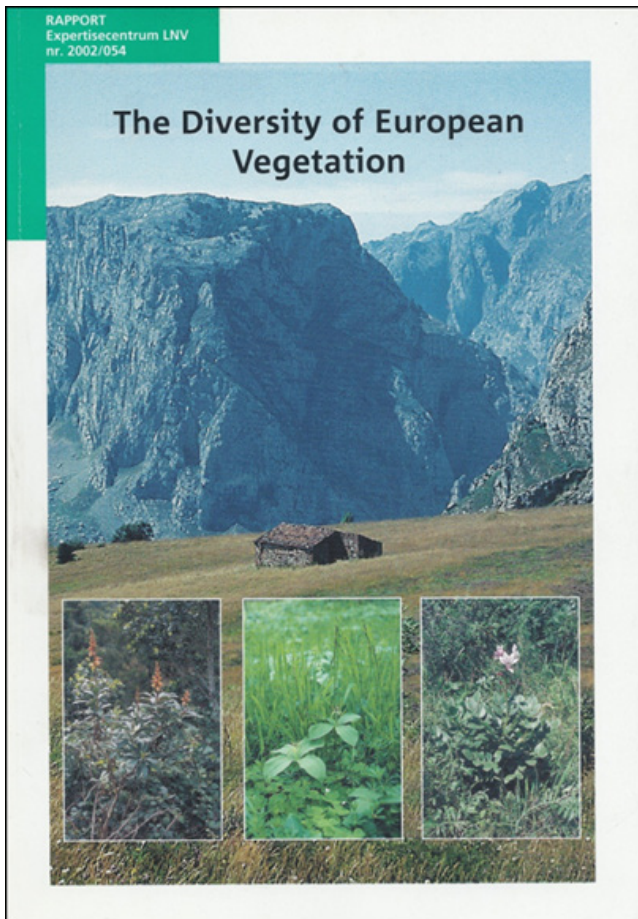


Figure 7. In 2011, Sandro Pignatti invited a small team of phytosociologists at his office in the orto botanico in Rome to discuss the classification of European vegetation. The meetings not only resulted in a first comprehensive frame of high-level syntaxa in Europe but also in a crosswalk between the list of alliances and the developing EUNIS habitat classification of the European Environmental Agency (EEA) in Copenhagen.

From a worldwide perspective, the tradition and intensity of vegetation plot sampling is much stronger in Europe than on any other continents, as can be seen from the Global Index of Vegetation-Plot databases (Dengler et al., 2011). By May 2012, 66.6 % of all data were from European databases (Jansen et al., 2012). The European Vegetation Archive also includes ReSurveyEurope, a European database of repeated records from the same plots (Knollová et al., 2024). A major obstacle to the integration of national and regional vegetation databases was the use of different species lists, usually following the taxonomy and nomenclature of the national floras or checklists. Therefore, the SynBioSys Europe team was established in 2002, involving vegetation scientists from several European countries who aimed at the development of an information system on European vegetation, integrating vegetation-plot data from different European databases (Schaminée et al., 2007). For this purpose, a working checklist of European vascular plants, bryophytes, lichens and macroalgae (SynBioSys Taxon Database) was established, and the species lists used in several European vegetation-plot databases were linked to this checklist by regional experts. The SynBioSys Europe project failed to obtain funding, but some of the original plans are realized along other pathways, like *FloraVeg.eu*, a European database on flora and vegetation, managed by the team at Masaryk University in Brno (Chytrý et al., 2024; Fig. 8).

At the annual meeting of the European Vegetation Survey at Perugia, March 2025, it was mentioned that the European Vegetation Archive comprised 108 databases with 2,086,610 vegetation plots. Of these plots, 82% were accessible under the semi-restricted regime, 15% under the restricted regime, and 3% were open access. The database of resurveyed plots included 507 datasets with 439,663 plot observations. EVA data were provided to 241 research projects. The distribution of the relevés reveals that a large part of Europe has been covered already, with the emphasis of Western, Central and Southern Europ (Fig. 9).

In 2014, the European Vegetation Archive became the European partner of a broader international initiative, called sPlot (Bruehlheide et al. 2019), hosted by the German Centre of Integrative Biodiversity Research. The aim of sPlot is to collect representative data sets of vegetation plots from global biomes and link them to the data on plant traits from the TRY database (Kattge et al., 2011) for use in macroecological analyses at continental to global scales.

EUROPEAN NATURE POLICY

Not foreseen at the beginning of the European Vegetation Archive, but without any doubt a major achievement, is

the bridge that was made between the European Vegetation Classification and the policy makers in Paris, Brussels and Copenhagen. Already in *The Diversity of European Vegetation* (Rodwell et al., 2002), a link was provided between the European classification system and EUNIS, the European Nature Information System. The EUNIS Habitat Classification is a widely used framework for European habitats, but – in its early form – lacked formal definitions of the individual habitat types that would enable their unequivocal identification and recognition. Cross references to vegetation types provided floristic and ecological content to the EUNIS types, and as such a fundament for European nature policy. To improve the use of the EUNIS Habitat Classification, the EEA initiated a process of revising the classification, in which the European Vegetation Survey received a central role. This revision should establish more consistency, remove ambiguity and overlap in definitions of types, and extend the typology to the entire European continent, whereas the

improved classification would also serve as a basis for the Habitats Directive of Natura 2000. The resulting proposals for revision of the EUNIS habitat classification were summarized in a series of reports (Schaminée et al., 2012, 2013, 2014, 2016). The revisions included additions of new units, splitting or merging existing units and changes in habitat names and definitions. After consultations with international experts and country representatives, a refinement of the classification for grassland, shrubland and forest habitats was made by Schaminée et al. (2018), for coastal and wetland habitats by Schaminée et al. (2019) and for vegetated man-made habitats by Schaminée et al. (2020). The resulting EUNIS classification has been linked to the Habitats Directive of the European Union and ultimately also evolved in the *Red List of European Habitat Types*, commissioned by DG Environment of the European Union, under the guidance of John Rodwell, John Janssen and – for the marine habitat types – Susan Gubbay (Janssen et al., 2016).



Figure 8. FloraVeg.eu is a European website and database, managed by the team of Masaryk University in close collaboration with the European Vegetation Survey. The website offers a huge amount of information on species, vegetation and habitats. The habitat part of the database presents the terrestrial sections of the EUNIS Habitat Classification managed by the European Environment Agency (Chytrý et al., 2020).

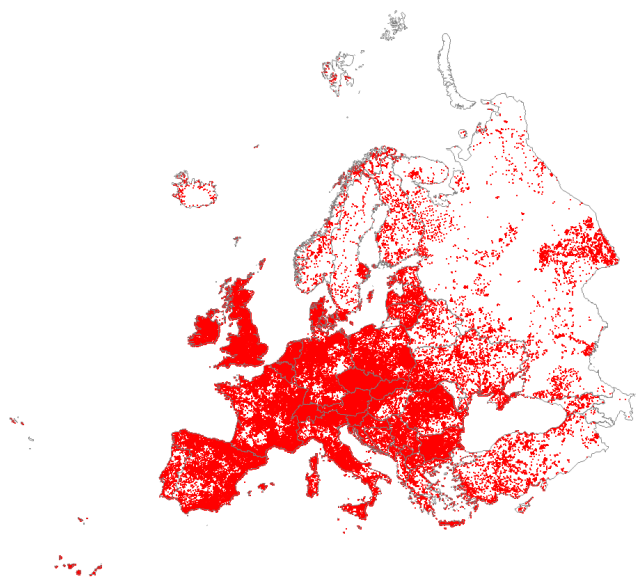


Figure 9. Distribution of georeferenced vegetation plots included in the European Vegetation Archive (February 2026).

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