VEGETATION CLASSIFICATION AND SURVEY

International Association for Vegetation Science (IAVS)

Vegetation Classification and Survey 6: 301–327
doi: 10.3897/VCS.175402

RESEARCH PAPER

SPECIAL COLLECTION ISLANDS AND ARCHIPELAGOS

Dry grasslands of Sicily: Multi-taxon diversity and classification challenges

Riccardo Guarino[1], Thomas Becker[2], Iwona Dembicz[3,4], Christian Dolnik[5], Łukasz Kozub[3], Jürgen Dengler[4,6]

1 *Department of Biological, Chemical and Pharmaceutical Sciences and Technologies (STEBICEF), University of Palermo, Palermo, Italy*
2 *Geobotany, Regional and Environmental Sciences, University of Trier, Trier, Germany*
3 *Institute of Environmental Biology, Faculty of Biology, University of Warsaw, Warsaw, Poland*
4 *Bayreuth Center of Ecology and Environmental Research (BayCEER), University of Bayreuth, Bayreuth, Germany*
5 *Institute of Natural Resource Conservation, University of Kiel, Kiel, Germany*
6 *Vegetation Ecology Research Group, Institute of Natural Resource Sciences (IUNR), Zurich University of Applied Sciences (ZHAW), Wädenswil, Switzerland*

Corresponding author: Jürgen Dengler (juergen.dengler@zhaw.ch)

Academic editor: Erwin Bergmeier
Received 19 October 2025 ♦ **Accepted** 16 December 2025 ♦ **Published** 29 December 2025

Abstract

Aims: In Southern Europe, grassland phytosociologists typically do not record non-vascular plant taxa and focus either on annual or perennial vascular plants even when both groups co-occur spatially. By contrast, researchers from temperate and northern Europe typically aim to record the entire community. We thus asked how such a comprehensive sampling approach would affect vegetation classification and biodiversity analyses when applied to Mediterranean dry grasslands. **Study area:** Island of Sicily, Italy. **Methods:** We sampled homogeneous stands of dry grasslands of different soil types and from sea level to 1200 m a.s.l. with nested-plot series and additional 10-m² plots, each with a complete list of all terricolous vascular plant, bryophyte and lichen taxa. For the 67 10-m² plots we additionally estimated the cover values of the species and determined structural, topographic and soil variables. We subjected these 67 plots to TWINSPAN and determined diagnostic taxa for the clusters at two hierarchical levels. **Results:** The mean total species richness increased from 2.1 in 0.0001 m² to 60.6 in 100 m² with 15% non-vascular plant taxa on average. The four main TWINSPAN clusters corresponded to base-rich coastal sands (mainly *Ammophiletea*), acidic inland sands (mainly *Poetea bulbosae*), nutrient-rich loamy soils (mainly *Chenopodietea*) and alkaline clayish soils (mainly *Lygeo-Stipetea*). Each cluster contained annual and perennial plants and mostly also non-vascular plant taxa, both in the species combination and the diagnostic species. **Conclusions:** Alpha and beta diversity of Mediterranean grasslands is higher than previously thought. While our numerical analyses yielded well characterised and ecologically meaningful units, there was no separation of annual and perennial grassland types at the higher level. We thus recommend recording all vascular plant species occurring in the plot also in Mediterranean regions, so as to allow straightforward comparisons with the rest of Europe in biodiversity studies.

Taxonomic reference: Euro+Med (2025) for vascular plants and bryophytes (with very few exceptions given in the Methods), ITALIC 8.0 (Nimis et al. 2025) for lichens.

Syntaxonomic references: Mucina et al. (2016) for alliances, orders and classes, except for the *Ammophiletea* where we adopt the European revision by Marcenò et al. (2024), while those for associations are provided in the syntaxonomic overview.

Abbreviations: ANOVA = analysis of variance; CSR = competitive/stress-tolerant/ruderal; DCA = detrended correspondence analysis; EDGG = Eurasian Dry Grassland Group; EIVE = Ecological Indicator Values for Europe 1.0; NMDS = non-metric multidimensional scaling; TWINSPAN = two-way indicator species analysis.

Keywords

biodiversity, bryophyte, *Chenopodietea*, classification approach, diagnostic species, lichen, *Lygeo sparti-Stipetea tenacissimae*, Mediterranean grassland, phytosociology, *Poetea bulbosae*, soil parameter, *Stipo-Trachynietea distachyae*

Introduction

In the warmest and most arid sectors of the Mediterranean bioclimatic region, dry grasslands are often divided into two structural types: those dominated by therophytes and those dominated by perennial bunchgrasses and other hemicryptophytes (Guarino et al. 2020). Geophytes are common in both types and significantly contribute to the overall physiognomy. As a matter of fact, the distinction between the two structural types is not always easy, because the main species of both kinds often live together, with alternating dominance, depending on environmental filtering and stochasticity. The Mediterranean dry grasslands are influenced not only by the site conditions, but also by management-induced disturbances (Naveh 1991; Gaujour et al. 2012) and by unevenly distributed environmental drivers, like the volatilisation of organic matter through periodical fires (Blasi et al. 2004; Bonanomi et al. 2018) or the seed rearrangement and predation by ants (Guarino et al. 2005). Winter grazing, intense summer drought, and competition for seasonally limited soil resources tend to favour the annual strategy (Westoby 1980; Aboling et al. 2008). Conversely, early spring grazing and recurrent fires may promote the establishment of hard-leaved perennial grasses by reducing the likelihood of a persistent seed bank of therophytes (Russi et al. 1992; Mossa et al. 2004). The density of perennial vs. annual grasses can be influenced also by the soil compaction: an excessive grazing pressure during the rainy season compacts the soil near the surface, which reduces infiltration, percolation, and water holding capacity, pushing the rhizosphere near the surface (Menke 1989). Soil compaction also impedes root elongation, placing deep rooted species at a disadvantage during seedling establishment and facilitating the affirmation of annual plants and small caespitose grasses, like *Poa bulbosa*. Also, differences in germination date and early seedling vigour, interacting with environmental drivers and stochastic events, may determine the competitive ability of one functional group against the other (Joffre 1990; Garnier 1992).

Taken together, these ecological processes create fine-scale mosaics of annual- and perennial-dominated patches. This ecological heterogeneity has direct methodological consequences on how vegetation is sampled and classified. Different life strategies pose a serious methodological issue in phytosociological investigations. Thus, in recent decades the idea has emerged to separate therophytic from perennial vegetation units and to treat mixed annual-perennial stands as quasi-synusiae (e.g. Rivas-Martínez 1978; Géhu 1996) and is now relatively widely followed by Mediterranean phytosociologists (Guarino et al. 2018). Accordingly, mixed stands are often sampled with differently sized plots, in which the representatives of one of the two concerned life forms will be carefully and exhaustively recorded, together with the most common and frequent representatives of the other, seen in that context as "companion" species. Thus, for instance, the class *Thero-Brachypodietea* Br.-Bl. ex Br.-Bl. et al. 1952, which in the original definition included both perennial, annual and mixed Mediterranean dry grasslands (Bolòs and Bolòs 1950) has been split by Rivas-Martínez (1978) into two classes comprising, respectively, therophytes or hemicryptophytes only.

From an ecological perspective, this separation aligns with the contrasting adaptive strategies of annual and perennial species. According to Madon and Médail (1997), the interstitial spaces occupied by annuals correspond to 'gradient wells', i.e. micro-sites characterized by more severe drought, often due to thinner and/or more compact soils. In such xeric conditions, patches may remain devoid of perennials for extended periods and can be regarded and interpreted as independent microhabitats. Also, nutrients can be unevenly distributed in the soils of Mediterranean drylands. Areas near perennial bunchgrasses often contain higher nutrient concentrations than the interstitial spaces occupied by annuals, due to interactions among water circulation, microbiotic soil crusts, and hydrological processes (Puigdefábregas et al. 1999; Belnap et al. 2025).

The application of this quasi-synusial sampling method, which records annual and perennial species separately, has an important consequence: not only was species cover estimated visually, as is usually done in the phytosociological approach, but the surface of sampled area was also very often approximated by eye (Guarino et al. 2018). Consequently, caution should be exercised when using such data, especially in macroecological comparative studies on species distribution and diversity patterns (Graco-Roza et al. 2022; Sabatini et al. 2022; Večeřa et al. 2023). In temperate and boreal Europe, phytosociological sampling of grasslands is designed to record all vascular plants and, particularly in dry grasslands, also terricolous bryophytes and lichens within a precisely delimited plot. This approach provides an accurate representation of overall grassland species diversity but, for the reasons above, available data are much less precise for the Mediterranean Region.

The Eurasian Dry Grassland Group (EDGG; https://www.edgg.org) is an international network of vegetation ecologists devoted to the study, conservation, and promotion of dry grasslands across the Palaearctic. Among its core activities are the Research Expeditions

(Field Workshops), during which international teams of experts jointly collect high-quality vegetation-plot data following standardized protocols (Dengler et al. 2018; Biurrun et al. 2019). In this way, EDGG expeditions contribute simultaneously to both regional and macroecological research, as well as to evidence-based conservation strategies.

Against this background, the fourth EDGG Research Expedition was organized in Sicily, a biogeographically complex region at the centre of the Mediterranean Basin, characterized by pronounced climatic gradients, high geological diversity, and a remarkable proportion of endemic species (Guarino 2011; Guarino et al. 2012). The advantage of organising the EDGG Research Expedition in Sicily lies primarily in the fact that the island's herbaceous vegetation has been the subject of numerous phytosociological studies, ranging from ruderal and synanthropic communities (Brullo and Marcenò 1985) to perennial grasslands (Brullo et al. 2010), along with a wide array of sub-regional contributions (a comprehensive bibliography is reported in Guarino and Pasta 2017). The main aims of the expedition were: (1) to shed light on the syntaxonomic position of Sicilian dry grasslands, with particular attention to the relationship between annuals- and perennials-dominated grasslands; (2) to analyse patterns of species diversity and life-form strategies, evaluating species-area relationships and quantifying the relative contributions of annuals, perennials, bryophytes, and lichens to overall community structure, richness, and physiognomy; (3) to identify some environmental and land-use drivers that mediate the balance between annual- and perennial-dominated stands.

Study area

Sicily, located in southern Italy, is the largest Mediterranean island, covering about 25,700 km^2 (Figure 1). It extends from c. 36.7° to 38.3° northern latitude and from c. 12.5° to 15.6° eastern longitude. The Sicilian landscapes are predominantly hilly or mountainous: 24.5% of the island is above 700 m a.s.l.; 61.4% between 300 and 700; 14.1% below 300 m a.s.l.

The climate of the investigated areas is typically Mediterranean, characterized by a pronounced summer drought and mean temperatures of the coldest month exceeding 6 °C. Average temperatures range from 7 to 11 °C in winter to 22–26 °C in summer. Annual precipitation varies between 450 and 990 mm, with up to 80% occurring between October and April (Bazan et al. 2015). Temperature decreases and precipitation increases with altitude. According to the bioclimatic classification of Rivas-Martínez et al. (2007), all sampled plots fall within the thermo- and mesomediterranean thermotypes and the subhumid to humid ombrotypes.

Sicily exhibits a remarkable variety of soils, differing in both chemical and textural properties (Fierotti 1997). The development and diversification of Mediterranean dry grasslands on the island have been facilitated by the combined effects of high topographic heterogeneity and diverse land-use practices. Naturally, dry grasslands occur mainly on steep slopes, from where they expand across the landscape, particularly in rangelands, abandoned fields, and areas frequently affected by fire (Guarino et al. 2020).

Our study sites encompassed the foothills and lower slopes of: (i) the Panormid Complex (western Sicily),

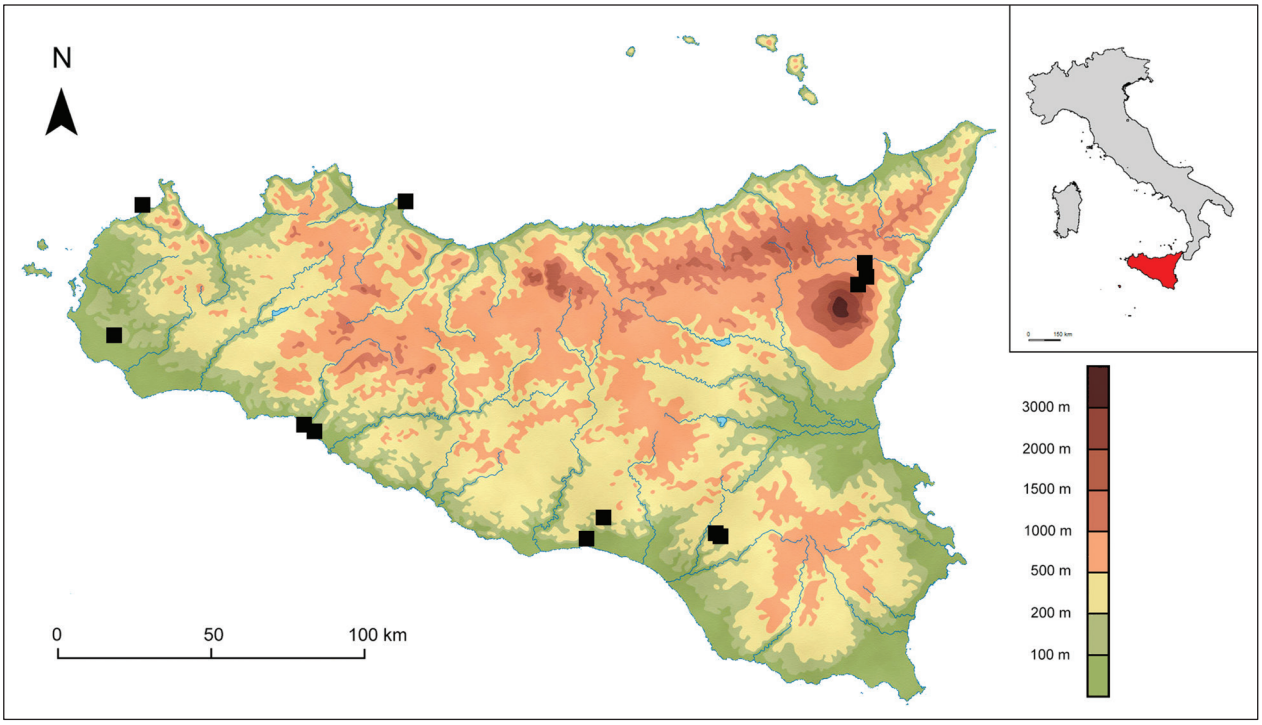

Figure 1. Map showing the position of Sicily in Italy and the distribution of the sampling sites on the island (black squares).

composed of carbonate rocks overlying a basal complex of carbonate sands and clays; (ii) the 'Gessoso-Solfifera' formation (central and southern Sicily), characterised by hilly outcrops of the Messinian evaporitic series, interspersed with whitish late Pliocene marls and yellowish Plio-Pleistocene calcareous sandstones; (iii) coastal and inland sand dunes in south-eastern Sicily (Caltagirone, Niscemi, Gela); and (iv) the northeastern flank of Mt. Etna, the largest active volcano in the Mediterranean Basin, up to an elevation of 1200 m a.s.l. (Finetti et al. 2005) (Figure 1). These four areas were selected because they offer representative examples of Sicilian dry grasslands within the thermomediterranean vegetation belt, where the sampling period allowed us to capture the optimal phenological stage of the herbaceous communities. The sites in southern and western Sicily, in particular, encompass a wide selection of geo-lithological contexts in which thermomediterranean dry grasslands typically occur. The inclusion of Mt. Etna's northeastern flank, although outside the core area of our sampling focus, was motivated by the ecological uniqueness of its volcanic substrates, which offered an opportunity to compare dry grassland assemblages under contrasting environmental conditions.

Methods

Field sampling

The sampling took place from March 29th to April 5th, 2012, in the optimal period to observe early-flowering geophytes and therophytes. That time was a bit too early for the full blossom of the perennial vegetation, but the identification of non-flowering species from vegetative traits has been possible in most cases. To cover a broad range of different types, we sampled dry grasslands in different sites across the island, from lowlands to mid-elevations (Figure 1), with a diversity of soil types. Within each sampling site, we subjectively selected homogeneous stands of the different physiognomic and ecological types that could be recognized in the field, trying to sample replicates of the same structural type whenever possible. While various phytosociological studies on dry grasslands of Sicily exist (for reviews, see de Foucault 1999; Brullo et al. 2007a, 2007b, 2010), the syntaxonomical attribution was disregarded and the only criteria to choose the sampling stands were the structural homogeneity and the lack of shrubs and trees. Accordingly, the sampled vegetation plots reflected common structural types and their "typical" floristic composition.

We sampled in total 21 "EDGG Biodiversity Plots", i.e. nested plot series with seven grain sizes from 0.0001 to 100 m^2, where the six smaller grain sizes are replicated in two opposite corners of the 100 m^2 plot (Dengler et al. 2016). To complement the sampling and cover broader variety of dry grasslands, we additionally sampled 25 "EDGG Normal Plots" of 10 m^2. Thus, in total 67 10-m^2 plots were available for the classification. All terricolous species observed in the plots were recorded with the shoot presence method (Dengler 2008), including perennial and annual vascular plants, bryophytes, and lichens (Dengler et al. 2016). Only saxicolous and epiphytic non-vascular plant taxa were excluded from sampling. We estimated each species' percentage cover on a continuous scale (for discussion of advantages of this method compared to ordinal scales, see Dengler and Dembicz 2023).

Following the EDGG sampling methodology (Dengler et al. 2016), we recorded the following *in situ* environmental and structural variables: geographical position (latitude, longitude), elevation (m a.s.l.), slope aspect (°), slope inclination (°), maximum microrelief (cm), soil depth (cm, mean and SD of five measurements per plot), vegetation covers (%; total vegetation, shrub layer, herb layer, moss layer), cover of litter (%), covers of stones and rocks, gravel, and fine soil (all three fractions summing up to 100%), maximum height of shrubs (m), maximum height of herbs (cm), height of herb layer (cm, mean and SD of five measurements with a free falling disc per plot), and land use details (evidence of grazing, mowing, burning, abandonment).

Plant species were mostly determined in the field; specimens of species that were not confidently determined *in situ* were collected for further identification, with the help of floras and stereo-microscopes. Vascular plants were primarily identified using Flora d'Italia (Pignatti 1982) and the interactive identification tools of its second edition (Pignatti et al. 2017–2019). Bryophytes were identified using mainly Frey et al. (2006) and Frahm (2010), while lichens were identified mainly with Nimis et al. (2025, respectively, its older editions) and Wirth et al. (2013). Critical taxa of vascular plants were compared with herbarium specimens (PAL and CAT). Taxonomy was standardised to Euro+Med (2025) for vascular plants and bryophytes and to Nimis et al. (2025) for lichens. In addition to these general standards, we accepted *Rubus canescens* aggr. (*R. canescens* and related species), *Rubus aetnicus* Weston, *Adenocarpus complicatus* subsp. *bivonae* (C. Presl) Peruzzi and *Fissidens kosaninii* Latzel, the latter three being accepted in GBIF (2025), but not included in Euro+Med (2025), not even as a synonym. In the Italian bryophyte checklist, *F. kosaninii* is included in *F. viridulus* s.l. (Aleffi et al. 2020). We also used Euro+Med (2025), Aleffi et al. (2020) and ITALIC 8.0 (Nimis et al. 2025) to assess whether a taxon possibly was recorded for the first time for Sicily.

The data of the 10-m^2 as well as those of the other grain sizes are provided as Suppl. material 1 and stored in and available from the GrassPlot database (Dengler et al. 2018; Biurrun et al. 2019, 2021; https://edgg.org/databases/GrassPlot) as dataset IT_A.

Life forms and life strategies

To explore floristic differences among the investigated grasslands and their phytosociological interpretation, we evaluated the percentage frequency of life forms according to Raunkiaer's definitions (Raunkiaer 1905) in each

sampled plot. However, life-form spectra alone were considered insufficient to fully capture the observed compositional and structural variation, since annual species can occur abundantly in both natural and synanthropic habitats. Therefore, life forms were combined with Grime's CSR life-strategy framework (Grime 1988), assigned through expert assessment based on the preferential habitat of each species in Sicily - due to the lack of a comprehensive CSR system for Mediterranean species. Given that all species of Mediterranean dry grasslands must be stress-tolerant to some extent in order to withstand summer drought, the competitive (C) strategy was assigned to species believed to primarily occur in vegetation of the classes *Lygeo sparti-Stipetea tenacissimae*, *Molinio-Arrhenatheretea*, *Ononido-Rosmarinetea* (sprouters), and *Quercetea ilicis*. The stress-tolerant (S) strategy was attributed to species whose preferential habitats belong to *Ammophiletea*, *Poetea bulbosae*, *Helianthemetea guttati*, *Asplenietea trichomanis* (*Asplenietalia glandulosi*), *Ononido-Rosmarinetea* (seeders), *Pegano harmalae-Salsoletea vermiculatae*, and *Drypidetea spinosae*. Finally, the ruderal (R) strategy was assigned to species typical of *Chenopodietea*, *Artemisietea vulgaris*, *Cymbalario-Parietarietea diffusae*, and *Polygono-Poetea annuae*. Thus, our CSR assignment is a simplified version, not accounting for the numerous intermediate strategies (Pierce et al. 2017), while being restricted to the scope of the present study. Both assignments used here are provided in Suppl. material 2 together with the plant nomenclature used here and in "Flora d'Italia" (Pignatti et al. 2017–2019).

Site conditions

Soil samples were collected from the topsoil (0–15 cm) at five randomly selected points within each plot after the surface litter had been removed. The field-moist soil samples were air-dried and sieved at 2 mm to remove the soil skeleton. The soil texture class of each sample was determined using the haptic test (Schlichting et al. 1995). The percentage content of each fine soil fraction (i.e. sand: 2–0.02 mm, silt: 0.02–0.002 mm, and clay: < 0.002 mm) was then calculated as the midpoint of the typical range for each texture class according to Schlichting et al. (1995). Soil pH and electrical conductivity (EC) were measured in a suspension with distilled water at a soil/water mass ratio of 1:2.5 using a glass membrane electrode. The organic matter content was measured using the loss on ignition method with dry combustion at a temperature of 550 °C for 4 hours.

To infer further site conditions that are not easy to measure in the field, we applied mean ecological indicator values (Diekmann 2003). Specifically, we used the Ecological Indicator Values for Europe (EIVE) 1.0 (Dengler et al. 2023) as they are to date the taxonomically most comprehensive system and have been shown to outperform regional systems (Ostrowski et al. 2025). We used unweighted means as they are usually much stronger correlated with measured environmental variables than weighted means (Ostrowski et al. 2025). Selecting all currently available EIVE indicators, we covered the niches for soil moisture (M), reaction (R) and nitrogen (N) as well as light (L) and temperature (T) of vascular plants. For subspecies not covered by EIVE, we used the EIVEs of the species level. Similarly, "cf." determinations were considered as the respective taxon in the calculation of mean EIVEs. Only very few species were missing in EIVE 1.0.

Statistical analyses

We used unsupervised cluster analysis to identify the main vegetation units based on floristic similarity only (De Cáceres et al. 2015). Specifically, we applied Two-way indicator species analysis (TWINSPAN; Hill 1979) in its modified version (Roleček et al. 2009) as implemented in the JUICE software (Tichý 2002) because this algorithm is supposed to mimic phytosociological classification (Hill 1979). We used the following settings: (i) maximum number of clusters: 15; (ii) minimum group size for division: 2; (iii) clustering algorithm: average Sørensen dissimilarity. While the definitive analysis was done with all taxa in the plots, for comparison, we conducted the same analysis also for the following subsets of species: only vascular plants, only perennial vascular plants, only annual vascular plants, and only non-vascular plant taxa. The distance between the clusters obtained through the hierarchical classification of the whole dataset and the corresponding ones of each subset was then evaluated by means of the Jaccard similarity index. After the clustering, the optimal number of clusters was determined with crispness analysis (Botta-Dukát et al. 2005), based on 30 species randomly selected among those having more than 50% occurrences in the dataset.

Finally, we applied ordination techniques to visualise how well the obtained clusters are separated in the floristic space. On the one hand, we performed non-metric multidimensional scaling (NMDS) on square-root transformed data with down-weighting of rare species. This was done for the entire dataset by the 'vegan' package (Oksanen et al. 2025) in the statistical software R (R Core Team 2025). On the other hand, we conducted detrended correspondence analyses (DCA) for the entire dataset as well as for three subsets (perennial vascular plants, annual vascular plants, non-vascular plant taxa). This was done in PCOrd 6.0 (McCune and Grace 2002) on log(x+1) transformed data with down-weighting of rare species. We applied both NMDS and DCA because the two techniques address different methodological needs. NMDS provides a robust, non-parametric representation of floristic dissimilarities and is less constrained by assumptions about species–environment relationships, making it suitable for visualising overall compositional patterns. DCA, by contrast, offers axis scaling in units of species turnover and therefore allows a direct ecological interpretation of gradient lengths. Running DCA on the full dataset and on taxonomic subsets (perennials, annuals, non-vascular plant taxa) enabled us to assess whether the main floristic gradients are consistent across life-form groups.

For the resulting hierarchical classification, we determined diagnostic species at a higher and at a lower cluster resolution. We did so with the phi coefficient of association (Chytrý et al. 2002), standardised to equal number of plots at the lower hierarchical level (Tichý and Chytrý 2006). Since hierarchical phi-values are not available in JUICE (Tichý 2002), we calculated them in MS Excel (see Vassilev et al. 2024 for a similar implementation of a hierarchical system of phi-values). For a taxon to be diagnostic, we required phi > 0.5 and for being highly diagnostic phi > 0.7. At the same time, we required delta-phi ≥ 0.5 towards the cluster of the same level with the next-highest phi-value (see Vassilev et al. 2024). To avoid spurious results, we disregarded cases where a diagnostic taxon occurred only once in the characterised cluster. If a taxon fulfilled the criteria of a diagnostic species at both hierarchical levels, it was considered at the level with the higher phi-value.

Finally, the resulting clusters at the lower hierarchical level were characterised and compared by means of analyses of variance (ANOVA) and visualised by means of boxplots. We conducted these analyses in R (R Core Team 2025) for a wide range of community characteristics, namely species richness, vegetation cover (total and per layer), fractional cover of life forms, share of CSR strategy types, measured soil variables, measured topographic variables and mean EIVEs. Since we were not interested in particular contrasts between clusters, we only provide the overall *p*-values from the ANOVAs.

Syntaxonomy

Each vegetation plot was assigned by the first author to one or several syntaxa based on expert-knowledge, mimicking the syntaxonomic interpretation adopted in many studies concerning the Mediterranean dry grasslands (Guarino et al. 2018). For alliances, orders and classes, we adopted the syntaxonomic view of the "EuroVegChecklist" (Mucina et al. 2016), except for the class *Ammophiletea*, where we followed the most up-to date European revision by Marcenò et al. (2024). Association names follow regional studies in Sicily. For the syntaxa considered here, the full names and authorities are provided in a "syntaxonomic overview", allowing to omit authorities and in absence of ambiguity also epitheta elsewhere in the text. Only syntaxon names not listed in the overview and not accepted in Mucina et al. (2016) are given with authorities in the text.

Results

Flora and scale-dependent biodiversity

In all plots combined (including the 100 m² plots), we found 597 taxa (562 in the 10 m² plots), including 505 (476) vascular plants, 71 (68) bryophytes, 20 (17) lichens and 1 cyanobacterium (*Nostoc* sp.). The most frequent vascular plants were *Hypochaeris achyrophorus* (66% of all 10 m² plots), *Anagallis foemina* (48%), *Arisarum vulgare* (48%), *Dactylis glomerata* subsp. *hispanica* (48%), *Galactites tomentosus* (48%), *Anisantha rubens* (42%), *Asphodelus ramosus* (42%) and *Euphorbia peplus* (42%). The most frequent bryophytes were *Bryum dichotomum* (57%), *Trichostomum brachydontium* (37%), *Didymodon fallax* (34%), *Dicranella howei* (30%) and *Cephaloziella baumgartneri* (28%), while the most frequent lichen, *Echylium tenax*, occurred only in 21% of the plots.

A noteworthy result concerns the discovery of *Agonimia globulifera* on the western slopes of Mt. Cofano (W Sicily), and of *Steinia geophana* and *Thelidium minutulum* on evaporitic sediments near the archaeological site of Heraclea Minoa (SW Sicily). Based on ITALIC 8.0, these findings represent first records from Sicily, thereby expanding the known distribution range of these taxa in Italy.

At the 10-m² scale, the mean overall species richness of the vegetation was 42.4 (9–72). On average vascular plants contributed 35.4 (9–68) species, bryophytes 6.0 (0–19) species and lichens 0.9 (0–9) species (Table 1). The fraction of non-vascular plant taxa was on average 15% but varied between 0% and 38%. In the 21 EDGG Biodiversity Plots, mean total species richness increased from 2.1 (0–7) in 1 cm² via 24.9 (5–50) in 1 m² to 60.6 (13–120) in 100 m², while the corresponding numbers for vascular plant species richness were 1.7 (0–4) in 1 cm², 21.0 (5–39) in 1 m² and 50.7 (13–98) in 100 m², respectively (Table 1).

Table 1. Descriptive statistics of the scale- and taxon-dependent species richness in dry grasslands of Sicily. The data are based on the 21 "EDGG Biodiversity Plots", while the row "10*" refers to all 67 10-m² plots.

Area [m²]	n	All taxa				Vascular plants				Bryophytes				Lichens			
		Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD	Min	Max	Mean	SD
0.0001	42	0	7	2.1	1.5	0	4	1.7	1.0	0	4	0.4	0.9	0	1	0.0	0.2
0.001	42	0	14	3.8	2.9	0	9	3.2	2.0	0	7	0.6	1.4	0	1	0.0	0.2
0.01	42	0	22	7.5	5.0	0	14	6.4	3.6	0	8	1.0	2.1	0	3	0.1	0.5
0.1	42	1	35	15.3	8.2	1	27	12.8	6.0	0	9	2.2	2.7	0	5	0.3	1.0
1	42	5	50	24.9	10.3	5	39	21.0	8.2	0	11	3.4	3.2	0	5	0.5	1.2
10	42	9	70	40.0	13.6	9	68	33.8	11.4	0	13	5.2	3.8	0	9	1.0	1.9
10*	**67**	**9**	**72**	**42.4**	**14.8**	**9**	**68**	**35.4**	**12.4**	**0**	**19**	**6.0**	**4.2**	**0**	**9**	**0.9**	**1.7**
100	21	13	120	60.6	25.0	13	98	50.7	20.0	0	18	7.9	5.2	0	10	1.6	2.6

Cluster analysis and ordination

The peak of the crispness curve for the TWINSPAN classification of both the complete dataset and the vascular plant subset (Suppl. material 3: figure S3.1) indicates that the optimal number of clusters is four. Secondary optimal clustering levels were identified at six and nine clusters. Thus, to reflect the hierarchical philosophy of phytosociological classification, we selected four clusters as the upper hierarchical level (coded by letters) and nine clusters as the lower hierarchical level (coded by numbers) to be described in the following sections.

In the case of the perennial subset, three and eight clusters achieved a similar level of crispness (i.e. had local maxima). In the case of the annual subset, the optimal number of clusters was four. For the non-vascular plant subset, the optimal number of clusters was just two, one cluster grouped the relevés from Mt. Etna, while the other included the remaining relevés. It should be noted, however, that non-vascular plant taxa were absent from 11 relevés, including all those recorded in coastal psammophilous vegetation. The TWINSPAN analysis of the vascular plant subset closely matched that of the complete dataset (Figure 2). The only minor discrepancies involve Clusters B.1–B.2 and D.1–D.3, where non-vascular plant taxa exerted some influence on the vegetation classification. Concordance between clusters progressively decreased when only perennials, annuals, or non-vascular plant taxa were considered (Figure 2). Cluster A.1, representing psammophilous coastal vegetation, was the only unit consistently recognized by all subsets, except for the non-vascular plant one, due to the absence of non-vascular plant taxa in its relevés.

The three-dimensional NMDS ordination shows that all nine terminal clusters are reasonably well floristically separated, with only Clusters D.1–D.3 being relatively close together (Suppl. material 3: figure S3.2). The first dimension of the NMDS separated the coastal dune vegetation (Cluster A.1) from the inland clusters. Along the second NMDS axis, a clear distinction emerged between the

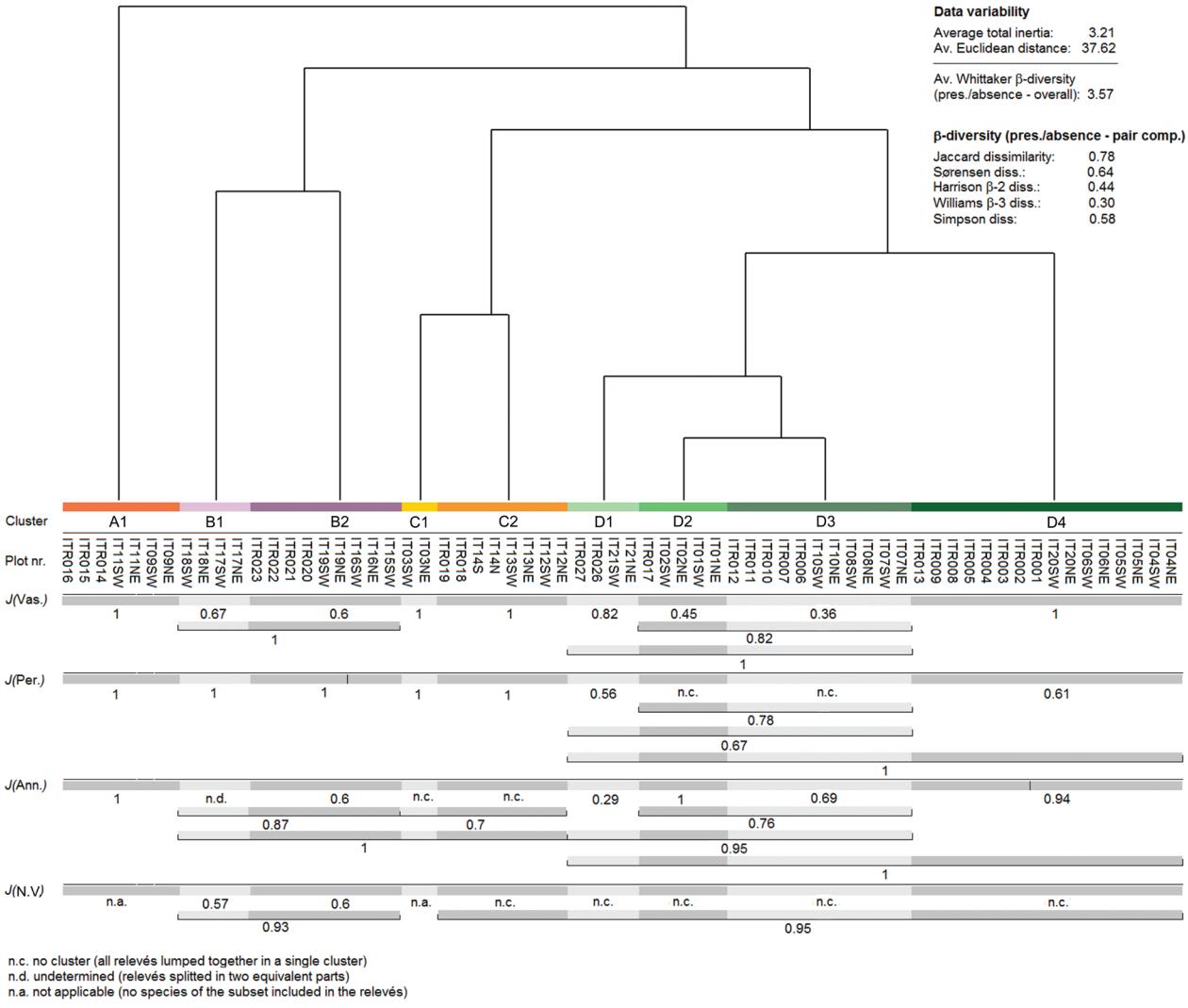

Figure 2. Cluster diagram (modified TWINSPAN - average Sørensen dissimilarity) for the complete dataset. Below each cluster, its similarity to the corresponding clusters derived from the modified TWINSPAN classification of the vascular (Vas.), perennial (Per.), annual (Ann.), and non-vascular plant taxa (N.V.) subsets is reported, as measured by the Jaccard similarity index (J).

Etnean vegetation (Clusters B.1–B.2), the hilly vegetation (Cluster C.2), and that of the lowlands (Clusters D.1–D.4), likely reflecting climatic and edaphic differentiation. The third axis appears to correspond to a disturbance gradient: Cluster C.1 was situated at one extreme, whereas the vegetation types with a strong prevalence of ruderals (Clusters B.2, C.2, D.3 and D.4) were distributed along the positive side of the axis. In terms of life forms, the third NMDS axis was positively correlated with therophytes and negatively with chamaephytes and nanophanerophytes, thus representing a gradient from highly disturbed to less disturbed habitat conditions (not shown).

The DCA ordinations (Figure 3) demonstrate that the overall floristic gradient is quite large, with 10 units on the first and 6 units on the second axis, corresponding to 2.5 and 1.5 complete species turnovers. The by far best separation of units was achieved with the entire dataset, while the separation was less pronounced for non-vascular plant taxa and perennial vascular plants and most blurred when considering only annual vascular plants.

Biodiversity, vegetation structure and site conditions of the clusters in comparison

Total species richness in 10 m^2 was below 20 in Cluster A.1, around 30 in Cluster B.1, but mostly between 35 and 60 in the remaining seven clusters (Figure 4). The diversity patterns of vascular plants and bryophytes largely mirrored those of total richness. By contrast, lichens were virtually absent from Clusters A.1–C.1 and present at a low level of ca. 1–2 species in 10 m^2 in the remaining five clusters.

Total vegetation cover differed largely among the clusters, with ca. 25% in Cluster A.1, ca. 50% in Cluster B.1, and ca. 75% in the remaining seven clusters (Suppl. material 3: figure S3.3). This pattern was largely mirrored by the herb layer cover, while the cover of the non-vascular plant layer was generally low and showed no significant pattern among the clusters. Considering the fractional cover of the six life forms (Figure 5), the clusters did not show significant differences for phanerophytes and non-vascular plant taxa. By contrast the four other live forms demonstrated strong variation, interestingly mostly within and not between the four main clusters (A, B, C, D). The Clusters A.1, D.1 and D.3 were (co-)dominated by geophytes, while hemicryptophytes were prevalent in the Clusters B.1, C.1, D.1 and D.4, and chamaephytes in B.1. Conversely, the Clusters A.1, B.2, C.2 and D.2 had a strong therophyte component of 50% and more. The shares of our "ad hoc" CSR strategy types also differed significantly among the clusters (Figure 6). The competitive strategy prevailed in the Clusters B.1, D.1, D.3 and D.4. The stress strategy was prominent mainly in A.1 and to a lesser degree in D.1, while the ruderal strategy prevailed in the C clusters and to a lesser degree in B.2 and D.2.

The nine clusters showed a moderate differentiation regarding topographic variables (Suppl. material 3: figure S3.4). The elevation was the most-differentiating factor and followed the four main clusters: A minimally above sea level, D between 0 and 200 m a.s.l., C between 200 and 300 m a.s.l. and B above 600 m a.s.l. While most clusters occur on plains or at slightly inclined slopes, D.1, D.3 and D.4 were found on slopes between 10° and 45° inclination. The differentiation concerning heat load index and maximum microrelief was very small. By contrast, the nine clusters were clearly separated regarding all six considered soil variables (Figure 7). Regarding soil pH, the coastal dunes of Cluster A.1 had the highest values (around 8) and the two B-clusters the lowest values (around 6.5), while the C- and D-clusters were all around pH = 7.5. Electrical conductivity was particularly high in Clusters C.1 and D.3, and particularly low in Cluster B.1. Loss at ignition (humus content) was very high in Cluster C.1 (around 15%), very low in Clusters A.1 and B.1 (below 2%) and intermediate in the rest of the clusters (around 3–10%). The penetrable soil depth stood out with ca. 60 cm in the coastal dunes (A.1), while it was only 10–40 cm in the rest of the clusters. Sand content differentiated the main Clusters A and B (high) against the main Clusters C and D (low). Finally, a significant clay content (of about 20%) was restricted to the main Cluster D and the second-order Cluster C.1, while in all other clusters, the clay content was close to zero.

The five assessed mean EIVEs also showed highly significant variation between the clusters (Figure 8). Accordingly, soil moisture was particularly low in A.1 and D.1, and relatively high in C.1, while all plots are in the dry range (mean EIVEs between 2.4 and 3.3). Soil nitrogen is predicted to be particularly low in B.1 and particularly high in C.1. Mean reaction values were relatively low in the Cluster B, higher in A and C, and highest in D. The mean EIVEs for temperature closely mirrored the elevation (Suppl. material 3: figure S3.4), with warmest conditions in A.1 and coolest conditions in B.1. According to EIVEs for light, all clusters are adapted to full-light conditions, but A.1 even more than the rest.

Description of the clusters

The clusters resulting from the clustering with all taxa were translated into a classification system, in which diagnostic species were determined both at the four- and at the nine-cluster level. The resulting synoptic table is provided in an abbreviated manner in Table 2 and in a full version with both synoptic columns and individual relevés in Suppl. material 4. Photos of representative stands of the nine clusters are shown in Figure 9. For each terminal cluster, we provide the most frequent species of each cluster (those occurring in more than half of the plots) at the start of each cluster description (with diagnostic species labelled as such) and highlight in the text the correspondences to described syntaxa (from the perspective of Mediterranean phytosociologists). The relevant syntaxa of the contemporary system are listed in Table 3.

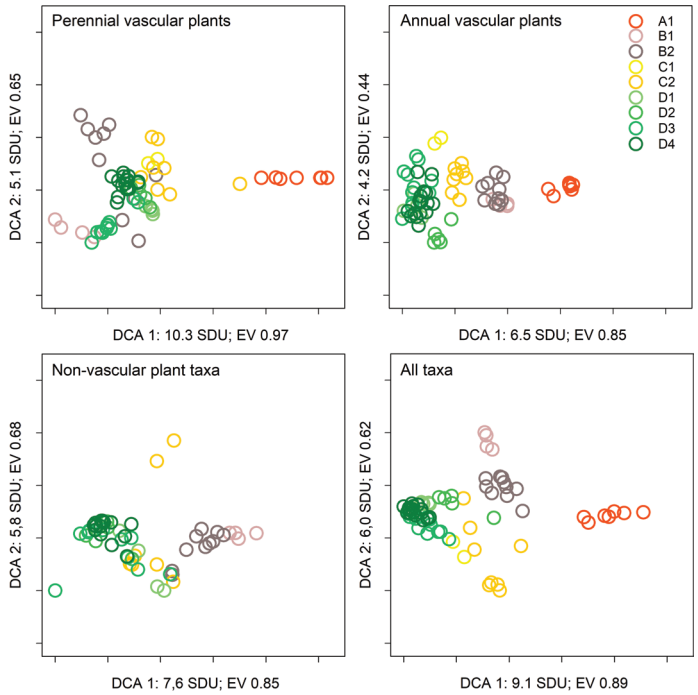

Figure 3. DCA ordinations of the entire dataset (bottom right) and three subsets of life forms. The colouring is according to the nine lower-rank clusters. Note that Clusters A1 and C1 did not contain any non-vascular plant taxa and thus are absent in the lower-left figure (56 vs. 67 relevés). Lengths and eigenvalues of gradients are given in axis titles.

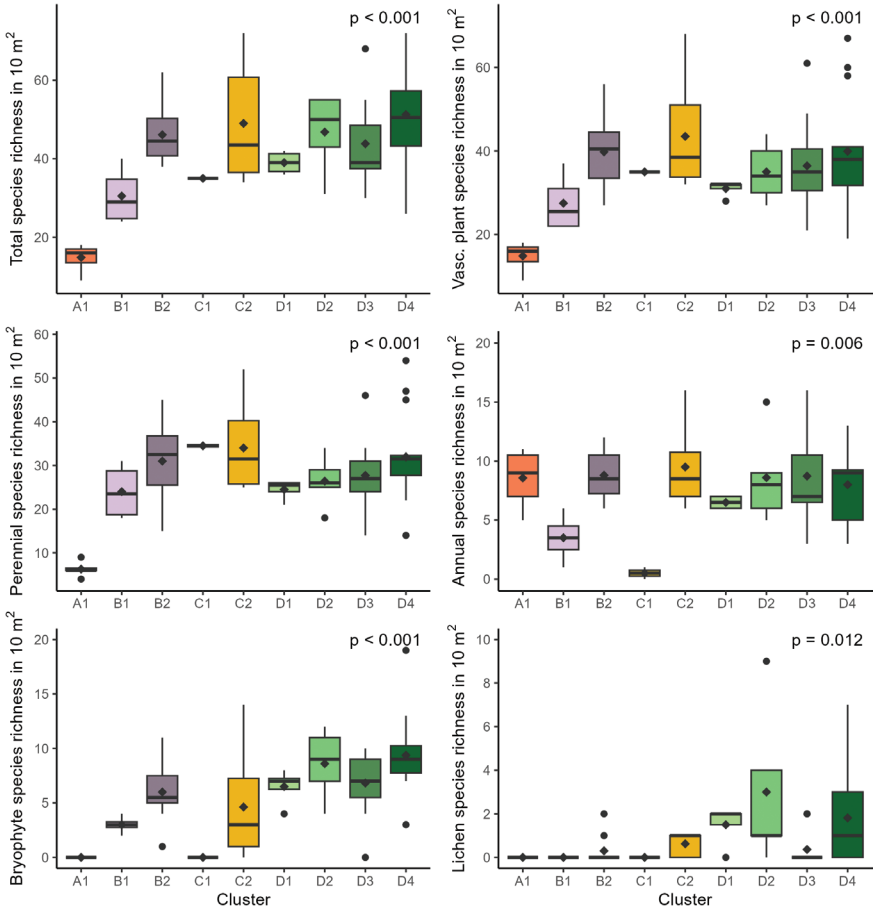

Figure 4. Comparison of species richness among the nine distinguished clusters of dry grasslands in Sicily for all terricolous taxa combined, for vascular plants in general, for perennial and annual vascular plants separately, for bryophytes and for lichens. Boxplots denote median, inter-quartile range, total range and outliers, while the rhombuses stand for the arithmetic means. Note the different scaling of the y-axes. The *p*-values are from an ANOVA.

Table 2. Abbreviated synoptic table of dry grasslands of Sicily (based on 67 10-m² plots). The clusters resulting from the TWINSPAN classification, at the upper (4 cluster) and lower (9 cluster) level are shown. Values in the columns are given in percent constancies. Species are sorted by decreasing phi values in the respective cluster and by decreasing overall constancy in the case of the companion species. The table is abbreviated to contain in each cluster the eight species with the highest fidelity plus additionally all species with a total constancy of at least 15%. For each cluster the total number of diagnostic taxa is given, while omissions of taxa are indicated with "[...]". The column "LF" to the right of the species name give the life form of the species: P = phanerophyte, C = chamaephyte, H = hemicryptophyte, G = geophyte, T = therophyte, B = bryophyte, L = lichen. The complete sorted synoptic table including the individual relevés is provided in Suppl. material 4.

Number of plots	LF	All	A	B	C	D	A1	B1	B2	C1	C2	D1	D2	D3	D4
		67	7	14	10	36	7	4	10	2	8	4	5	11	16
Diagnostic species A (19 taxa)															
Silene niceensis	T	10	100	.	.	.	100	.	.	.	.	.	.	.	.
Ononis variegata	T	10	100	.	.	.	100	.	.	.	.	.	.	.	.
Senecio glaucus subsp. *coronopifolius*	T	9	86	.	.	.	86	.	.	.	.	.	.	.	.
Silene colorata	T	15	100	.	.	8	100	.	.	.	.	.	20	.	13
Eryngium maritimum	G	7	71	.	.	.	71	.	.	.	.	.	.	.	.
Echinophora spinosa	H	7	71	.	.	.	71	.	.	.	.	.	.	.	.
Launaea fragilis	H	7	71	.	.	.	71	.	.	.	.	.	.	.	.
Pseudorlaya pumila	T	7	71	.	.	.	71	.	.	.	.	.	.	.	.
Euphorbia terracina	T	15	100	7	.	6	100	.	10	.	.	.	20	9	.
[...]															
Erodium alnifolium	T	16	86	7	20	6	86	.	10	.	25	25	20	.	.
[...]															
Diagnostic species B (14 taxa)															
Anisantha tectorum	T	18	.	86	.	.	.	100	80	.	.	.	.	.	.
Ptychostomum capillare	B	21	.	79	.	8	.	50	90	.	.	.	.	.	19
Scrophularia canina subsp. *bicolor*	C	10	.	50	.	.	.	50	50	.	.	.	.	.	.
Silene vulgaris	H	10	.	50	.	.	.	50	50	.	.	.	.	.	.
Isatis tinctoria	H	9	.	43	.	.	.	50	40	.	.	.	.	.	.
Cerastium pumilum subsp. *pumilum*	T	9	.	43	.	.	.	50	40	.	.	.	.	.	.
Daucus carota	T	30	.	71	30	19	.	100	60	.	38	.	20	18	25
Ornithopus compressus	T	15	.	57	20	.	.	50	60	.	25	.	.	.	.
[...]															
Aira caryophyllea subsp. *caryophyllea*	T	19	.	64	40	.	.	50	70	.	50	.	.	.	.
[...]															
Diagnostic species B1 (19 taxa)															
Festuca circummediterranea	H	7	.	36	.	.	.	100	10	.	.	.	.	.	.
Rumex acetosella subsp. *angiocarpus*	H	7	.	36	.	.	.	100	10	.	.	.	.	.	.
Jasione montana	H	4	.	21	.	.	.	75	.	.	.	.	.	.	.
Sedum amplexicaule subsp. *tenuifolium*	C	4	.	21	.	.	.	75	.	.	.	.	.	.	.
Ceratodon purpureus	B	12	.	57	.	.	.	100	40	.	.	.	.	.	.
Crepis leontodontoides	H	10	.	43	10	.	.	100	20	50	.	.	.	.	.
Anthemis aetnensis	H	3	.	14	.	.	.	50	.	.	.	.	.	.	.
Clinopodium vulgare subsp. *orientale*	H	3	.	14	.	.	.	50	.	.	.	.	.	.	.
[...]															
Diagnostic species B2 (19 taxa)															
Myosotis ramosissima	T	9	.	43	.	.	.	.	60	.	.	.	.	.	.
Sedum stellatum	T	9	.	43	.	.	.	.	60	.	.	.	.	.	.
Syntrichia ruralis	B	9	.	43	.	.	.	.	60	.	.	.	.	.	.
Trifolium subterraneum	T	15	.	64	10	.	.	25	80	.	13	.	.	.	.
Anchusella cretica	T	7	.	36	.	.	.	.	50	.	.	.	.	.	.
Stellaria media subsp. *cupaniana*	T	7	.	36	.	.	.	.	50	.	.	.	.	.	.
Verbascum macrurum	H	7	.	36	.	.	.	.	50	.	.	.	.	.	.
Cardamine hirsuta	T	6	.	29	.	.	.	.	40	.	.	.	.	.	.
[...]															
Diagnostic species C (4 taxa)															
Calendula arvensis	T	21	.	14	90	8	.	.	20	100	88	.	.	27	.
Plantago lagopus	T	13	.	.	70	6	.	.	.	50	75	.	.	9	6
Medicago polymorpha	T	18	.	7	60	14	.	.	10	100	50	.	20	18	13
Anagallis arvensis	T	31	.	7	80	33	.	.	10	100	75	25	60	45	19

Number of plots	LF	All	A	B	C	D	A1	B1	B2	C1	C2	D1	D2	D3	D4
		67	7	14	10	36	7	4	10	2	8	4	5	11	16
Diagnostic species C1 (9 taxa)															
Beta vulgaris subsp. *maritima*	H	3	.	.	20	.	.	.	.	100	.	.	.	.	.
Carduus argyroa	T	3	.	.	20	.	.	.	.	100	.	.	.	.	.
Torilis pseudonodosa	T	4	.	.	20	3	.	.	.	100	.	.	.	9	.
Mandragora autumnalis	H	4	.	.	20	3	.	.	.	100	.	.	.	9	.
Borago officinalis	H	6	.	.	40	.	.	.	.	100	25	.	.	.	.
Cynara cardunculus	H	7	.	.	50	.	.	.	.	100	38	.	.	.	.
Diplotaxis erucoides	T	7	.	.	20	8	.	.	.	100	.	.	20	18	.
Euphorbia helioscopia	T	9	.	7	20	8	.	.	10	100	.	.	40	.	6
Geranium molle	T	15	.	36	40	3	.	.	50	100	25	.	.	9	.
Diagnostic species C2 (9 taxa)															
Centaurea sicula	H	9	.	.	60	.	.	.	.	.	75	.	.	.	.
Hypericum triquetrifolium	T	7	.	.	50	.	.	.	.	.	63	.	.	.	.
Silene nocturna	T	7	.	.	50	.	.	.	.	.	63	.	.	.	.
Erodium ciconium	T	6	.	.	40	.	.	.	.	.	50	.	.	.	.
Verbascum sinuatum	H	6	.	.	40	.	.	.	.	.	50	.	.	.	.
Sagina apetala	T	7	.	7	40	.	.	.	10	.	50	.	.	.	.
Tordylium apulum	T	13	.	.	50	11	.	.	.	.	63	.	.	18	13
Echium sabulicola	T	4	.	.	30	.	.	.	.	.	38	.	.	.	.
[...]															
Diagnostic species D (12 taxa)															
Brachypodium distachyon	T	31	.	.	.	58	.	.	.	.	.	100	20	73	50
Hyparrhenia hirta	H	19	.	.	.	36	.	.	.	.	.	100	80	18	19
Reichardia picroides	H	25	.	7	.	44	.	.	10	.	.	75	80	27	38
Avena barbata	T	21	.	.	10	36	.	.	.	.	13	100	80	27	13
Trichostomum brachydontium	B	37	.	.	10	67	.	.	.	.	13	25	40	55	94
Scorpiurus muricatus	T	30	.	.	10	53	.	.	.	.	13	75	20	73	44
Arisarum vulgare	G	48	.	.	20	83	.	.	.	100	.	50	80	82	94
Cephaloziella baumgartneri	B	28	.	.	.	53	.	.	.	.	.	.	80	18	81
Asphodelus ramosus	G	42	.	14	30	64	.	.	20	.	38	100	40	45	75
Nigella damascena	T	18	.	.	.	33	.	.	.	.	.	100	20	45	13
Weissia longifolia	B	18	.	.	.	33	.	.	.	.	.	75	40	45	13
Dicranella howei	B	30	.	.	10	53	.	.	.	.	13	.	60	55	63
Diagnostic species D1 (12 taxa)															
Cenchrus ciliaris	H	6	.	.	.	11	.	.	.	.	.	100	.	.	.
Bituminaria bituminosa	H	10	.	.	.	19	.	.	.	.	.	100	.	.	19
Aschisma carniolicum	B	4	.	.	.	8	.	.	.	.	.	75	.	.	.
Weissia condensa	B	4	.	.	.	8	.	.	.	.	.	75	.	.	.
Asparagus albus	P	13	.	.	.	25	.	.	.	.	.	100	.	27	13
Urospermum picroides	T	15	.	7	20	19	.	.	10	.	25	100	.	27	.
Hippocrepis ciliata	T	7	.	.	.	14	.	.	.	.	.	75	20	.	6
Heteropogon contortus	H	3	.	.	.	6	.	.	.	.	.	50	.	.	.
[...]															
Tripodion tetraphyllum	T	22	.	.	.	42	.	.	.	.	.	100	20	36	38
[...]															
Diagnostic species D2 (9 taxa)															
Vulpia ligustica	T	13	.	7	.	22	.	.	10	.	.	.	80	.	25
Didymodon acutus	B	6	.	.	.	11	.	.	.	.	.	.	60	9	.
Tortella fasciculata	B	7	.	.	.	14	.	.	.	.	.	.	60	.	13
Trifolium nigrescens	T	6	.	.	10	8	.	.	.	.	13	.	60	.	.
Bryum radiculosum	B	3	.	.	.	6	.	.	.	.	.	.	40	.	.
Convolvulus lineatus	C	3	.	.	.	6	.	.	.	.	.	.	40	.	.
Hypochaeris laevigata	G	3	.	.	.	6	.	.	.	.	.	.	40	.	.
Medicago lupulina	H	3	.	.	.	6	.	.	.	.	.	.	40	.	.
[...]															
Diagnostic species D3 (5 taxa)															
Lygeum spartum	G	19	.	.	.	36	.	.	.	.	.	.	.	82	25
Hedysarum spinosissimum subsp. *capitatum*	T	15	.	.	.	28	.	.	.	.	.	.	.	73	13
Adonis microcarpa	T	9	.	.	.	17	.	.	.	.	.	.	.	55	.
Convolvulus pentapetaloides	T	6	.	.	.	11	.	.	.	.	.	.	.	36	.
Linum decumbens	H	6	.	.	.	11	.	.	.	.	.	.	.	36	.

Number of plots	LF	All	A	B	C	D	A1	B1	B2	C1	C2	D1	D2	D3	D4
		67	7	14	10	36	7	4	10	2	8	4	5	11	16
Diagnostic species D4 (9 taxa)															
Ampelodesmos mauritanicus	H	27	.	.	10	47	.	.	.	.	13	.	.	9	100
Anthyllis vulneraria subsp. *maura*	H	10	.	.	.	19	.	.	.	.	.	.	.	.	44
Teucrium fruticans	P	10	.	.	.	19	.	.	.	.	.	.	.	.	44
Pulicaria odora	H	9	.	.	.	17	.	.	.	.	.	.	.	.	38
Selaginella denticulata	T	9	.	.	.	17	.	.	.	.	.	.	.	.	38
Bellevalia dubia	G	7	.	.	.	14	.	.	.	.	.	.	.	.	31
Eryngium tricuspidatum subsp. *bocconei*	T	7	.	.	.	14	.	.	.	.	.	.	.	.	31
Gymnostomum calcareum	B	7	.	.	.	14	.	.	.	.	.	.	.	.	31
[...]															
Companion species															
Hypochaeris achyrophorus	T	66	.	71	80	72	.	50	80	.	100	25	80	82	75
Bryum dichotomum	B	57	.	93	40	58	.	100	90	.	50	100	20	55	63
Galactites tomentosus	H	49	.	7	100	61	.	.	10	100	100	75	40	82	50
Anagallis foemina	T	48	.	14	60	67	.	.	20	.	75	75	60	64	69
Dactylis glomerata subsp. *hispanica*	H	48	.	36	30	67	.	50	30	50	25	.	80	55	88
Anisantha rubens	T	42	.	.	60	61	.	.	.	100	50	75	20	64	69
Euphorbia peplus	T	42	.	7	50	61	.	.	10	.	63	50	100	9	88
Sherardia arvensis	T	39	.	36	60	42	.	.	50	50	63	.	20	55	50
Sonchus oleraceus	T	39	14	14	50	50	14	25	10	100	38	100	40	91	13
Didymodon fallax	B	34	.	.	20	58	.	.	.	.	25	.	40	55	81
Stipa capensis	T	33	29	14	30	42	29	.	20	.	38	100	100	45	6
Linum strictum	T	30	.	.	10	53	.	.	.	50	.	100	20	27	69
Fossombronia caespitiformis	B	27	.	.	10	47	.	.	.	.	13	.	40	45	63
Lotus tetragonolobus	T	27	.	.	20	44	.	.	.	100	.	.	60	73	31
Rumex bucephalophorus	T	27	14	57	70	6	14	.	80	.	88	.	40	.	.
Moraea sisyrinchium	G	25	.	.	10	44	.	.	.	.	13	.	60	55	44
Microbryum davallianum var. *commutatum*	B	24	.	.	30	36	.	.	.	.	38	75	40	18	38
Carduus pycnocephalus	T	22	.	29	50	17	.	.	40	.	63	.	.	27	19
Galium verrucosum	T	22	.	.	.	42	.	.	.	.	.	.	20	45	56
Ptychostomum torquescens	B	22	.	.	20	36	.	.	.	.	25	.	40	27	50
Sonchus asper	T	22	14	14	30	25	14	.	20	.	38	.	.	36	31
Enchylium tenax	L	21	.	.	20	33	.	.	.	.	25	75	40	9	38
Ephemerum recurvifolium	B	21	.	.	.	39	.	.	.	.	.	.	40	55	38
Fedia graciliflora	T	21	.	.	30	31	.	.	.	.	38	.	60	27	31
Fissidens viridulus	B	21	.	.	10	36	.	.	.	.	13	50	.	36	44
Squilla pancration	G	21	.	.	.	39	.	.	.	.	.	25	.	55	44
Anemone hortensis	G	19	.	.	.	36	.	.	.	.	.	.	20	27	56
Anisantha madritensis	T	19	.	.	50	22	.	.	.	50	50	.	40	55	.
Coronilla scorpioides	T	19	.	.	.	36	.	.	.	.	.	.	20	27	56
Romulea bulbocodium	G	19	.	29	10	22	.	25	30	.	13	.	.	27	31
Thapsia garganica	H	19	.	14	20	25	.	.	20	.	25	25	20	18	31
Barbula unguiculata	B	18	.	.	20	28	.	.	.	.	25	75	20	36	13
Blackstonia perfoliata	T	18	.	.	20	28	.	.	.	.	25	.	.	18	50
Coleostephus myconis	T	18	.	7	40	19	.	.	10	.	50	.	.	18	31
Euphorbia exigua	T	18	.	.	10	31	.	.	.	.	13	.	40	73	6
Fissidens kosaninii	B	18	.	.	.	33	.	.	.	.	.	.	20	27	50
Lagurus ovatus	T	18	29	36	30	6	29	.	50	.	38	.	.	.	13
Lotus ornithopodioides	T	18	.	.	10	31	.	.	.	50	.	50	80	18	19
Biscutella maritima	T	16	.	29	10	17	.	.	40	.	13	.	20	.	31
Blennothallia crispa	L	16	.	.	30	22	.	.	.	.	38	75	60	18	.
Galium murale	T	16	.	29	30	11	.	.	40	.	38	.	.	9	19
Hippocrepis biflora	T	16	.	.	.	31	.	.	.	.	.	25	20	36	31
Lotus corniculatus	H	16	.	.	.	31	.	.	.	.	.	.	60	.	50
Lotus parviflorus	T	16	.	7	50	14	.	.	10	.	63	.	40	9	13
Scandix australis	T	16	.	.	10	28	.	.	.	.	13	.	80	45	6
Vulpia ciliata	T	16	.	29	70	.	.	.	40	.	88	.	.	.	.
Catapodium rigidum subsp. *rigidum*	T	15	.	14	20	17	.	25	10	.	25	.	.	.	38
Cerastium glomeratum	T	15	.	43	40	.	.	.	60	.	50	.	.	.	.

Number of plots	LF	All	A	B	C	D	A1	B1	B2	C1	C2	D1	D2	D3	D4
		67	7	14	10	36	7	4	10	2	8	4	5	11	16
Chamaerops humilis	P	15	.	.	10	25	.	.	.	50	.	.	20	.	50
Ferula communis	H	15	.	29	.	17	.	.	40	.	.	25	20	9	19
Lathyrus clymenum	T	15	.	14	.	22	.	.	20	.	.	.	.	27	31
Lotus edulis	T	15	.	.	.	28	.	.	.	.	.	75	.	45	13
Muscari comosum	G	15	.	29	60	.	.	50	20	.	75	.	.	.	.
Poa bulbosa	H	15	.	43	20	6	.	50	40	.	25	.	.	18	.
Trifolium stellatum	T	15	.	14	10	19	.	.	20	50	.	.	40	36	6

Table 3. Syntaxonomic overview listing those units to which our plots (or parts of them) would traditionally be assigned. The class, order and alliance levels follow Mucina et al. (2016) with the partial update by Marcenò et al. (2024) while the association rank is based on regional literature from Sicily. The primary corresponding clusters are indicated in brackets.

Ammophiletea arundinaceae Br.-Bl. et Tx. ex Westhoff et al. 1946
- *Ammophiletalia arundinaceae* Br.-Bl. 1933
  - *Ammophilion arundinaceae* Br.-Bl. 1933
    - *Medicagini marinae-Ammophiletum arundinaceae* Br.-Bl. 1933 (Cluster A.1)

Drypidetea spinosae Quézel 1964
- *Scrophulario-Helichrysetalia* S. Brullo 1984
  - *Linarion purpureae* S. Brullo 1984 (Cluster B.2 p.p.)

Poetea bulbosae Rivas Goday et Rivas-Mart. in Rivas-Mart. 1978
- *Poetalia bulbosae* Rivas Goday & Rivas-Mart. in Rivas Goday et Ladero 1970
  - *Trifolio subterranei-Periballion* Rivas Goday 1964
    - *Poo bulbosae-Trifolietum subterranei* Rivas Goday 1964 (Clusters B.1–2)

Lygeo sparti-Stipetea tenacissimae Rivas-Mart. 1978
- *Cymbopogono-Brachypodietalia ramosi* Horvatić 1963
  - *Hyparrhenion hirtae* Br.-Bl., Pinto da Silva et Rozeira 1956
  - *Helictotricho convoluti-Ampelodesmetum mauritanici* Minissale 1995 (Cluster D.4)
    - *Hyparrhenietum hirto-pubescentis* A. Bolòs et O. Bolòs et Br.-Bl. in A. Bolòs et O. Bolòs 1950 (Cluster D.2)
    - *Cenchro ciliaris-Hyparrhenietum hirtae* Wildpret et Rodriquez in Rivas-Mart. et al. 1993 (Cluster D.1)
- *Lygeo-Stipetalia tenacissimae* Br.-Bl. et O. Bolòs 1958
  - *Moricandio-Lygeion sparti* S. Brullo et al. 1990
    - *Phagnalo annotici-Lygeetum sparti* Biondi et Mossa 1993 (Cluster D.3)

Stipo-Trachynietea distachyae S. Brullo in S. Brullo et al. 2001
- *Brachypodietalia distachyi* Rivas-Mart. 1978
  - *Trachynion distachyae* Rivas-Mart. 1978
    - *Vulpio-Trisetarietum aureae* Brullo 1975 (Cluster C.2 p.p.)
  - *Stipion retortae* O. Bolòs 1957
    - *Reichardio-Stipetum capensis* Rivas-Mart. et al. 1992 (Clusters D.2–4 p.p.)

Helianthemetea guttati Rivas Goday et Rivas-Mart. 1963
- *Helianthemetalia guttati* Br.-Bl. in Br.-Bl. et al. 1940
  - *Helianthemion guttati* Br.-Bl. in Br.-Bl. et al. 1940 (Cluster B.1 p.p.)
- *Vulpietalia* Pignatti 1953
  - *Alkanno-Maresion nanae* Rivas Goday in Rivas Goday et Rivas-Mart. 1963 corr. Díez-Garretas et al. 2001
    - *Sileno coloratae-Ononidetum variegatae* Gèhu & Gèhu-Franck 1986 (Cluster A.1 p.p.)

Artemisietea vulgaris Lohmeyer et al. in Tx. ex von Rochow 1951
- *Carthametalia lanati* S. Brullo in S. Brullo et Marcenò 1985
  - *Onopordion illyrici* Oberd. 1954 (Cluster C.1 p.p.)

Chenopodietea Br.-Bl. in Br.-Bl. et al. 1952
- *Brometalia rubenti-tectorum* (Rivas Goday et Rivas-Mart. 1973) Rivas-Mart. et Izco 1977
  - *Hordeion murini* Br.-Bl. in Br.-Bl. et al. 1936
    - *Hordeo-Carduetum argyroae* S. Brullo et Marcenò 1985 (Cluster C.1)
  - *Echio-Galactition tomentosae* O. Bolòs et Molinier 1969 (Cluster B.2 p.p.)
    - *Silene nocturna-Vulpia ciliata* comm. (Cluster C.2)
- *Geranio purpureae-Cardaminetalia hirsutae* S. Brullo in S. Brullo et Marcenò 1985
    - *Valantio muralis-Galion muralis* S. Brullo in S. Brullo et Marcenò 1985 (Cluster B.1 p.p.)

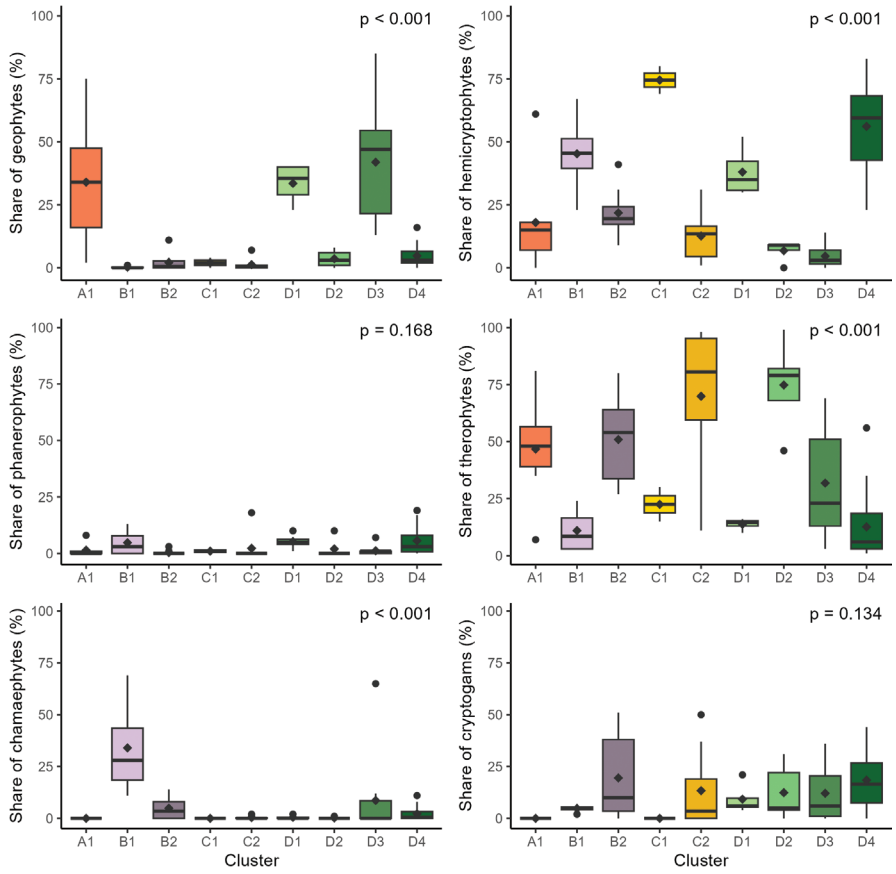

Figure 5. Comparison of the fractional cover of six life forms among the nine distinguished clusters of dry grasslands in Sicily. Boxplots denote median, inter-quartile range, total range and outliers, while the rhombuses stand for the arithmetic means. The *p*-values are from an ANOVA.

Cluster A.1

Frequent taxa: *Cutandia maritima* (A), *Echinophora spinosa* (A), *Erodium alnifolium* (A), *Eryngium maritimum* (A), *Euphorbia terracina* (A), *Launaea fragilis* (A), *Maresia nana* (A), *Ononis variegata* (A), *Pseudorlaya pumila* (A), *Senecio glaucus* subsp. *coronopifolius* (A), *Silene colorata* (A), *Silene niceensis* (A).

The coastal white dunes of the Mediterranean region are frequently colonized by a mixture of annual and perennial species, which have been ascribed to different associations in the phytosociological literature of recent decades. Our plots were sampled on the coastal dunes of Manfria, near Gela, in the same stands where two associations had previously been recorded (Brullo et al. 2000; Guarino et al. 2008): *Medicagini marinae-Ammophiletum australis* and *Sileno coloratae-Ononidetum variegatae*. Notably, in the original description of the latter, it is specified that the association refers to "therophytic vegetation growing at springtime amidst the perennial plants of the *Ammophilion australis*" (Géhu and Géhu-Frank 1986). In fact, all our relevés include both perennial and annual species; stress-tolerance is the predominant life strategy (Figure 6), and the plots were species-poor, reflecting the strong selective pressure of the habitat conditions (Table 2; Suppl. material 4).

Cluster B.1

Frequent taxa: *Allium sphaerocephalon*, *Anisantha tectorum* (B), *Bryum dichotomum* (bryophyte), *Ceratodon purpureus* (bryophyte; B.1), *Crepis leontodontoides* (B.1), *Daucus carota* (B), *Festuca circummediterranea* (B.1), *Jasione montana* (B.1), *Rumex acetosella* subsp. *angiocarpus* (B.1), *Sedum amplexicaule* subsp. *tenuifolium* (B.1).

This cluster comprises plots sampled at around 1200 m a.s.l. on the eastern flank of Mt. Etna (Sant'Alfio), within vegetation colonizing embryonic soils rich in pyroclastic scoriae on a narrow lava flow, partially shaded by adjacent *Pino-Quercion congestae* woodlands, as evidenced by the occurrence of relatively mesophilous species such as *Crepis leontodontoides*. The annual component consists of a mixture of *Geranio-Cardaminetalia* (*Valantio-Galion muralis*) and *Helianthemetalia guttati* (*Helianthemion guttati*) species. These herbaceous stands interspersed with woodland patches are traditionally used as summer rangelands, a practice that likely facilitated the establishment of *Poa bulbosa* and *Festuca circummediterranea*.

The class *Poetea bulbosae*, originally described from the Iberian Peninsula (Rivas-Martínez 1978), encompasses dwarf, caespitose perennial pastures dominated by a relatively small pool of prostrate hemicryptophytes, especially *Poa bulbosa* and different clover species, maintained by intensive sheep grazing. These anthropogenic meadows

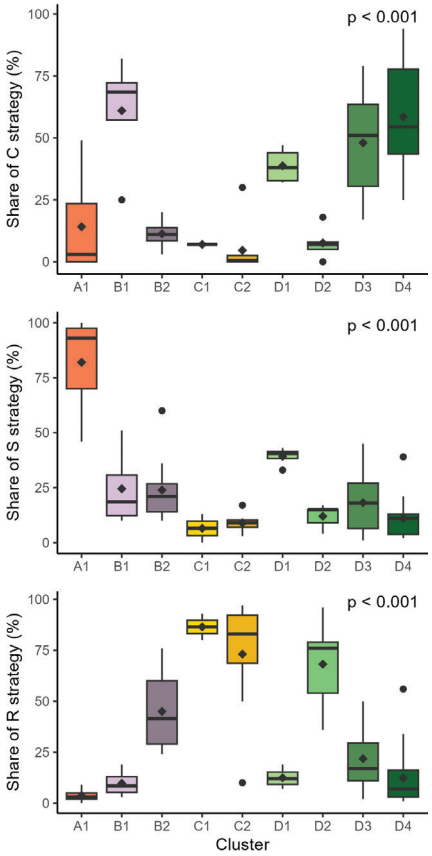

Figure 6. Comparison of the share of the CSR strategy types of vascular plants among the nine distinguished clusters of dry grasslands in Sicily. Boxplots denote median, inter-quartile range, total range and outliers, while the rhombuses stand for the arithmetic means. The *p*-values are from an ANOVA.

typically desiccate in summer but remain green from autumn to early summer, providing an ideal spring habitat for therophytic plants, particularly species of *Chenopodietea* or *Helianthemetea guttati*, depending on nutrient availability and disturbance.

In line with the modern phytosociological approach adopted in southwestern Europe, annual and perennial species could be sampled separately. Nonetheless, although many therophytes and two moss species occur among the diagnostic taxa, our relevés can be confidently interpreted as relatively undisturbed, shaded stands of the *Poo bulbosae-Trifolietum subterranei*, an association already recorded from Mt. Etna and widely distributed across the central and western Mediterranean (Galán de Mera et al. 2000). In support of this interpretation, the proportion of perennial species nearly doubles that of annuals (Suppl. material 4), and competitive and stress-tolerant strategies largely prevail over ruderal ones (Figure 6).

Cluster B.2

Frequent taxa: *Aira caryophyllea* subsp. *caryophyllea* (B), *Anisantha tectorum* (B), *Bryum dichotomum* (bryophyte), *Cerastium glomeratum*, *Daucus carota* (B), *Hypochaeris achyrophorus*, *Myosotis ramosissima* (B.2), *Ornithopus compressus* (B), *Ptychostomum capillare* (bryophyte, B), *Ranunculus millefoliatus*, *Rumex bucephalophorus*, *Sedum stellatum* (B.2), *Syntrichia ruralis* (bryophyte, B.2), *Trifolium subterraneum* (B.2).

This cluster comprises plots sampled between 590 and 870 m a.s.l. on flat or gently sloping pyroclastic deposits along the eastern and northeastern flanks of Mt. Etna (Sant'Alfio and Linguaglossa). As in Cluster B.1 the vegetation can be assigned to *Poo bulbosae-Trifolietum subterranei*; however, in this case the stands were more disturbed and heavily grazed, as indicated by the abundant contingent of annual species—particularly those of *Echio-Galactition tomentosae* (*Brometalia rubenti-tectorum*)—which were absent from Cluster B.1. Mosses were well represented, with four diagnostic or constant species, one of which (*Syntrichia ruralis*) was dominant.

In the relevés of Cluster B.2, the ruderal life strategy is more prevalent than the stress-tolerant one (Figure 6). The intensity of grazing is further evidenced by the frequent occurrence of large, toxic species such as *Verbascum macrurum*, *Ferula communis*, *Euphorbia characias*, *Asphodelus ramosus*, and *Thapsia garganica*, which emerge conspicuously above the dwarf vegetation layer (Suppl. material 4).

Cluster C.1

Frequent taxa: *Anagallis arvensis* (C), *Anisantha rubens*, *Arisarum vulgare*, *Beta vulgaris* subsp. *maritima* (C.1), *Borago officinalis* (C.1), *Calendula arvensis* (C), *Carduus argyroa* (C.1), *Cynara cardunculus* (C.1), *Diplotaxis erucoides* (C.1), *Euphorbia helioscopia* (C.1), *Galactites tomentosus*, *Geranium molle* (C.1), *Lotus tetragonolobus*, *Mandragora autumnalis* (C.1), *Medicago polymorpha* (C), *Sonchus oleraceus*, *Torilis pseudonodosa* (C.1).

This cluster includes two plots sampled at 250 m a.s.l. on the eastern flank of Mt. Cofano, in western Sicily, next to the temporary pond of Baglio Cofano. The stands represent typical wintergreen thermomediterranean cattle rangelands, heavily grazed, species-poor, and dominated by thorny thistles (Suppl. material 4). In this case, they occurred on flat, Mediterranean red soils surrounding a temporary pond within a karstic doline. The sampled vegetation can be confidently assigned to *Hordeo-Carduetum argyroae*, although it included a few, yet extremely abundant, perennial representatives of the alliance *Onopordion illyrici*, such as *Mandragora autumnalis*, *Cynara cardunculus*, and *Scolymus grandiflorus* (Suppl. material 4). This cluster represents the most ruderal grassland type recorded during our survey (Figure 6).

Cluster C.2

Frequent taxa: *Anagallis arvensis* (C), *Anagallis foemina*, *Arenaria leptoclados*, *Calendula arvensis* (C), *Carduus pycnocephalus*, *Centaurea sicula* (C.2), *Euphorbia peplus*, *Galactites tomentosus*, *Hypericum triquetrifolium* (C.2), *Hypochaeris achyrophorus*, *Lotus parviflorus*, *Medicago minima*, *Muscari comosum*, *Plantago lagopus* (C), *Rumex bucephalophorus*, *Sherardia arvensis*, *Silene nocturna* (C.2), *Tordylium apulum* (C.2), *Vulpia ciliata*.

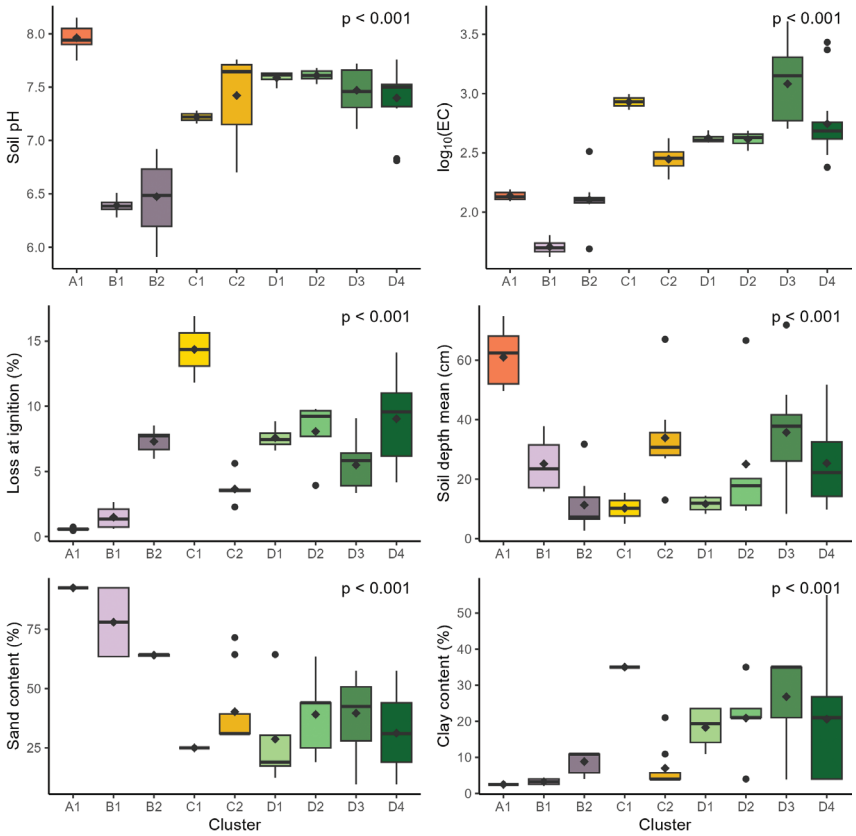

Figure 7. Comparison of six measured soil variables among the nine distinguished clusters of dry grasslands in Sicily. Boxplots denote median, inter-quartile range, total range and outliers, while the rhombuses stand for the arithmetic means. The *p*-values are from an ANOVA.

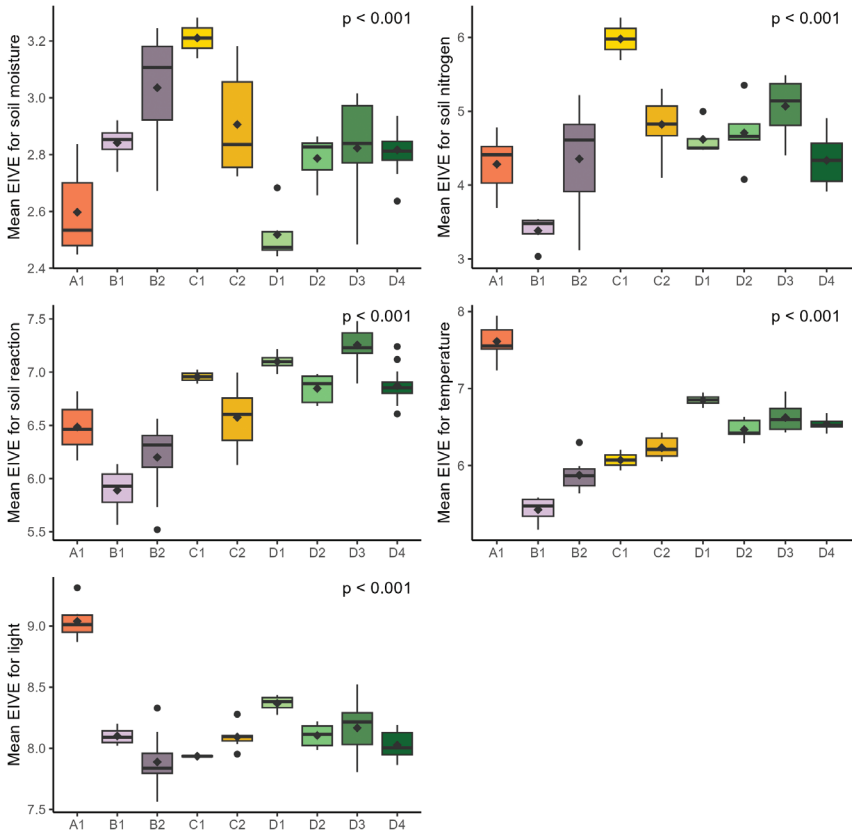

Figure 8. Comparison of the mean Ecological Indicator Values for Europe (EIVE) 1.0 among the nine distinguished clusters of dry grasslands in Sicily. Boxplots denote median, inter-quartile range, total range and outliers, while the rhombuses stand for the arithmetic means. The *p*-values are from an ANOVA.

Figure 9. Photos showing typical stands of the nine distinguished clusters. Locations and vegetation types are provided in the text under the cluster ID shown in the photo (Photos: J. Dengler).

This cluster comprises plots sampled between 280 and 320 m a.s.l. on the loose sandy soils of fossil dunes near Niscemi (SE Sicily), within thermomediterranean annual vegetation colonizing abandoned fields and olive groves. Among the surveyed grasslands, this was the richest in therophytes, forming relatively dense stands with highly variable species richness, ranging from 34 to 71 species per relevé (Suppl. material 4). The ruderal life strategy predominates (Figure 6), and character species of *Echio-Galactition tomentosae* (*Brometalia rubenti-tectorum*) are widely represented (Table 2).

In terms of structure and floristic composition, this vegetation resembles the association *Phleo echinati-Silenetum tenuiflorae* Bartolo et al. 1990, described from NE Sicily near Fiumedinisi (Bartolo et al. 1990). The annual grassland we studied may thus be interpreted as a southern vicariant of that association, and it might warrant formal recognition (*Sileno nocturnae-Vulpietum ciliatae* prov.), pending a comprehensive comparative analysis. Floristic elements of *Vulpio-Trisetarietum aureae* (*Trachynion distachyae*), which commonly occurs in less disturbed sites of the Hyblaean territory, were also well represented.

Cluster D.1

Frequent taxa: *Anagallis foemina*, *Anisantha rubens*, *Aschisma carniolicum* (D.1), *Asparagus albus* (D.1), *Asphodelus ramosus* (D), *Avena barbata*, *Barbula unguiculata*, *Bituminaria bituminosa* (D.1), *Blennothallia crispa* (lichen), *Brachypodium distachyon* (D), *Bryum dichotomum* (bryophyte), *Cenchrus ciliaris* (D.1), *Convolvulus althaeoides* (D.1), *Crupina crupinastrum* (D.1), *Enchylium tenax* (lichen), *Galactites tomentosus*, *Hippocrepis ciliata* (D.1), *Hyparrhenia hirta* (D), *Linum strictum*, *Lotus edulis*, *Microbryum davallianum* var. *commutatum* (bryophyte), *Nigella damascena* (D), *Prospero autumnale* (D.1), *Reichardia picroides* (D), *Scorpiurus muricatus* (D), *Sonchus oleraceus*, *Stipa capensis*, *Tripodion tetraphyllum* (D.1), *Urospermum picroides* (D.1), *Weissia condensa* (bryophyte, D.1), *Weissia longifolia* (bryophyte, D).

This cluster comprises plots sampled between 70 and 200 m a.s.l. on the southeastern slopes of Mt. Catalfano (NW Sicily), within thermoxerophilous grasslands colonizing stony, eroded, well-drained soils derived from the degradation of carbonate rocks. These stands correspond closely to *Cenchro ciliaris-Hyparrhenietum hirtae*, already reported from Sicily, besides of Mt. Catalfano, also near Taormina and in the Aeolian Islands (Brullo et al. 2010). Compared to relevés published from the same locality in the phytosociological literature (Gristina and Marcenò 2008), our samples are richer in therophytes, especially those of *Echio-Galactition tomentosae* (*Brometalia rubenti-tectorum*) and of *Brachypodietalia distachyi*. The balance between perennial and annual species, as well as between ruderal and stress-tolerant therophytes, is likely influenced by the combined effects of summer drought intensity, general disturbance, and fire frequency. This issue will be revisited in the Discussion.

Cluster D.2

Frequent taxa: *Anagallis arvensis*, *Anagallis foemina*, *Arisarum vulgare* (D), *Avena barbata* (D), *Blennothallia crispa* (lichen), *Cephaloziella baumgartneri* (bryophyte, D), *Dactylis glomerata* subsp. *hispanica*, *Dicranella howei* (bryophyte, D), *Didymodon acutus* (bryophyte, D.2), *Eryngium campestre*, *Euphorbia peplus*, *Fedia graciliflora*, *Hyparrhenia hirta* (D), *Hypochaeris achyrophorus*, *Linum trigynum*, *Lotus corniculatus*, *Lotus ornithopodioides*, *Lotus tetragonolobus*, *Moraea sisyrinchium*, *Reichardia picroides* (D), *Scandix australis*, *Stipa capensis*, *Tortella fasciculata* (bryophyte, D.2), *Trifolium campestre*, *Trifolium nigrescens* (D.2), *Vulpia ligustica* (D.2).

This cluster includes plots sampled between 10 and 100 m a.s.l. in frequently burnt wintergreen rangelands of SW and NW Sicily, on soils derived from carbonatic (Monte Cofano) or calcarenitic (Sciare di Mazara) parent material. Thermoxerophilous rangelands dominated by *Hyparrhenia hirta* are widespread across Sicily, from sea level up to 600 m a.s.l., and are typically created and maintained by recurrent fire. In this vegetation type, therophytes invariably co-occur amidst perennial species, and—as in the previous case—their frequency and composition are strongly influenced by human disturbance, particularly fire frequency and grazing pressure. The vegetation grouped in Cluster D.2, sampled in relatively disturbed stands, represents a mixture of two units widely recognized in the phytosociological literature of southwestern Europe: *Hyparrhenietum hirto-pubescentis* (when perennial species are sampled) and *Reichardio-Stipetum capensis* (when annual species are sampled). The perennial association is referred to *Hyparrhenion hirtae* (*Hyparrhenietalia*), whereas the therophytic one belongs to *Stipion retortae* (*Brachypodietalia distachyi*).

Cluster D.3

Frequent taxa: *Adonis microcarpa* (D.3), *Anagallis foemina*, *Anisantha madritensis*, *Anisantha rubens*, *Arisarum vulgare* (D), *Avena fatua*, *Brachypodium distachyon* (D), *Bryum dichotomum* (bryophyte), *Dactylis glomerata* subsp. *hispanica*, *Dicranella howei* (bryophyte, D), *Didymodon fallax* (bryophyte), *Ephemerum recurvifolium* (bryophyte), *Euphorbia exigua*, *Galactites tomentosus*, *Hedysarum spinosissimum* subsp. *capitatum* (D.3), *Hypochaeris achyrophorus*, *Lotus tetragonolobus*, *Lygeum spartum* (D.3), *Malope malacoides*, *Moraea sisyrinchium*, *Scorpiurus muricatus* (D), *Sherardia arvensis*, *Sonchus oleraceus*, *Squilla pancration*, *Trichostomum brachydontium* (bryophyte, D).

This cluster comprises plots sampled between 10 and 180 m a.s.l. in frequently burnt wintergreen rangelands of southern Sicily (Monte San Nicola, Butera), on clay-rich soils. All the considerations made for Cluster D.2 apply equally here, with the only difference that in this case the perennial subset can be assigned to the alliance *Moricandio-Lygeion sparti* and to the association *Phagnalo annotici-Lygeetum sparti*.

Cluster D.4
Frequent taxa: *Ampelodesmos mauritanicus* (D.4), *Anagallis foemina*, *Anemone hortensis*, *Anisantha rubens*, *Arisarum vulgare* (D), *Asphodelus ramosus* (D), *Bryum dichotomum* (bryophyte), *Cephaloziella baumgartneri* (bryophyte, D), *Coronilla scorpioides*, *Dactylis glomerata* subsp. *hispanica*, *Dicranella howei* (bryophyte, D), *Didymodon fallax* (bryophyte), *Euphorbia peplus*, *Fossombronia caespitiformis* (bryophyte), *Galium verrucosum*, *Hypochaeris achyrophorus*, *Linum strictum*, *Trichostomum brachydontium* (bryophyte, D).

This cluster comprises plots sampled between 40 and 220 m a.s.l. in frequently burnt wintergreen rangelands of central and western Sicily (Cattolica Eraclea, Monte Cofano), on limestone-rich, sloping, relatively deep soils. All the considerations made for Cluster D.2 apply equally here, with the only difference that in this case the perennial subset can be assigned to *Helictotricho convoluti-Ampelodesmetum mauritanici*.

Correspondence of the clusters with "classical" syntaxa

Based on the expert-assessment mimicking the prevailing practice of Mediterranean phytosociologists, only six out of the 67 10-m² plots would belong to a single class, while 33 could be assigned to two and 22 even to three classes simultaneously (Table 4). In nearly all cases, annual- and perennial-dominated classes co-occur in the same plot, rarely also a bryophyte community. The four main clusters differed clearly in their class combinations (Table 4): Cluster A combines *Helianthemetea guttati* with *Ammophiletea*, Cluster B *Poetea bulbosae* with *Chenopodietea* (and rarely *Drypidetea spinosae*), Cluster C *Chenopodietea* with *Artemisietea vulgaris* and Cluster D *Lygeo-Stipetea* with *Stipo-Trachynietea* (often combined with *Chenopodietea*). In some cases, the sequence of included classes is changing between lower-level clusters of the same main cluster. For example, in Cluster D.2 the annual class *Stipo-Trachynietea* is thought to prevail over the perennial class *Lygeo-Stipetea*, while it is the other way round for almost all plots of D.1, D.3 and D.4. Most of the lower-level clusters largely correspond to one recognised association within their prevailing class (see Suppl. material 3: table S3.1).

Discussion

Biodiversity

If we compare the vascular plant species richness in the Mediterranean grasslands of Sicily with the overall means for natural and semi-natural grasslands (groups A and B) of the Palaearctic in the GrassPlot Diversity Explorer (v.2.10; https://edgg.org/databases/GrasslandDiversityExplorer; see Biurrun et al. 2021) an interesting pattern emerges. While the Sicilian grasslands are on average 30% poorer in species at 0.0001 m², their richness increases faster with area so that the values are similar to the Palaearctic mean at 0.01 and 0.1 m², while from 1 m² upwards they are richer, reaching on average 32% more species in 100 m² (50.7 vs. 38.4 species). The finding of extraordinarily high species richness at the 100 m² grain size for grasslands in the southern Mediterranean was already reported by Biurrun et al. (2021; including the data of the present paper). Likewise, Dembicz et al. (2021, also including the current data) found that the species-area relationships become significantly steeper (i.e. have higher *z*-values) in Palaearctic grasslands when moving from the temperate zone south to a latitude like Sicily. One possible explanation for this phenomenon could be that at the small scales, the harsher conditions (compared to temperate grasslands, i.e. severe summer drought and heat) do not allow more species to occur, while at the larger spatial scales the much higher species pools in Southern Europe compared to temperate and Northern Europe come in. Interestingly, using the data from the European Vegetation Archive (EVA; Chytrý et al. 2016), mainly derived from traditional phytosociological sampling, Sabatini et al. (2022) found only average species richness in Sicily (and likewise other regions of the Mediterranean Basin at the same latitude) at 10 m² (ca. 16 species vs. 35.4 in our study) and 100 m² (ca. 25 vs. 50.7 in our study) and also only intermediate increments of the species-area relationship. One might wonder why the Sicilian data hand and the GrassPlot data in general (Biurrun et al. 2021) tell the opposite from the EVA data. We believe that one reason is that average phytosociological data are less complete because they were not sampled with the aim of biodiversity analyses. Second, this issue might be more pronounced in Mediterranean grasslands than elsewhere due to the sampling approach, commonly applied in this region, to disregard annual species when aiming to sample perennial communities and vice versa (see below). To test this assumption requires more extensive comparison of EVA and GrassPlot data, but if it would turn out true, this would render any continental or global scale diversity modelling based on phytosociological data problematic.

Non-vascular plant taxa on average contributed 15% to the taxonomic richness, mainly bryophytes with a tiny fraction of lichens (see Table 1). These fractions were almost identical across the seven grain sizes (Table 1) but varied much among vegetation types and sometimes also among plots within the same cluster, with up to 19 bryophytes (one plot of D.4) and up to 9 lichens (one plot of D.2) in 10 m² (see Figure 4). At least bryophytes are thus an important element of the Mediterranean dry grasslands. Compared to the mean of Palaearctic grasslands (groups A and B in the GrassPlot Diversity Explorer; https://edgg.org/databases/GrasslandDiversityExplorer; Biurrun et al. 2021), bryophytes were poorer in the smaller scales and richer in the two largest scales - and probably the same reasoning as for vascular plants could apply. By contrast, lichens were clearly poorer than in the Palaearctic average

Table 4. Correspondence of the nine clusters and the included vegetation plots to classes of the Mediterranean classification system (based on expert assessment by R. Guarino). A more detailed view including the alliance and association level is available in Suppl. material 3: table S3.1. The colours in the left part of the table refer to the coding of the nine clusters, while in the right part the phytosociological classes are grouped in perennial (red), annual (blue) and bryophyte-dominated (yellow). The classes are sorted from left to right according to their perceived prevalence in the plot.

Cluster	ID	Class 1	Class 2	Class 3
A.1	**IT09NE**	*Helianthemetea guttati*	*Ammophiletea*	
A.1	**IT09SW**	*Helianthemetea guttati*	*Ammophiletea*	
A.1	**IT11NE**	*Helianthemetea guttati*	*Ammophiletea*	
A.1	**IT11SW**	*Helianthemetea guttati*	*Ammophiletea*	
A.1	**ITR014**	*Helianthemetea guttati*	*Ammophiletea*	
A.1	**ITR015**	*Helianthemetea guttati*	*Ammophiletea*	
A.1	**ITR016**	*Helianthemetea guttati*	*Ammophiletea*	
B.1	**IT17NE**	*Chenopodietea*	*Poetea bulbosae*	*Drypidetea spinosae*
B.1	**IT17SW**	*Chenopodietea*	*Poetea bulbosae*	*Drypidetea spinosae*
B.1	**IT18NE**	*Poetea bulbosae*	*Chenopodietea*	
B.1	**IT18SW**	*Poetea bulbosae*	*Chenopodietea*	
B.2	**IT15NE**	*Chenopodietea*	*Poetea bulbosae*	
B.2	**IT15SW**	*Chenopodietea*	*Poetea bulbosae*	
B.2	**IT16NE**	[bryophyte comm.]	*Poetea bulbosae*	
B.2	**IT16SW**	*Poetea bulbosae*	*Poetea bulbosae*	
B.2	**IT19NE**	*Poetea bulbosae*	*Chenopodietea*	
B.2	**IT19SW**	*Chenopodietea*	*Poetea bulbosae*	
B.2	**ITR020**	*Chenopodietea*	*Poetea bulbosae*	
B.2	**ITR021**	*Chenopodietea*	*Poetea bulbosae*	
B.2	**ITR022**	*Poetea bulbosae*	*Chenopodietea*	
B.2	**ITR023**	[bryophyte comm.]	*Chenopodietea*	
C.1	**IT03NE**	*Artemisietea vulgaris*	*Chenopodietea*	
C.1	**IT03SW**	*Artemisietea vulgaris*	*Chenopodietea*	
C.2	**IT12NE**	*Chenopodietea*		
C.2	**IT12SW**	*Chenopodietea*		
C.2	**IT13NE**	*Chenopodietea*		
C.2	**IT13SW**	*Chenopodietea*		
C.2	**IT14N**	[bryophyte comm.]	*Chenopodietea*	
C.2	**IT14S**	[bryophyte comm.]	*Chenopodietea*	
C.2	**ITR018**	*Chenopodietea*		
C.2	**ITR019**	*Chenopodietea*		
D.1	**IT21NE**	*Lygeo-Stipetea*	*Stipo-Trachynietea*	*Chenopodietea*
D.1	**IT21SW**	*Lygeo-Stipetea*	*Stipo-Trachynietea*	*Chenopodietea*
D.1	**ITR026**	*Lygeo-Stipetea*	*Stipo-Trachynietea*	*Chenopodietea*
D.1	**ITR027**	*Lygeo-Stipetea*	*Stipo-Trachynietea*	*Chenopodietea*
D.2	**IT01NE**	*Stipo-Trachynietea*	*Lygeo-Stipetea*	*Chenopodietea*
D.2	**IT01SW**	*Stipo-Trachynietea*	*Lygeo-Stipetea*	*Chenopodietea*
D.2	**IT02NE**	*Stipo-Trachynietea*	*Lygeo-Stipetea*	*Chenopodietea*
D.2	**IT02SW**	*Stipo-Trachynietea*	*Lygeo-Stipetea*	*Chenopodietea*
D.2	**ITR017**	*Stipo-Trachynietea*	*Lygeo-Stipetea*	*Chenopodietea*
D.3	**IT07NE**	*Lygeo-Stipetea*	*Stipo-Trachynietea*	*Chenopodietea*
D.3	**IT07SW**	*Lygeo-Stipetea*	*Stipo-Trachynietea*	*Chenopodietea*
D.3	**IT08NE**	*Lygeo-Stipetea*	*Stipo-Trachynietea*	*Chenopodietea*
D.3	**IT08SW**	*Lygeo-Stipetea*	*Stipo-Trachynietea*	*Chenopodietea*
D.3	**IT10NE**	*Lygeo-Stipetea*	*Stipo-Trachynietea*	*Chenopodietea*
D.3	**IT10SW**	*Lygeo-Stipetea*	*Stipo-Trachynietea*	*Chenopodietea*
D.3	**ITR006**	*Stipo-Trachynietea*	*Lygeo-Stipetea*	*Chenopodietea*
D.3	**ITR007**	*Stipo-Trachynietea*	*Lygeo-Stipetea*	*Chenopodietea*
D.3	**ITR010**	*Lygeo-Stipetea*	*Stipo-Trachynietea*	*Chenopodietea*
D.3	**ITR011**	*Lygeo-Stipetea*	*Stipo-Trachynietea*	*Chenopodietea*
D.3	**ITR012**	*Lygeo-Stipetea*	*Stipo-Trachynietea*	*Chenopodietea*
D.4	**IT04NE**	*Lygeo-Stipetea*	*Stipo-Trachynietea*	
D.4	**IT04SW**	*Lygeo-Stipetea*	*Stipo-Trachynietea*	
D.4	**IT05NE**	*Lygeo-Stipetea*	*Stipo-Trachynietea*	
D.4	**IT05SW**	*Lygeo-Stipetea*	*Stipo-Trachynietea*	

Cluster	ID	Class 1	Class 2	Class 3
D.4	**IT06NE**	*Lygeo-Stipetea*	*Stipo-Trachynietea*	
D.4	**IT06SW**	*Lygeo-Stipetea*	*Stipo-Trachynietea*	
D.4	**IT20NE**	*Lygeo-Stipetea*	*Stipo-Trachynietea*	
D.4	**IT20SW**	*Lygeo-Stipetea*	*Stipo-Trachynietea*	
D.4	**ITR001**	*Lygeo-Stipetea*	*Stipo-Trachynietea*	
D.4	**ITR002**	*Stipo-Trachynietea*	*Lygeo-Stipetea*	
D.4	**ITR003**	*Lygeo-Stipetea*	*Stipo-Trachynietea*	
D.4	**ITR004**	*Lygeo-Stipetea*	*Stipo-Trachynietea*	
D.4	**ITR005**	*Lygeo-Stipetea*	*Stipo-Trachynietea*	
D.4	**ITR008**	*Lygeo-Stipetea*	*Stipo-Trachynietea*	
D.4	**ITR009**	*Lygeo-Stipetea*	*Stipo-Trachynietea*	
D.4	**ITR013**	*Lygeo-Stipetea*	*Stipo-Trachynietea*	

across all grain sizes. Very limited lichen components in dry grasslands had previously been reported in two other EDGG expeditions (with the same methodology), also from regions with rather warm and dry summers, namely the Central Apennines in Italy (Cancellieri et al. 2024) and Armenia (Vynokurov et al. 2024). While many lichens are well-adapted to drought, on soil they are mainly distributed in cooler climates. Epilithic lichens present on small stones and boulders in our sampling unit were not included in the species list, due to the sampling approach. By contrast, the average bryophyte richness in 10 m^2 plots in Sicily (6.0 species in 10 m^2) was much higher than in the Apennines (Cancellieri et al. 2024: 3.8 species) or Armenia (Vynokurov et al. 2024: 0.4 species). One reason for that might be the fact that many of our plots in Sicily had very clayish soils, which support a large diversity of tiny bryophytes, mainly from the family *Pottiaceae*.

Site conditions and life strategies

The site conditions, particularly the soils properties, varied widely among the dry grassland plots on Sicily – as expected given the highly diverse geology of the island. Soil texture ranged from sands to very clayish soils. Also soil reaction varied clearly between the plots, but even the most acidic plots had a pH of 6 and more. The absence of very low pH values is typical for arid regions where leaching is reduced since water in the soil mainly moves upwards, not downwards (Badía-Villas and del Moral 2015). The four main clusters were clearly separated by their soil conditions showing that soils are a primary driver of species composition. While the mean ecological indicator values largely matched the patterns of measured environmental variables, there was one notable exception. Cluster A.1 had by far the highest soil pH values (around 8), but at the same time the third-lowest mean EIVEs for soil reaction. One possible explanation could be that Mediterranean phytosociologists possibly assigned low R values to the typical species due to assumed acidity of sandy substrates. This explanation would also fit to the fact that the annual fraction of the community of cluster A.1 is traditionally placed in the class *Helianthemetea guttati* of therophyte-dominated acidic grasslands in the Mediterranean Basin (Mucina et al. 2016).

All our relevés included a mixture of stress-tolerant, competitive, and opportunistic species, though in varying proportions. Despite the limitations of our expert-based assignment of Grime's plant life strategies, it is noteworthy that the most species-rich stands were those characterized by a balance of all three strategies. This finding is consistent with other studies reporting positive effects of slight disturbance on the β-diversity of Mediterranean pastures (Rundel et al. 1998).

Our results suggest that, across the wide range of habitats we investigated, fine-scale species richness in Mediterranean dry grasslands is primarily driven by the equilibrium between stress-tolerant and competitive species. This balance is largely shaped by seasonal drought, which prevents competitive species from producing enough biomass to exclude annual plants from the interstitial spaces beneath perennial tussocks. The carrying capacity of Mediterranean ecosystems is not constant throughout the year: during the rainy season, soils temporarily become more "fertile" due to nutrient mobilization from soil water. This enrichment is quickly exploited by a wide range of annual plants, which, following Madon and Médail (1997), may be considered highly specialized stress-tolerant species. These Mediterranean therophytes play a crucial ecological role: they reduce soil erosion during heavy rains, substantially contribute to biomass production, and provide food for a large array of granivores, pollinators, and herbivores (Guarino et al. 2020). In phytosociological terms, this fundamental relationship between perennial and annual species coexisting in most Mediterranean dry grasslands is expressed in terms of *Lygeo-Stipetea*, with reference to perennial species, and *Stipo-Trachynietea* or *Helianthemetea guttati*, with reference to annual species on alkaline or subacid soils, respectively. With reference to coastal psammophilous vegetation, analogous relationship links the perennial vegetation of the order *Ammophiletalia arundinaceae* and the annual vegetation of the *Vulpietalia*. Likewise, with reference to sheep pasturelands, between the perennial *Poetea bulbosae* and the annual *Helianthemetea guttati*.

Disturbance represents the second major driver of fine-scale species assemblages in Mediterranean dry grasslands. It favours the establishment of species with a ruderal life strategy; in our plots, several taxa of the order *Brometalia rubenti-tectorum* were consistently recorded across vegetation types. These highly adaptable, wide-ranging

synanthropic species can complicate the phytosociological classification of Mediterranean dry grasslands. Disturbance introduces substantial floristic "noise", which may obscure the original community structure, especially in secondary, man-made habitats (Fernández Alés et al. 1993; Lavorel et al. 1999). It should be noted that the boundaries and floristic differences between alliances such as *Stipion retortae*, assigned to the class *Stipo-Trachynietea*, and alliances such as *Echio-Galactition*, assigned to the class *Chenopodietea*, are rather vague. This reflects the fact that the Mediterranean region is the centre of origin for many synanthropic *Chenopodietea* species, which often occur not only in man-made habitats but also in sites disturbed by natural processes, such as coastal slopes frequented by seagulls.

Syntaxonomy of the studied grasslands vs. diverging sampling approaches in phytosociology

Our results suggest that in Sicily there are floristically well-separated dry grassland types, as demonstrated by the long lists of diagnostic species both for the higher and lower TWINSPAN cluster resolution. The units at both hierarchical levels are also well characterised ecologically, with clear differences in site conditions, particularly soils. Four main clusters were distinguished: coastal dunes on basic sands (Cluster A), lowland dry grasslands on alkaline clayish soils (Cluster D), acidic dry grasslands found at higher elevation (Cluster B), and sub-ruderal, relatively base-rich dry grasslands at intermediate elevation (Cluster C). While elevational differentiation might have been partially exaggerated by the limited sample size, soil differences are beyond doubt, being directly reflected in the ecological traits of the included species (CSR, EIVE).

Annual and perennial vascular plant species were recorded in all relevés, while non-vascular plant taxa were absent only from coastal sand dunes (Cluster A) and from heavily grazed and trampled rangelands (Cluster C.1). Importantly, bryophytes contributed substantially to overall plot-scale species richness, particularly in stands dominated by perennials, and some species even proved to have diagnostic value, though lower than that of vascular plant taxa. This finding is consistent with observations in other Mediterranean vegetation types where bryophytes have traditionally been overlooked, such as Mediterranean temporary ponds (Poponessi et al. 2015).

We did not find in our unsupervised classification groups corresponding to the "contemporary" Mediterranean vegetation classes that are nowadays typically restricted to either annual or perennial vegetation (see Table 4; Mucina et al. 2016; https://floraveg.eu/vegetation). For example, our main Cluster D included communities traditionally assigned both to perennial grasslands on basic soils (*Lygeo-Stipetea*) and to annual grasslands on basic soils (*Stipo-Trachynietea*). At a lower hierarchical level, a separation emerged between units dominated by annual vascular plants (B.2, C.2, D.2) and those dominated by perennials (hemicryptophytes or geophytes). However, viewed from the Mediterranean phytosociological perspective, not only the main clusters but almost every single plot represented a mixture of annual and perennial communities, despite having been selected for homogeneity. Every plot included both annual and perennial vascular plants, and all except clusters A.1 and C.1 also contained non-vascular plant taxa. This applied not only to overall composition but also to diagnostic species combinations of both higher- and lower-level clusters, which included annual and perennial vascular plants and frequently bryophytes (see Table 2 and Suppl. material 4).

By contrast, the diagnostic species lists of Mediterranean classes provided by Mucina et al. (2016) suggest that "perennial" grassland classes such as *Lygeo-Stipetea* include almost only perennial diagnostic species (with few annual exceptions, e.g. *Cerastium* taxa), while "annual" classes such as *Stipo-Trachynietea* list almost exclusively annual species (but include the perennial *Sanguisorba verrucosa*). However, considering the recent revisions of two of the "perennial" Mediterranean grassland classes based on comprehensive datasets, *Ammophiletea* by Marcenò et al. (2018) and *Lygeo-Stipetea* by Marcenò et al. (2019), it becomes evident that the picture drawn by the diagnostic species lists of Mucina et al. (2016) is largely unrealistic. In both cases, the authors demonstrated that the so-called "perennial" syntaxa include a substantial number of annual diagnostic species, sometimes even exclusively annual ones. This is essentially due to two reasons. First, as already mentioned, in the sampling approach adopted by many Mediterranean phytosociologists following Rivas-Martínez (1978) and Gèhu (1996), the representatives of one life form were recorded together with frequent "companion" species of the other, thus inevitably mixing annuals and perennials. Second, the consensus around the "choosy" sampling approach emerged in Spain during the late 1970s and soon spread to France, Italy and beyond, whereas the datasets incorporated in the European Vegetation Archive also include older surveys pre-dating this approach (e.g. Bolòs and Bolòs 1950; Rivas Goday 1957). It should also be noted that the sampling approach of Mediterranean phytosociologists was far from being unanimous; for instance, relevés from Mediterranean dry grasslands sampled by Quézel and his school (Aydogdu et al. 1994; Akman et al. 1996) are on average richer in species than those sampled by Gèhu, Rivas-Martínez, and their followers (Géhu et al. 1987; Martínez Parras and Peinado 1987; Rivas-Martínez et al. 1990).

In our dataset, even the grassland types dominated by perennials have specific annual species that occur there more often than in predominantly therophytic grasslands (see, for example, annual species more frequent in perennial clusters D.1, D.3, D.4 than in the therophytic cluster D.2). In principle, one or several vegetation classes could still represent predominantly therophytic grasslands. However, our analyses suggest that such therophytic types (B.2, C.2, D.2) are nested within broader grassland types defined primarily by soil and elevation and thus might be better treated at the order or alliance level. Similarly,

Vassilev et al. (2024) found that in the Central Balkan Peninsula, from the various Mediterranean grassland classes given in the literature, only one on acidic and one on base-rich soil could be distinguished. Despite analysing large datasets, they were unable to separate annual and perennial Mediterranean grasslands at the alliance level. While their study area lies at the northern distributional border of these syntaxa – where separation might be blurred – also García-Mijangos et al. (2021) in the fully Mediterranean Ebro valley in Spain could not distinguish the *Stipo-Trachynietea* from the *Lygeo-Stipetea* at class level. Together these observations suggest that the number of grassland classes recognised by Mucina et al. (2016) in the Mediterranean lowlands may be excessive.

Part of the reason for this inflation of higher syntaxa is the widespread adoption of what could be called a "pseudo-synusial" approach. While the integrated synusial method (Gillet and Julve 2018) records and classifies tree, shrub, herb, and moss layers separately, many Mediterranean authors partially separate annual and perennial vascular plants within the same relevés but then analyse them together. This leads to inconsistent and poorly reproducible results. Although these authors often claim to follow Braun-Blanquet's methodology, they in fact depart from it. In Braun-Blanquet's (1961) seminal study of xerothermic vegetation in inner alpine valleys, he recorded all life forms—chamaephytes, hemicryptophytes, geophytes, therophytes, and non-vascular plant taxa—within the same relevé. The pseudo-synusial practice complicates vegetation mapping, as many plots end up representing multiple higher syntaxa, and it undermines conservation assessments and biodiversity analyses, since area-based indicators based on incomplete species records yield biased results. In biodiversity assessments, the inclusion of multiple life forms invariably improves accuracy and robustness across ecosystems. For strictly phytosociological classification of Mediterranean dry grasslands, however, recording vascular plants only remains acceptable, provided the limitations are clearly acknowledged and data comparability is ensured (Guarino et al. 2022).

Turning to the central question of the syntaxonomic position of Sicilian dry grasslands and the relationship between annual- and perennial-dominated grasslands, our results indicate that while pure stands of annual species may occur in extreme habitats or under strong disturbance, most stands host both life forms together. Had we adopted the synusial approach, we would have missed what we consider the most interesting outcome of our study: the coexistence of contrasting life forms within the same stands and the ecological insights that this coexistence provides. A possible way to reconcile syntaxa based on merocoenoses with those representing entire communities would be to return to the original concept of *Thero-Brachypodietea* and re-establish distinct orders for vegetation dominated by annuals versus perennials, as in early Mediterranean phytosociological research.

Setting syntaxonomical issues aside, our recommendation is to adopt the most comprehensive sampling possible, recording all life forms together and later analysing their relative contributions as we did. Relevés should be assigned to phytosociological units only after careful evaluation of diagnostic, constant, and dominant species. This approach avoids discarding syntaxa described under the synusial perspective but integrates them within a more inclusive framework. In the long run, such a strategy will promote more objective, comparable, and ecologically meaningful results.

Conclusions and outlook

We found that the communities of the dry grasslands in Sicily are floristically very well characterised and ecologically well separated, but they hardly matched the contemporary syntaxonomic system as implemented in the "EuroVegChecklist" (Mucina et al. 2016). With essentially each stand being composed by a mixture of different vascular and non-vascular plant life forms, the Sicilian dry grasslands are not an exception, but fully match patterns found in dry grasslands throughout Europe. Thus, it is hardly justifiable to treat them in a deviating methodological manner as some Mediterranean authors did by mentally splitting them in "perennial" and "annual" communities. This approach, where homogeneous plots mostly would belong to two or even three phytosociological classes, impedes the application in conservation and mapping. Moreover, it creates inconsistencies in the European syntaxonomic classification system (Mucina et al. 2016), which thereby would not meet the central requirement for a sound classification system to be built on one consistent methodology (De Càceres et al. 2015). Finally, this approach of intentionally not recording certain species in a plot leads to erroneous biodiversity assessments, ranking Mediterranean grasslands as having only average alpha and beta diversity (Sabatini et al. 2022), while in reality their alpha and beta diversity is clearly above average (Dengler et al. 2020; Biurrun et al. 2021). We thus recommend recording and sampling Mediterranean grassland in the same way as this is done for grasslands in the rest of Europe. With our regional study and limited dataset, we cannot forecast what the consequence of such a consistent methodology across Europe would be but likely the number of dry grassland classes in the Mediterranean lowlands would have to be reduced when future broad-scale classification syntheses are conducted. For these as well as for studies on biodiversity patterns, it would be crucial to find a way to filter out from the EVA database (Chytrý et al. 2016) those plots that were recorded with what we call the "pseudo-synusial" approach as these are strongly biasing any results.

Data availability

The original data underlying this study are provided in Suppl. material 1 and are also stored in the GrassPlot database (Dengler et al. 2018).

Author contributions

JD developed the EDGG sampling methodology, while RG organised the fourth EDGG Field Workshop, in which all authors participated and contributed to the data collection in the field. RG revised critical vascular plants, while microscopical determination of lichens and bryophytes were done by CD. RG, JD, TB, ID and CD jointly planned the manuscript. Statistical analyses were mainly conducted by TB and ID, diagnostic species analysed by JD and the syntaxonomic interpretation contributed by RG. The text was drafted jointly by RG and JD, while all other authors revised and approved the manuscript.

Acknowledgements

We thank those participants of the Field Workshop who greatly helped with field sampling, but opted not to be co-authors of this paper: Ute Becker, Eleonora Giarizzo, Gianpietro Giusso del Galdo, Martin Rejžek, Ieva Rove and Aslan Ünal. ID acknowledges a BayFOR short-term scholarship, which allowed her to work on the study during a research stay with JD in Bayreuth. Finally, we are grateful to Erwin Bergmeier and three anonymous reviewers who with their speedy and detailed recommendations contributed significantly to the refinement of the manuscript.

References

Aboling S, Sternberg M, Perevolotsky A, Kigel J (2008) Effects of cattle grazing timing and intensity on soil seed banks and regeneration strategies in a Mediterranean grassland. Community Ecology 9: 97–106. https://doi.org/10.1556/ComEc.9.2008.S.14

Akman Y, Vural M, Quézel P, Kurt L, Ketenoğlu O, Serin M, Barbero M (1996) Etude de la végétation steppique de la région de Karaman et d'Ermenek (sud de l'Anatolie Centrale). Ecologia Mediterranea 22(3–4): 1–7. https://doi.org/10.3406/ecmed.1996.1804

Aleffi M, Tacchi R, Poponessi S (2020) New checklist of the bryophytes of Italy. Cryptogamie, Bryologie 41: 147–195. https://doi.org/10.5252/cryptogamie-bryologie2020v41a13

Aydogdu M, Akman Y, Quézel P, Barbero M, Ketenoğlu O, Kurt L (1994) Syntaxonomic analysis of gypsaceous vegetation of the surrounding area between Ayas-Polatli and Beypazari (Ankara, Turkey). Ecologia Mediterranea 20(3–4): 9–19. https://doi.org/10.3406/ecmed.1994.1738

Badía-Villas D, del Moral F (2015) Soils of the arid areas. In: Gallardo JF (Ed.) The soils of Spain. Springer, Cham, CH, 145–161. https://doi.org/10.1007/978-3-319-20541-0_4

Bartolo G, Minissale P, Sorbello R, Spampinato G (1990) Su alcuni aspetti di vegetazione nitrofila della valle del Fiumedinisi (Sicilia orientale) [On some aspects of nitrophilous vegetation of the Fiumedenisi valley (eastern Sicily]. Bollettino dell'Accademia Gioenia di Scienze Naturali 28: 5–18.

Bazan G, Marino P, Guarino R, Domina G, Schicchi R (2015) Bioclimatology and vegetation series in Sicily: a geostatistical approach. Annales Botanici Fennici 52: 1–18. https://doi.org/10.5735/085.052.0202

Belnap J, Welter JR, Grimm NB, Barger N, Ludwig JA (2005) Linkages between microbial and hydrologic processes in arid and semiarid watersheds. Ecology 86: 298–307. https://doi.org/10.1890/03-0567

Biurrun I, Burrascano S, Dembicz I, Guarino R, Kapfer J, Pielech R, Garcia-Mijangos I, Wagner V, Palpurina S, … Dengler J (2019) GrassPlot v. 2.00 – first update on the database of multi-scale plant diversity in Palaearctic grasslands. Palaearctic Grasslands 44: 26–47. https://doi.org/10.21570/EDGG.PG.44.26-47

Biurrun I, Pielech R, Dembicz I, Gillet F, Kozub Ł, Marcenò C, Reitalu T, van Meerbeek K, Guarino R, … Dengler J (2021) Benchmarking plant diversity of Palaearctic grasslands and other open habitats. Journal of Vegetation Science 32: e13050. https://doi.org/10.1111/jvs.13050

Blasi C, Bovio G, Corona P, Marchetti M, Maturani A (2004) Incendi e complessità ecosistemica [Fires and ecosystem complexity]. Palombi ed., Roma, IT, 355 pp.

Bolòs A, Bolòs O (1950) Vegetación de las comarcas barcelonesas. Instituto Español de Estudios Mediterráneos, Barcelona, ES, 579 pp.

Bonanomi G, Incerti G, Abd El-Gawad AM, Cesarano G, Sarker TC, Saulino L, Lanzotti V, Saracino A, Rego FC, … Mazzoleni S (2018) Comparing chemistry and bioactivity of burned vs. decomposed plant litter: different pathways but same result? Ecology 99: 158–171. https://doi.org/10.1002/ecy.2053

Botta-Dukát Z, Chytrý M, Hajková P, Havlová M (2005) Vegetation of lowland wet meadows along a climatic continentality gradient in Central Europe. Preslia 77: 89–111.

Braun-Blanquet J (1961) Die inneralpine Trockenvegetation. Fischer, Stuttgart, DE, 273 pp.

Brullo S, Marcenò C (1985) Contributo alla conoscenza della vegetazione nitrofila della Sicilia [Contribution to the knowledge of nitrophilous vegetation in Sicily]. Colloques Phytosociologiques 12: 23–148.

Brullo S, Guarino R, Ronsisvalle G (2000) La vegetazione del litorale di Manfria, presso Gela (Sicilia), area soggetta a vincolo archeologico [The vegetation of the Manfria coastline near Gela (Sicily), an area subject to archaeological protection]. Archivio Geobotanico 4: 91–107.

Brullo S, Cormaci A, Guarino R, Musarella CM (2007a) Syntaxonomical survey of *Geranio-Cardaminetalia hirsutae*: semi-natural therophytic vegetation of the Mediterranean Region. Annali di Botanica N.S. 7: 183–216.

Brullo S, Giusso del Galdo G, Guarino R, Minissale P, Spampinato G (2007b) A survey of the weedy communities of Sicily. Annali di Botanica N.S. 7: 127–161.

Brullo C, Brullo S, Giusso del Galdo G, Guarino R, Minissale P, Scuderi L, Siracusa G, Sciandrello S, Spampinato G (2010) The *Lygeo-Stipetea* class in Sicily. Annali di Botanica, IV Serie 0: 57–84.

Cancellieri L, Sperandii MG, Rosati L, Bellisario B, Franceschini C, Aleffi M, Bartolucci F, Becker T, Belonovskaya E, … Filibeck G (2024) Drivers of vascular plant, bryophyte and lichen richness in grasslands along a precipitation gradient (central Apennines, Italy). Journal of Vegetation Science 35: e13305. https://doi.org/10.1111/jvs.13305

Chytrý M, Tichý L, Holt J, Botta-Dukát Z (2002) Determination of diagnostic species with statistical fidelity measures. Journal of Vegetation Science 13: 79–90. https://doi.org/10.1111/j.1654-1103.2002.tb02025.x

Chytrý M, Hennekens SM, Jiménez-Alfaro B, Knollová I, Dengler J, Jansen F, Landucci F, Schaminée JHJ, Aćić S, … Yamalov S (2016) European Vegetation Archive (EVA): an integrated database of European vegetation plots. Applied Vegetation Science 19: 173–180. https://doi.org/10.1111/avsc.12191

De Cáceres M, Chytrý M, Agrillo E, Attorre F, Botta-Dukát Z, Capelo J, Czúcz B, Dengler J, Ewald J … Wiser SK (2015) A comparative framework for broad-scale plot-based vegetation classification. Applied Vegetation Science 18: 543–560. https://doi.org/10.1111/avsc.12179

de Foucault B (1999) Nouvelle contribution à une synsystématique des pelouses sèches à thérophytes. Documents Phytosociologiques N.S. 19: 47–105.

Dembicz I, Dengler J, Steinbauer MJ, Matthews TJ, Bartha S, Burrascano S, Chiarucci A, Filibeck G, Gillet F, … Biurrun I (2021) Fine-grain beta diversity of Palaearctic grassland vegetation. Journal of Vegetation Science 32: e13045. https://doi.org/10.1111/jvs.13045

Dengler J (2008) Pitfalls in small-scale species-area sampling and analysis. Folia Geobotanica 43: 269–287. https://doi.org/10.1007/s12224-008-9014-9

Dengler J, Dembicz I (2023) Should we estimate plant cover in percent or on ordinal scales? Vegetation Classification and Survey 4: 131–138. https://doi.org/10.3897/VCS.98379

Dengler J, Boch S, Filibeck G, Chiarucci A, Dembicz I, Guarino R, Henneberg B, Janišová M, Marcenò C, … Biurrun I (2016) Assessing plant diversity and composition in grasslands across spatial scales: the standardised EDGG sampling methodology. Bulletin of the Eurasian Dry Grassland Group 32: 13–30.

Dengler J, Wagner V, Dembicz I, García-Mijangos I, Naqinezhad A, Boch S, Chiarucci A, Conradi T, Filibeck G, … Biurrun I (2018) GrassPlot – a database of multi-scale plant diversity in Palaearctic grasslands. Phytocoenologia 48: 331–347. https://doi.org/10.1127/phyto/2018/0267

Dengler J, Biurrun I, Boch S, Dembicz I, Török P (2020) Grasslands of the Palaearctic biogeographic realm: introduction and synthesis. In: Goldstein MI, Della Sala DA, Di Paolo DA (Eds) Encyclopedia of the world's biomes. Volume 3: Forests - trees of life. Grasslands and shrublands - sea of plants. Elsevier, Amsterdam, NL, 617–637. https://doi.org/10.1016/B978-0-12-409548-9.12432-7

Dengler J, Jansen F, Chusova O, Hüllbusch E, Nobis MP, Van Meerbeek K, Axmanová I, Bruun HH, Chytrý M, … Gillet F (2023) Ecological Indicator Values for Europe (EIVE) 1.0. Vegetation Classification and Survey 4: 7–29. https://doi.org/10.3897/VCS.98324

Diekmann M (2003) Species indicator values as an important tool in applied plant ecology – a review. Basic and Applied Ecology 4: 493–506. https://doi.org/10.1078/1439-1791-00185

Euro+Med (2025) Euro+Med PlantBase - the information resource for Euro-Mediterranean plant diversity. http://ww2.bgbm.org/EuroPlusMed/ [accessed 26 Sep 2025]

Fernández Alés R, Laffarga JM, Ortega F (1993) Strategies in Mediterranean grassland annuals in relation to stress and disturbance. Journal of Vegetation Science 4: 313–322. https://doi.org/10.2307/3235589

Fierotti G (1997) I suoli della Sicilia [The soils in Sicily]. D. Flaccovio Editore, Palermo, IT, 359 pp.

Finetti IR, Lentini F, Carbone S, Del Ben A, Di Stefano A, Forlin E, Guarnieri P, Pipan M, Prizzon A (2005) Geological outline of Sicily and lithospheric tectono-dynamics of its Tyrrhenian margin from new CROP seismic data. In: Finetti IR (Ed.) CROP PROJECT: Deep seismic exploration of the central Mediterranean and Italy. Elsevier, Amsterdam, NL, 319–371.

Frahm JP (2010) Mosses and liverworts of the Mediterranean. Books on Demand, Norderstedt, DE, 140 pp.

Frey W, Frahm JP, Fischer E, Lobin W (2006) The liverworts, mosses and ferns of Europe. Harley, Colchester, Essex, UK. https://doi.org/10.1163/9789004475434

Galán de Mera A, Morales R, Vicente JA (2000) Pasture communities linked to ovine stock. A synthesis of the *Poetea bulbosae* class in the western Mediterranean Region. Phytocoenologia 30: 223–267. https://doi.org/10.1127/phyto/30/2000/223

García-Mijangos I, Berastegi A, Biurrun I, Dembicz I, Janišová M, Kuzemko A, Vynokurov D, Ambarlı D, Etayo J, … Dengler J (2021) Grasslands of Navarre (Spain), focusing on the *Festuco-Brometea*: classification, hierarchical expert system and characterisation. Vegetation Classification and Survey 2: 195–231. https://doi.org/10.3897/VCS/2021/69614

Garnier E (1992) Growth analysis of congeneric annual and perennial grass species. Journal of Ecology 80: 665–675. https://doi.org/10.2307/2260858

Gaujour E, Amiaud B, Mignolet C, Plantureux S (2012) Factors and processes affecting plant biodiversity in permanent grasslands: a review. Agronomy for Sustainable Development 32: 133–160. https://doi.org/10.1007/s13593-011-0015-3

GBIF (2025) GBIF - Global Biodiversity Information Facility: free and open access to biodiversity data. https://www.gbif.org [accessed 27 Sep 2025]

Géhu JM, Géhu-Frank J (1986) Données synsystematiques et synchorologiques sur la végétation du littoral tunisien de Bizerte a Gabes. Documents Phytosociologiques 10b: 127–155.

Géhu JM (1996) Épistémologie de la territorialité en phytosociologie. Giornale Botanico Italiano 130: 189–199. https://doi.org/10.1080/11263509609439526

Géhu JM, Costa M, Biondi E, Franck J, Arnold N (1987) Données sur la végétation littorale de la Crète (Grèce). Ecologia Mediterranea 13: 93–105. https://doi.org/10.3406/ecmed.1987.1615

Gillet F, Julve F (2018) The integrated synusial approach to vegetation classification and analysis. Phytocoenologia 48: 141–152. https://doi.org/10.1127/phyto/2017/0164

Graco-Roza C, Aarnio S, Abrego N, Acosta ATR, Alahuhta J, Altman J, Angiolini C, Aroviita J, Attorre F, … Soininen J (2022) Distance decay 2.0 – A global synthesis of taxonomic and functional turnover in ecological communities. Global Ecology and Biogeography 31: 1399–1421. https://doi.org/10.1111/geb.13513

Grime JP (1988) The C -S -R model of primary plant strategies - origins, implications and tests. In: Gottlieb LD, Jain SK (Eds) Plant evolutionary biology. Chapman & Hall, London, UK, 371–393. https://doi.org/10.1007/978-94-009-1207-6_14

Gristina AS, Marcenò C (2008) Gli indici di bioindicazione di Pignatti-Ellenberg nello studio floristico-vegetazionale del promontorio di Capo Zafferano (Sicilia nord-occidentale) [The Pignatti-Ellenberg bioindication indices in the floristic-vegetational study of the Capo Zafferano promontory (NW Sicily)]. Naturalista Siciliano 32: 61–96.

Guarino R (2011) Green landscapes of Sicily. Bulletin of the Eurasian Dry Grassland Group 13: 16–25.

Guarino R, Pasta S (2017) Botanical excursions in central and western Sicily. Field Guide for the 60th IAVS Symposium Palermo, 20–24 June 2017. Palermo University Press, Palermo, IT, 604 pp.

Guarino R, Ferrario E, Mossa L (2005) A stochastic model of seed dispersal pattern to assess seed predation by ants in annual dry grasslands. Plant Ecology 178: 225–235. https://doi.org/10.1007/s11258-004-3655-4

Guarino R, Minissale P, Sciandrello S (2008) La biodiversità vegetale e relativa cartografia del pS.I.C. "Torre Manfria" (Gela – CL) [Plant biodiversity and related mapping in the "Torre Manfria S.C.I." (Gela – CL)]. Quaderni di Botanica Ambientale e Applicata 19: 37–66.

Guarino R, Becker T, Dembicz I, Dolnik C, Kacki Z, Kozub Ł, Rejzek M, Dengler J (2012) Impressions from the 4th EDGG Research Expedition to Sicily: community composition and diversity of Mediterranean grasslands. Bulletin of the Eurasian Dry Grassland Group 15: 12–22.

Guarino R, Willner W, Pignatti S, Attorre F, Loidi J (2018) Spatio-temporal variations in the application of the Braun-Blanquet approach in Europe. Phytocoenologia 48: 239–250. https://doi.org/10.1127/phyto/2017/0181

Guarino R, Vrahnakis M, Rodriguez Rojo MP, Giuga L, Pasta S (2020) Grasslands and shrublands of the Mediterranean region. In: Goldstein MI, Della Sala DA, Di Paolo DA (Eds) Encyclopedia of the world's biomes. Volume 3: Forests - trees of life. Grasslands and shrublands – sea of plants. Elsevier, Amsterdam, NL, 638–655. https://doi.org/10.1016/B978-0-12-409548-9.12119-0

Guarino R, Guccione M, Gillet F (2022) Plant communities, synusiae and the arithmetic of a sustainable classification. Vegetation Classification and Survey 3: 7–13. https://doi.org/10.3897/VCS.60951

Hill MO (1979) TWINSPAN – A Fortran program for arranging multivariate data in an ordered two-way table by classification of the individuals and attributes. Cornell University, Ithaca, NY, US.

Joffre R (1990) Plant and soil nitrogen dynamics in Mediterranean grasslands: a comparison of annual and perennial grasses. Oecologia 85: 142–149. https://doi.org/10.1007/BF00317355

Lavorel S, McIntyre S, Grigulis K (1999) Plant response to disturbance in a Mediterranean grassland: How many functional groups? Journal of Vegetation Science 10: 661–672. https://doi.org/10.2307/3237081

Madon O, Médail F (1997) The ecological significance of annuals on a Mediterranean grassland (Mt Ventoux, France). Plant Ecology 129: 189–199. https://doi.org/10.1023/A:1009759730000

Marcenò C, Guarino R, Loidi J, Herrera M, Isermann M, Knollová I, Tichý L, Tzonev RT, Acosta ATR, … Chytrý M (2018) Classification of European and Mediterranean coastal dune vegetation. Applied Vegetation Science 21: 533–559. https://doi.org/10.1111/avsc.12379

Marcenò C, Guarino R, Mucina L, Biurrun I, Deil U, Shaltout K, Finckh M, Font X, Loidi J (2019) A formal classification of the *Lygeum spartum* vegetation of the Mediterranean Region. Applied Vegetation Science 22: 593–608. https://doi.org/10.1111/avsc.12456

Marcenò C, Danihelka J, Dziuba T, Willner W, Chytrý M (2024) Nomenclatural revision of the syntaxa of European coastal dune vegetation. Vegetation Classification and Survey 5: 27–37. https://doi.org/10.3897/VCS.108560

Martínez Parras JM, Peinado M (1987) La vegetación de la alianza *Andryalion agardhii* Rivas Martínez 1961. Lazaroa 7: 293–300.

McCune B, Grace JB (2002) Analysis of ecological communities. MjM Software Design, Gleneden Beach, Oregon, US, 300 pp.

Menke JW (1989) Management controls on productivity. In: Huenneke LF, Mooney H (Eds) Grassland structure and function: California annual grassland. Kluwer Academic Publisher, Dordrecht, NL, 173–199. https://doi.org/10.1007/978-94-009-3113-8_15

Mossa L, Guarino R, Fogu MC (2004) La componente terofitica della flora della Sardegna. Forme di crescita, ecologia, corologia e sinsistematica [The therophytic component of the flora of Sardinia. Growth forms, ecology, chorology and synsystematics]. Rendiconti del Seminario della Facoltà di Scienze dell'Università di Cagliari 73: 1–209.

Mucina L, Bültmann H, Dierßen K, Theurillat JP, Raus T, Čarni A, Šumberová K, Willner W, Dengler J, … Tichý L (2016) Vegetation of Europe: Hierarchical floristic classification system of vascular plant, bryophyte, lichen, and algal communities. Applied Vegetation Science 19(suppl. 1): 3–264. https://doi.org/10.1111/avsc.12257

Naveh Z (1991) Mediterranean uplands as anthropogenic perturbation dependent systems and their dynamic conservation management. In: Ravera OA (Ed.) Terrestrial and aquatic ecosystems, perturbation and recovery. Ellis Horwood, New York, US, 544–556.

Nimis PL, Conti M, Martellos S (2025) ITALIC – The Information System on Italian Lichens. Version 8.0. University of Trieste. [accessed 26 Sep 2025]

Oksanen J, Blanchet FG, Kindt R, Legendre P, Minchin PR, O'Hara RB, Simpson GL, Solymos P, Stevens MHH, Wagner H (2025) vegan: community ecology package. R package version 2.7-1. http://cran.r-project.org/package=vegan [accessed 26 Sep 2025]

Ostrowski G, Aicher S, Mankiewicz A, Chusova O, Dembicz I, Widmer S, Dengler J (2025) Mean ecological indicator values: use EIVE but no cover-weighting. Vegetation Classification and Survey 6: 57–67. https://doi.org/10.3897/VCS.134800

Pierce S, Negreiros D, Cerabolini BEL, Kattge J, Díaz S, Kleyer M, Shipley B, Wright SJ, Soudzilovskaia NA, … Tampucci D (2017) A global method for calculating plant CSR ecological strategies applied across biomes world-wide. Functional Ecology 31: 444–457. https://doi.org/10.1111/1365-2435.12722

Pignatti S (1982) Flora d'Italia. 3 vols. Edagricole, Bologna, IT.

Pignatti S, Guarino R, La Rosa M (2017–2019) Flora d'Italia. 4 vols. Edagricole, Bologna, IT.

Poponessi S, Aleffi M, Bricchi E, Maneli F, Venanzoni R, Gigante D (2015) Role of bryophytes in the vegetation of Mediterranean temporary ponds close to the temperate bioclimatic border. In: Pisanu S, Bagella S (Eds) International Symposium on Mediterranean Temporary Ponds. Book of abstracts. Edizioni P. Ass. I. Flora Ambiente, IT, 60–60.

Puigdefábregas J, Sole A, Gutierrez L, Del Barrio G, Boer M (1999) Scales and processes of water and sediment redistribution in drylands: results from the Rambla Honda field site in Southeast Spain. Earth-Science Reviews 48: 39–70. https://doi.org/10.1016/S0012-8252(99)00046-X

R Core Team (2025) R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna, AT. http://www.R-project.org/ [accessed 26 Sep 2025]

Raunkiaer C (1905) Types biologiques pour la géographie botanique – Planterigets Livsformer og deres Betydning for Geografien. Bulletin de l'Académie royale des sciences et des lettres de Danemark 5: 347–407.

Rivas Goday S (1957) Nuevos órdenes y alianzas de *Helianthemetea annua* Br.-Bl. Anales Instituto Botanico Cavanilles 15: 539–651.

Rivas-Martínez S (1978) Sur la syntaxonomie des pelouse thérophytiques de l'Europe occidentale. Colloques Phytosociologiques 6: 55–71.

Rivas-Martínez S [Ed.] (2007) Mapa de series, geoseries y geopermaseries de vegetación de España. Itinera Geobotanica 17: 5–436.

Rivas-Martínez S, Lousã M, Díaz TE, Fernández-González F, Costa JC (1990) La vegetación del sur de Portugal (Sado, Alentejo y Algarve). Itinera Geobotanica 3: 5–126.

Roleček J, Tichý L, Zelený D, Chytrý M (2009) Modified TWINSPAN classification in which the hierarchy respects cluster heterogeneity. Journal of Vegetation Science 20: 596–1602. https://doi.org/10.1111/j.1654-1103.2009.01062.x

Rundel PW, Montenegro G, Jaksic FM [Eds] (1998) Landscape disturbance and biodiversity in Mediterranean-type ecosystems. Ecological Studies 136: 1–450. https://doi.org/10.1007/978-3-662-03543-6

Russi L, Cocks PS, Roberts EH (1992) Seed bank dynamics in a Mediterranean grassland. Journal of Applied Ecology 29: 763–771. https://doi.org/10.2307/2404486

Sabatini FM, Jiménez-Alfaro B, Jandt U, Chytrý M, Field R, Kessler M, Lenoir J, Schrodt F, Wiser SK, … Bruelheide H (2022) Global patterns of vascular plant alpha diversity. Nature Communications 13: e4683. https://doi.org/10.1038/s41467-022-32063-z

Schlichting E, Blume HP, Stahr K (1995) Bodenkundliches Praktikum. 2nd ed. Blackwell, Berlin, DE, 266 pp.

Tichý L (2002) JUICE, software for vegetation classification. Journal of Vegetation Science 13: 451–453. https://doi.org/10.1111/j.1654-1103.2002.tb02069.x

Tichý L, Chytrý M (2006) Statistical determination of diagnostic species for site groups of unequal size. Journal of Vegetation Science 17: 809–818. https://doi.org/10.1111/j.1654-1103.2006.tb02504.x

Vassilev K, Bergmeier E, Boch S, Pedashenko H, Sopotlieva D, Tsiripidis I, Apostolova I, Fotiadis G, Ganeva A, … Dengler J (2024) Classification of the high-rank syntaxa of the Balkan dry grasslands with a new hierarchical expert system approach. Applied Vegetation Science 27: e12779. https://doi.org/10.1111/avsc.12779

Večeřa M, Axmanová I, Chytrý M, Divíšek J, Ndiribe C, Velasco Mones G, Čeplová N, Aćić S, Bahn M, … Lososová Z (2023) Decoupled phylogenetic and functional diversity in European grasslands. Preslia 95: 413–445. https://doi.org/10.23855/preslia.2023.413

Vynokurov D, Aleksanyan A, Becker T, Biurrun I, Borovyk D, Fayvush G, García-Mijangos I, Magnes M, Palpurina S, … Dengler J (2024) Dry grasslands and thorn-cushion communities of Armenia: a first syntaxonomic classification. Vegetation Classification and Survey 5: 39–73. https://doi.org/10.3897/VCS.119253

Westoby M (1980) Elements of a theory of vegetation dynamics in arid rangelands. Israel Journal of Botany 28: 169–194.

Wirth V, Hauck M, Schultz M (2013) Die Flechten Deutschlands. 2 vols. Ulmer, Stuttgart, DE, 1244 pp.

E-mail and ORCID

Riccardo Guarino (riccardo.guarino@unipa.it), ORCID: https://orcid.org/0000-0003-0106-9416
Thomas Becker (beckerth@uni-trier.de), ORCID: https://orcid.org/0000-0002-7942-5575
Iwona Dembicz (iwona.dembicz@uw.edu.pl), ORCID: https://orcid.org/0000-0002-6162-1519
Christian Dolnik (cdolnik@ecology.uni-kiel.de), ORCID: https://orcid.org/0009-0001-2826-2876
Łukasz Kozub (lkozub@uw.edu.pl), ORCID: https://orcid.org/0000-0002-6591-8045
Jürgen Dengler (Corresponding author, juergen.dengler@zhaw.ch), ORCID: https://orcid.org/0000-0003-3221-660X

Supplementary material

Supplementary material 1
Complete vegetation data (header and species) (*.xlsx)
Link: https://doi.org/10.3897/VCS.175402.suppl1

Supplementary material 2
Vascular plant taxa in this study with their life form and CSR assignments (*.xlsx)
Link: https://doi.org/10.3897/VCS.175402.suppl2

Supplementary material 3
Additional results (*.pdf)
Link: https://doi.org/10.3897/VCS.175402.suppl3

Supplementary material 4
Complete sorted relevé and constancy table (*.xlsx)
Link: https://doi.org/10.3897/VCS.175402.suppl4