

Broom-dominated shrublands of Sicily: revisiting the syntaxonomy of the *Cytisetea scopario-striati* at the south-eastern margin of their range

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Abstract

Aims: This study focuses on the shrublands growing on siliceous and calcium-poor substrates in the hilly and mountainous regions of northern Sicily. These vegetation types, typically found in abandoned rangelands, forest edges, and clearings, are dominated by several acidophilous shrubs. The aim is to analyze their composition, distribution, and ecological relationships with allied syntaxa. **Location:** Tyrrhenian mountain ranges of Northern Sicily (Nebrodi and Peloritani mountain ranges), extending from the Strait of Messina in the east to the central-western part of the island, encompassing diverse terrains characterized by nutrient-poor, acidic soils, influenced by a Mediterranean climate. **Methods:** Vegetation surveys were conducted using the Braun-Blanquet method; vegetation plots were classified using a modified TWINSpan approach, and the resulting groups were floristically characterized by their diagnostic, constant, and dominant species. Multivariate statistical analyses were employed to classify the vegetation plots and to investigate their ecological relationships, distribution and syntaxonomy, compared with related vegetation described in Sicily and Southern Peninsular Italy (Calabria). **Results:** The study identified several new associations of shrubland vegetation, such as *Carlino globosae-Cytisetum scoparii*, *Origano viriduli-Cytisetum villosi*, *Carlino globosae-Telinium monspessulanae*, and *Achilleo ligusticae-Spartietum juncei*, among others. Comparative analysis revealed many differences from the Siculo-Calabrian supramediterranean broom heath ascribed to the *Violo messanensis-Adenocarpion commutati*, leading to the description of a new alliance, named *Achilleo ligusticae-Telinium monspessulanae*, which can be considered a more thermophilic and mesophilous vicariant of the former. **Conclusions:** Our findings provide new insights into the vegetation classification of the Sicilian acidophilous shrublands. By identifying several new vegetation associations and analyzing their relationships with allied communities in Southern Italy, this study contributes substantially to the knowledge of the class *Cytisetea scopario-striati* in the south-eastern most limit of its distribution range.

Taxonomic reference: Flora d'Italia (Pignatti et al. 2017–2019) for vascular plants.

Syntaxonomic reference: Mucina et al. (2016) for alliances, orders and classes, Brullo et al. (2001b) and Guarino et al. (2017) for associations.

Abbreviations: ANOVA = analysis of variance; CPO = Calabria-Peloritani Orogen; EIVE = Ecological Indicator Values for Europe 1.0; ICPN = International Code of Phytosociological Nomenclature; NMDS = non-metric multidimensional scaling; TWINSpan = two-way indicator species analysis.

Keywords

Achilleo ligusticae-*Telinion monspessulanae*, biogeography, *Cytisetea scopario-striati*, diagnostic species, Mediterranean vegetation, phytosociology, shrubland, Sicily, synchorology, syntaxonomy, vegetation classification, *Viola messanensis*-*Adenocarpion commutati*

Introduction

The class *Cytisetea striato-scoparii* Rivas-Martínez 1974 includes forest mantles and shrub communities dominated by woody *Fabaceae* with reduced leaves and green, flexible, photosynthetic branches (as in the case of genera like *Adenocarpus*, *Cytisus*, *Genista*, *Retama*, etc.), often associated with *Erica arborea*, *E. scoparia* and *Pteridium aquilinum* (Rivas-Martínez et al. 2002).

Owing to their symbiosis with nitrogen-fixing bacteria, these broom-dominated communities can enhance nitrogen inputs and improve soil properties, thereby promoting early soil development and ecosystem recovery under Mediterranean conditions (Pérez-Fernández et al. 2016). In ecological successions, they are typically associated with seral stages heading to evergreen or deciduous *Fagaceae*-forests on loose, mostly acidic soils. According to the Rivas-Martínez's bioclimatic classification (Rivas-Martínez 1981), their optimal range spans across thermo- to supratemperate and supramediterranean bioclimatic belts, under subhumid to hyperhumid ombrotypes (Rivas-Martínez and Loidi 1999).

These communities are mainly distributed in sub-Atlantic and Atlantic regions, with the highest concentration in the Iberian Peninsula (Costa et al. 2003; Gavilán et al. 2011; Pinto-Gomes et al. 2012; De Foucault et al. 2013). Towards the north, they are progressively constrained by winter cold, gradually losing their characteristic species and becoming restricted to a narrow strip along the Atlantic coast (Weber 1998; Weber 2003; Haveman et al. 2017). South-eastwards, their post-glacial expansion during the ipsothermic ("Atlantic") phases (Guarino et al. 2020) followed a Mediterranean corridor involving southern France and the Tyrrhenian slopes of the Apennines and Calabrian ranges, with northern Sicily representing the south-western limit of their establishment (De Beaulieu et al. 2005).

In Sicily, these shrublands are mainly located in the north-eastern mountains (Peloritani and Nebrodi), on acidic soils derived from metamorphic siliceous rocks, quartz sandstones, or volcanic scoriae. They become increasingly sporadic westwards, in the Madonie and Sicani mountains (Guarino et al. 2021). The Sicilian vegetation of the *Cytisetea striato-scoparii* is found within the meso- and supramediterranean belts, with ombrotypes ranging from subhumid to hyperhumid. These communities are more frequent on sea-facing mountainsides, where they benefit from the condensation of moist air currents (Bartolo et al. 1994). They belong to vegetation series approaching oak-forests—both evergreen (*Q. ilex*, *Q. suber*) and deciduous (*Q. pubescens*, *Q. cerris*)—as well as to chestnut and beech forests. In most cases, they develop over very large

surfaces as secondary formations in landscapes deforested for grazing, developing distinctive physiognomic, floristic and phytocoenotic characteristics (Sciandrello et al. 2015).

Previous studies on the Sicilian *Cytisetea striato-scoparii* vegetation were restricted to the highest elevations of the Peloritani mountains, characterized by the presence of endemic species, such as *Adenocarpus commutatus* and *Viola aethnensis* subsp. *messanensis* (Bartolo et al. 1994). However, this vegetation also occurs along the Tyrrhenian slopes of the Nebrodi and Peloritani mountains, at lower elevations than those previously investigated.

The present contribution aims: (1) to strengthen the understanding of the class *Cytisetea scopario-striati* in Sicily, by documenting and describing related communities dominated by *Cytisus villosus*, *C. scoparius*, *C. infestus*, *Erica arborea*, *Teline monspessulana*, *Pteridium aquilinum* and *Spartium junceum*; (2) to provide an updated syntaxonomic overview for these communities, aligned with the European vegetation synthesis by Mucina et al. (2016).

Study area

The study area encompasses the submontane and montane belts of the northeastern sector of Sicily, along the Tyrrhenian ridge, including the Peloritani and Nebrodi Mountains (Figure 1), i.e. the Sicilian part of the Calabria-Peloritani Orogen (CPO; Siravo et al. 2022).

The Peloritani range, at the northeastern end of the study area, is predominantly composed of siliceous metamorphic rocks (schists and gneisses). From the narrow ridge line, with an average altitude of 800–1000 m, several streams flow down into deep gorges, which in the middle and lower reaches open up into wide rivers filled with debris, locally known as "fumare" (Lentini et al. 2000).

More to the west, the Nebrodi Mountains display progressively higher reliefs culminating at Mt. Soro (1847 m). Their flyschoid, pelitic–arenaceous substrata (Giunta et al. 2002) generate rounded landforms, with slopes occasionally arranged in stepped or terraced profiles, interrupted by rivers (Gianguzzi 1999).

Vegetation of the *Cytisetea striato-scoparii* has its optimum between 600 and 1300 m a.s.l., corresponding in the study area to the transition from the mesomediterranean to the supramediterranean bioclimatic belts, with mean annual temperatures ranging from 16–13 °C and 13–8 °C, respectively (Bazan et al. 2015; Gianguzzi et al. 2015). In altitudinal terms, this range broadly spans the lower submontane to upper montane belts. The ombrotype varies from subhumid in the lower part of this range, where mean annual precipitation is approximately 600–1000 mm, to humid

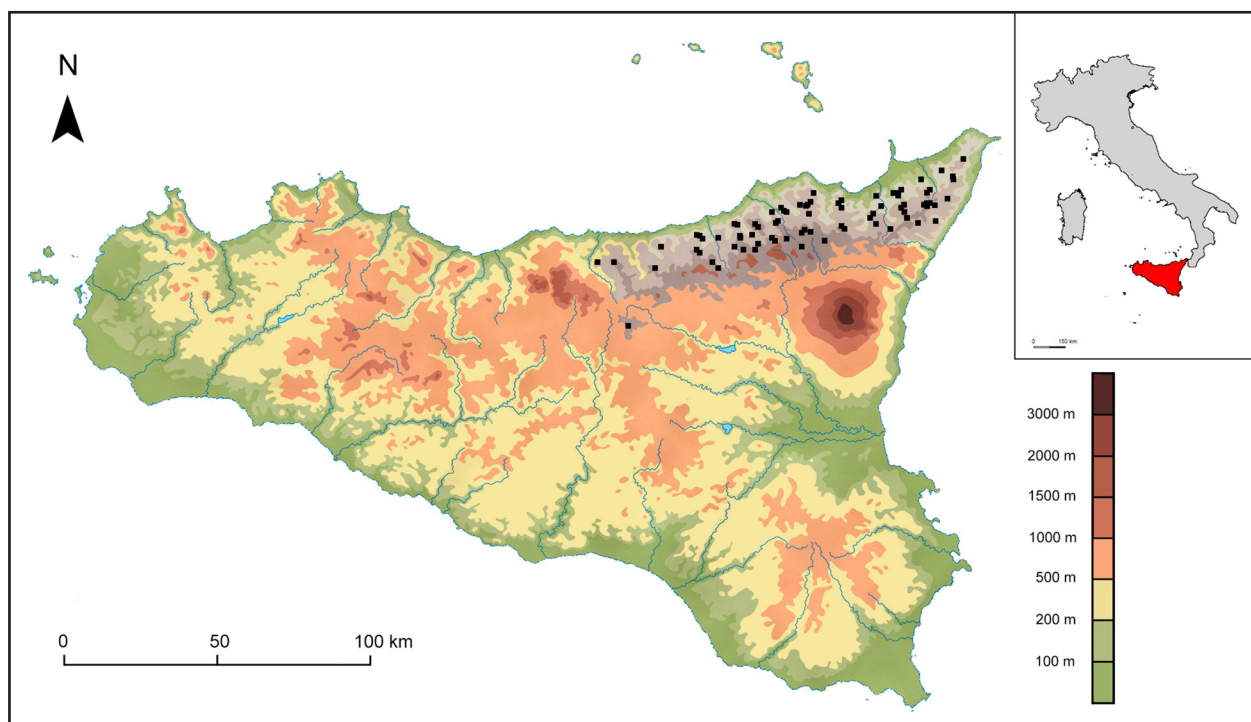


Figure 1. Map showing the position of Sicily in Italy, the study area (grey) and the distribution of sampling sites on the island (black squares). In Suppl. material 2: figure S2.1, individual distribution maps of the newly described vegetation units are displayed.

at higher elevations, where precipitation generally exceeds 1000 mm. Most of the investigated areas were traditionally used as rangelands and periodically burned to prevent shrub encroachment. Following abandonment and the reduced frequency of fires, the areas examined have been extensively colonized by the vegetation covered in this study.

Methods

Field sampling and data collection

The vegetation was studied using the phytosociological method of the Zurich-Montpellier school (Braun-Blanquet 1964), as modified by Géhu and Rivas-Martínez (1981). Between 3 May and 19 June, 2019, 50 relevés were sampled at multiple locations in the study area. These were added to another 78 unpublished relevés sampled by us in the same area between 1996 and 2018. Plot size ranged between 50 and 150 m² (Suppl. material 1).

Field surveys were conducted opportunistically within physiognomically homogeneous shrubby vegetation patches. Plot selection was based on the dominance of the target species listed at the end of the Introduction. Consequently, secondary communities such as open rangelands dominated by herbaceous vegetation, as well as stands with sparse trees, were deliberately avoided, as the communities examined represent the intermediate successional stage between grasslands and closed forest within local vegetation dynamics.

Vegetation within the sampled plots consisted of dense shrublands, with mean canopy heights ranging from 0.7–0.9 m in *Pteridium aquilinum* and *Adenocarpus commutatus*

dominated stands to approximately 2.8 m in *Erica arborea* stands, and with ground cover values between 80% and 100%. After recording all vascular plant species within each plot, their cover values were visually estimated and expressed according to the 6-step Braun-Blanquet cover-abundance scale (+ ≤ 1%; 1 ≤ 10%; 2 ≤ 25%; 3 ≤ 50%; 4 ≤ 75%, 5 > 75%, see Dembicz and Dengler 2025). The following environmental and structural variables were also recorded: location, elevation (m a.s.l.), slope aspect (°), slope inclination (°), total vegetation cover (%); mean vegetation height (m), and land use details (evidence of grazing, burning, abandonment).

Most plant species were identified in the field; specimens that could not be reliably determined *in situ* were collected and subsequently identified using floras and stereomicroscopes. Vascular plants were primarily identified using Flora d'Italia (Pignatti et al. 2017–2019), which was also adopted as the taxonomic reference for the treatment of the genera *Adenocarpus* and *Quercus*. This choice was made because both genera include taxonomically critical groups (Peruzzi 2011; Di Pietro et al. 2020, 2021), for which the adoption of the nomenclature reported in Flora d'Italia was necessary to ensure consistency in species delimitation and syntaxonomical treatment throughout the study. The remaining nomenclature follows the most recent checklists of the Italian vascular flora (Bartolucci et al. 2024; Galasso et al. 2024). The phytosociological nomenclature follows the 4th edition of the International Code of Phytosociological Nomenclature (Theurillat et al. 2021) and if a syntaxon name did not match the taxonomic concepts in the checklists of the Italian vascular flora, we modified the names according to Art. 45 ICPN.

To complete the dataset and broaden the comparative framework, 79 relevés taken from literature and referring to the *Violo messanensis*-*Adenocarpion complicati*—an alliance of the *Cytisetalia scopario-striati*, originally named *Violion messanensis*, described for the northernmost sector of the Peloritani Mountains (Bartolo et al. 1994) and subsequently also recorded from the Aspromonte massif (Brullo et al. 2001b) and Sila Piccola (Maiorca et al. 2006) in southern and central Calabria—were added to the 128 unpublished relevés. The decision to include in the dataset all available relevés regarding the *Violo messanensis*-*Adenocarpion complicati*, including those from the southernmost part of the Italian peninsula, was based on the strong geological and geomorphological similarity between northeastern Sicily and central-southern Calabria. Indeed, the CPO constitutes an “exotic terrane” composed primarily of ancient metamorphic and igneous rocks forming the Hercynian crystalline basement. This distinct microplate, thrust over the sedimentary units of the surrounding Apennines and Maghrebides, represents a geologically foreign “crystalline backbone” linking Sicily and Calabria.

Data analysis

We used unsupervised cluster analysis to identify the main vegetation units based on floristic similarity only (De Cáceres et al. 2015).

The vegetation dataset was first classified in JUICE 7.1 (Tichý 2002) using the modified TWINSpan algorithm (Roleček et al. 2009) with minimum group size for division set at 2 and pseudospecies cut levels set at 0, 5 and 25. Species fidelity to the resulting clusters was evaluated in JUICE using the standardized phi coefficient (Tichý and Chytrý 2006), with equalized group sizes and Fisher's exact test ($P < 0.01$). Diagnostic species were defined according to the fidelity thresholds adopted for each syntaxonomic rank. Only taxa with a ϕ coefficient ≥ 0.25 and a probability of occurrence under random expectation lower than 0.05 (one-tailed Fisher's exact) were considered to be diagnostic for each cluster. Constant species were defined as those with a frequency $\geq 40\%$ within each group. Dominant species were defined as those occurring in at least 50% of the relevés of a given cluster with a cover value $\geq 25\%$ (Braun-Blanquet scale values ≥ 3).

Rarefaction curves of endemic species were computed separately from Twinspan clusters using presence/absence data. Rarefaction was performed by random permutation of relevés (500 iterations), and 95% confidence intervals were calculated using percentile limits.

To explore the main compositional gradients within the dataset, non-metric multidimensional scaling (NMDS) was performed through the ordiJuice interface, which runs the metaMDS function of the VEGAN package in R (Oksanen et al. 2025; R Core Team 2025) directly from JUICE. The analysis was based on Bray-Curtis dissimilarity calculated from square-root transformed Braun-Blanquet cover-abundance data with downweighting of rare

species, using the standard numerical transformation implemented in JUICE. Braun-Blanquet cover-abundance scores were numerically transformed by JUICE before calculating Bray-Curtis dissimilarities. The ordination was run in two dimensions, and stress values were used to evaluate the goodness of fit. Ordination results were visualised by plotting individual relevés, association centroids, and concave hulls (alpha-shapes) delimiting the ordination space occupied by each association.

To infer further site conditions that are not easy to measure in the field, we applied mean ecological indicator values (Diekmann 2003; Tichý et al. 2023). These were extracted from the most recent database (EIVE 1.0, Dengler et al. 2023) to calculate unweighted means, as they better correlate with measured environmental variables than weighted means (Ostrowski et al. 2025). The statistical significance of differences between groups was evaluated using the Mann-Whitney U test. Statistical comparisons and graphical outputs were produced in Canoco 5 (ter Braak and Šmilauer 2012).

Results

The final dataset included 207 relevés and 398 vascular plant species (Suppl. material 1). The mean overall species richness of the sampled plots was 26.4 (min. 5; max. 53). The most frequent species were *Pteridium aquilinum* (88%), *Dactylis glomerata* (58%), *Anthoxanthum odoratum* (54%), *Erica arborea* and *Thymus longicaulis* subsp. *longicaulis* (both 53%), *Carlina hispanica* subsp. *globosa* (52%), *Cistus salviifolius* and *Cytisus scoparius* (both 49%), *Viola aethnensis* subsp. *messanensis* and *Cytisus laniger* (both 46%).

Numerical analyses

The TWINSpan classification first divided the dataset into two main groups: one comprising shrublands occurring on windswept ridges (Figure 2, Group A), and the other including secondary shrublands developed on deeper soils, potentially representing successional stages toward forest vegetation (Figure 2, Group B). These two groups were subsequently resolved into a total of 15 terminal clusters, six of which (clusters A2–7) matched closely with already described communities, eight (clusters A1, B1–3, B5–8) were interpreted as newly defined plant communities, and one (cluster B4) as mixed transitional vegetation.

The NMDS ordination (Figure 3) is largely consistent with the TWINSpan results, supporting the main division in two groups while indicating a relatively weak floristic differentiation among the vegetation units corresponding to the 15 clusters, with partial overlaps and gradual transitions between neighbouring units. Axis 1 reflects structural and compositional variation along the altitudinal gradient, whereas Axis 2 corresponds to an edaphic gradient, contrasting communities of shallow, skeletal soils (Group A) with those of deeper and more evolved soils (Group B).

Although none of the EIVE showed statistically significant differences, temperature (T), soil reaction (R) and nitrogen (N) values approached significance ($p = 0.083$, $p = 0.067$, $p = 0.058$, respectively). These differences suggest a weak but coherent differentiation between Group

A and Group B along climatic and edaphic gradients, in line with the main vegetation units identified by both the TWINSpan classification and the NMDS ordination, suggesting gradual ecological shifts rather than sharp discontinuities between the two groups. In particular, Group

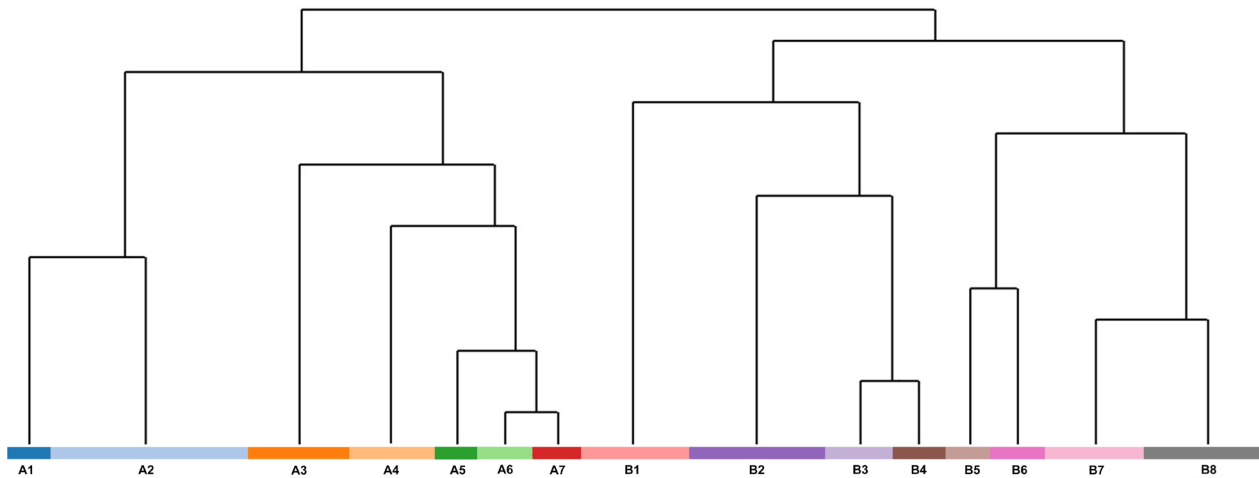


Figure 2. Cluster diagram (modified TWINSpan - average Sørensen dissimilarity) of the complete dataset. Cluster labels correspond to the vegetation units analytically as described in the "Description and syntaxonomic interpretation of the clusters" section.

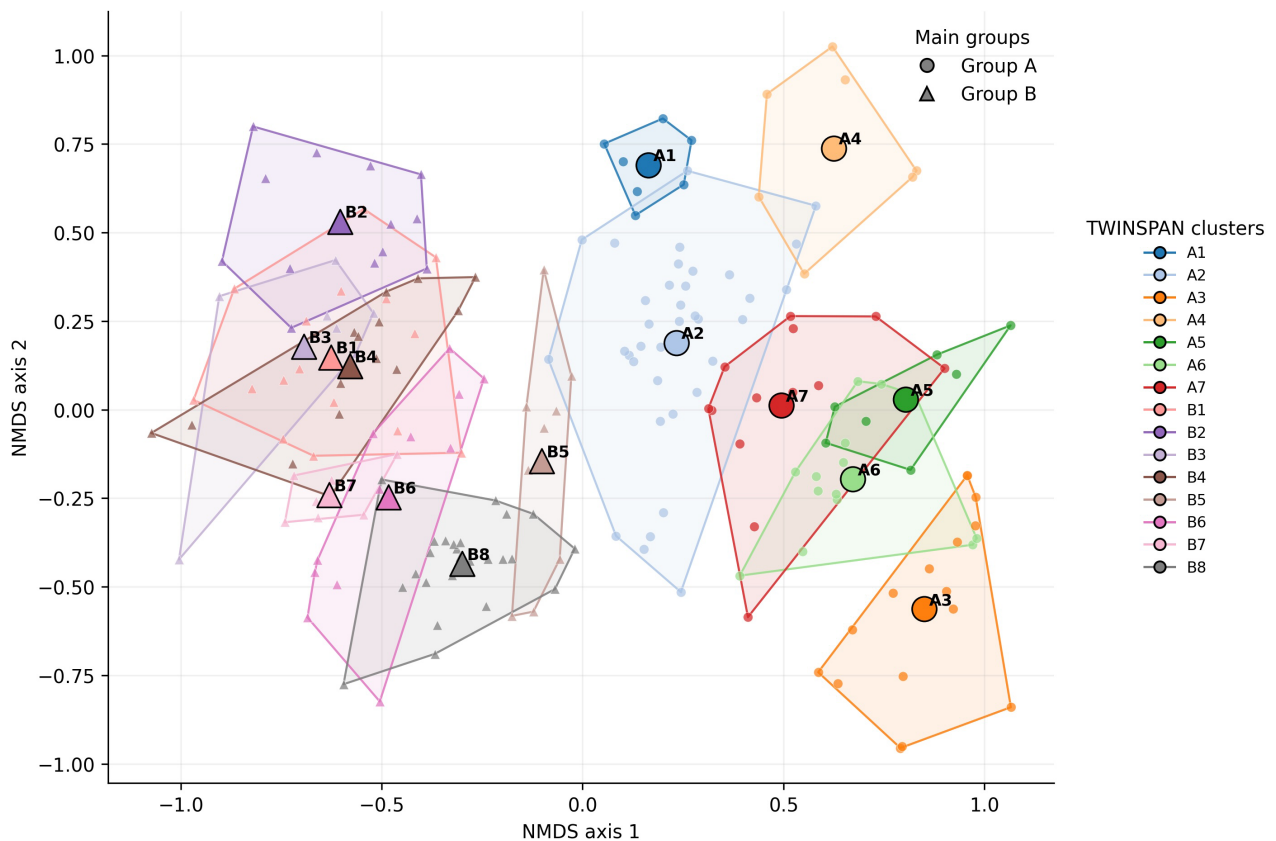


Figure 3. NMDS ordination of the complete dataset, based on Bray-Curtis dissimilarities calculated from square-root transformed and Wisconsin-standardized species cover data (stress = 0.28). Symbols refer to the two main groups identified by TWINSpan (Group A: circles; Group B: triangles), while colours distinguish the 15 terminal clusters (A1-A7, B1-B8) as described in the "Description and syntaxonomic interpretation of the clusters" section. Individual relevés are shown together with cluster centroids (larger symbols). The overlap among several clusters reflects the continuous nature of the environmental gradients structuring these shrub communities and the relatively high stress value of the two-dimensional ordination.

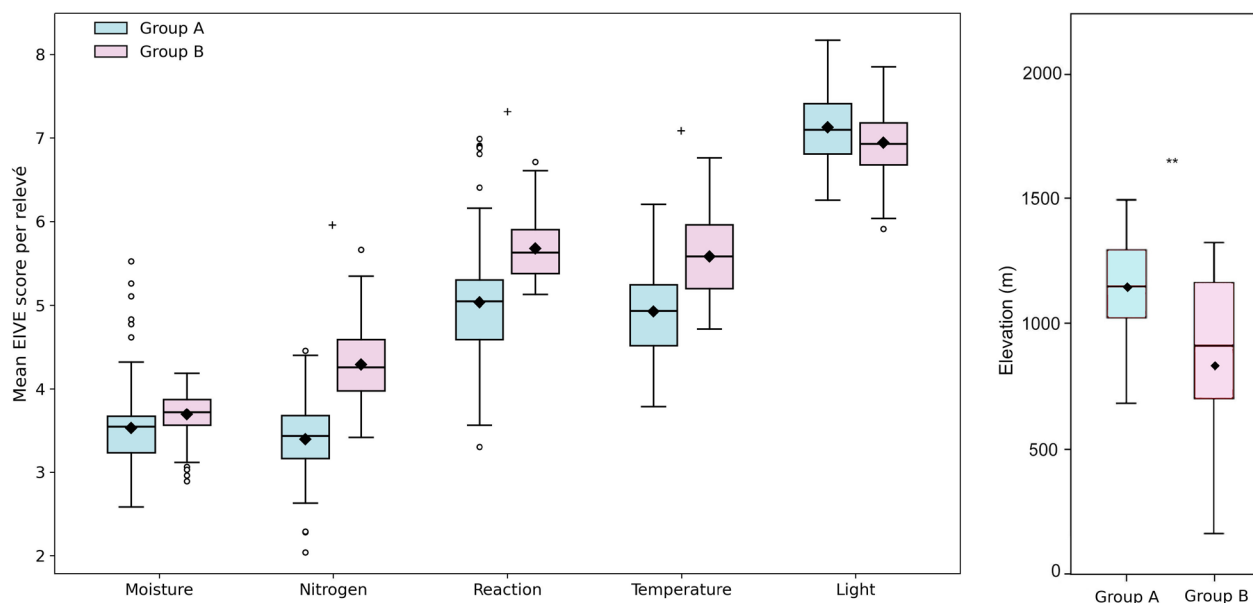


Figure 4. Comparison of the mean Ecological Indicator Values (left) and of the elevation (right) between the two groups of the main TWINSpan division. Boxplots show median, interquartile range, total range and outliers; diamonds indicate means. Abbreviations: L-light; T-temperature; C-continentality; M-soil moisture; R-soil reaction; N-soil nitrogen.

B exhibited higher median values of T, R and N, whereas Group A showed comparatively lower values. By contrast, light (L) largely overlapped between the two groups and Moisture (M) values were consistently low in both groups (Figure 4). Elevation differed significantly between the two groups, with Group A occurring at higher altitudes than Group B (Mann–Whitney U test, $p < 0.001$).

At a finer scale, radar diagrams of individual vegetation units (Suppl. material 2: figure S2.2) assigned to Group A (A1–A7) displayed relatively homogeneous EIVE profiles, with lower T and N values and limited dispersion, corresponding to their clustering in the upper-elevation sector of the ordination space. Conversely, Group B units (B1–B8) showed higher T, R, and N values and a broader range of EIVE profiles, in agreement with their wider spread along the second NMDS axis and their classification as secondary communities.

Description and syntaxonomic interpretation of the clusters

The first division obtained through TWINSpan revealed two ecologically distinct vegetation units (Figure 2, Table 1). The first one (Figure 2, Group A) refers to shrublands that develop under harsh ecological conditions, where climatic stress and edaphic limitations constrain vegetation structure and dynamics. They typically occur between 1,000 and 1,500 m a.s.l. on exposed, wind-swept ridges and rocky crests, where mechanical disturbance, windiness and strong insolation limit tree establishment. These sites are often characterized by shallow, skeletal soils or by extensive rock outcrops, as a result of both limited pedogenesis and continuous erosion. From a climatic perspective, these shrublands are typically found at montane elevations, where Mediterranean climatic features

interact with cooler temperatures and frequent cloud cover. Winters are often cold, with recurrent frost and occasional snow cover, while summers remain relatively dry but less thermally extreme than at lower elevations. Ecologically, these shrublands are not transitional stages toward forest communities but represent stable, long-lasting vegetation types maintained by topographic exposure and soil constraints. They play an important role in slope stabilization and often host endemic or relict species, such as *Adenocarpus commutatus*, *Fritillaria messanensis*, *Anthemis cretica* subsp. *messanensis*, *Genista brutia*, *Polygala angelisii*, *Silene sicula*, *Viola aethnensis* subsp. *messanensis* (Figure 5). Taken together, these shrublands correspond to a coherent set of communities that, despite local floristic differentiation and their current isolation on the highest elevations of the CPO, share a common ecological

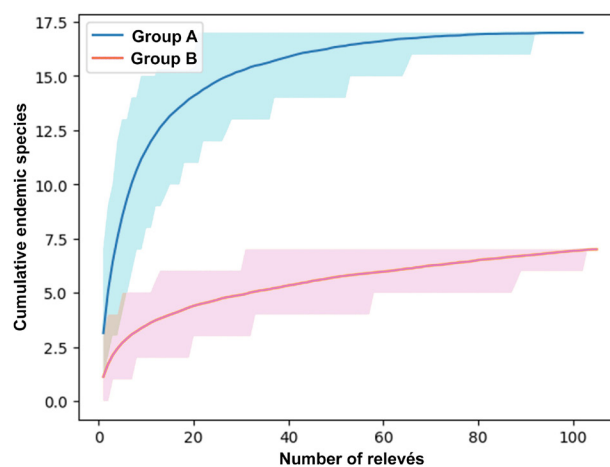


Figure 5. Rarefaction curves of endemic species in Group A and Group B. Curves represent mean cumulative endemic species richness as a function of the number of relevés. Shaded areas indicate 95% confidence intervals (Permutation test on rarefied richness: $p < 0.05$).

Table 1. Floristic comparison of the two major vegetation groups identified by the first TWINSpan division (Group A: clusters A1–A7; Group B: clusters B1–B8). Species recorded in at least 20% of the relevés of either group are ranked according to their percentage frequency in Groups A and B. Their affinity for Group A and Group B (ΔF) is expressed as follows: A $\rightarrow \Delta F \geq +20\%$; B $\rightarrow \Delta F \leq -20\%$; Shared (AB) $\rightarrow |\Delta F| < 20\%$. The standardized ϕ coefficient of fidelity for the two major TWINSpan groups is also reported (Dark grey: ϕ coefficient ≥ 0.8 ; Medium grey: ϕ coefficient ≥ 0.5 ; light grey: ϕ coefficient ≥ 0.4). The full synoptic tables and species matrix are available in Suppl. material 1.

	Group A (%)	Group B (%)	ΔF (A–B)	ϕ Group A	ϕ Group B	Affinity
<i>Viola aethnensis</i> subsp. <i>messanensis</i>	90	9	81	0.8	-0.8	A
<i>Thymus longicaulis</i> subsp. <i>longicaulis</i>	79	30	49	0.5	-0.5	A
<i>Helianthemum nummularium</i> subsp. <i>tomentosum</i>	45	0	45	0.6	-0.6	A
<i>Jasione echinata</i>	48	6	42	0.5	-0.5	A
<i>Cytisus scoparius</i>	71	30	41	0.4	-0.4	A
<i>Petrosedum tenuifolium</i>	41	9	32	0.3	-0.3	A
<i>Silene sicula</i>	47	16	31	0.2	-0.2	A
<i>Micromeria graeca</i> subsp. <i>tenuifolia</i>	51	22	29	0.3	-0.3	A
<i>Helianthemum nummularium</i> subsp. <i>obscurum</i>	34	11	24	0.1	-0.1	A
<i>Erica arborea</i>	65	42	22	0.1	-0.1	A
<i>Cistus salviifolius</i>	60	39	22	0.1	-0.1	A
<i>Spartium junceum</i>	5	60	-55	-0.5	0.5	B
<i>Achillea ligustica</i>	27	82	-55	-0.5	0.5	B
<i>Origanum vulgare</i> subsp. <i>viridulum</i>	13	65	-52	-0.5	0.5	B
<i>Clinopodium vulgare</i> subsp. <i>arundanum</i>	6	50	-43	-0.4	0.4	B
<i>Daucus carota</i>	23	65	-42	-0.4	0.4	B
<i>Pyrus spinosa</i>	0	40	-40	-0.4	0.4	B
<i>Rubus canescens</i>	9	49	-39	-0.5	0.5	B
<i>Rubus ulmifolius</i>	3	41	-38	-0.4	0.4	B
<i>Asperula laevigata</i>	1	39	-38	-0.5	0.5	B
<i>Teline monspessulana</i>	1	37	-36	-0.4	0.4	B
<i>Brachypodium sylvaticum</i>	16	50	-35	-0.4	0.4	B
<i>Carlina hispanica</i> subsp. <i>globosa</i>	33	68	-34	-0.3	0.3	B
<i>Calamintha nepeta</i>	3	37	-34	-0.3	0.3	B
<i>Holcus lanatus</i>	16	49	-33	-0.4	0.4	B
<i>Pulicaria odora</i>	3	36	-33	-0.4	0.4	B
<i>Oenanthe pimpinelloides</i>	4	36	-32	-0.4	0.4	B
<i>Bellis perennis</i> var. <i>perennis</i>	9	38	-28	-0.3	0.3	B
<i>Asphodelus ramosus</i>	26	51	-25	-0.2	0.2	B
<i>Anthoxanthum odoratum</i>	42	66	-24	-0.3	0.3	B
<i>Cynosurus cristatus</i>	18	39	-21	-0.3	0.3	B
<i>Pteridium aquilinum</i>	79	96	-17	-0.3	0.3	AB
<i>Dactylis glomerata</i>	53	63	-10	-0.1	0.1	AB
<i>Cytisus infestus</i>	54	52	2	0.0	0.0	AB
<i>Hypochoeris laevigata</i>	40	37	3	0.0	0.0	AB
<i>Cytisus laniger</i>	34	34	0	0.1	-0.1	AB
<i>Teucrium siculum</i>	30	25	5	0.0	0.0	AB
<i>Crepis leontodontoides</i>	27	26	1	-0.1	0.1	AB
<i>Hypochoeris radicata</i>	22	29	-7	-0.3	0.3	AB
<i>Luzula forsteri</i>	14	32	-19	-0.3	0.3	AB

and biogeographical background. Accordingly, they have been grouped into the phytosociological alliance *Viola messanensis-Adenocarpion complicati*, which encompasses montane Mediterranean shrublands developing on acidic substrates under conditions of strong climatic and edaphic constraint, and represents a distinctive vegetation unit within the order *Cytisetalia scopario-striati*.

The second division (Figure 2, Group B) refers to shrublands developing under markedly different ecological and dynamic conditions than those in Group A, as they replace evergreen or deciduous *Fagaceae*-forests that represent the potential natural vegetation. These shrublands are mainly the result of land abandonment after a long-lasting human

disturbance, such as repeated cutting, burning, and grazing which have prevented forest recovery over extended periods. They occur on average at lower elevations than those of Group A, between 300 and 1000 m a.s.l., with optimum occurrence in the mesomediterranean bioclimatic belt. Compared with the montane environments, wind exposure is usually less extreme, although local topography may still favor relatively dry and sun-exposed conditions. From an edaphic point of view, these secondary shrublands often develop on acidic substrates like those of Group A, but soils are usually deeper and more evolved, reflecting their origin under former forest cover. However, repeated disturbance and erosion may have caused partial



Twinspan groups	All	A	A1	A2	A3	A4	A5	A6+A7	A6	A7	B	B1	B2	B3+B4	B3	B4	B5	B6	B7	B8
No. of relevés	207	95	7	29	17	14	7	21	13	8	112	18	22	18	11	7	6	9	16	23
Diagnostic species A4																				
<i>Adenocarpus brutius</i>	8	18	.	.	.	100	43	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Anthemis cretica</i> subsp. <i>calabrica</i>	4	8	.	.	.	50	.	5	.	13	.	.	.	.	.	.	.	.	.	.
<i>Galium corrudifolium</i>	2	5	.	.	.	36	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Helianthemum oelandicum</i> subsp. <i>italicum</i>	2	5	.	.	.	36	.	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Tuberaria lignosa</i>	4	9	.	10	.	36	.	5	.	13	.	.	.	.	.	.	.	.	.	.
Diagnostic species A5																				
<i>Aristolochia lutea</i>	3	7	.	.	.	.	100	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Asphodelus macrocarpus</i>	3	7	.	.	.	.	100	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Cerastium arvense</i>	5	10	.	.	.	21	100	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Bromopsis caprina</i>	7	16	.	.	.	.	100	38	62	.	.	.	.	.	.	.	.	.	.	.
<i>Lilium bulbiferum</i> subsp. <i>croceum</i>	2	4	.	.	.	.	57	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Silene commutata</i>	2	4	.	.	.	.	57	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Centaurea poeltiana</i>	7	15	.	.	.	57	86	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Crepis vesicaria</i>	2	4	.	.	.	.	57	.	.	.	1	.	.	6	9	.	.	.	.	.
<i>Carlina nebrodensis</i>	5	10	.	.	.	36	71	.	.	.	.	.	.	.	.	.	.	.	.	.
<i>Lathyrus grandiflorus</i>	2	3	.	.	.	.	43	.	.	.	1	.	.	.	.	.	.	.	.	4
<i>Pilosella piloselloides</i>	2	4	.	.	.	.	43	5	8	.	.	.	.	.	.	.	.	.	.	.
<i>Rumex acetosella</i> subsp. <i>multifidus</i>	6	11	.	10	18	.	43	10	.	25	1	.	.	.	.	.	.	11	.	.
Diagnostic species A6+A7																				
<i>Helianthemum nummularium</i> subsp. <i>tomentosum</i>	21	45	.	.	47	50	100	100	100	100	.	.	.	.	.	.	.	.	.	.
<i>Galium album</i>	15	32	.	.	.	50	100	81	85	75	.	.	.	.	.	.	.	.	.	.
<i>Teucrium siculum</i>	28	30	.	45	.	14	.	67	46	100	25	39	18	28	45	.	33	22	38	9
<i>Jasione echinata</i>	26	48	.	59	24	64	57	57	38	88	6	6	5	.	.	.	.	11	19	4
<i>Cytisus laniger</i>	34	34	29	24	.	43	14	81	69	100	34	44	27	28	45	.	.	22	100	4
Diagnostic species A6																				
<i>Bellis perennis</i> var. <i>aspromontana</i>	6	14	.	.	24	.	.	43	69	.	.	.	.	.	.	.	.	.	.	.
<i>Pedicularis comosa</i>	5	10	.	.	.	.	43	33	54	.	.	.	.	.	.	.	.	.	.	.
<i>Euphorbia meuselii</i>	4	9	.	.	.	.	43	29	46	.	.	.	.	.	.	.	.	.	.	.
Diagnostic species A7																				
<i>Centaurea aspromontana</i>	4	8	.	.	.	.	.	38	.	100	.	.	.	.	.	.	.	.	.	.
<i>Rubus hirtus</i>	7	10	.	.	24	.	.	29	.	75	5	.	.	28	.	71	.	.	.	.
Diagnostic species B																				
<i>Achillea ligustica</i>	57	27	.	59	.	21	57	10	.	25	82	89	68	83	100	57	50	67	100	87
<i>Origanum vulgare</i> subsp. <i>viridulum</i>	41	13	100	14	.	.	.	.	.	.	65	67	36	67	45	100	67	33	88	87
<i>Spartium junceum</i>	35	5	43	7	.	.	.	.	.	.	60	100	59	56	91	.	.	22	88	43
<i>Daucus carota</i>	45	23	29	48	.	21	.	14	.	38	65	61	59	50	36	71	17	33	81	96
<i>Brachypodium sylvaticum</i>	34	16	.	.	.	.	.	67	69	63	50	61	14	44	55	29	83	67	94	39
<i>Clinopodium vulgare</i> subsp. <i>arundanum</i>	29	6	.	.	.	.	29	19	8	38	50	11	36	44	27	71	67	78	63	70
<i>Holcus lanatus</i>	33	16	.	21	41	.	.	10	15	.	49	22	32	61	64	57	33	67	56	65
<i>Rosa canina</i>	18	.	.	.	.	.	.	.	.	.	33	50	9	17	27	.	.	11	38	70
Diagnostic species B1																				
<i>Bromus hordeaceus</i>	5	2	.	.	.	.	.	10	15	.	7	39	.	.	.	.	.	11	.	.
<i>Foeniculum vulgare</i> subsp. <i>vulgare</i>	7	.	.	.	.	.	.	.	.	.	14	44	23	.	.	.	.	11	6	.
Diagnostic species B2																				
<i>Dactylis glomerata</i> subsp. <i>hispanica</i>	7	.	.	.	.	.	.	.	.	.	14	.	68	.	.	.	.	.	.	.
<i>Daphne gnidium</i>	6	.	.	.	.	.	.	.	.	.	12	17	41	6	9	.	.	.	.	.
<i>Ampelodesmos mauritanicus</i>	16	.	.	.	.	.	.	.	.	.	31	50	64	28	45	.	.	22	25	.
Diagnostic species B3+B4																				
<i>Trifolium pratense</i> subsp. <i>pratense</i>	2	.	.	.	.	.	.	.	.	.	5	.	.	67	64	71	.	.	.	.
<i>Tolpis virgata</i> subsp. <i>virgata</i>	1	.	.	.	.	.	.	.	.	.	2	.	.	44	54	29	.	.	.	.
Diagnostic species B3																				
<i>Teline monspessulana</i>	20	1	.	.	.	.	.	5	.	13	37	11	55	61	100	.	.	22	63	17

Twinspan groups	All	A	A1	A2	A3	A4	A5	A6+A7	A6	A7	B	B1	B2	B3+B4	B3	B4	B5	B6	B7	B8
No. of relevés	207	95	7	29	17	14	7	21	13	8	112	18	22	18	11	7	6	9	16	23
<i>Rubus ulmifolius</i>	24	3	.	.	.	21	.	.	.	.	41	83	77	61	100	.	.	22	.	4
<i>Pulicaria odora</i>	21	3	.	10	.	.	.	.	.	.	36	39	59	50	82	.	.	22	50	4
<i>Calystegia silvatica</i>	4	.	.	.	.	.	.	.	.	.	8	17	.	22	36	.	.	22	.	.
<i>Ranunculus pratensis</i>	14	.	.	.	.	.	.	.	.	.	25	22	9	39	64	.	.	67	38	13
Diagnostic species B4																				
<i>Conopodium capillifolium</i>	3	.	.	.	.	.	.	.	.	.	6	.	.	28	.	71	.	.	.	9
<i>Euphorbia corallioidea</i>	3	.	.	.	.	.	.	.	.	.	6	.	.	28	.	71	.	.	.	9
<i>Geranium sanguineum</i>	8	.	.	.	.	.	.	.	.	.	15	.	.	28	.	71	.	11	6	43
<i>Geranium robertianum</i>	1	.	.	.	.	.	.	.	.	.	3	.	.	17	.	43	.	.	.	.
<i>Geranium versicolor</i>	1	.	.	.	.	.	.	.	.	.	2	.	.	11	.	29	.	.	.	.
<i>Daphne laureola</i>	6	.	.	.	.	.	.	.	.	.	12	.	9	17	.	43	17	.	.	30
<i>Hypochoeris radicata</i>	26	22	.	59	18	.	.	5	.	13	29	.	41	33	.	86	67	44	6	35
<i>Luzula forsteri</i>	24	14	14	34	.	.	.	10	8	13	32	.	.	44	18	86	67	44	25	70
Diagnostic species B5																				
<i>Cyclamen repandum</i>	3	2	.	3	.	.	.	.	.	.	4	.	5	.	.	.	67	.	.	.
<i>Cynosurus echinatus</i>	6	2	.	3	.	.	.	.	.	.	9	.	23	6	.	14	67	.	.	4
<i>Prunella laciniata</i>	3	.	.	.	.	.	.	.	.	.	5	6	.	.	.	.	50	.	.	9
<i>Poa trivialis</i>	5	1	.	.	.	.	.	.	.	.	9	.	.	6	.	14	67	33	.	13
<i>Aira caryophylla</i>	7	5	.	14	.	.	.	.	.	.	9	.	.	6	.	14	67	22	6	13
<i>Geranium lucidum</i>	3	1	.	.	.	.	.	.	.	.	5	.	.	6	.	14	50	11	.	4
<i>Sherardia arvensis</i>	6	1	.	.	.	.	.	.	.	.	10	.	.	6	.	14	67	44	.	13
<i>Geum urbanum</i>	7	2	.	.	.	.	.	5	8	.	11	.	.	11	9	14	67	33	.	17
<i>Lactuca muralis</i>	1	.	.	.	.	.	.	.	.	.	3	.	.	.	.	.	33	11	.	.
<i>Allium subhirsutum</i>	5	.	.	.	.	.	.	.	.	.	9	11	.	.	.	.	50	11	25	.
<i>Ornithogalum montanum</i>	2	.	.	.	.	.	.	.	.	.	5	.	.	.	.	.	33	.	.	13
<i>Polystichum setiferum</i>	2	.	.	.	.	.	.	.	.	.	4	.	.	6	.	14	33	11	.	.
<i>Hyoseris radiata</i>	15	18	.	55	.	.	.	.	.	.	13	6	5	17	9	29	67	22	13	9
<i>Tolpis virgata</i> subsp. <i>grandiflora</i>	8	4	.	10	.	.	.	.	.	.	11	6	14	6	.	14	50	22	.	13
<i>Asperula laevigata</i>	21	1	.	.	.	.	.	.	.	.	39	11	5	28	27	29	83	56	38	87
<i>Geranium purpureum</i>	9	.	.	.	.	.	.	.	.	.	16	11	5	6	9	.	50	33	19	22
<i>Silene sicula</i>	30	47	86	83	.	21	29	43	31	63	16	6	5	33	.	86	100	11	6	13
Diagnostic species B6																				
<i>Cynosurus elegans</i>	3	.	.	.	.	.	.	.	.	.	6	.	.	.	.	.	.	44	19	.
<i>Symphytum tuberosum</i>	2	.	.	.	.	.	.	.	.	.	4	.	.	6	9	.	33	.	.	.
<i>Pentanema squarrosus</i>	2	.	.	.	.	.	.	.	.	.	5	6	.	.	.	.	33	6	.	.
<i>Hordeum bulbosum</i>	4	.	.	.	.	.	.	.	.	.	8	.	5	6	9	.	17	44	13	.
<i>Fedia cornucopiae</i>	3	.	.	.	.	.	.	.	.	.	6	.	14	.	.	.	33	6	.	.
<i>Rubus canescens</i>	30	9	.	31	.	.	.	.	.	.	49	6	14	6	.	14	67	100	100	87
<i>Oenanthe pimpinelloides</i>	21	4	.	10	.	.	.	5	.	13	36	39	41	33	55	.	50	89	44	.
Diagnostic species B7																				
<i>Euphorbia characias</i>	6	.	.	.	.	.	.	.	.	.	12	22	14	.	.	.	.	.	38	.
<i>Ferula communis</i>	5	.	.	.	.	.	.	.	.	.	9	11	5	6	9	.	.	.	31	4
<i>Rubia peregrina</i>	7	.	.	.	.	.	.	.	.	.	14	11	27	6	9	.	.	.	38	.
<i>Doronicum orientale</i>	5	.	.	.	.	.	.	.	.	.	9	11	.	.	.	.	.	11	31	9
Diagnostic species B8																				
<i>Hermodactylus tuberosus</i>	9	.	.	.	.	.	.	.	.	.	16	.	.	.	.	.	.	11	6	70
<i>Symphytum gussonei</i>	10	.	.	.	.	.	.	.	.	.	18	.	.	.	.	.	.	.	31	65
<i>Ranunculus velutinus</i>	3	.	.	.	.	.	.	.	.	.	6	.	.	.	.	.	.	.	.	30
<i>Silene vulgaris</i> subsp. <i>vulgaris</i>	15	.	.	.	.	.	.	.	.	.	29	17	5	11	18	.	.	44	25	78
<i>Pyrus spinosa</i>	21	.	.	.	.	.	.	.	.	.	40	39	41	11	9	14	17	11	25	87
<i>Tanacetum corymbosum</i> subsp. <i>siculum</i>	12	.	.	.	.	.	.	.	.	.	22	17	14	6	9	.	.	11	13	61
<i>Anisantha sterilis</i>	18	.	.	.	.	.	.	.	.	.	33	50	.	33	55	.	.	11	19	78
<i>Galium aparine</i>	9	.	.	.	.	.	.	.	.	.	17	28	.	6	9	.	.	11	13	43
<i>Lathyrus pratensis</i>	7	2	.	.	.	.	29	.	.	.	12	.	.	11	.	29	.	11	.	43

Table 3. Syntaxonomic overview of the plant communities corresponding to the terminal clusters of the TWINSpan classification. The class, order and alliance levels follow Mucina et al. (2016).

<i>Cytisetea scopario-striati</i> Rivas-Mart. 1974
<i>Cytisetalia scopario-striati</i> Rivas-Mart. 1974
<i>Violo messanensis-Adenocarpion commutati</i> Mucina 2016 <i>mut.</i> Guarino et al. <i>hoc loco</i> (Cluster A)
<i>Phlomis fruticosa-Cytisus infestus</i> comm. (Cluster A1)
<i>Cytiso infesti-Adenocarpion commutati</i> Bartolo, Brullo & Pulvirenti 1994 <i>nom. corr.</i> (Cluster A2)
<i>Cytiso scoparii-Genistetum brutiae</i> Brullo, Scelsi et Spampinato 2001 (Cluster A3)
<i>Centaureo-Adenocarpion brutii</i> Brullo et Furnari in Barbagallo et al. 1982 <i>corr.</i> Brullo, Scelsi et Spampinato 2001 (Cluster A4)
<i>Asphodelo macrocarpi-Pteridetum aquilini</i> Brullo, Scelsi et Spampinato 2001 (Cluster A5)
<i>Polygalo-Cytisetum scoparii</i> Brullo et Furnari in Barbagallo et al. 1982 (Cluster A6)
<i>Cytisetum villosa-scoparii</i> Brullo, Scelsi et Spampinato 2001 (Cluster A6 + A7)
– <i>bromopsietosum caprinae</i> Brullo, Scelsi et Spampinato 2001 <i>nom. corr.</i> (Cluster A6)
– <i>cytisetosum infesti</i> Brullo, Scelsi et Spampinato 2001 <i>nom. corr.</i> (Cluster A7)
<i>Cytiso villosi-Telinetalia monspessulanae</i> Rivas-Mart. et al. 2002
<i>Achilleo ligusticae-Telinion monspessulanae</i> Guarino et Gianguzzi <i>all. nova</i> (Cluster B)
<i>Achilleo ligusticae-Spartietum juncei</i> Gianguzzi <i>ass. nova</i> (Cluster B1)
<i>Erico arborea-Cytisetum infesti</i> Gianguzzi <i>ass. nova</i> (Cluster B2)
<i>Carlino globosae-Telinetum monspessulanae</i> Gianguzzi <i>ass. nova</i> (Cluster B3)
<i>Pteridium aquilinum-Erica arborea</i> comm. (Cluster B5)
<i>Pentanema squarrosum-Pteridium aquilinum</i> comm. (Cluster B6)
<i>Origano viriduli-Cytisetum villosi</i> Gianguzzi <i>ass. nova</i> (Cluster B7)
<i>Hermodyctylo tuberosi-Cytisetum scoparii</i> Gianguzzi <i>ass. nova</i> (Cluster B8)

Cluster A1 – *Phlomis fruticosa-Cytisus infestus* community

Frequent taxa: 100% *Asphodelus ramosus*, *Brachypodium rupestre* (dominant), *Centaurea parlatoris*, *Cytisus infestus* (dominant), *Dactylis glomerata*, *Erica arborea*, *Euphorbia rigida*, *Festuca marginata* subsp. *marginata*, *Origanum vulgare* subsp. *viridulum*, *Phlomis fruticosa* (dominant), *Thalictrum calabricum*, *Thymus longicaulis* subsp. *longicaulis*; ≥ 80% *Asphodeline lutea*, *Cistus salviifolius*, *Helianthemum nummularium* subsp. *obscurum*, *Micromeria graeca* subsp. *tenuifolia*, *Poterium sanguisorba* subsp. *balearicum*, *Silene sicula*, *Viola aethnensis* subsp. *messanensis*.

Structure and ecology: Dense shrubland dominated by *Cytisus infestus* and *Phlomis fruticosa*, with abundant presence of *Brachypodium rupestre* in the herbaceous layer (Figure 6, A1). The shrub layer has an average height of about 1.3 m, while the herbaceous layer reaches approximately 35 cm. This vegetation unit occurs exclusively in the central part of the Peloritani Mountains, between 900 and 1200 m a.s.l., and it is strictly associated with outcrops of the Mandanici geostratigraphic unit. It thrives on slopes with calcschist outcrops, which in the Mandanici unit are frequently and characteristically interbedded with siliceous phyllites.

Local enrichment of soils in carbonate material results in a partial decline of the typical species of *Cytisetea scopario-striati* and a marked reduction of the most calcifuge taxa, thereby allowing the emergence of *Phlomis fruticosa*, a calciphilous species with an eastern Mediterranean distribution that is highly localized and rare in the Peloritani Mts., where it was possibly introduced in ancient times by pastoralism. Nevertheless, the limited and patchy extent of carbonate intercalations, compared

with the predominantly siliceous nature of the Mandanici nappes, prevents strong soil alkalization and allows species of the class *Cytisetea scopario-striati* to characterize this vegetation.

Syndynamics: With increasing slope, where calcschists form rocky outcrops, the association comes into contact with the *Arabido-Hypochoeridetum laevigatae*. Where phyllitic calcschists grade into phyllites and phylladic quartzites, transitional contacts with the *Cytiso infesti-Adenocarpion commutati* may occur, while at lower elevations the vegetation may come into contact with the *Erico arborea-Cytisetum infesti* (described below, see Cluster B2).

Location of the plots (Suppl. material 1: table A1): central part of the Peloritani Mountains, upslope from the village of Mandanici.

Clusters A2 to A7 – other associations of *Violo messanensis-Adenocarpion commutati*

These clusters correspond to associations already known in the phytosociological literature and assigned to the alliance *Violo messanensis-Adenocarpion commutati* (Suppl. material 1: tables A2–A7). In particular, cluster A2 includes relevés referred to the association *Cytiso infesti-Adenocarpion commutati*, which is restricted to elevations above 900 m a.s.l. and occurs in summit areas exposed to strong winds, on outcrops of meso- and epimetamorphic rocks. Under these conditions, *Adenocarpus commutatus*, typically growing closely appressed to the bedrock, reaches particularly high cover values (Figure 6, A2). In secondary habitats created by pastoral activities, *Adenocarpus* becomes subordinate to *Cytisus infestus* and *Erica arborea*, eventually disappearing.

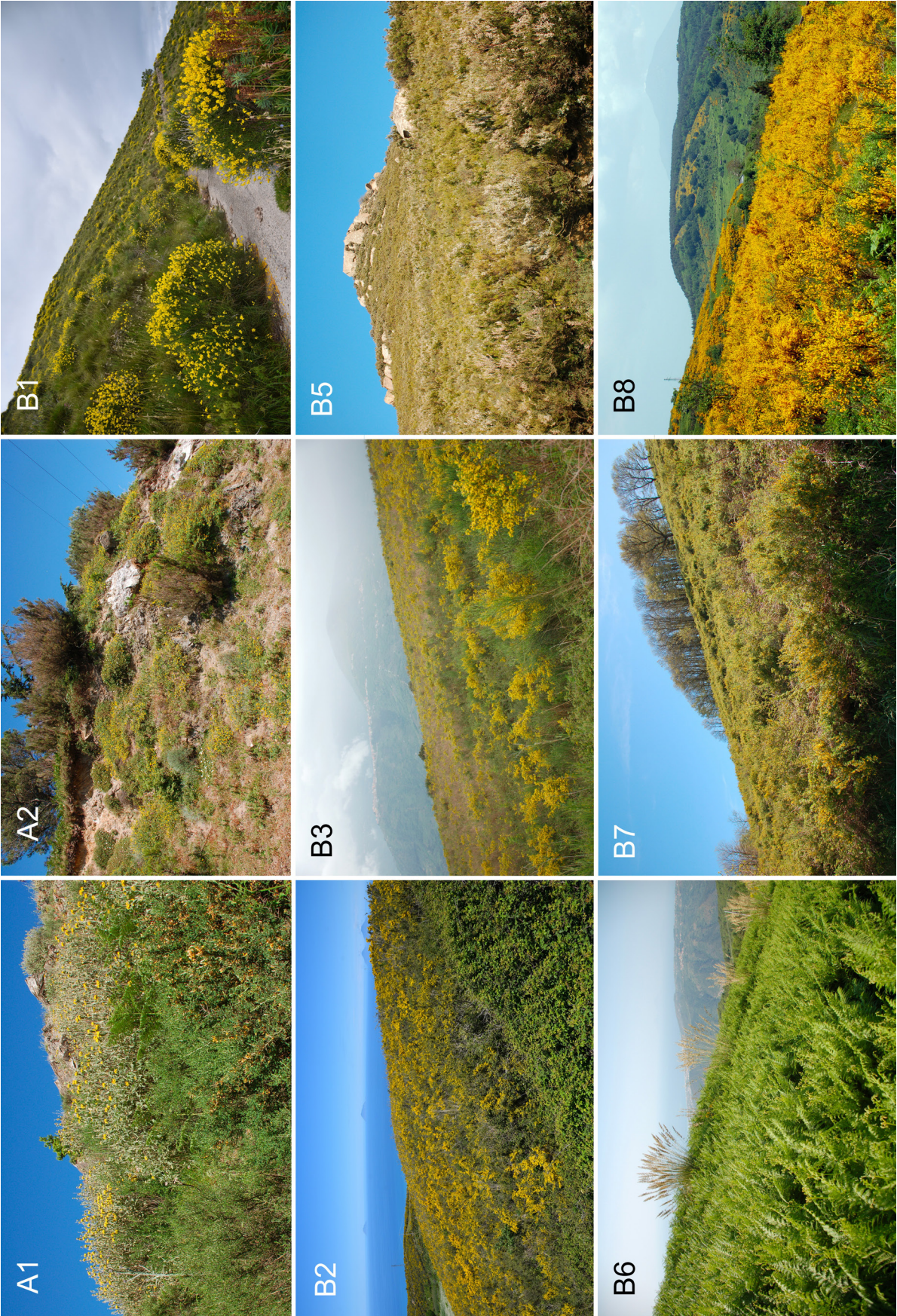


Figure 6. Photos showing typical stands of the TWINSpan terminal clusters. Locations and vegetation types are provided in the text under the cluster ID shown in the photo (Photos: L. Gianguzzi).

Clusters A3 to A7 refer to plant associations described from the Aspromonte massif. These include the *Cytiso scoparii-Genistetum brutiae* (A3), linked to flat sites occasionally waterlogged, above 1000 m a.s.l.; the *Centaureo-Adenocarpetum brutii* (A4), thriving at comparable elevations on relatively steep slopes with outcrops of gneiss, micaschists, and granites; the *Asphodelo macrocarpi-Pteridetum aquilini* (A5), found along valley slopes frequently affected by fog at elevations between 1300 and 1500 m a.s.l.; the *Cytisetum villosa-scoparii bromopsietosum caprinae* (A6), representing the pre-forest mantle of the *Hypochoerido-Pinetum calabricae*. This cluster also includes the *Polygalo-Cytisetum scoparii*, described as the pre-forest mantle of the *Galio hirsuti-Fagetum sylvaticae*, but not separated from the former in the TWINSPAN analysis of our dataset. Slightly more floristically differentiated is the *Cytisetum villosa-scoparii cytisetosum infesti* (A7), which extends down to approximately 700 m a.s.l. and represents the pre-forest mantle of the *Teucrio siculi-Quercetum ilicis*; in steep, semi-rocky sites, it can be regarded as a relatively more thermophilous vicariant of the *Centaureo-Adenocarpetum brutii*.

Cluster B - *Achilleo ligusticae-Telinion monspessulanae* Guarino & Gianguzzi all. nova

Holotypus: *Carlino globosae-Telinetum monspessulanae*, hoc loco.

Territorial character species and differential taxa: *Cytisus villosus*, *Spartium junceum*, *Teline monspessulana*, *Achillea ligustica*, *Origanum vulgare* subsp. *viridulum*, *Rubus canescens*, *Carlina hispanica* subsp. *globosa*, *Clinopodium vulgare* subsp. *arundanum*.

Description: This alliance includes secondary broom-dominated shrublands occurring on acidic, deep and relatively evolved soils in the meso- to locally supra-mediterranean belts of northern Sicily. Communities referred to the *Achilleo ligusticae-Telinion monspessulanae* are mostly secondary shrublands linked to post-disturbance dynamics and to the vegetation series of cork oak and deciduous oak forests. They are characterized by the combination of acidophilous broom species with a thermophilous Mediterranean cohort of herbaceous species frequently associated with forest mantles, abandoned pastures and shrub encroachment stages.

The *Achilleo ligusticae-Telinion monspessulanae* can be interpreted as a geographical vicariant of the *Telinion monspessulano-linifoliae*, described from the Iberian Peninsula and subsequently recorded also in Sardinia and along the Tyrrhenian coasts of central Italy (Vagge et al. 2004; Farris et al. 2007). In the CPO, at the south-eastern margin of the distribution range of the *Cytisetea scopario-striati*, the floristic contingent of the class and of the order *Cytiso villosi-Telinetalia monspessulanae* is markedly impoverished. Consequently, the territorial character species and differential taxa of the alliance largely coincide, at the local scale, with those of the order itself.

Cluster B1 - *Achilleo ligusticae-Spartietum juncei* Gianguzzi ass. nova

Holotypus: see Appendix 1.

Frequent taxa: 100% *Pteridium aquilinum* (dominant), *Spartium junceum* (dominant); $\geq 80\%$ *Achillea ligustica*, *Asphodelus ramosus*; $\geq 60\%$ *Brachypodium sylvaticum*, *Carlina hispanica* subsp. *globosa*, *Cytisus infestus*, *Cytisus villosus*, *Dactylis glomerata*, *Origanum vulgare* subsp. *viridulum*, *Rubus ulmifolius*, *Thapsia garganica*.

Structure and ecology: Shrubby vegetation dominated by *Spartium junceum*, forming a dense canopy with a height of 1.8–2.5 m (Figure 6, B1). The shaded understorey hosts several taxa with variable frequency, including several acidophilous taxa that in the study area are linked to the alliance *Achilleo ligusticae-Telinion monspessulanae*, such as *Achillea ligustica*, *Carlina hispanica* subsp. *globosa*, *Teucrium siculum*, *Pulicaria odora*, *Tanacetum vulgare* subsp. *siculum*, as well as of the class *Cytisetea scopario-striati* (*Pteridium aquilinum*, *Cytisus villosus*, *Teline monspessulana*, *Erica arborea*). This vegetation occurs on sloping sites with deep soils, within the thermo- and mesomediterranean bioclimate with subhumid to humid ombrotype, at elevations ranging from 450 to 1170 m a.s.l. Despite being very common in Sicily, shrublands dominated by *Spartium junceum* remain poorly investigated from a phytosociological perspective. In the study area, these shrublands were traditionally exploited by farmers and woodcutters for poles and firewood (“*frasca*”), which was used both for bread ovens and lime kilns.

Syndynamics: Pre-forest mantle linked to acidophilous woodlands, such as the series of white oak (locally represented by the *Erico-Quercetum virgiliana* and the *Festuco heterophyllae-Quercetum congestae*), and *Quercus cerris* (*Arrhenathero nebrodensis-Quercetum cerridis*). Under regressive dynamics, driven by repeated fire, it is typically replaced by the *Pentanema squarrosus-Pteridium aquilinum* community (Cluster B6).

Location of the plots (Suppl. material 1: table B1): This plant community was recorded across a wide area encompassing the Peloritani and Nebrodi Mountains.

Cluster B2 - *Erico arboreae-Cytisetum infesti* Gianguzzi ass. nova

Holotypus: see Appendix 1.

Frequent taxa: 100% *Cytisus infestus* (dominant); $\geq 80\%$ *Erica arborea*, *Pteridium aquilinum*, *Rubus ulmifolius*; $\geq 60\%$ *Achillea ligustica*, *Ampelodesmos mauritanicus*, *Anthoxanthum odoratum*, *Carlina hispanica* subsp. *globosa*, *Dactylis glomerata*, *Daucus carota*, *Pulicaria odora*, *Spartium junceum*, *Teline monspessulana*.

Structure and ecology: This vegetation consists of a very dense and intricate shrubland, 1.3–2.4 m tall, with a well-developed bistratified structure. The canopy is dominated by *Calicotome infesta*, commonly accompanied by *Erica arborea*, *Spartium junceum* and *Teline monspessulana* (Figure 6, B2). The floristic composition further includes several diagnostic and companion species of the

class *Cytisetea scopario-striati*, such as *Achillea ligustica*, *Cistus salviifolius*, *Micromeria graeca* subsp. *tenuifolia*, *Pulicaria odora*, *Pteridium aquilinum* and *Teucrium siculum*. This shrubland is typically found on ridges and slopes with strongly eroded soils, at elevations between 200 and 900 m a.s.l., within the mesomediterranean bioclimatic belt and marginally in the thermomediterranean one. It is favoured by periodic fire and by the abandonment of farming activities (cultivation and grazing). Only exceptionally it extends to higher elevations, up to about 1200 m a.s.l., where it occurs in floristically impoverished variants.

Syndynamics: A large proportion of the areas colonised by this vegetation represents secondary stages of edaphoxerophilous series linked to acidophilous woodlands (*Genisto aristatae-Quercetum suberis* and *Teucrio siculi-Quercetum ilicis*), occurring within the thermo- and mesomediterranean bioclimatic belts. In these contexts, it frequently intermingles with garrigues dominated by *Cistus salviifolius* (*Cisto-Ericion*), which represents a seral stage of further degradation. On deeper soils, this vegetation is replaced by the *Achilleo ligusticae-Spartietum juncei* (Cluster B1), and occasionally by the *Carlino globosae-Telinetum monspessulani* (Cluster B3) or by the *Origano viriduli-Cytisetum villosi* (Cluster B7) under conditions of higher environmental humidity.

Location of the plots (Suppl. material 1: table B2): This plant community was recorded across a wide area encompassing the Peloritani and Nebrodi Mountains.

Cluster B3 – *Carlino globosae-Telinetum monspessulanae* Gianguzzi ass. nova

Holotypus: see Appendix 1.

Frequent taxa: 100% *Achillea ligustica*, *Pteridium aquilinum*, *Rubus ulmifolius* (dominant), *Teline monspessulana* (dominant); $\geq 80\%$ *Pulicaria odora*, *Spartium junceum*; $\geq 60\%$ *Carlina hispanica* subsp. *globosa*, *Holcus lanatus*, *Ranunculus pratense*.

Structure and ecology: dense shrubland, 1.2–1.8 m in height, with the upper layer dominated by *Teline monspessulana*, and *Rubus ulmifolius* occurring abundantly in the lower stratum (Figure 6, B3). The floristic composition commonly includes also *Achillea ligustica*, *Pteridium aquilinum*, *Pulicaria odora* and *Spartium junceum*, plus *Carlina hispanica* subsp. *globosa*, endemic to the mountain massifs of the CPO and neighbouring areas. The association typically occupies extensive areas with deep sandy to loamy soils and is promoted by grazing abandonment. It is confined to the mesomediterranean bioclimatic belt within subhumid ombrotype, between 550 and 1000 m a.s.l.

Syndynamics: The *Carlino globosae-Telinetum monspessulani* typically replaces the *Pentanema squarrosom-Pteridium aquilinum* community (Cluster B6) along the successional stages leading to deciduous oak woods ascribed to the *Festuco heterophyllae-Quercetum congestae*. Occasionally, it may also occur within the series of *Quercus virgiliana* (*Erico-Quercetum virgilianae*) and of the holm oak (*Teucrio siculi-Quercetum ilicis*); however,

on less loose substrates, with higher clay content, it is replaced by the *Achilleo ligusticae-Spartietum juncei* (Cluster B1). The relevés included in **Cluster B4** can be interpreted as a transitional facies towards deciduous oak woods, being characterized by a pool of species related to forest fringes, such as *Conopodium capillifolium*, *Daphne laureola*, *Euphorbia corallioidea*, *Geranium sanguineum*.

Location of the plots (Suppl. material 1: table B3): This plant community was recorded in the westernmost sector of the Peloritani Mountains (Novara di Sicilia) and throughout the northern slope of the Nebrodi Mountains.

Cluster B5 – *Pteridium aquilinum-Erica arborea* community

Frequent taxa: 100% *Cistus salviifolius*, *Dactylis glomerata*, *Erica arborea* (dominant), *Pteridium aquilinum*; $\geq 80\%$ *Brachypodium sylvaticum*, *Festuca marginata* subsp. *marginata*, *Silene sicula*; $\geq 60\%$ *Aira caryophylla*, *Asphodelus ramosus*, *Brachypodium rupestre*, *Carlina hispanica* subsp. *globosa*, *Crepis leontodontoides*, *Cytisus infestus*, *Geum urbanum*, *Hyoseris radiata*, *Origanum vulgare* subsp. *viridulum*, *Sherardia arvensis*, *Thymus longicaulis* subsp. *longicaulis*.

Structure and ecology: Dense, monospecific shrub vegetation dominated by *Erica arborea*, with a height ranging from 1.8 to 2.5 m (Figure 6, B5). The herbaceous-chamaephytic layer includes several acidophilous species, some of which are highlighted in Suppl. material 1: table B5 as differential taxa of this community. This community represents a permanent vegetation, typical of steep slopes in semi-rupestrian habitats, from which it spreads into secondary environments characterised by eroded and very stony soils, largely created by human activities such as deforestation and the opening of grazing areas. It occurs between 900 and 1200 m a.s.l., within the meso- to supramediterranean bioclimatic belt, under humid ombrotype conditions.

Syndynamics: In semi-rupestrian habitats, this vegetation represents a long-lasting stage, but it is also widespread in secondary habitats related to the degradation of holm oak forests (*Teucrio siculi-Quercetum ilicis*) or turkey oak forests (*Arrhenathero nebrodensis-Quercetum cerridis*). At lower elevations or under more xeric conditions, it shifts towards the *Erico arborea-Cytisetum infesti* (Cluster B2), whereas in windy, summit environments it grades into the *Cytiso infesti-Adenocarpum commutati* (Cluster A2).

Location of the plots (Suppl. material 1: table B5): This community was recorded all along the Peloritani Mountains, from Dinnammare (near Messina) to Novara di Sicilia.

Cluster B6 – *Pentanema squarrosom-Pteridium aquilinum* community

Frequent taxa: 100% *Pteridium aquilinum* (dominant), *Rubus canescens*, $\geq 80\%$ *Pentanema squarrosom*, *Oenanthe pimpinelloides*; $\geq 60\%$ *Achillea ligustica*, *Anthoxanthum odoratum*, *Brachypodium sylvaticum*, *Carlina hispanica*

subsp. *globosa*, *Crepis leontodontoides*, *Dactylis glomerata*, *Holcus lanatus*, *Ranunculus pratensis*, *Trifolium pratense* subsp. *semipurpureum*.

Structure and ecology: Closed, bistratified community, 0.8–1.8 m tall, dominated by *Pteridium aquilinum* (Figure 6, B6). In the shaded understorey, *Rubus canescens*, *Pentanema squarrosus* and *Oenanthe pimpinelloides* are very frequent. The floristic composition is further characterised by the occurrence of several meadow species of the class *Molinio-Arrhenatheretea*, such as *Anthoxanthum odoratum*, *Dactylis glomerata*, *Holcus lanatus*, *Ranunculus pratensis* and *Trifolium pratense* subsp. *semipurpureum*. This vegetation occurs on deep soils between 500 and 1100 m a.s.l., within the meso- and supramediterranean bioclimatic belts, under subhumid to humid ombrotypes. In the study area, it occupies extensive surfaces, typically colonising abandoned pastures and former arable land, and is favoured by recurrent fire disturbance, which promotes the persistence and spatial expansion of bracken-dominated stands.

Syndynamics: Within the mesomediterranean bioclimatic belt, this community typically shows a successional trend towards the *Achilleo ligusticae-Spartietum juncei* (Cluster B1), which belongs to the series of the deciduous oak woodland *Festuco heterophyllae-Quercetum congestae*. At higher elevations, in the supramediterranean belt, succession proceeds instead towards the *Origano viriduli-Cytisetum villosi* (Cluster B7) and *Hermodactylo tuberosi-Cytisetum scoparii* (Cluster B8), in their turn associated with the series of Turkey oak (*Arrhenathero nebrodensis-Quercetum cerridis*) and of beech forests (*Anemone apenninae-Fagetum sylvaticae*), respectively.

Location of the plots (Suppl. material 1: table B6): This community is widely distributed throughout the study area.

Cluster B7 – *Origano viriduli-Cytisetum villosi* Gianguzzi ass. nova

Holotypus: see Appendix 1.

Frequent taxa: 100% *Achillea ligustica*, *Cytisus villosus* (dominant), *Pteridium aquilinum*; *Rubus canescens*; ≥ 80% *Brachypodium sylvaticum*, *Daucus carota*, *Origanum vulgare* subsp. *viridulum*, *Spartium junceum*; ≥ 60% *Clinopodium vulgare* subsp. *arundanum*, *Erica arborea*, *Teline monspessulana*.

Structure and ecology: Shrub vegetation with a canopy height ranging from 1.4 to 2.1 m, dominated by *Cytisus villosus*, in which several acidophilous species of the class *Cytisetea scopario-striati* co-occur (Figure 6, B7). Among these are *Pteridium aquilinum*, *Erica arborea*, *Teline monspessulana*, *Thymus longicaulis* subsp. *longicaulis*, *Cytisus scoparius* and *Orobancha rapum-genistae*. In addition, *Achillea ligustica*, *Origanum vulgare* subsp. *viridulum* and *Rubus canescens* were recorded in all sampled plots. This association occurs on deep soils, in flat or gently sloping sites, between 600 and 1000 m a.s.l. (exceptionally up to 1100 m), within the humid mesomediterranean bioclimatic belt.

Syndynamics: Its development is generally promoted by grazing abandonment, and it commonly replaces the bracken-dominated community (*Pentanema squarrosus-Pteridium aquilinum* community, cluster B6) along the successional transition tending towards deciduous oak forests (mainly the *Arrhenathero nebrodensis-Quercetum cerridis* but occasionally also the *Festuco heterophyllae-Quercetum congestae*).

Location of the plots (Suppl. material 1: table B7): This association was recorded from the central sector of Peloritani Mountains up to the western sector of Nebrodi Mountains.

Cluster B8 – *Hermodactylo tuberosi-Cytisetum scoparii* Gianguzzi ass. nova

Holotypus: see Appendix 1.

Frequent taxa: 100% *Cytisus scoparius* (dominant), *Pteridium aquilinum*; ≥ 80% *Achillea ligustica*, *Anthoxanthum odoratum*, *Asperula laevigata*, *Carlina hispanica* subsp. *globosa*, *Cynosurus cristatus*, *Dactylis glomerata*, *Daucus carota*, *Origanum vulgare* subsp. *viridulum*, *Pyrus spinosa*, *Rubus canescens*; ≥ 60% *Asphodelus ramosus*, *Bellis perennis*, *Clinopodium vulgare* subsp. *arundanum*, *Hermodactylus tuberosus*, *Holcus lanatus*, *Luzula forsteri*, *Rosa canina*, *Symphytum gussonei*, *Tanacetum vulgare* subsp. *siculum*, *Thymus longicaulis* subsp. *longicaulis*.

Structure and ecology: Dense shrub vegetation, with a canopy height ranging from 1 to 2.2 (occasionally up to 2.5) m, dominated by *Cytisus scoparius* (Figure 6, B8). The herbaceous layer is characterised by abundant geophytes (*Asphodelus ramosus*, *Hermodactylus tuberosus* and *Leopoldia comosa*), as well as by many transgressive species of the class *Molinio-Arrhenatheretea*. Numerous acidophilous elements of the class *Cytisetea scopario-striati* are also present. This association occurs between 900 and 1300 m a.s.l., on deep, flat or gently sloping soils, within the meso- and supramediterranean bioclimatic belts, under a humid ombrotype.

Syndynamics: This association represents a secondary successional community replacing bracken stands (*Pentanema squarrosus-Pteridium aquilinum* community, cluster B6) within dynamic series leading towards beech forests. In the Peloritani Mountains it is included in the series heading to the *Melittido albidiae-Fagetum sylvaticae*, whereas in the Nebrodi Mountains it belongs to the series of the *Anemone apenninae-Fagetum sylvaticae*.

Location of the plots (Suppl. material 1: table B8): This association was recorded all over the Nebrodi mountains, up to the SW sector of Peloritani mountains.

Discussion

To date, most phytosociological attention devoted to the *Cytisetea scopario-striati* in the massifs of the CPO has focused on communities hosting endemic species and confined to wind-exposed ridges and summit areas within the meso-supramediterranean bioclimatic belt (Bartolo et al.

1994; Brullo et al. 2001b). These communities, referred to the *Violo messanensis-Adenocarpion commutati*, have been interpreted as relictual or long-lasting formations linked to eroded soils and windswept ridges (Guarino et al. 2005). However, the present study highlights that a much larger proportion of the area currently occupied by broom-dominated shrublands in northern Sicily consists of secondary formations, whose expansion has been largely favoured by historical deforestation for agro-pastoral land use.

Recent land-use abandonment has further enhanced the spatial continuity and ecological relevance of these shrublands, triggering successional pathways that, under reduced disturbance, tend to converge towards forest vegetation dominated by *Fagaceae*. In this context, the broom-dominated communities analysed here represent intermediate, dynamic stages within broader vegetation series rather than stable endpoints. This dynamic character is particularly evident in the vegetation units grouped within cluster B of our TWINSPAN analysis (Figure 2; Table 1).

Unlike the communities of cluster A, the vegetation units of cluster B do not host many rare, endemic or narrowly distributed species. Nevertheless, by adopting physiognomic dominance as the primary criterion—namely the dominance of *Cytisus villosus*, *C. scoparius*, *C. infestus*, *Erica arborea*, *Teline monspessulana*, *Pteridium aquilinum* and *Spartium junceum*, which constitute the main structural elements of the studied vegetation—it was possible to detect several floristically coherent assemblages, composed of widely distributed species, such as *Achillea ligustica*, *Carlina hispanica* subsp. *globosa*, *Hermodactylus tuberosus*, *Pulicaria odora*, *Tanacetum vulgare* subsp. *siculum*, and *Teucrium siculum*. These species cannot be attributed to the class *Cytisetea scopario-striati* sensu stricto, but they locally contribute to the floristic differentiation and ecological characterization of the investigated vegetation units (Table 2). This applies also to *Cytisus infestus* and *Spartium junceum* which, although they can be regarded within the study area as local diagnostic elements of the class *Cytisetea scopario-striati*, are edaphically indifferent, disturbance-favoured species with a distribution far wider than that of the truly characteristic elements of the class.

As expected for secondary shrublands lacking true character species, the vegetation units of cluster B show broad floristic overlaps and gradual transitions, with no sharp boundaries between neighbouring units. Such patterns reflect the combined effects of land-use history, local site conditions and ongoing successional dynamics (La Mantia et al. 2007). In the study area, these communities clearly derive from anthropogenic disturbances that have strongly favoured broom-dominated formations, allowing shrub species that were probably confined in the past to marginal refugia—characterized by high wind exposure and persistent atmospheric humidity typical of maritime mountain ranges—to spread extensively, in some cases down to near sea level.

This interpretation is further supported by the frequent occurrence, within the species combinations characterizing cluster B (Table 1), of transgressive herbaceous species belonging to the *Molinio-Arrhenatheretea* (in particular the *Cirsietalia vallis-demonis*), as well as, depending on altitude,

species of the *Quercetea ilicis* and of the *Quercio-Fagetea* (e.g. *Brachypodium sylvaticum*, *Asperula laevigata*). These floristic elements testify to the serial nature of this vegetation, documenting transitions from formerly grazed grasslands towards shrublands and, ultimately, towards forest communities. The different species pools highlighted as “transgressive” in Tables B1–B8 (Suppl. material 1) provide clear evidence of the origin and ecological role of the vegetation referred here to the alliance *Achilleo ligusticae-Telinion monspessulanae*.

The classification of these secondary broom communities inevitably raises several problems. As said, their study must rely primarily on physiognomic-structural dominance criteria, as true character species are largely absent. This issue is not specific to Sicily but reflects a more general problem in the classification of marginal or impoverished scrub communities at the edges of the distribution range of the *Cytisetea scopario-striati*. Similar difficulties have been highlighted for Atlantic and sub-Atlantic Europe, where broom and gorse thickets show strong floristic impoverishment and borrow diagnostic elements from structurally related vegetation classes (Haveman et al. 2017).

Comparable challenges have also emerged from recent floristic-ecological classifications of Iberian gorse scrub communities, where the predominance of physiognomic dominants and the wide ecological amplitude of key shrub species result in syntaxa with blurred boundaries and partial affinities to multiple higher-rank units (Pulgar Sañudo and Herrera Rodríguez 2025). These studies converge in emphasizing that, in such contexts, classification should aim to capture ecologically meaningful variation rather than forcing rigid syntaxonomic schemes. From a broader Mediterranean perspective, broom-dominated shrublands are dynamic systems hosting high levels of biodiversity, and playing a crucial role in landscape resilience. Their classification, therefore, must balance floristic resolution with ecological realism. In highly dynamic, secondary vegetation types dominated by widespread species, excessive subdivision risks generating poorly informative units. Nevertheless, the criterion adopted here (physiognomic dominance by single shrub species) inevitably required us to take responsibility for proposing a syntaxonomic interpretation of the terminal clusters produced by the TWINSPAN analysis. We are fully aware that the units thus defined do not represent sharply delimited vegetation types in the field, but rather conceptual entities characterized by broad overlaps and gradual transitions. In this sense, the proposed associations should be regarded as interpretative constructs, aimed at organizing continuous ecological variation into a coherent framework, rather than as discrete and mutually exclusive phytosociological entities.

In this sense, the present contribution aligns with recent reflections on the epistemological limits of vegetation classification, which emphasize that any syntaxonomic system represents an approximation of ecological reality, constructed for practical and communicative purposes rather than a definitive representation of nature (Guarino et al. 2022).

Ultimately, most of the broom-dominated shrublands of northern Sicily represent a complex and heterogeneous set of secondary communities whose classification cannot

rely on classical diagnostic species concepts alone. A pragmatic approach based on physiognomic dominance, ecological coherence and serial interpretation appears more appropriate to capture their variability and ecological role. While the syntaxonomic framework proposed here provides a useful working hypothesis, it should be regarded as a flexible tool, open to future refinement as new data and broader comparative analyses become available.

Syntaxonomy

Regarding the syntaxonomic framework of the newly proposed alliance *Achilleo ligusticae-Telinion monspessulanae*, it should be noted that Mucina et al. (2016) recognize three orders within the class *Cytisetea scopario-striati*:

- (1) *Cytisetalia scopario-striati* (“Western and Central Mediterranean thermo- to supramediterranean and submediterranean broomy cytisoid scrub”), comprising seven alliances, one of which occurs in Italy (*Violo messanensis-Adenocarpion complicati*, “Siculo-Calabrian meso-supramediterranean broom heath”);
- (2) *Cytiso villosi-Telinetalia monspessulanae* (“Aljibic, Tyrrhenian and Catalanian thermo-mesomediterranean subhumid–humid silicicolous genistoid retamal”), including four alliances, one of which is reported for Italy (*Telinion monspessulano-linifoliae*, “Western communities. In Italy, they only grow on the Tyrrhenian coasts of the islands and of the peninsula”);
- (3) *Spartio juncei-Cytisetalia scoparii* (“a cool-temperate and submediterranean analogon of the *Cytisetalia scopario-striati*, comprising species-poorer communities lacking the core stock of Mediterranean retamoid and genistoid broom taxa”), with three alliances, one of which occurs in Italy (*Erico scopariae-Cytision scoparii*, “Apennine broomy heath vegetation”, see also Vagge 2002; Angiolini et al. 2007; Landi et al. 2009).

Within this framework—consistent with the schemes proposed by Rivas-Martínez et al. (2002) for the Iberian Peninsula, Biondi et al. (2014) for Italy, and Škvorc et al. (2017) for Croatia—based on the evidence presented in this study, we consider the most appropriate placement of *Achilleo ligusticae-Telinion monspessulanae* to be within the order *Cytiso villosi-Telinetalia monspessulanae*. In Sicily, which represents the south-easternmost limit of the distribution range of the *Cytisetea scopario-striati*, the order *Cytisetalia scopario-striati* reaches its ecological optimum in the supramediterranean belt, whereas the vegetation referred to *Achilleo ligusticae-Telinion monspessulanae* appears more closely related to the thermo- and mesomediterranean belts. For the same reasons, assigning this new alliance to the *Spartio juncei-Cytisetalia scoparii* would be inappropriate, as the vegetation investigated here is clearly associated with a typically Mediterranean climate, rather than with the cool-temperate submediterranean conditions characterizing that order.

From a phytogeographical perspective, we have already highlighted the peculiarities of the Calabro-Peloritan Orogen

(CPO), which clearly distinguish it from the Apennine Range. For this reason, and owing to the absence of character species such as *Cytisus arboreus*, *C. baeticus*, *C. catalaunicus* and *Teline linifolia*, we believe it would be inappropriate to extend the distribution range of the alliance *Telinion monspessulano-linifoliae* up to Sicily. Similarly, on biogeographical grounds, we propose here to modify the name of the alliance *Violo messanensis-Adenocarpion complicati* to *Violo messanensis-Adenocarpion commutati* (Appendix 2).

Although the syntaxonomic framework adopted here is shared by the majority of authors, it is worth recalling that De Foucault et al. (2013) deem it more appropriate to assign to the *Ericion arboreae* (alliance of the *Pistacio lentisci-Rhamnetalia alaterni*, class *Quercetea ilicis*) the character species of the *Cytiso villosi-Telinetalia monspessulanae* and *Telinion monspessulano-linifoliae* occurring in France, namely *Cytisus villosus*, *Teline linifolia* and *Teline monspessulana*. The validity of this proposal, however, requires confirmation through broader comparative analyses across the Mediterranean region, in order to assess the ecological amplitude and syntaxonomic coherence of this view at higher hierarchical levels.

A further issue concerns the syntaxonomic interpretation of the secondary broom shrublands referred here to the *Achilleo ligusticae-Telinion monspessulanae*. One could argue that the absence of exclusive character species does not justify the recognition of a separate alliance and that these communities might instead be accommodated within a broader concept of the *Violo messanensis-Adenocarpion commutati*. Such a solution would reduce the syntaxonomic inflation and deserves serious consideration.

However, this interpretation would have consequences extending beyond the alliance rank. The communities included in the *Violo messanensis-Adenocarpion commutati* are referred to the *Cytisetalia scopario-striati*, whereas the forest mantles most closely related to the communities ascribed to the newly proposed alliance have been assigned to the *Cytiso villosi-Telinetalia monspessulanae* by several authors, not only in the Iberian Peninsula, but also in Italy (Vagge et al. 2004; Farris et al. 2007). Consequently, merging the two alliances discussed here would implicitly question the distinctiveness of the corresponding orders, at least for the Italian territory.

Preliminary comparisons based on the Italian phytosociological literature suggest that this possibility cannot be ruled out. In fact, some preliminary analyses conducted on a broader dataset, including relevés from Central Italy and Sardinia originally assigned to the *Sarothamnion scoparii* and to the *Telinion monspessulano-linifoliae*, suggest a relatively weak floristic separation between communities currently referred to *Cytisetalia scopario-striati* or to *Cytiso villosi-Telinetalia monspessulanae* by the Italian authors, while the broom shrublands from Calabria and Sicily emerge as a comparatively coherent biogeographical entity (Suppl. material 2: figure S2.3).

As in the case of the previously mentioned relationship with the *Ericion arboreae*, assessing whether the distinction between *Cytisetalia scopario-striati* and *Cytiso villosi-Telinetalia monspessulanae* should be maintained, and

to what extent, would require a comprehensive revision based on a much broader geographical framework than that considered here, including representative material from the Iberian Peninsula. Such a revision clearly falls beyond the scope of the present contribution. Pending a critical reassessment of the higher-rank syntaxa involved, we retain the *Achilleo ligusticae-Telinion monspessulanae* as an alliance concept that acknowledges the floristic and ecological differentiation observed within the Sicilian dataset.

Conclusions

This study provides a comprehensive reassessment of the broom-dominated shrublands of the class *Cytisetea scopario-striati* in northern Sicily, at the south-eastern margin of the class distribution range. By combining extensive field sampling, numerical classification and a critical syntaxonomic interpretation, we have clarified the ecological role, floristic composition and biogeographical relationships of these shrublands, distinguishing between environmentally constrained montane communities and secondary formations resulting from long-lasting human disturbance.

Our results confirm the existence of two major ecological and dynamic groups. The first group encompasses shrublands developing under strong climatic and edaphic constraints, often hosting endemic or biogeographically significant species and representing long-lasting vegetation types. These communities are coherently framed within the alliance *Violo messanensis-Adenocarpion commutati*, whose syntaxonomic circumscription is here refined on biogeographical and nomenclatural grounds. The second group includes a set of ecologically dynamic shrublands with ecological optimum at lower elevations, mostly as secondary mantles of acidophilous forest series. These communities are here interpreted as belonging to a newly proposed alliance, the *Achilleo ligusticae-Telinion monspessulanae*, which can be regarded as a central-Mediterranean vicariant of the *Telinion monspessulano-linifoliae*.

The classification of these secondary shrublands poses intrinsic difficulties, as they are largely dominated by widespread species and lack narrowly defined characteristic taxa. Consequently, their recognition necessarily relies

on physiognomic dominance and on recurrent species assemblages rather than on strict floristic exclusivity. The syntaxonomic units proposed here should therefore be understood as interpretative constructs aimed at organising continuous ecological variation into a coherent and operational framework, rather than as sharply delimited entities. This approach is consistent with recent perspectives in vegetation science that emphasise ecological realism and explanatory power over rigid typological subdivision.

From a historical-ecological perspective, it is important to stress that the present extent and structure of these shrublands are tightly linked to land-use dynamics. Until the mid-20th century, the frequency of wildfires was better controlled than at present times, as broom-dominated shrublands represented an important resource for rural communities. Shrubs such as *Cytisus infestus*, *Spartium junceum*, *Cytisus villosus* and *Genista monspessulana* were widely exploited for poles used in vineyards and gardens, as well as for firewood (“frasca”) supplying bread ovens and lime kilns. Their relevance in traditional rural economies is further testified by the rich vernacular nomenclature associated with these species, which varied locally: in Frazzanò (Nebrodi Mts.), for example, *Cytisus infestus* was known as “Làstra”, *Spartium junceum* as “Jnèstra”, *Cytisus villosus* as “Muddacchina fimminina”, *Teline monspessulana* as “Muddacchina masculina”, and *Erica arborea* as “Lència”. Even *Pteridium aquilinum* (“Filicia”) was actively managed, being cut to limit its spread and used to cover haystacks, protect sheaves or as bedding in livestock shelters.

The abandonment of these traditional practices after World War II profoundly altered disturbance regimes, favouring shrub encroachment, biomass accumulation and, paradoxically, an increase in fire frequency and intensity. In this context, the shrublands studied here should not be regarded merely as degraded or transient vegetation types, but as key components of Mediterranean cultural landscapes, shaped by the long-term interaction between ecological processes and human management.

While any classification inevitably represents an approximation of ecological reality, the framework proposed here provides an informed and pragmatic basis for understanding, comparing and managing broom-dominated shrublands in Sicily and across the Mediterranean region.

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Appendix 1: Type relevés of the new phytosociological associations

Achilleo ligusticae-Spartietum juncei Gianguzzi *ass. nova hoc loco*

Holotypus (Suppl. material 1: table B1, rel. N9): Elevation 1025 m a.s.l.; Slope 30%; Aspect E; Plot size 100 m²; Total vegetation cover 100%; Shrub layer cover 100%; Herb layer cover 60%; Mean canopy height 2.5 m; Char. and diff. association: *Spartium junceum* 5, *Achillea ligustica* +; Diagnostic species alliance, order and class: *Cytisus infestus* 1, *Pteridium aquilinum* 3, *Origanum vulgare* subsp. *viridulum* 1, *Carlina hispanica* subsp. *globosa* +; Other species: *Rubus ulmifolius* 3, *Teucrium siculum* 1, *Foeniculum vulgare* subsp. *vulgare* 1, *Dactylis glomerata* 1, *Anthoxanthum odoratum* 1, *Asphodelus ramosus* 1, *Cistus salviifolius* +, *Daucus carota* +, *Brachypodium sylvaticum* +, *Anisantha sterilis* +, *Eryngium campestre* +, *Bromus hordeaceus* +, *Vicia cracca* +, *Urospermum dalechampii* +. Location: Ucria, along State Route 116, 6 July 2011.

Erico arborea-Cytisetum infesti Gianguzzi *ass. nova hoc loco*

Holotypus (Suppl. material 1: table B2, rel. N14): Elevation 650 m a.s.l.; Slope 55%; Aspect SW; Plot size 100 m²; Total vegetation cover 100%; Shrub layer cover 100%; Herb layer cover 40%; Mean canopy height 1.8 m; Diagnostic species association: *Cytisus infestus* 5, *Erica arborea* 1; Diagnostic species alliance, order and class: *Micromeria graeca* subsp. *tenuifolia* 1; *Achillea ligustica* 1, *Carlina hispanica* subsp. *globosa* 1, *Teline monspessulana* +, *Spartium junceum* +, *Origanum vulgare* subsp. *viridulum* +; Other species: *Ampelodesmos mauritanicus* 4, *Cistus salviifolius* 3, *Rubus ulmifolius* 3, *Daphne gnidium* 1, *Dittrichia viscosa* 1, *Asparagus acutifolius* 1, *Dactylis glomerata* 1, *Hypochoeris laevigata* 1, *Carlina gummifera* 1, *Daucus carota* +, *Clinopodium vulgare* subsp. *arundanum* +, *Pulicaria odora* +, *Calamintha nepeta*

+, *Foeniculum vulgare* subsp. *vulgare* +, *Poterium sanguisorba* subsp. *balearicum* +, *Vicia villosa* subsp. *varia* +, *Hypochoeris radicata* +, *Avena barbata* +, *Sixalix atropurpurea* var. *maritima* +, *Pallenis spinosa* +, *Astragalus epiglottis* +, *Cynosurus echinatus* +. Location: San Marco d'Alunzio, Serra di Caprileone, 26 May 2019.

***Carlino globosae-Telinetum monspessulanae* Gianguzzi ass. nova hoc loco**

Holotypus (Suppl. material 1: table B3, rel. N9): Elevation 700 m a.s.l.; Slope 10%; Aspect N; Plot size 100 m²; Total vegetation cover 100%; Shrub layer cover 100%; Herb layer cover 40%; Mean canopy height 1.5 m; Diagnostic species association: *Teline monspessulana* 5, *Carlina hispanica* subsp. *globosa* 1; Diagnostic species alliance, order and class: *Pteridium aquilinum* 3, *Spartium junceum* 1, *Cytisus infestus* 1, *Cytisus villosus* 1, *Achillea ligustica* 1; Other species: *Cistus salviifolius* 3, *Quercus virgiliana* 2, *Anthoxanthum odoratum* 2, *Ampelodesmos mauritanicus* 2, *Pulicaria odora* 2, *Anisantha sterilis* 1, *Rubus ulmifolius* 1, *Holcus lanatus* 1, *Ranunculus pratensis* 1, *Plantago serraria* +, *Carex flacca* 1, *Euphorbia exigua* 1, *Clinopodium vulgare* subsp. *arundanum* +, *Teucrium siculum* +, *Picris hieracioides* +, *Bellis perennis* 1, *Daphne gnidium* +, *Dittrichia viscosa* +. Location: Frazzanò, Pomorazzo, 24 April 2010.

***Origano viriduli-Cytisetum villosi* Gianguzzi ass. nova hoc loco**

Holotypus (Suppl. material 1: table B7, rel. N15): Elevation 965 m a.s.l.; Slope 40%; Aspect W; Plot size 100 m²; Total vegetation cover 100%; Shrub layer cover 100%; Herb layer cover 40%; Mean canopy height 2 m; Diagnostic species association: *Cytisus villosus* 5, *Rubus canescens* 4, *Origanum vulgare* subsp. *viridulum* 1; Diagnostic species alliance, order and class: *Spartium junceum* 2, *Teline monspessulana* 2, *Achillea ligustica* 2, *Carlina hispanica* subsp. *globosa* +, *Pteridium aquilinum* 2, *Erica arborea* 1, *Micromeria graeca* subsp. *tenuifolia* +; Other species: *Poterium sanguisorba* subsp. *balearicum* 2, *Asphodelus ramosus* 2, *Brachypodium sylvaticum* 2, *Ampe-*

lodesmos mauritanicus 2, *Teucrium siculum* 2, *Oenanthe pimpinelloides* 1, *Brachypodium rupestre* 1, *Pulicaria odora* 1, *Cistus salviifolius* 1, *Holcus lanatus* 1, *Daucus carota* 1, *Dactylis glomerata* +, *Anthoxanthum odoratum* +, *Anisantha sterilis* +, *Clinopodium vulgare* subsp. *arundanum* +, *Calamintha nepeta* +, *Picris hieracioides* +, *Bellis perennis* +, *Hypochoeris laevigata* +, *Vicia villosa* subsp. *varia* +, *Ranunculus pratensis* +, *Plantago serraria* +, *Asperula laevigata* +, *Silene vulgaris* subsp. *vulgaris* +, *Thymus longicaulis* subsp. *longicaulis* +, *Geranium sanguineum* +, *Arenaria agrimonoides* +, *Allium subhirsutum* +, *Crataegus monogyna* +, *Jasione echinata* +, *Hyoseris radiata* +, *Carex distachya* +, *Thapsia garganica* +, *Trifolium bivonae* +, *Trifolium repens* +, *Hypericum australe* +, *Festuca heterophylla* +, *Hypericum hircinum* +, *Lathyrus sphaericus* +, *Medicago lupulina* +. Location: San Marco d'Alunzio, Contrada Feudo La Montagna, 26 May 2019.

***Hermodactylo tuberosi-Cytisetum scoparii* Gianguzzi ass. nova hoc loco**

Holotypus (Suppl. material 1: table B8, rel. P6): Elevation 1290 m a.s.l.; Slope 5%; Aspect NW; Plot size 100 m²; Total vegetation cover 100%; Shrub layer cover 100%; Herb layer cover 90%; Mean canopy height 2 m; Diagnostic species association: *Cytisus scoparius* 5, *Muscari comosum* 1, *Hermodactylus tuberosus* +; Diagnostic species alliance, order and class: *Pteridium aquilinum* 3, *Rubus canescens* 2, *Achillea ligustica* 1, *Carlina hispanica* subsp. *globosa* +, *Origanum vulgare* subsp. *viridulum* +; Other species: *Dactylis glomerata* 2, *Calamintha nepeta* 2, *Anthoxanthum odoratum* 1, *Brachypodium sylvaticum* 1, *Cynosurus cristatus* 1, *Symphytum gussonei* 1, *Galium aparine* 1, *Asperula laevigata* 1, *Silene vulgaris* subsp. *vulgaris* 1, *Thymus longicaulis* subsp. *longicaulis* 1, *Clinopodium vulgare* subsp. *arundanum* 1, *Anisantha sterilis* +, *Daucus carota* +, *Asphodelus ramosus* +, *Picris hieracioides* +, *Bellis perennis* +, *Geranium sanguineum* +, *Luzula forsteri* +, *Tanacetum vulgare* subsp. *siculum* +, *Anemone hortensis* +, *Leontodon tuberosus* +, *Pyrus spinosa* +, *Trifolium pratense* subsp. *semipurpureum* +. Location: Montalbano Elicona, road to Contrada Argimusco, 8 May 2019.

Appendix 2: Alterations of syntaxon names and proposed *nomina mutata*

***Violo messanensis-Adenocarpion commutati* Mucina 2016 nom. mut. nov. (Art. 45 ICPN)**

(=) *Violo messanensis-Adenocarpion complicati* Mucina 2016

Original diagnosis: Bartolo et al. 1994: 401 et seq. as *Violion messanensis*

Taxonomic source: Pignatti et al. (2017–2019).

The genus *Adenocarpus* is represented in Italy by five clearly disjunct populations (Brullo et al. 2001a), three of which (*A. brutius*, *A. commutatus* and *A. tenoreanus*) are restricted to the massifs of the CPO, one is endemic to Mt. Etna (*A. bivonae*), and another one (*A. samniticus*) occurs on volcanic and quartzitic substrates in central Italy.

Although some authors treat these populations as subspecies of *A. complicatus* (Bernardo et al. 2010; Peruzzi

2011), it is beyond doubt that the nomenclatural type of *A. complicatus* refers to populations from the western Iberian Peninsula (Cubas et al. 2010) and that the nomenclatural type indicated by Mucina et al. (2016) for the alliance *Violo messanensis-Adenocarpion complicati*,

i.e. the association *Cytiso infesti-Adenocarpetum commutati*, was described from the Peloritani range, where *Adenocarpus commutatus* (or *A. complicatus* subsp. *commutatus*, following the combination proposed by Peruzzi 2011) is the only representative of the genus.

Additional information

Conflict of interest

The authors have declared that no competing interests exist.

Ethical statement

The research does not involve humans or animals, so no ethical statement was reported.

Artificial Intelligence (AI) use

No AI tool was used for conducting the research and writing the manuscript.

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Author contributions

RG and LG planned the research. RG, LG and OC sampled the vegetation. RG and CM performed the statistical analyses, being supported by ASG. RG drafted the manuscript, with substantial inputs from LG for the syntaxonomic interpretation. All authors critically revised and approved the manuscript.

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Data availability

The original data underlying this study are provided in Suppl. material 1.

Supplementary material

Supplementary material 1

Full synoptic tables and species matrix (*.xlsx)

Link: <https://doi.org/10.3897/VCS.183815.suppl1>

Supplementary material 2

Additional figures (*.pdf)

Link: <https://doi.org/10.3897/VCS.183815.suppl2>