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Numerical classification of the *Carici caryophylleae-Genistetea lobelii* in Corsica (France)

Pauline Delbosc[1], Mathieu Le Dez[2], Jan-Bernard Bouzillé[3], Kevin Cianfaglione[4] & Frédéric Bioret[1]

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Abstract. The class '*Carici caryophylleae-Genistetea lobelii* Klein 1972' corresponds to Cyrno-Sardian oromediterranean cushion-scrubs and related grasslands. In France, this class is only present in Corsica and the syntaxonomic scheme is debated among phytosociologists. This paper aims to highlight the main plant associations of the *Carici caryophylleae-Genistetea lobelii* Klein 1972 and to define the diagnostic species for each phytosociological unit. Diagnostic species are defined as species with a distinct concentration of occurrence or abundance in a particular vegetation unit. We compiled 519 vegetation plots and we applied the EuroVegChecklist expert system for the classes of European vegetation to only retain vegetation plots belonging to the *Carici caryophylleae-Genistetea lobelii*. We obtained a dataset with 189 vegetation plots, and we classified them using the Modified TWINSPAN classification. Our analyses identified six plant associations and three sub-associations that have already been described in the literature; and we were able to describe a new alliance corresponding to supramediterranean plant communities (*Genistion salzmannii*). For each of them, we identified diagnostic, constant, and dominant species and produced their distribution map. Formal definitions were then written for each phytosociological unit (from sub-association to class) and grouped in an expert system to classify the plant communities of the *Carici caryophylleae-Genistetea lobelii*.

Keywords: *Carici caryophylleae-Genistetea lobelii* Klein 1972; Corsica; TWINSPAN; Expert System.

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Introduction

Corsican oromediterranean cushion-scrubs and related grasslands represent the main plant communities of the mountain landscapes of Corsica (Gamisans 1977, 1979, 1991). Given their floristic composition made up of numerous endemic species and because they represent endemic bird habitats (*Sylvia sarda, Serinus citrinella corsicana*), supra- and oromediterranean cushion-tragacanthic scrub and related grasslands are classified as a habitat of community interest in the European Union Habitats Directive: '4090 - Endemic oromediterranean heaths with gorse' (Romao *et al.*, 2015). The characterization of this habitat is based on expert judgment reflecting traditional phytosociological units. The description of habitat type 4090 refers only to the *Anthyllidion hermanniae* alliance assigned to the *Carici caryophylleae-Genistetea lobelii* class (Bardat *et al.,* 2004; Bensettiti *et al.,* 2005).

However, in France, the classification of the *Carici caryophylleae-Genistetea lobelii* is complex because initial descriptions of these cushion-scrubs and grasslands also included grassland species characteristic of rocky scree habitats (*Arrhenatherum elatius* subsp. *sardoum, Rumex scutatus*, *Sedum annuum*, *Galium comethorizon, Saxifraga pedemontana* subsp. *cervicornis*) (Gamisans, 1977; Reymann *et al.,* 2016). This class is debated among phytosociologists, which can be summarised as follows, in chronological order:

- Litardière and Malcuit (1926) were the first to assign subalpine and alpine (lower horizon) scrubland and grassland to the *Carici caryophylleae-Genistetea lobelii* class from a phytosociological point of view. They described the *Juniperetum nanae* which corresponds to spiny xerophytes vegetation that covers scorched slopes, and they described the *Plantaginetum insularis* for alpine meso-xeric grasslands.
- Klein (1972) described the *Carici caryophylleae-Genistetea lobelii* class in scrublands with spiny xerophytes. He proposed a single order, the *Carici caryophylleae-Genistetalia lobelii,* comprising two

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[1] Laboratoire Géoarchitecture, University of Western Brittany, F. 29200 Brest, France. Email: delboscpauline@gmail.com; frederic.bioret@univ-brest.fr
[2] LETG UMR 6554 CNRS, Université de Nantes. Chemin de la Censive du Tertre, B.P. 81227, 44312 Nantes, France. Email: mathieu.ledez29@gmail.com
[3] ECOBIO UMR 6553 CNRS, Université de Rennes, Avenue du Général Leclerc. 35042 Rennes, France. Email: jbbouzille@gmail.com
[4] UMR UL/AgroParisTech/INRAE 1434 Silva, Université de Lorraine, Faculté des Sciences et Techniques. BP 70239-54506 Vandoeuvre-lès-Nancy, France. Email : kevin.cianfaglione@univ-lorraine.fr

alliances: the *Anthyllion hermanniae* (supra- and oromediterranean cushion-scrubs) and the *Plantaginion insularis* (supra- and oromediterranean grasslands). The French plant communities of the *Carici caryophylleae-Genistetea lobelii* were initially divided into two associations: the *Ligusticetum corsici* and the *Genisto-Carlinetum macrocephalae* (Klein 1972).

- Gamisans (1977) named this class the '*Carlinetea macrocephalae*', which includes chamephytic scrubs (*Anthyllidion hermanniae*) and mesoxeric grasslands (*Caricion caryophylleae*). This author described one plant community for the *Caricion caryophylleae* (*Sagino-Caricetum caryophylleae*) and three plant communities for the *Anthyllidion hermanniae* (*Helichryso-Genistetum salzmanni, Triseto-Genistetum corsicae* (only in Sardinia), *Berberido-Genistetum lobelioides*). Gamisans (1977) described the *Helichryso-Genistetum salzmanni cerastietosum boissieri* sub-association that he considered as a synonym of the *Genisto salzmannii-Alyssetum robertiani* Ro. Molinier 1959. In his study, Gamisans assumed similarities in the floristic composition for three associations (*Juniperetum nanae* Litardière & Malcuit 1928, *Genisto-Carlinetum macrocephalae* Klein 1972 and *Berberido aetnensis-Genistetum lobelioidis* Gamisans 1977) but no comparative table analysis was provided. Gamisans (1977) did not recognize the *Ligusticetum corsici*. He considered the *Ligusticetum corsici* as a heterogeneous plant community, which can be divided into two associations: the *Paronychio-Armerietum armerietosum* and the *Acino-Tanacetum tomentosi*.
- De Foucault (2012) highlighted that the inclusion of the *Caricion caryophylleae* in the *Carici caryophylleae-Genistetea lobelii* seems problematic because it includes grasslands that may be related to the *Caricetea curvulae* (Bardat *et al*., 2004) or the *Nardetea strictae* (de Foucault, 2012).

In the Prodrome of Corsican Vegetation (Reymann *et al*., 2016), the authors retain the *Carici caryophyllae-Genistetea lobelii* (*Carlinetea macrocephalae* is a synonym), one order '*Carlinetalia macrocephalae*' and two alliances (*Caricion caryophylleae* and *Anthyllidion hermanniae).* They also classified the *Genisto salzmannii-Alyssetum robertiani* Ro. Molinier 1959 in the *Anthyllidion hermanniae,* and a vegetation unit of *Trifolium campestre* and *Carex caryopyllea* and the *Anthoxantho odorati-Brachypodietum rupestris* Gamisans 1989 into the *Caricion caryophylleae.*

There are many studies concerning the *Carici caryophylleae-Genistetea lobelii* class in France, however, all the analyses were based on expert judgment and to date, there has been no synthesis using vegetation plots. It is, therefore, necessary to revise the classification of this class to update its syntaxonomic scheme as well as to be able to propose relevant management measures for their conservation. This revision is also part of the Prodrome of French Vegetation conducted by the French Society of Phytosociology (Bioret *et al*., 2013).

The divergence in opinions on the taxonomy and nomenclature surrounding *Genista salzmannii* and *Genista lobelii* is also of concern. Gamisans (1973) recognized *Genista lobelii* var. *salzmannii* and *Genista lobelii* var. *lobelioides*. He retained this terminology in his thesis (Gamisans, 1975) and also in his survey of the Corsican vegetation (Gamisans, 1991). However, Gamisans & Jeanmonod (1993) modified the previous classification and distinguished the following taxa:

- *Genista salzmannii* DC. var. *salzmannii* (= *Genista lobelii* var. *salzmannii* (DC.) Spach); this is an endemic species that occurs in Corsica, Sardinia, Elba, and peninsular Italy. In Corsica, this species is found at low and medium elevations (< 1600 m asl).
- *Genista salzmannii* var. *lobelioides* (Gamisans) Gamisans & Jeanm. (= *Genista lobelii* var. *lobelioides* Gamisans). This is an endemic species of Corsica and its distribution is limited to high elevations (> 1600 m asl).

This taxonomic classification was also retained by *Flora Corsica* (Jeanmonod & Gamisans 2007, 2013).

Genista lobelii DC. is considered as an endemic taxon of western Provence in France with a distribution limited to the French departments of Bouches-du-Rhône and Var (Tison *et al*., 2014; Tison & de Foucault, 2014; Coulot & Rabaute, 2016).

Concerning the divergences that exist in the floristic and syntaxonomic terms for the classification of the *Carici caryophylleae-Genistetea lobelii*, we aim to classify the vegetation of this class at a plant community (association) level. The aim of this study is to use a plot-based numerical analysis of the *Carici caryophylleae-Genistetea lobelii* in Corsica, and specifically to: i) classify the *Carici caryophylleae-Genistetea lobelii* plant communities; ii) describe the plant communities (associations) of this vegetation; iii) characterize the environmental range of each plant community in terms of climate and soil conditions; iv) devise an expert system to formally identify the *Carici caryophylleae-Genistetea lobelii* units; and, v) update the classification of the *Carici caryophylleae-Genistetea lobelii* within the framework of the Prodrome of the French Vegetation.

Study area

The *Carici caryophylleae-Genistetea lobelii* plant communities correspond to low-scrubs occurring within supramediterranean and oromediterranean belts (Figure 1). They are distributed under supra- and oromediterranean bioclimates with high humidity. These plant communities occur on acidic to neutrocline and mesic to mesoxeric substrates in Corsica, Sardinia, and Sicily (Klein, 1972). In France, this class is characterized floristically by many Corsican and Sardinian endemic species (*Viola corsica* subsp. *corsica, Genista salzmannii, Alyssum robertianum*, *Peucedanum officinale* subsp. *paniculatum*) and endemic Corsican taxa (*Potentilla rupestris* var. *pygmaea*, *Arrhenatherum elatius* subsp. *sardoum*, *Helleborus lividus* subsp. *corsicus*, *Poa nemoralis* subsp. *balbisii*, *Silene nodulosa*, *Astragalus* *genargenteus* var. *greuteri*, *Ruta corsica*, *Saponaria ocymoides* subsp. *alsinoides*).

Fire is the most significant factor determining these plant communities, depending on its frequency and intensity (Gamisans, 1989, 1991, 2010). Recent fires over the past several years may explain the regression of these communities and also have an extremely negative effect on their biome as they dry up the soil and microclimate, and they make way for the development of secondary vegetation such as the *Pruno spinosae-Rubion ulmifolii* thickets (Gamisans & Grüber, 1979; Gamisans, 1990). Recurrent trampling by cattle also favors nitrophilous grasslands. Human exploitation of the land over the past thousands of years, forest destruction, in particular, has led to soil erosion in some areas. The erosion then intensified by grazing and overgrazing. *Helichrysum italicum* subsp. *italicum*, *Genista salzmannii, Berberis aetnensis, Thymus herba-barona*, etc. have been able to establish in habitats subject to deforestation and soil erosion (Gamisans, 1968). Regular grazing has facilitated the selection of species that are resistant to trampling, such as thorny or toxic species which livestock refuse to eat (*Genista salzmannii, Berberis aetnensis, Anthyllis hermanniae* subsp. *Corsica*, etc.). In some places after pastures abandonment, the *Carici caryophylleae-Genistetea lobelii* communities could proceed along the secondary succession up to *Pinus nigra* subsp. *laricio* formations (Gamisans, 2007; Delbosc, 2015)

This vegetation is of major conservation interest because it falls within the habitat 4090 (Romao *et al*., 2015). Bensettiti *et al.* (2005) distinguished, within this habitat, two habitat sub-types: (4090-8) 'Mountain low-scrubs of Corsica' (*Berberido aetnensis-Genistetum lobelioidis and Thymo herbae-baronae-Genistetum lobelioidis*); (4090-7) 'Supramediterranean low-scrubs of Corsica' (*Helichryso italici-Genistetum salzmannii, Genisto salzmannii-Alyssetum robertiani*). This low-scrub scrub formation represents an important biotope for animals such as Corsica mouflon (*Ovis gmelini musimon* var. *corsicana* Beyth) and the Corsican subspecies of Northern Goshawk (*Accipiter gentilis* subsp. *arrigonii* Kleinschmidt).

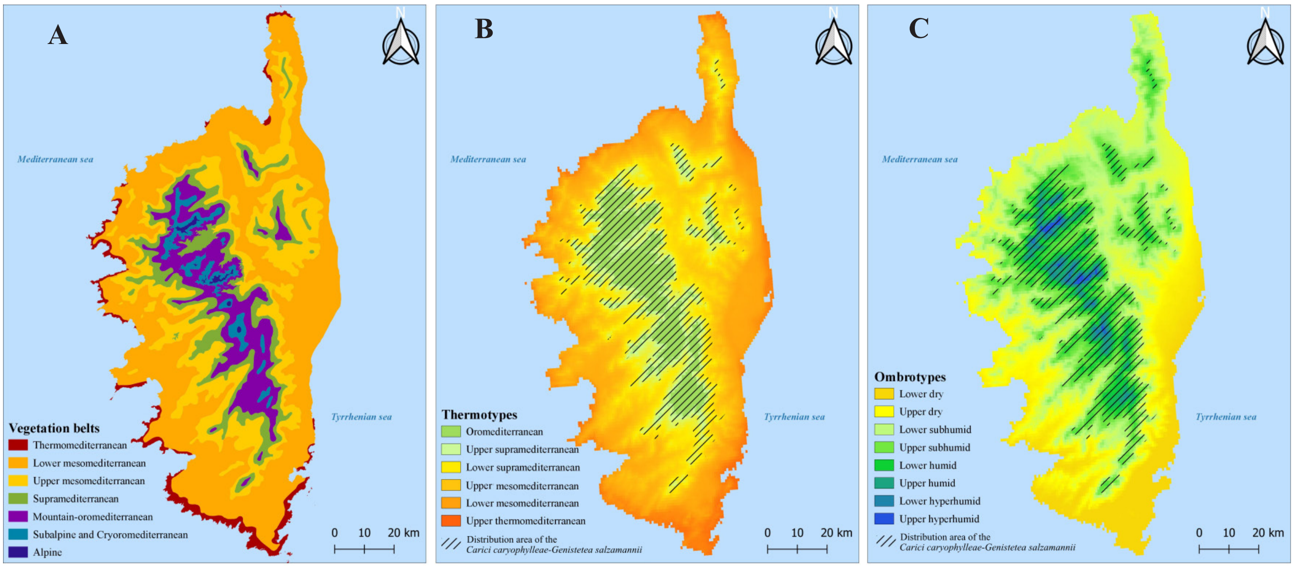


Figure 1.Vegetation and bioclimatic maps of Corsica. A, map of vegetation belts, following the Gamisans' typology (1991); B, map of thermotypes; C, map of ombrotypes following the Rivas-Martínez *et al.*'s typology (2011).

Material and Methods

The procedures implemented in this revision are captured in Figure 2, The analytic pathway is explained in detail below.

Dataset

The data used were provided by the bibliography (Table 1, Appendix S1 for the list of data sources) and vegetation plots that were carried out under the CarHAB Program between 2012 and 2014 according to sigmatist phytosociology (Dengler, 2017). We have taken into account all the vegetation plots found in the literature that were assigned to the *Carici caryophylleae-Genistetea lobelii* communities by the authors. We also considered plant communities for which the syntaxonomic inclusion within the *Carici caryophylleae-Genistetea lobelii* was uncertain. This is the case for the *Paronychio polygonifoliae-Armerietum multicepitis*, which has a very similar floristic composition to the *Berberido aetnensis-Genistetum lobelioidis* but which was included in the *Caricetea curvulae* (Reymann *et al.,* 2016). Therefore, we have integrated all the vegetation plots assigned to the *Paronychio polygonifoliae-Armerietum multicepitis* in our database, to compare the floristic composition with that of other plant communities and to verify its syntaxonomic inclusion in the synsystem. We also retained the vegetation plots which were characterized as = 'scrubs' or 'grasslands' by these authors. In total, 519 vegetation plots sharing 651 taxa were stored in Turboveg 2

(Hennekens & Schaminée, 2001). The vegetation data are phytosociological vegetation plots with specific reference to the cover-abundance for each species, recorded between 1926 and 2014. The dataset was filtered using the species list for the *Carici caryophylleae-Genistetea lobelii* class as listed in an appendix to the EuroVegChecklist (Mucina *et al*., 2016). To obtain a selection of the vegetation plots corresponding to this class, we classified the initial dataset using the EuroVegChecklist expert system for the classes of European vegetation in the JUICE program (Tichý, 2002). For our study, we selected only those vegetation plots that have been recognized as the *Carici caryophylleae-Genistetea lobelii* (code 'GEN' in the EuroVegChecklist).

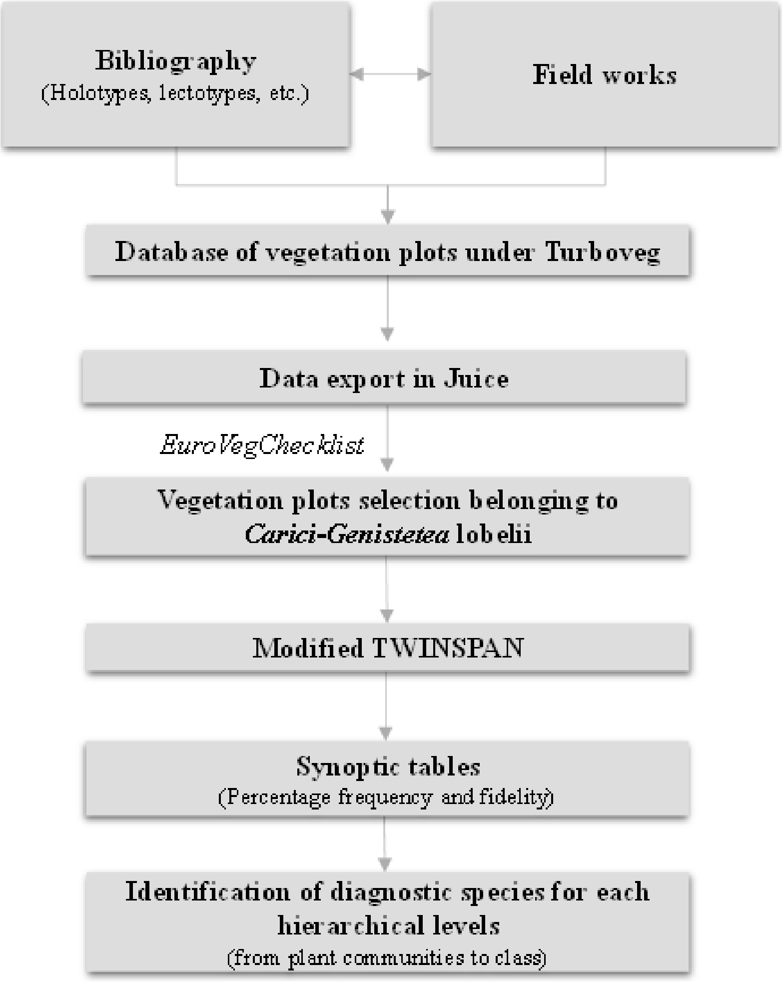


Figure 2. Methodological scheme to produce a formalized classification of the *Carici caryophylleae-Genistetea lobelii* plant communities in France.

Vegetation plots that contained a total of more than 20% trees or scrubs were excluded. Vegetation plots with fewer than five species (representing < 1% of the selected plots) were excluded because they were considered to be poorly representative of these typically species-rich scrubs and related grasslands. We chose to analyze all the plots except those with an area smaller than 1 m^2 or larger than > 100 m^2. We did not exclude plots that did not indicate their surface area because we assumed that most of them were sampled on plots ranging in size from 5 to 100 m^2 and that their exclusion would result in the loss of data. The dataset contains 189 vegetation plots and 399 species. Vegetation plots without geographical coordinates were georeferenced, using the QGIS software, according to the descriptions of their localities reported in the original publications. The uncertainty of the georeferencing was less than 1 km in most cases.

Species list and nomenclature

We checked and homogenized the species lists using the taxonomic nomenclature in the book *Flora Corsica* (Jeanmonod & Gamisans, 2013) because numerous origins have been listed in the vegetation plots. Once the typing errors and synonymy problems were resolved, we deleted the rare species (less than 0.1% of occurrence) to avoid a biased analysis for this rare species. As we used plots sampled by numerous different authors over several decades, in some cases it was not possible to determine the original description of the taxon, particularly when subspecies belonging to the same species have an overlapping geographic distribution. The selected dataset counted 189 vegetation plots which contain a total of 262 plant species.

The nomenclature of the syntaxa follows the EuroVegChecklist (Mucina *et al*., 2016) for European alliances, and Reymann *et al.* (2016) for plant associations according to the International Code of Phytosociological Nomenclature (ICPN) (Theurillat *et al*., 2020).

Pooling analysis

We classified our dataset using the modified TWINSPAN classification (Roleček *et al.,* 2009) in version 7.0.208 of the JUICE program (Tichý, 2002) to obtain a hierarchical pool. We used the default settings (cut levels = 0%, 5%, 25%; minimum group size = 5) and the Bray-Curtis index as a dissimilarity measure producing 15 terminal pools. To obtain this number of pools, we did several iterations to highlight the most coherent number of pools with the literature and our field knowledge. The number of pools greater than 15 led to the identification of a syntaxonomic level lower than the sub-association (facies in particular). In contrast, a number lower than 15 pools led to the identification of a higher level (alliance level). However, we are aware that the definition of the number of pools and the dissimilarity measures are the main limitations of this method because it mainly depends on the choice of the authors (Chuman & Romportl, 2010).We characterized the resulting pools at different hierarchical levels of the classification (in particular, sub-association, association and alliance). We interpreted these pools based on their species composition, their distribution and previous literature (holotypus; Table 1 see Appendix S1). When we found a pool that corresponded to a syntaxa recognized in the literature, we did not interpret its subordinate pools at the lower hierarchical levels. In the event of disagreements between the plant communities identified among the various sources, we followed the classification of the plant communities accepted in the literature. We grouped adjacent pools with similar species compositions, and with a similar position along a geographical gradient and similar ecological conditions.

Diagnostic species

The diagnostic species of each plant community were determined based on their fidelity, calculated using the phi coefficient (Φ; Chytrý *et al*., 2002). The *phi* coefficient was calculated and we only accepted positive values for species with significant occurrences in the group based on Fisher's exact test at $p < 0.01$ (Tichý & Chytrý, 2006). Only species with a Φ value greater than 0.2 were considered to be diagnostic of a vegetation unit. We considered species with a Φ value greater than 0.4 to be 'highly diagnostic'. We chose these thresholds arbitrarily and considered them as a compromise to distinguish species with high diagnostic value from those with low diagnostic value. We have defined constant species as those with a percentage occurrence frequency greater than 20% and dominant species as those occurring in at least 10% of vegetation plots with a percentage of cover greater than 20%.

Expert system

An Expert System (ES) is a tool that is used to identify vegetation based on the floristic and geographical boundaries of the syntaxa (Kočí *et al.,* 2003). The ES is based on formal definitions, which are written as logical formulas in an editable script stored as a TXT file (Tichý *et al*., 2019). The ES script contains logical formulas of the *Carici caryophylleae-Genistetea lobelii* plant communities consisting of relational operators, which define individual assignment criteria, and the logical operators AND, OR, and NOT, which combine the individual assignment criteria (Bruelheide, 1997). Similarly to Mucina *et al.* (2016), the ES that we built took into account discriminating species of each alliance and assigned each plot to that alliance whose discriminating species occurring in the plots had the highest sum of square-rooted percentage covers. The ES was run using a software tool implemented in the JUICE 7 software (Tichý, 2002).

The species identified as diagnostic, constant, and dominant based on our TWINSPAN analysis were used as discriminating species groups; these groups of species were used to design the ES that could then be used to classify any vegetation plot from the *Carici caryophylleae-Genistetea lobelii*. The ES is based on the different species groups of the classification developed by Mucina *et al*. (2016) for the EuroVegChecklist classes, and it also takes into account the indicator species groups of all the alliances we have identified. Then it was applied to assign each plot to the plant communities for which the indicator species in the plot had the highest sum of square-rooted percentage covers. We merged the diagnostic species groups when two or more pools were interpreted as belonging to the same plant community.

Since the *Carici caryophylleae-Genistetea lobelii* are regularly in contact with mesomediterranean vegetation, part of their floristic composition corresponds to mesomediterranean species. We have therefore added formal definitions for the classes containing mesomediterranean scrublands (*Cisto ladaniferi-Lavanduletea stoechadis*) and relict oromediterranean silicicolous swards (*Saginetea piliferae*). In these formulas, we also fixed an arbitrary maximum threshold of 5% tree and shrub cover that may occur in the plots to be assigned to the syntaxa discussed in this present work. We chose this threshold to the ES can better distinguish the grasslands of *Carici caryophylleae-Genistetea lobelii* which occur in small areas and are very overlapping with the low-scrub.

To show that the established ES was close to our original classification, a confusion matrix was created between the TWINSPAN pools and the alliances obtained via the ES. We used the same procedure for the orders and classes and the diagnostic species of these units were added in the ES. The ES was tested on the dataset (189 vegetation plots), which was also used to characterize each alliance, to define the diagnostic constant and dominant species, and to create the distribution maps for each alliance.

Ordination analysis

We used a Principal Component Analysis (PCA) to visualize the main environmental gradients. A PCA aims to analyze the variance in the multivariate data onto a few components (Borcard *et al.*, 2011; Cornillon *et al.*, 2012). A standardised PCA was performed using the vegan package in R (version 1.15-4, http://cc.oulu.fi/jarioksa/softhelp/vegan.html). We used the WorldClim dataset (Fick & Hijmans, 2017; accessed on 14 September 2019) to collect bioclimatic data characterizing each alliance. Bioclimatic variables (http://www.worldclim.org/bioclim) for the phytosociological plots were obtained through the overlay of the vegetation plot coordinates with the QGIS application, version 2.18.14 (open source; www.qgis.org/en/site/). The bioclimatic variables were plotted on the PCA diagrams to help interpret the ecological differences among the plant communities.

Results

Hierarchical pool analysis

We interpreted 15 pools obtained from the modified Twinspan hierarchical classification. They are classified into two main groups of pools according to bioclimate (Figure 3): (A) supramediterranean plant communities dominated by *Genista salzmannii* var. *salzmannii* [pools 1 to 7] and (B) oromediterranean plant communities dominated by *Genista salzmannii* var. *lobelioides* [pools 8 to 15].

The second division concerning pools 1 to 7 corresponds to a geographical division: it separates the plant communities of Alpine Corsica (Pool 1) from Hercynian Corsica (Pool 2 to 7). For pools 8 to 15, the division distinguishes scrubs and related grasslands of the oromediterranean belt (pools 8 to 11) from cushion-scrubs of the upper supramediterranean belt (pools 12 to 15).

Of the 15 pools, six were assigned to a plant association, six were assigned to a sub-association and three were assigned to a higher level (alliance) because their floristic composition was too heterogeneous to be assigned to a plant association. These two pools were not used to create an expert system. The diagnostic, constant, and dominant species of the 15 pools and their distribution maps are presented in Appendix S2.

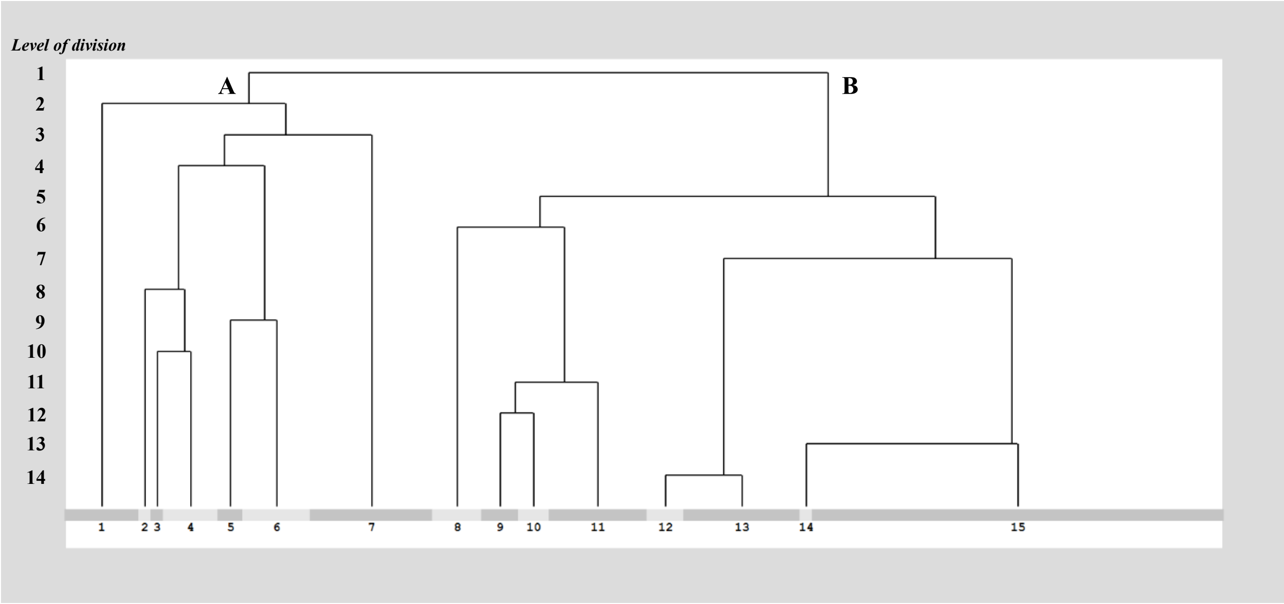


Figure 3. Dendrogram of the Twinspan analysis applied to the dataset, with 189 vegetation plots and 262 species. Pool numbers (1–15) correspond to those provided in the synoptic table (Table 2).

Species groups and formal definitions

We have formulated formal definitions for one class, one order, three alliances, eight plant associations, and three sub-associations. We have also added formal definitions for the classes which are very specific to these plant communities: the *Cisto ladaniferi-Lavanduletea stoechadis* and *the Saginetea piliferae*. Besides, we also integrated three other groups of 'Tree', 'Shrub', and 'Low-Shrub' species, which allow us to better distinguish scrub and related grasslands within the *Carici caryophylleae-Genistetea lobelii*.

An expert system based on the modified Twinspan classification was developed and applied to the complete dataset of 189 vegetation plots of which 155 (82%) were classified (Appendix S3). For the vegetation plots that were not assigned to a plant association: 25 vegetation plots contain maquis dominated by *Erica arborea*, and nine belong to the *Anthyllidion hermanniae* and correspond to transitional vegetation between the supramediterranean and oromediterranean belts.

The consensus between the pools obtained by the TWINSPAN analysis and the alliances classified by our expert system is presented in a confusion matrix (Appendix S4).

Distribution maps, climatic characterization, and lists of diagnostic and constant species for each hierarchical level (classes, orders, and alliances) were prepared from the results of the expert system classification (Figures 4, 5, Table 1, Appendix S5). Photographs of certain associations are presented in Appendix S6. The synoptic table of the plant communities recognized in this classification is presented in Table 1. Distribution maps for the 10 plant communities identified in this study are presented in Figure 3.

Table 1. Shortened synoptic table of the percentage frequencies of the diagnostic species in the plant communities classified by the expert system. Abbreviations are: Ag, *Alysso robertiani-Genistetum salzmannii*; Hgh, *Helichryo italici-Genistetum salzmannii helichrysetosum italici*; Hgc, *Helichryo italici-Genistetum salzmannii cerastietosum boissieriani*; Lc, *Ligusticetum corsici*; Tg, *Thymo herbae-baronae-Genistetum lobelioidis*; Tga, *Thymo herbae-baronae-Genistetum lobelioidis allietosum schoenoprasi*; Pg, *Paronychio polygonifoliae-Genistetum lobelioidis*; Jn, *Juniperetum nanae*.

Alliance	A1.1			A1.2	A1.3			
Plant communities	Ag	Hgh	Hgc	Lc	Pg	Tg	Tga	Jn
Number of vegetation plots	12	25	22	8	14	6	16	74
Alysso robertiani-Genistetum salzmannii								
Crocus corsicus	100							5
Viola corsica subsp. *corsica*	92	28						4
Teesdalia coronopifolia	92	12	9					
Carex halleriana subsp. *corsica*	83							
Morisia monanthos	75							
Cerastium diffusum subsp. *diffusum*	58	4	5					5
Teucrium capitatum subsp. *capitatum*	42	24	14					
Gagea bohemica	33							
Plantago lagopus	33							
Sagina subulata	25							3
Sherardia arvensis	25	12	5					
Helichryo italici-Genistetum salzmannii helichrysetosum italici								
Linum trigynum		40	9					
Dianthus sylvestris subsp. *longicaulis*		32	5					1
Carlina corymbosa		36	18					
Genista corsica		28	9					
Anthyllis vulneraria subsp. *rubriflora*		20						
Silene paradoxa		12						
Sedum album		12	5					
Helichryo italici-Genistetum salzmannii cerastietosum boissieriani								
Carlina macrocephala subsp. *macrocephala*			77	13			25	34
Pteridium aquilinum			36					8
Vulpia ciliata subsp. *ciliata*		16	41					
Asphodelus cerasiferus			27					
Luzula forsteri			27					
Bellis perennis		4	27					
Trifolium arvense		4	27					
Sanguisorba minor		28	50				19	7
Trifolium campestre		8	27					
Bromus hordeaceus subsp. *hordeaceus*		8	50	25				3
Cynosurus echinatus		16	59				25	23
Briza minor		4	23					
Poa bulbosa subsp. *bulbosa*		4	41	13			13	3
Petrorhagia prolifera		4	18					
Lotus corniculatus		16	50			33	13	14
Petrorhagia saxifraga subsp. *gasparrinii*		20	50		7	33	6	30
Filago vulgaris		8	18					
Trifolium repens var. *repens*			14	13				3
Ligusticetum corsici								
Luzula spicata subsp. *italica*				88				11
Sedum alpestre				50			13	

Alliance		A1.1		A1.2		A1.3		
Plant communities	Ag	Hgh	Hgc	Lc	Pg	Tg	Tga	Jn
Number of vegetation plots	12	25	22	8	14	6	16	74
Sagina pilifera				63				14
Euphrasia nana				38				
Thlaspi brevistylum				38				9
Mutellina corsica				38				15
Chenopodium bonus-henricus				25				
Phyteuma serratum				25				
Alchemilla alpina				25				
Acer pseudoplatanus				25			6	
Poa alpina				25	7			1
Digitalis purpurea				25	14		19	12
Galium cometorhizon				13				
Saxifraga pedemontana subsp. *cervicornis*				13				
Phleum pratense subsp. *nodosum*				13				
Agrostis rupestris				13				
Acinos corsicus				13				
Poa pratensis				13				
Geum montanum				13				
Hieracium murorum				13				1
Fagus sylvatica				13				1
Gagea soleirolii subsp. *soleirolii*				13				1
Poa nemoralis				13				3
Armeria leucocephala var. *leucocephala*		4		13				
Daphne oleoides			5					15
Potentilla micrantha		4						15
Arabidopsis thaliana			5					4
Luzula pedemontana				13				5
Paronychio polygonifoliae-Genistetum lobelioidis								
Scleranthus burnatii					43			1
Veronica fruticans					36			1
Reseda phyteuma subsp. *phyteuma*				13	43			5
Trisetum gracile subsp. *conradiae*					21			
Trisetum gracile					21			
Paronychia polygonifolia					21			3
Astragalus genargenteus var. *greuteri*					14		6	9
Thymo herbae-baronae-Genistetum lobelioidis								
Orobanche rigens						67		
Cuscuta epithymum						67		1
Lolium perenne		8	9			67	6	
Hypochaeris cretensis		28	14		43	100	19	30
Pilosella officinarum		4				33		
Cynosurus cristatus						33	6	
Festuca rubra subsp. *rubra* var. *rubra*		4	18			33		7
Thymo herbae-baronae-Genistetum lobelioidis allietosum schoenoprasi								
Micropyrum tenellum		4					38	
Briza maxima		16					31	
Pancratium illyricum							19	
Crucianella angustifolia		12	18				31	1
Potentilla crassinervia							13	
Anarrhinum corsicum							13	
Festuca sardoa							13	3
Potentilla rupestris var. *pygmaea*							13	3
Hypochaeris glabra		4					13	
Cruciata glabra			14				19	7

Alliance	A1.1			A1.2	A1.3			
Plant communities	Ag	Hgh	Hgc	Lc	Pg	Tg	Tga	Jn
Number of vegetation plots	12	25	22	8	14	6	16	74
Juniperetum nanae								
Odontites corsicus			5					27
Ruta corsica			5				13	24
Agrostis stolonifera				13				18
Viola reichenbachiana								8
Vincetoxicum hirundinaria subsp. *contiguum*							13	15
Potentilla rupestris					7		13	16
Genistion salzmannii								
Cerastium boissierianum	100	40	55					1
Alyssum robertianum	33	24	5					1
Brachypodium retusum	42	44	9				6	
Rosa serafinii	42	24	36					22
Euphorbia spinosa	33	32	9				13	
Orchis mascula	25							
Luzula campestris	25					33	6	1
Dactylis glomerata subsp. *glomerata*	25	28	18					
Buxus sempervirens	25	52	5					1
Erica arborea	50	52	50				31	
Genista salzmannii var. *salzmannii*	65	80	50					4
Teucrium marum		52	45				56	4
Polygala vulgaris subsp. *vulgaris*		36	45				6	4
Plantago lanceolata		32	27				13	8
Carex caryophyllea		48	36		43		19	31
Helichrysum italicum subsp. *italicum*	42	52	68	13		67	31	
Helleborus lividus subsp. *corsicus*		8	41					27
Anthyllidion hermanniae								
Genista salzmannii var. *lobelioides*		4			79	100	88	84
Armeria multiceps				38	50			4
Brachypodium pinnatum subsp. *rupestre*		8	14		43	50	75	62
Allium schoenoprasum				13	21		38	5
Filago minima						33	25	
Jasione montana subsp. *montana*		16	27			33	44	5
Saginetea piliferae								
Plantago sarda				63				1
Nardus stricta				38	71			12
Bellardiochloa variegata				13	64		6	16
Deschampsia flexuosa			18	63	86		25	69
Pilosella piloselloides subsp. *praealta*				13			13	
Silene vulgaris		8	5	50	7	100	50	22
Sedum brevifolium		4		63	71	67		16
Arrhenatherum elatius subsp. *sardoum*					21		38	36
Agrostis capillaris subsp. *castellana*		12	9		21	33	44	39
Hypochaeris robertia	33	36	5	88	71	67	6	43
Rumex acetosella subsp. *pyrenaicus*	50	16	45	50	21	33	6	15
Galium corsicum		24	50	13	21	33	63	46
Anthoxanthum odoratum	42	20	73	13	14	67	56	39
Carici caryophylleae-Genistetea salzmannii								
Stachys corsica				50	43	33	38	32
Poa nemoralis subsp. *balbisii*			9	63	7	33	44	9
Cerastium soleirolii		8		88	71	100	56	64
Anthyllis hermanniae subsp. *corsica*	50	84	100		21	100	100	68
Juniperus communis subsp. *alpina*			36	25	79	67	25	72
Berberis aetnensis	92		5	13	14		13	58
Bellium bellidioides	92	36	45	13	36		56	59

Alliance	A1.1			A1.2	A1.3			
Plant communities	Ag	Hgh	Hgc	Lc	Pg	Tg	Tga	Jn
Number of vegetation plots	12	25	22	8	14	6	16	74
Pilosella kralikii			32	38	86			42
Thymus herba-barona	92	60	59		57	100	75	69
Veronica verna subsp. *brevistyla*			36			33	6	12
Saponaria ocymoides subsp. *alsinoides*		4	9				19	18
Silene nodulosa		16	14				13	7
Peucedanum paniculatum	8	12	18				13	
Bunium alpinum subsp. *corydalinum*	100	28		13	7		13	5
Aira caryophyllea		36	64			100	38	16
Alnus alnobetula subsp. *suaveolens*				25				

Carici caryophylleae-Genistetea salzmannii Klein 1972 *nom. corr. nov.*

Cyrno-Sardian supra- and oromediterranean cushion-tragacanthic scrub and related grasslands.

Holotypus: Carici caryophylleae – Genistetalia lobelii J.-C. Klein 1972 (*Vegetatio* 25: 322).
Synonymous: *Carlinetea macrocephalae* Gamisans 1977

Carici caryophylleae-Genistetalia salzmannii Klein 1972 *nom. corr. nov.*

Cyrno-Sardian supra- and oromediterranean cushion-tragacanthic scrub and related grasslands
Holotypus: Anthyllidion hermanniae J.-C. Klein 1972 (*Vegetatio* 25: 329).
Synonymous: *Carlinetalia macrocephalae* Gamisans 1977

Supramediterranean communities (*Genistion salzmannii* Delbosc, Bioret et Panaïotis *all. nov.*; Table 1, A1.1)

Holotypus: Helichryso italici-Genistetum salzmannii Gamisans 1977 (Gamisans, 1977, tab. 19 -p. 82/83))
Diagnostic taxa: *Genista salzmannii* var. *salzmannii*, *Helichrysum italicum* subsp. *italicum*, *Asphodelus cerasiferus*, *Genista corsica*, *Euphorbia spinosa*, *Alyssum robertianum*.
Description: supramediterranean chamephytic scrub occurring on mesoxeric and xeric substrates. This syntaxa is widely spread around Corsica from 800 to 1300 m a.s.l., on sunny slopes. It is mainly dominated by *Genista salzmannii* var. *salzmannii* and grows on granite and schist substrates. They are physiognomically dominated by nanophanerophytes and chamaephytes species, some of which are endemic to Corsica (*Alyssum robertianum*) or endemic of Corsica and Sardinia (*Genista corsica*). From a climatic point of view, these vegetations develop under average annual temperatures between 10 and 13°C with rainfall between 700 mm and 1500 mm per year. This vegetation can withstand a more or less long period of summer drought from June to September.

- *Alysso robertiani-Genistetum salzmannii* Ro. Molinier 1959 *nom. invers.* [synonymous: *Genisteto-Alyssetum robertiani* Ro. Molin. 1959]: this is a supramediterranean chamephytic scrub that develops on schist and ophiolitic substrates in Alpine Corsica. This vegetation is dominated by *Genista salzmannii* var. *salzmannii* and other chamephytic species such as *Anthyllis hermanniae* subsp. *corsica*, *Helichrysum italicum* subsp. *italicum* and *Thymus herba-barona*. It is an endemic plant association found on the Cap Corse crests where it is exposed to very strong winds, as well as on the San Pedrone Massif. From a dynamic point of view, this vegetation is maintained by grazing activities and when these activities disappear, the vegetation is colonized by *Buxus sempervirens* and *Erica arborea*.
- *Helichryo italici-Genistetum salzmannii* Gamisans 1977*:* this is a supramediterranean chamephytic scrub that grows on shallow crystalline soils. It is characterized by *Helichrysum italicum* subsp. *italicum* and *Genista salzmannii* var. *salzmannii*. These cushion-scrubs are widespread throughout the geologic province of 'Crystalline Corsica'; they occur on slopes but do not always occupy crests. When these plant communities are located at the edge of *Pinus nigra* subsp. *laricio* forests, they could be colonized by pine trees. This plant association includes two sub-associations: (i) *helichrysetosum italici* Gamisans 1977 widespread on the supramediterranean slopes of siliceous Corsica (rarely on the crests) and are characterized by *Linum trigynum, Dianthus sylvestris* subsp. *longicaulis* and *Carlina corymbosa*; (ii) *cerastietosum boissieriani* Gamisans 1977 is frequently found on upper supramediterranean it occurs on schist and siliceous substrates and is characterized by *Carlina macrocephala* subsp. *macrocephala*, *Thymus herba-barona,* and *Juniperus communis* subsp. *alpina*.

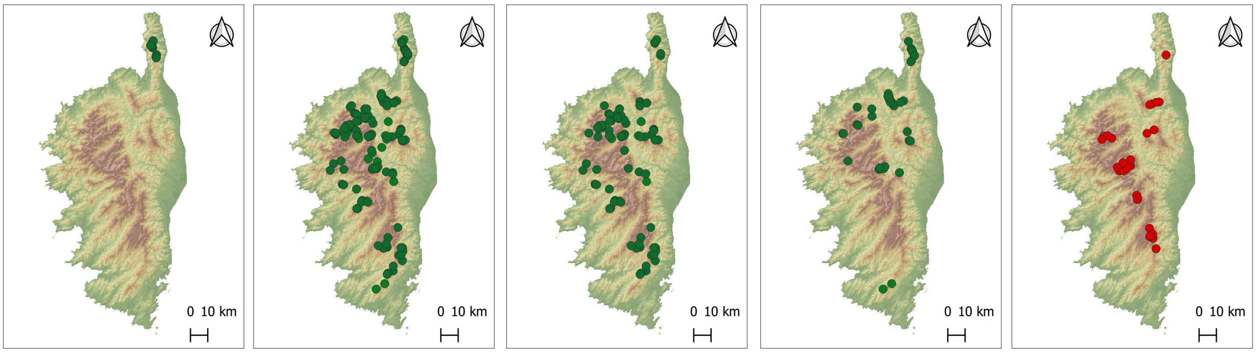
Cushion-scrubs of the oromediterranean belt (*Anthyllidion hermanniae* Klein 1972; Table 1, A1.3)

- *Paronychio polygonifoliae-Genistetum lobelioides* Gamisans 1977 *nom. invers.* [Synonymous: Synonym: *Paronychio polygonifoliae-Armerietum multicepitis* Gamisans 1977 *genistetosum lobelioides* Gamisans 1977]: this oromediterranean low-scrub grows on siliceous substrates and is subject to long periods of snow cover. This vegetation is dominated by *Genista salzmannii* var. *lobelioides* and *Juniperus communis* subsp. *alpina*. It is common on upper southward-facing slopes. This plant community is also characterized by constant species such as *Deschampsia flexuosa* and *Bellardiochloa variegata*, typical species of *Saginetea piliferae*. The presence of numerous spiny nanophanerophytic and chamephytic species show their resilience to summer droughts.

- *Juniperetum nanae* Litardière & Malcuit 1926 [Synonymous: *Berberideto – Genistetum lobelioidis* Gamisans 1977 (nom illégitime selon l'article 2 du code de nomenclature phytosociologique), *Genisto-Carlinetum macrocephalae* Klein 1972, groupement à *Juniperus nana* Gamisans 1991]: this oromediterranean low-scrub consists mainly of spiny nanophanerophytes and chamaephytics. This plant community develops on well-preserved soils and is dominated by *Berberis aetnensis*, *Genista salzmannii* var. *lobelioides,* and *Juniperus communis* subsp. *alpina*. It is characterized by the presence of grassland species such as *Odontites corsicus*, *Brachypodium pinnatum* subsp. *rupestre* and *Deschampsia flexuosa*. It is common on most Corsican massifs from San Pedrone to Bavella.
- *Thymo herbae-baronae-Genistetum lobelioides* Gamisans 1989: this low-scrub develops on shallow soils and is distinguished from the previous plant association by the very rare *Juniperus communis* subsp. *alpina*. This plant community constitutes the most degraded stage of oromediterranean vegetation and develops on eroded and stony soils. Due to the soil conditions, its dynamic trajectory towards the forest seems slower. It includes a sub association *allietosum schoenoprasi* that is common on most Corsican massifs occurring on the most eroded soils and is closely linked to strong grazing pressure. It is characterized by *Allium schoenoprasum* and the predominance of *Genista salzmannii* var. *lobelioides* and *Anthyllis hermanniae* subsp. *corsica*.

Oromediterranean grassland (*Plantaginion insularis*; Table 1, A1.2)

- *Ligusticetum corsici* Klein 1972 [Synonym: *Paronychio polygonifoliae-Armerietum multicepitis* Gamisans 1977 *armerietosum multicepitis* Gamisans 1977]: this plant community corresponds to oromediterranean grasslands on the southern and northern slopes. It develops on soils that are subject to strong wind erosion. They appear in a very punctual manner in the landscape and occupy very small surface areas. This plant association is dominated by *Mutellina corsica*, *Luzula spicata* subsp. *italica, Poa balbisii,* or *Plantago sarda*. The floristic composition includes many species of the *Saginetea piliferea* but is distinguished by the presence of *Cerastium soleirolii*, *Stachys corsica*, *Euphrasia nana*, and *Sedum alpestre*, i.e., characteristic species of the *Carici caryophylleae-Genistetea salzmannii.*



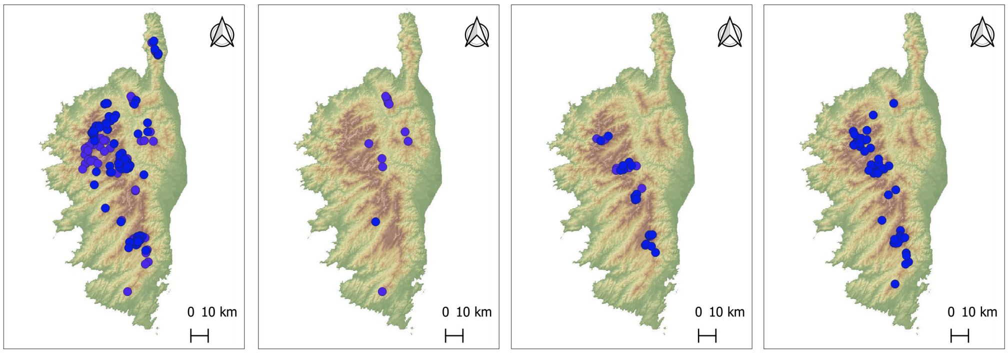
Alysso robertiani-Genistetum salzmannii

Helichryo italici-Genistetum salzmannii

Helichryo italici-Genistetum salzmannii helichrysetosum italici

Helichryo italici-Genistetum salzmannii cerastietosum boissieriani

Ligusticetum corsici



Thymo herbae-baronae-Genistetum lobelioides

Thymo herbae-baronae-Genistetum lobelioides allietosum schoenoprasi

Paronychio polygonifoliae-Genistetum lobelioides

Juniperetum nanae

Figure 3. Distribution map of the 10 plant communities of the *Carici caryophylleae-Genistetea salzmannii*. The various colors correspond to alliances: green indicates the plant communities belonging to the *Genistion salzmannii*; red indicates the communities belonging to the *Plantaginion insularis* and blue indicates the plant communities belonging to the *Anthyllidion hermanniae.*

Environmental gradients

Ecological differences between the plant associations highlighted are shown in Figure 4. The PCA reveals that the two main bioclimatic factors are the maximum temperature of the warmest month (WC05 - axis 1) and the precipitation during the wettest quarter (WC16 - axis 2) (Figure 4, Table 2). The PCA positions the plant communities based on a bioclimatic gradient that distinguishes between supramediterranean vegetation (top Figure 4-b) and oromediterranean plant communities (bottom Figure 4-b). Supramediterranean plant communities are related to a warm climate, whereas oromediterranean plant communities are related to more humid climatic conditions. The PCA also highlights an elevation gradient reflecting the vegetation belts of Corsica: supramediterranean belt (*Helichryo italici-Genistetum salzmannii*, *Alysso robertiani-Genistetum salzmannii*), oromediterranean belt (*Thymo herbae-baronae-Genistetum lobelioidis*, *Juniperetum nanae*, and *Ligusticetum corsici*, *Paronychio polygonifoliae-Genistetum lobelioidis*).

The *Alysso robertiani-Genistetum salzmannii* (Ag) appears to be separate from the other groups: it is an endemic plant association found on Cap Corse with a particular climate (heavy precipitation and high thermal amplitude). Moreover, the *Alysso robertiani-Genistetum salzmannii* is well separated from the *Helichryso italici-Genistetum salzmannii*: these plant communities are distinguished by different rainfall characteristics. The *Alysso robertiani-Genistetum salzmannii* receives more rain, 1042 mm per year on average versus 937 mm per year on average for the *Helichryso italici-Genistetum salzmannii*. With regards to the oromediterranean belts, the PCA shows that the *Thymo herbae-baronae-Genistetum lobelioidis*, the *Juniperetum nanae*, and the *Ligusticetum corsici* are more closely while the *Paronychio polygonifoliae-Genistetum lobelioidis* appears to be separated from them.

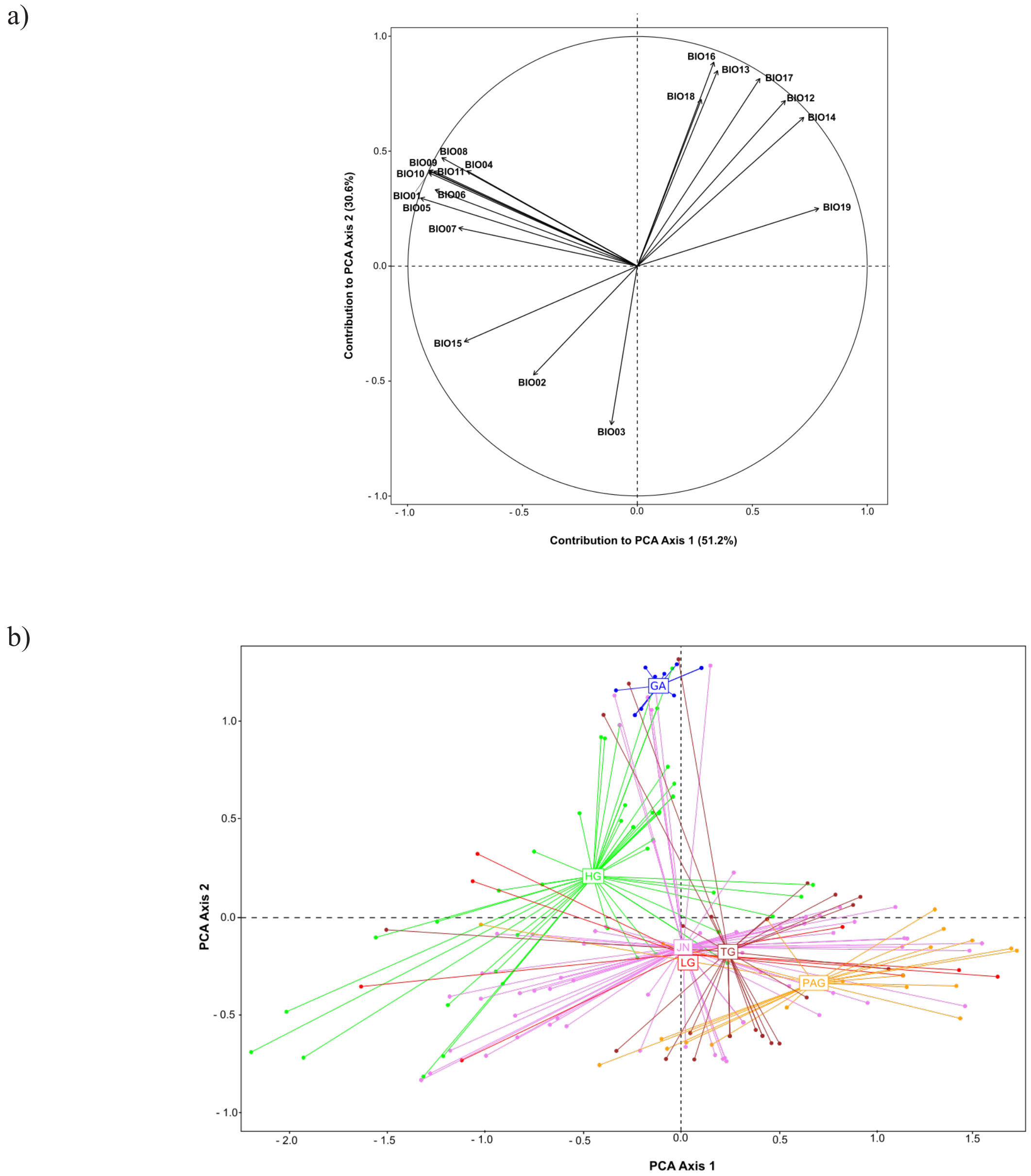


Figure 4. Principal component analysis based on vegetation plots using bioclimatic variables. For abbreviations on plant communities and bioclimatic variables see Tables 1 and 2.

Syntaxonomic scheme

We propose the following syntaxonomic scheme for the *Carici caryophylleae-Genistetea salzmannii* plant communities.

CARICI CARYOPHYLLEAE-GENISTETEA SALZMANNII Klein 1972 *corr.*
  Carici caryophylleae-Genistetalia salzmannii Klein 1972 *corr.*
    Genistion salzmannii Delbosc, Bioret et Panaïotis *in* Delbosc *et al.* 2021
      Alysso robertiani-Genistetum salzmannii Ro. Molinier 1959 *nom. invers*. (Ag)
      Helichryso italici-Genistetum salzmannii Gamisans 1977
        helichrysetosum italici Gamisans 1977 (Hgh)
        cerastietosum boissieri Gamisans 1977 (Hgc)
    Anthyllidion hermanniae Klein 1972
      Paronychio polygonifoliae-Genistetum lobelioidis Gamisans 1977 *nom. invers*. (Pg)
      Thymo herbae-baronnae-Genistetum lobelioidis Gamisans 1989 (Tg)
        allietosum schoenoprasi Gamisans 1989 (Tga)
      Juniperetum nanae Litard. & Malcuit 1926 (Jn)
    Plantaginion insularis Klein 1972
      Ligusticetum corsici Klein 1972 (Lc)

Discussion

Re-evaluation of the syntaxonomic scheme for the Carici caryophylleae-Genistetea lobelii Klein 1972 at the alliance level

We propose some changes in the syntaxonomic scheme of EuroVegChecklist. From a synsystematic and a floristic point of view, the *Carici caryophylleae-Genistetea lobelii* and the *Carici caryophylleae-Genistetalia lobelii* proposed by Klein (1972) should be modified as per article 43 of the ICPN. According to the recent literature (Jeamonod & Gamisans, 2013; Tison & de Foucault, 2014), *Genista lobelii* is absent from Corsica; *Genista salzmannii* is the species that has been retained for Corsica. In Table 2, we suggest correcting the class name to the *Carici caryophylleae-Genistetea salzmannii* and the order name to the *Carici caryophylleae-Genistetalia salzmannii* (i.e. the order name proposed by Gamisans (1977) is a later synonym and is therefore considered to be illegitimate).

The *Carici caryophylleae-Genistetea lobelii* class described by Klein (1972) concerned plant communities developing on scorched slopes and represented by scrublands with spiny xerophytes. Klein (1972) proposed a single order, the *Carici aryophylleae-Genistetalia lobelii* divided into two alliances: the *Anthyllidion hermanniae* (supra- and oromediterranean scrub) and the *Plantaginion insularis* (oromediterranean grasslands). It is complex to develop the synsystem for this class because the initial descriptions of this vegetation were too broad and included grassland species very similar to the *Saginetea piliferae* species (Gamisans, 1977; Reymann *et al*., 2016). In France, this classification was first reviewed as part of the Prodrome of French Vegetation (PVF1) within which the authors only retained the *Anthyllidion hermanniae* (Bardat *et al*., 2004). Reymann *et al.* (2016) selected the *Anthyllidion hermanniae* alliance and integrated the *Caricion caryophylleae* alliance, which corresponds to supra- and oromediterranean grasslands as proposed by Gamisans (1975). Our analyses did not find any plant associations of the *Caricion caryophylleae*: vegetation plots assigned by the authors to the *Sagino piliferae-Caricetum caryophylleae* or the *Anthoxantho odorati-Brachypodietum rupestris* belong to the class *Saginetea piliferae*. As a result, our analyses are in line with Mucina *et al*. (2016) since we assume that the *Caricion caryophylleae* should not be included in this class but rather in the *Saginetea piliferae*. On the other hand, our analyses do not correspond to the traditional classification which only recognizes two alliances: the *Anthyllidion hermanniae* (Cyrno-Sardian supra- and oromediterranean cushion-tragacanthic scrub on exposed and windy crests) and the *Plantaginion insularis* (Cyrno-Sardian oromediterranean grasslands in snow-carrying depressions). Our analyses have shown the existence of a pool group (1 to 7) corresponding to supramediterranean vegetation characterized by a floristic composition of the *Carici caryophylleae-Genistetea lobelii* (*Viola corsica* subsp. *corsica, Hypochaeris cretensis*, *Cerastium boissierianum, Rosa serafinii*) and which are distinguishable from the two alliances mentioned above. Article 24 of the ICPN implies that one of the two alliances should keep the original name: the *Anthyllidion hermanniae* Klein was attributed to the group of syntaxa described by Klein (1972) [*Genisteto-Carlinetum macrocephalae typicum* Klein 1972] and which corresponds in our analyses to pools 9 to 15 (Fig. 3). We, therefore, propose to create a new alliance for supramediterranean plant communities which could be named the *Genistion salzmannii*.

Brullo *et al.* (2001) proposed a new Tyrrhenian alliance: the *Berberidion aetnensis* considered to be synonymous with the *Anthyllidion hermanniae* Klein 1972. These authors divide this alliance into two sub-alliances, the first, the *Pinenion calabricae*, limited geographically to Sicily, and the second, the *Roso serafinii-Juniperenion nanae* (Brullo *et al*., 2001) limited geographically to Corsica and Sardinia. We did not retain the name *Berberidion aetnensis* because it is considered to be illegitimate according to article 29b of the ICPN (Theurillat *et al.,* 2020). The same applies to the sub-alliance the *Roso serafinii-Juniperenion nanae* typified by Brullo *et al*. (2001), which represents the diversity of the scrubs found on the Corsican and Sardinian siliceous substrates and the floristic composition of which is characterized by *Rosa serafinii* and *Juniperus communis* subsp. *nana*.

Our results do not correspond with the classifications proposed by Arrigoni (1986), Arrigoni & Di Tommaso (1991), Rivas-Martínez *et al.* (2002), and Biondi *et*

Table 2. Correlations of bioclimatic variables to the first two axes of PCA. All p-values are < 0.001.

Bioclimatic variables	Axis 1 Correlation	Axis 2 Correlation
BIO1 = Annual Mean Temperature	0.9072566	0.4059744
BIO2 = Mean Diurnal Range (Mean of monthly (max temp - min temp))	0.4516169	-0.4734575
BIO3 = Isothermality (BIO2/BIO7) (×100)	0.4232154	-0.6894381
BIO4 = Temperature Seasonality (standard deviation ×100)	0.7410577	0.4147291
BIO5 = Max Temperature of Warmest Month	0.9431082	0.2960139
BIO6 = Min Temperature of Coldest Month	0.8793822	0.332204
BIO7 = Temperature Annual Range (BIO5-BIO6)	0.7767231	0.1661514
BIO8 = Mean Temperature of Wettest Quarter	0.850342	0.4713645
BIO9 = Mean Temperature of Driest Quarter	0.9070533	0.4164849
BIO10 = Mean Temperature of Warmest Quarter	0.907928	0.4146708
BIO11 = Mean Temperature of Coldest Quarter	0.884827	0.4126684
BIO12 = Annual Precipitation	-0.6435118	0.719961
BIO13 = Precipitation of Wettest Month	-0.3485328	0.8499362
BIO14 = Precipitation of Driest Month	-0.7239439	0.6471142
BIO15 = Precipitation Seasonality (Coefficient of Variation)	0.7523971	-0.3287167
BIO16 = Precipitation of Wettest Quarter	-0.3328204	0.8872209
BIO17 = Precipitation of Driest Quarter	-0.5326372	0.8158797
BIO18 = Precipitation of Warmest Quarter	-0.2779185	0.7247949
BIO19 = Precipitation of Coldest Quarter	-0.788708	0.2507507

al. (2012; 2014): the supramediterranean vegetation (*Anthyllidion hermanniae*) identified in our study has a little floristic affinity with the *Cisto-Lavanduletea stoechadis* (occasional presence of *Cistus salviifolius* and *C. creticus* and absence of *Lavandula stoechas*) and should therefore not be included in this class. The same is true for the oromediterranean vegetation: our results disagree with the proposal of Biondi *et al.* (2012, 2014) to integrate the supra- and oromediterranean low-scrubs within the *Junipero sabinae-Pinetea sylvestris* because the floristic composition of the six plant associations that we highlighted here does not correspond to this class.

Re-evaluation of the syntaxonomic definition of the French Carici-Genistetea lobelii plant communities at the plant association scale

The typology of the plant associations was first reviewed within the Prodromus of Corsican Vegetation in which the *Carici caryophylleae-Genistetea lobelii* was divided into six plant associations (*Helichryso italici-Genistetum salzmannii*, *Alysso robertiani-Genistetum salzmannii*, *Berberido aetnensis-Genistetum lobelioidis*, *Thymo herbae-baronae-Genistetum lobelioidis, Anthoxantho odorati-Brachypodietum rupestris, Sagino piliferae-Caricetum caryophylleae*) (Reymann *et al*., 2016). Our study confirmed three plant associations (*Alysso robertiani-Genistetum salzmannii*, *Helichryso italici-Genistetum salzmannii*, *Thymo herbae-baronae-Genistetum lobelioidis*) and three sub-associations (*Helichryso italici-Genistetum salzmannii helichrysetosum italici*, *Helichryso italici-Genistetum salzmannii cerastietosum boissierianii*, *Thymo herbae-baronae-Genistetum lobelioidis allietosum schoenoprasi*).

The *Paronychio polygonifoliae-Armerietum multicepitis genistetosum lobelioides* association, which was classified in the *Caricetea curvulae* by Reymann *et al.* (2016), should be included in the *Carici-Genistetea salzmannii* class. This vegetation is dominated by chamephytes (*Genista salzmanni* var. *lobelioides* in particular) and its floristic composition is characterized by typical species of this class such as *Astragalus genargenteus* var. *greuteri, Trisetum gracile* subsp. *conradiae, Trisetum gracile, Hypochaeris cretensis, Stachys corsica*). This subassociation should be elevated to a plant association following the *Paronychio polygonifoliae-Genistetum lobelioidis*.

Other associations were merged because their floristic composition was similar:

- This was the case for the *Ligusticetum corsici* described by Klein (1972) and the *Paronychio polygonifoliae-Armerietum multicepitis armerietosum multicepitis* described by Gamisans (1977): the modified TWINSPAN classification showed that they were the same plant community because the vegetation plots from the princeps tables are in the same pool. This grassland is very similar to the *Saginetea piliferae*, which includes some characteristic taxa (*Sagina pilifera*, *Plantago sarda*, and *Luzula spicata* subsp. *italica*) but is distinguished by diagnostic taxa of the *Carici caryophylleae-Genistetea salzmannii* (*Poa nemoralis* subsp. *balbisii*, *Stachys corsica* and *Sedum alpestre).*
- This was also the case for the *Juniperetum nanae* Litardière & Malcuit 1926, the *Genisto-Carlinetum macrocephalae* Klein (1972), and the *Berberido aetnensis-Genistetum lobelioidis* Gamisans 1977.

The modified TWINSPAN classification showed that the records belonging to these three associations correspond to the same plant community. According to Article 22 of the Code of Phytosociological Nomenclature (Theurillat *et al*., 2020), the *Berberido aetnensis-Genistetum lobelioidis* Gamisans 1977 [Phytocoenologia 4(1): 80, p.p.,] is considered to be an illegitimate name. Therefore, the *Juniperetum nanae* Litardière and Malcuit 1926 could be the legitimate name of this plant association.

Ecological and geographical patterns of the plant communities

Our results show a distinction between the plant communities that occur under supramediterranean and oromediterranean thermotypes. The mean annual temperatures are higher and the continentality is not as distinct within the supramediterranean belt which is located between 600 and 1350 m asl and oromediterranean belts are found at high elevation (1300 m to 2200 m asl) and are characterized by a more humid climate with lower temperatures and a more rigorous general climate (winds, snow cover, insolation, etc.) (Jeanmonod & Gamisans, 2013). The high rainfall on Cap Corse can be explained by a long and narrow schist crest, which culminates at 1305 m asl. in its central part. In the north and south, with decreasing elevation, the rainfall decreases, and the tip of the peninsula only receives 500 to 600 mm of rainfall (Delbosc *et al*., 2020). The climatic particularities of the Cap Corse region can be used to distinguish the *Alysso robertiani-Genistetum salzmannii* as an endemic plant association from other supramediterranean plant communities (Molinier, 1959; Gamisans, 2004). In the rest of the supramediterranean belt, when the ecological conditions are less extreme, the *Helichyro italici-Genistetum salzmannii* occurs and replaces the previous plant community.

The oromediterranean belt (1300 m - 2000 m asl) is mainly composed of low-scrub dominated by *Genista salzmanii* var. *lobelioides* and *Juniperus communis* subsp. *alpina*. This belt is subject to strong winds and a long period of snow cover and is also mainly composed of grasslands (*Ligusticetum corsici*) and open low-scrub (*Paronychio polygonifoliae-Genistetum lobelioides*).

There is also a difference in the distribution of the *Carici caryophylleae-Genistetea salzmannii* plant communities between the Haute-Corse and Corse-du-Sud departments of Corsica. This difference can be explained by changes in the agricultural-grazing society during the 20th century, which has profoundly modified the vegetation landscape of Corsica and represents one of the fundamental issues that need to be taken into account to understand the changes in the dynamic trajectories of the vegetation (Rota & Cancellieri, 2001; Ravis-Giordani *et al.,* 2004). The opening up of supra- and mountain and oromediterranean woodlands via fires, cutting, and grazing favors the development of the *Carici caryophylleae-Genistetea salzmannii* plant communities. The Haute-Corse department has been more marked by fires than the Corse-du-Sud department whereas Southern Corsica comprises large areas of forest (IFN, 2010; INIGF, 2014). These observations explain the higher numbers and higher diversity of the *Carici caryophylleae-Genistetea salzmannii* plant communities in Haute-Corse than in Southern Corsica.

Advantages and limits of the method used

The main advantage of the methodological approach used in our study is that it centralizes all of the phytosociological data for a specific type of vegetation within one database. As a result, we were able to gather, under Turboveg, all the bibliographical vegetation plots, holotypes, original tables, and vegetation plots resulting from new field investigations. The second advantage is the definition of diagnostic, constant, and dominant species for each level of synsystem from plant communities to class. With this data, we were able to develop an expert system for all French vegetation in the *Carici caryophylleae-Genistetea salzmannii* (Appendix S3). This expert system includes a group of diagnostic species for each plant association as well as a group of diagnostic species for the higher levels (alliance, order, and class). Our expert system also integrates groups of 'trees', 'scrubs' and 'low scrubs'. This increases the accuracy when recognizing vegetation plots belonging to the *Carici caryophylleae-Genistetea salzmannii* plant community and avoids confusion with vegetation that is dominated by woody species because they are often found near thickets or forests and are colonized by species from these plant communities.

To better define the *Carici caryophylleae-Genistetea salzmannii* plant communities, we also include lists of species in the expert system for the classes that are similar to the *Carici caryophylleae-Genistetea salzmannii* such as the *Cisto ladaniferi-Lavanduletea stoechadis* (de Foucault *et al*., 2012) and the *Saginetea piliferae*. Some errors are still possible between the *Saginetea piliferae* and the *Plantaginion insularis* grasslands in the dataset including both types of vegetation because we have proposed a formal definition for this class without considering all the *Saginetea piliferae* vegetation. It is therefore advisable to follow two methodological steps, as we have done in our study: first, select vegetation plots belonging to the target vegetation to be studied from the expert system provided by Mucina *et al.* (2016) for the class level, and then second, apply our expert system to assign vegetation plots to the *Carici caryophylleae-Genistetea salzmannii* plant communities. Errors can occur when formal definitions are based on a small number of vegetation plots.

The significant advantages of an expert system are that it can be re-adjusted and can evolve as new vegetation plots are added to the database. This is also the case for species lists and formal definitions which can be modified according to new data.

Vegetation typology is an essential approach for describing vegetation communities and more broadly for describing habitats listed under the Habitats Directive (Gigante *et al*., 2016; Rodwell *et al*., 2018). The method we used allows us to cross-check between the phytosociological typology and the definition for the habitats given in the Habitats Directive. The description of habitat type 4090 – 'Endemic oromediterranean heaths with gorse' refers only to the *Anthyllidion hermanniae* and 6170 'Alpine and subalpine calcareous grasslands' refers to the *Pantaginion insularis* (Bensettiti *et al*., 2005; Romao *et al*., 2015). The separation into the three alliances that we have proposed provides further clarification that can be used to delimit these two habitats. Our results show that the *Pantaginion insularis* including the *Ligusticetum corsici,* has more floristic affinities with the *Carici caryophylleae-Genistetea salzmannii* (4090) than the *Saginetea pilifereae* which are included in habitat type 6170. The *Plantaginion insularis* grasslands are distinguished from those of the 6170 habitat because they are dominated by hemicryptophytes (*Poa nemoralis* subsp. *balbisii*, *Thlaspi brevistylum*) and some nanophanerophytes such as *Juniperus communis* subsp. *alpina*. Moreover, these grasslands essentially develop at high elevations starting from 1900 m asl on the screes of south-facing upper slopes where a fine accumulation of substrates occur and are subject to a long period of snow cover. Its ecology does not correspond to that of habitat 6170 which only occupies the northern slopes and is not subject to a period of drought (Bensettiti *et al*., 2005). We, therefore, suggest that the *Plantaginion insularis* should be integrated into habitat 4090. According to the European Commission, habitat 4090 is considered to have a favorable conservation status in the Mediterranean region.

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Supplementary material

Appendix S1. Sources of the vegetation plots serving the synthesis of the *Carici caryophylleae-Genistetea lobelii.*

Appendix S2. Pool characteristics obtained from a modified TWINSPAN classification.

Appendix S3. Expert system for the *Carici caryophylleae-Genistetea salzmannii* communities.

Appendix S4. Confusion matrix between the TWINSPAN pools and the plant associations for which formal definitions were developed by our expert system.

Appendix S5. Diagnostic, constant, and dominant species for plant communities classified by an expert system.

Appendix S6. Photographs of the plant associations recognized in this paper.