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PHYTOGEOGRAPHIC SUBDIVISION OF ITALY USING ZONAL VEGETATION SERIES (SIGMETA): A FIRST APPROXIMATION

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Abstract: Most proposals concerning the phytogeographic regionalisation of Italy have been founded on the distribution of vascular flora. A new phytogeographic subdivision of Italy is herein proposed, based on occurrence of zonal vegetation series at administrative region level. For this purpose, the presence data were drawn from the Map of Vegetation Series of Italy [3]. Following some modifications (sigmetum additions and merging) and exclusion (azonal sigmeta and small islands), a presence-absence matrix composed of 20 administrative regions by 224 vegetation series was resulted and, subsequently involved in cluster analysis, indirect ordination and indicator analysis. The administrative regions were partitioned into 12 phytogeographic units (districts), of which six were composed of only one region. Sardinia is the only region not to share any sigmetum with others. The main inferred gradients underlying the sigmetum composition of region were latitude and oceanicity. The subdivision of Italy based on vegetation series is similar to that which would result on the basis of the distribution of vascular planta taxa, if a classification at higher levels of within-cluster floristic similarity were considered. The numerous phytogeographic units distinguished (12) is certainly due to the strong climatic gradients and geomorphologic variation traceable throughout Italy, but their number is probably overestimated as a consequence of some redundancy in syntaxonomic nomenclature. Along with vascular flora, zonal vegetation series demonstrate a reliable predictive power to distinguish terrestrial phytogeographic units.

Keywords: administrative regions, endemic sigmeta, latitudinal gradient, large islands, oceanicity, partitioning around medoids, vegetation series map

Introduction

The phytogeographic subdivision of the Earth can be achieved by reference to the flora, the vegetation types, and both the flora and vegetation together [20, 12, 11]. Subdivisions based on the flora lead to identification of regions and other smaller phytogeographic units, while subdivisions that take into consideration the vegetation types make it possible to “regionalise” the vegetation cover. Taking into account both the flora and the vegetation, various types of maps have been realised; the most complete proposal is that of Rivas Martinez (1987), which refers to sigmeta or vegetation series, defined not only on the basis of plant associations, but also on the occurrence of certain plant taxa.

The phytogeographic subdivisions proposed to date for Italy were done by reference to the flora, and made it possible to attribute its territory to the two classical Eurosiberian and Mediterranean regions, in turn divided into lower phytogeographic categories [7, 22, 13, 8, 14, 17, 2, 16, 6]. Bioclimatic studies have confirmed the classification into the two regions mentioned before, and have provided further information and detail [20].

The goal of the present paper is to achieve a phytogeographic subdivision of Italy on the basis of vegetation series distribution.

Materials and Methods

Data collection and transformation

The main source of information regarding the occurrence of various sigmeta in each administrative region of Italy, was the Map of Vegetation Series of Italy on a scale of 1:500,000, which is composed of three sheets [3]. A total of 279 vegetation series were represented on this map by grouping them into the two classic bioclimatic regions, Temperate and Mediterranean, with a transition belt in central Italy.

For the purposes of the present work, only 224 vegetation series were considered, as all azonal series, such as sigmeta of watercourses, lagoons, inland lakes, sand dunes and rocky coasts, were excluded. In addition, some modifications, such as the addition and merging of sigmeta, were made on the basis of personal knowledge about the regions of Trentino-Alto Adige, Marche, Umbria, Abruzzo, Molise and Puglia.

The vegetation series of small islands were not taken into account because the vegetation of these detached territories is often very different from that of the administrative zones to which they belong (for example, the islands of the Tuscan Archipelago, and the Aeolian Islands, Aegadian Islands, Pelagie Islands and the island of Pantelleria). Conversely, the islands around Sardinia and the Pontine Islands were included with the regions to which they belong, because they are close to the continent and do not have autochthonous vegetation series.

The data on the occurrence of sigmeta by administrative regions were summarised in a binary matrix (presence-absence), composed of 20 columns (regions) and 224 rows (vegetation series), which was subsequently used as input in various analyses.

Data analysis

The vegetational similarity between regions was assessed by the square root of the complement of the Sørensen index, the values of which were employed to build a symmetric distance matrix.

A non-hierarchical partitioning around medoids was performed in order to classify the administrative regions. The optimal number of clusters was estimated by the average silhouette width. Cluster stability was assessed by bootstrapping and computation of Jaccard similarities of the original clusters to the most similar clusters in the re-sampled data [9].

Strength of the association between each sigmetum and cluster was computed by using the fidelity (sensitivity) component (B) of indicator values IndVal [5].

Ordination of the 20 administrative regions was carried out through local non-metric multi-dimensional scaling (NMDS) using monotone regression and primary ("weak") treatment of ties.

All numerical analyses were performed in R [18] using the packages 'fpc' [10], 'indicspecies' [5] and 'vegan' [15].

Results and Discussion

The distribution of average silhouette by number of groups suggested an optimal solution corresponding to 12 clusters, reflecting the maximum value of the average silhouette (Fig. 1). The stability of each of these 12 clusters was confirmed by the values of the Jaccard bootstrap means, which were all over the conventional threshold of 0.6 (Fig. 2). The alternative solution with two partitions, corresponding to the second maximum of the average silhouette (Fig. 1), explained only a small amount of total variation, as Sardinia formed a cluster by itself and all other regions were grouped together.

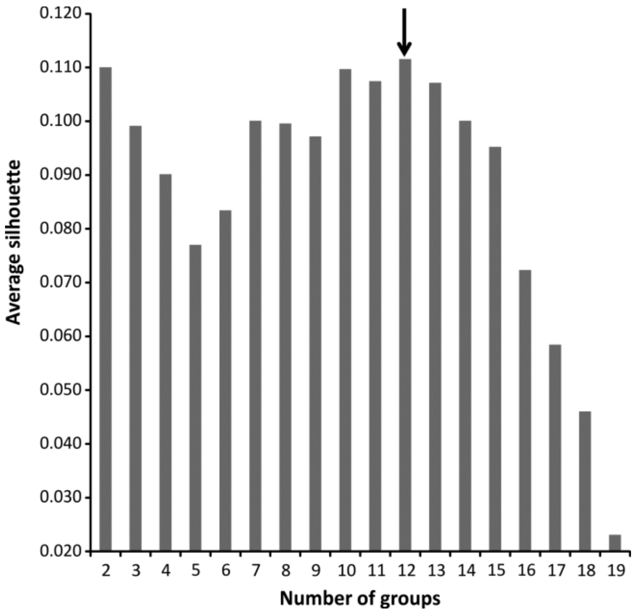

Fig. 1: Selection of the optimal number of clusters (shown with an arrow) on the basis of the maximum within-group average silhouette

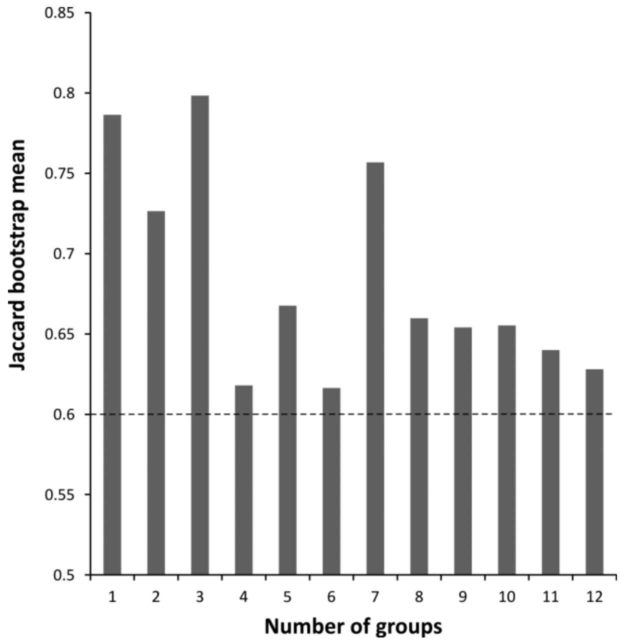

Fig. 2: Assessment of cluster stability for the optimal solution (12 groups). The dashed line indicates the (conventional) lower threshold of stability.

The 20 administrative regions were grouped into 12 phytogeographic units (districts), of which six comprised only one region (Fig. 3). Sardinia is the only region not sharing any sigmetum with the others. Apart from singleton clusters, all the others are composed of contiguous regions, which is certainly related to the continuum in vegetation type distribution. Each cluster of regions is perfectly distinguishable by at least one sigmetum, but Sardinia and Sicily have by far the most numerous endemic sigmeta (Table 1).

Table 1: List of perfect indicator sigmeta for each group of administrative regions. The sigmeta are indicated by means of the most mature (climax) communities, also known as head associations of the series

VAO + PIE	
3	Ultramafic geosigmetum (western Alps)
47a	Luzulo-Fagion (western Alps)
81	Deschampsio-Pinion
82a	Ononido-Pinetum
96	Quercion pubescenti-petraeae
LOM + TAA	
16	Calamagrostio villosae-Abietetum
46	Galio odorati-Fagetum
84	Vaccinio-Pinetum
102	Chamaecytiso purpureae-Pinetum sylvestris
109	Carpino betuli-Ostryetum carpinifoliae
VEN + FVG	
17	Polysticho lonchitis-Fagetum
27	Fraxino orni-Pinetum nigrae
49	Aremonio-Fagion
91	Carici umbrosae-Quercetum petraeae

LIG	
35	Vaccinio-Piceion (south-western fir forests)
69	Fagion sylvaticae
112	Plagio-Ostryetum carpinifoliae
118	Seslerio-Ostryetum carpinifoliae
127	Lathyro montani-Quercetum cerridis
141	Campanulo-Quercetum pubescentis
168	Rubio-Quercetum pubescentis
229	Viburno tini-Quercetum ilicis (Ligurian)
EMR	
8	Acidophilous geosigmetum (northern Appenines)
36	Trochiscantho nodiflori-Fagetum
55	Seslerio cylindricae-Fagetum
98b	Knautio purpureae- Quercetum pubescentis
119	Dryopterido-Ostryetum carpinifoliae
120	Ostryo-Aceretum opulifolii
129	Erythronio-Quercetum petraeae
TOS	
20	Seslerio tenuifoliae-Semperviretum
121	Roso caninae-Ostryetum carpinifoliae
122	Daphno laureolae-Ostryetum carpinifoliae
131	Frangulo alni-Quercetum petraeae
214	Roso sempervirentis-Quercetum ilicis
MAR + UMB	
58	Dactylorhizo fuchsii-Fagetum
73	Carici sylvaticae-Quercetum cerridis
159	Asparago-Ostryetum carpinifoliae
LAZ + ABR + MOL	
75	Aremonio agrimonioidis-Quercetum cerridis
CAM + LUC + CAL	
80	Seslerio autumnalis-Aceretum obtusati
PUL	
165	Doronico orientalis-Carpinetum betuli
173	Cyclamino hederifoliae-Quercetum virgilianae
198	Ptilostemo-Quercenion cerridis
200	Stipo bromoidis-Quercion dalechampii
201	Irido collinae-Quercetum virgilianae
208	Teucrio siculi -Quercetum trojanae
209	Euphorbio api-Quercetum trojanae
211	Carici halleranae-Quercetum suberis
237	Sigmetum of Quercus itaburensis ssp. macrolepis (aggr.)
241	Hedero ilicis-Quercetum calliprini
246	Plantago albicantis-Pinetum halepensis
249	Pistacio lentisci-Pinetum halepensis
SIC	
175	Rumici aetnensis-Astragalion siculi
178	Junipero hemisphaericae-Abietetum nebrodensis
179	Epipactido meridionalis-Fagetum
180	Luzulo siculae-Fagetum
183	Agropyro panormitanae-Quercetum congestae
184	Arrhenathero nebrodensis-Quercetum cerridis
185	Geranio versicoloris-Quercetum ilicis

187 Ilici aquifoli-Quercetum austrothyrrenicae
188 Festuco heterophyllae-Quercetum congestae
202 Sorbo torminalis-Quercetum virgilianae
203 Mespilo germanicae-Quercetum virgilianae
204 Arabidi turritae-Quercetum congestae
205 Quercetum leptobalanae
206 Quercetum gussonei
218 Aceri campestris-Quercetum ilicis
219 Doronico orientalis-Quercetum ilicis
226 Genisto aristatae-Quercetum suberis
227 Stipo bromoidis-Quercetum suberis
231 Erico arboreae-Quercetum ilicis
232 Pistacio lentisci-Quercetum ilicis
239 Rhamno alaterni-Quercetum ilicis
243 Junipero turbinatae-Quercetum calliprini
245 Chamaeropo humilis-Quercetum calliprini
251 Cisto crispi-Pinetum pineae
258 Oleo sylvestris-Euphorbietum dendroidis
259 Pistacio lentisci-Chamaeropsetum humilis
260 Calicotomo infestae-Rhoetum tripartitae

SAR

156 Sigmetum of Juniperus oxycedrus ssp. macrocarpa
157 Glechomo sardoae-Quercetum congestae
158 Saniculo europeae-Quercetum ilicis
186 Cyclamino repandi-Ostryetum carpinifoliae
189 Galio scabri-Quercetum ilicis
192 Aceri monspessulani-Quercetum ilicis
207 Ornithogalo pyrenaici-Quercetum ichnusae
213 Violo denhardtii-Quercetum suberis
220 Ericion arboreae (with Pinus pinea)
225 Lonicero implexae-Quercetum virgilianae
228 Galio scabri-Quercetum suberis
233 Prasio majoris-Quercetum ilicis
235 Cyclamino repandi-Oleetum sylvestris
242 Pyro amygdaliformis-Quercetum ilicis
244 Rusco aculeati-Quercetum calliprini
252 Oleo sylvestris-Juniperetum turbinatae
253 Erico arboreae-Juniperetum turbinatae
254 Euphorbio characio-Juniperetum turbinatae
255 Chamaeropo humilis-Juniperetum turbinatae
256 Asparago albi-Oleetum sylvestris

The main inferred gradients underlying the sigmetum composition of regions are latitude and oceanicity (Fig. 4). Except for the two large islands (Sardinia and Sicily) that have higher loadings on the second NMDS axis, the separation of the Alpine regions (right) from the peninsular ones (left) along the first NMDS axis is consistent with the classic phytogeographic delimitation between Temperate and Mediterranean bioclimatic regions [17, 4]. The isolated position of Sardinia (outlier) on the ordination space is related to its total distinctiveness in terms of the sigmeta that occur.

[VAO, **PIE**] 1 1	[**LOM**, TAA] 2 2	[VEN, **FVG**] 3 3
[**LIG**] 4	[**EMR**] 5	[**TOS**] 6
[MAR, **UMB**] 7 7	[LAZ, **ABR**, MOL] 8 8 8	
[CAM, **LUC**, CAL] 9 9 9	[**PUL**] 10	
[**SIC**] 11	[**SAR**] 12	

Fig. 3: Clustering of administrative regions in Italy distinguished through vegetation series occurrence (cluster membership is indicated by numbers and medoids are in bold). Abbreviations: VAO - Val d'Aosta; PIE - Piemonte; LOM - Lombardia; TAA - Trentino-Alto Adige; VEN - Veneto; FVG - Friuli-Venezia Giulia; LIG - Liguria; EMR - Emilia-Romagna; TOS - Toscana; MAR - Marche; UMB - Umbria; LAZ - Lazio; ABR - Abruzzo; MOL - Molise; CAM - Campania; LUC - Lucania; CAL - Calabria; PUL - Puglia; SIC - Sicilia; SAR – Sardegna.

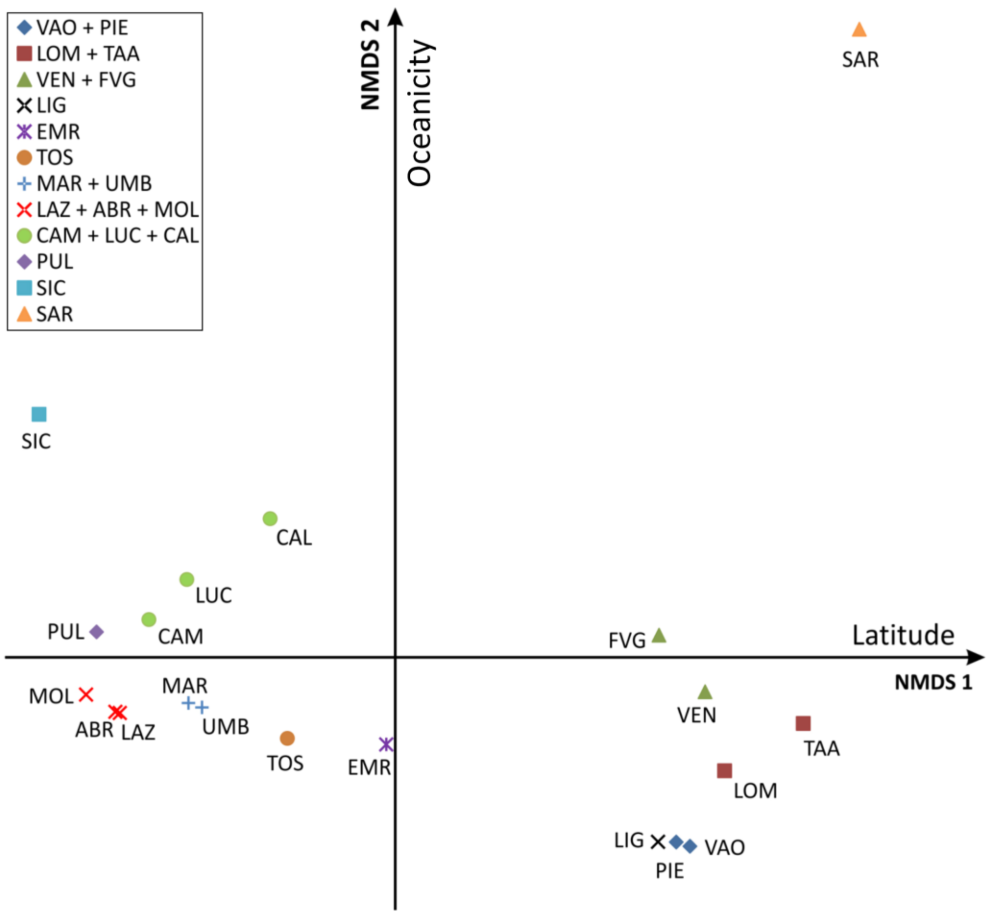

Fig. 4: NMDS ordination of the administrative regions of Italy based on the occurrence of sigmeta. Abbreviations as in Fig. 3.

The subdivision of Italy based on vegetation series (Fig. 5a) actually mirrors the one that could be inferred on the basis of the distribution of vascular plant taxa [6], if a classification at higher levels of within-cluster floristic similarity were to be considered (Fig. 5b).

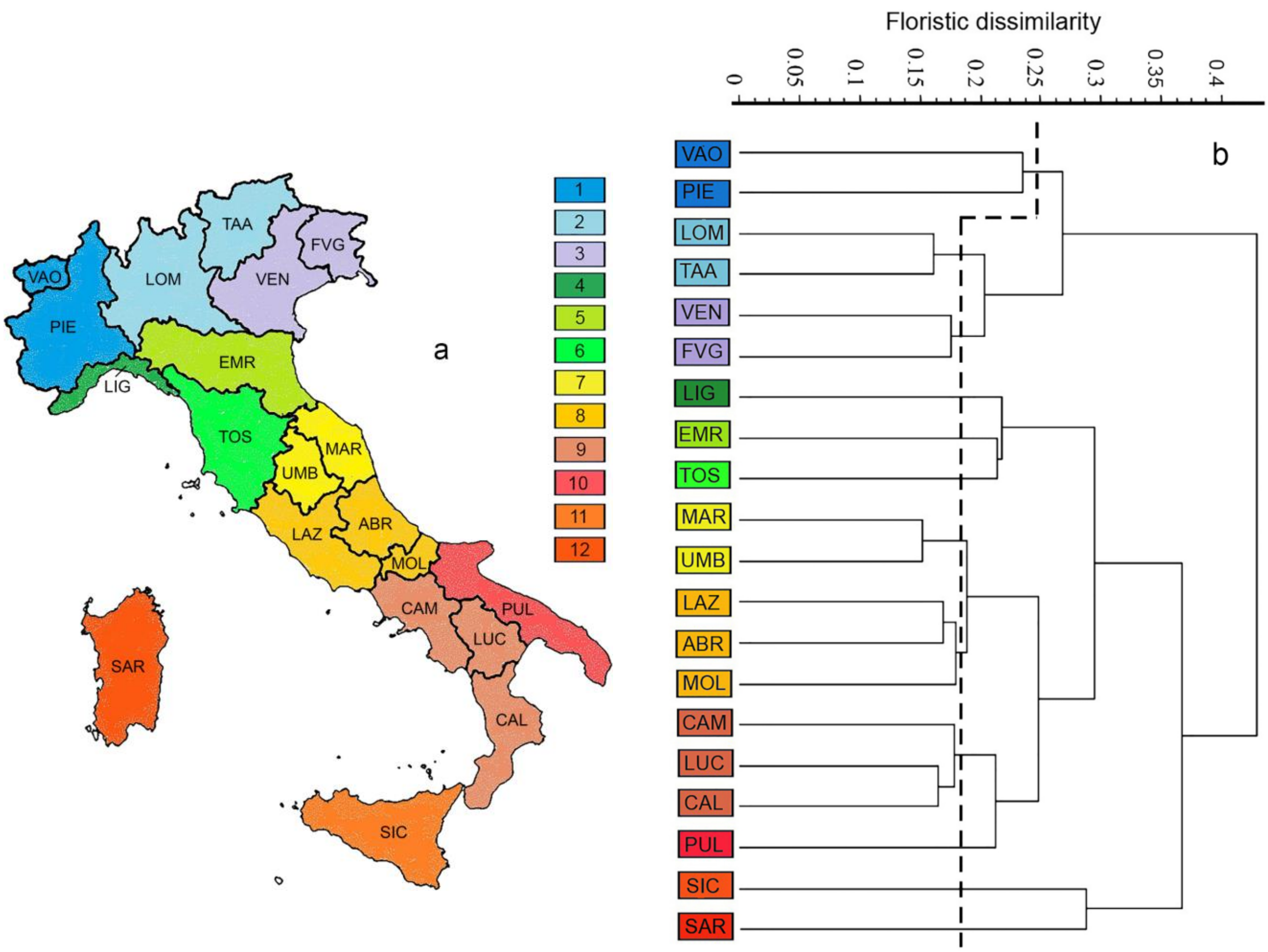

Fig. 5: a) Subdivision of Italy drawn from the classification of its administrative regions into 12 groups (corresponding to those of Fig. 3) on the basis of the distribution of vegetation series
b) Re-interpretation of Filibeck et al.'s (2005) dendrogramme at higher level of within-cluster similarity (abbreviations as in Fig. 3)

Conclusion

The large number of phytogeographic units distinguished (12) is certainly due to the strong climatic gradients and geomorphological variation traceable throughout Italy (e.g. great extension from north to south into the Mediterranean Sea), but also to the presence of the large islands of Sicily and Sardinia, which have many endemic vegetation series. However, the inferred number of phytogeographic units is probably overestimated because of some redundancy in syntaxonomic nomenclature (i.e. plant association synonymy).

The resulting phytogeographic units are approximately delimited because of the coarse and variable resolution of sigmetum occurrence data (the administrative regions of Italy are of very different sizes, from 3,263 km^2 – Val d'Aosta, to 25,711 km^2 – Sicily). Nevertheless, the convergence of results using different input data and numerical analyses ensures the reliability of the phytogeographic patterns detected. Along with vascular flora, zonal vegetation series demonstrate a reliable predictive power for the distinction of terrestrial phytogeographic units.

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SUBDIVIZAREA FITOGEOGRAFICĂ A ITALIEI PRIN UTILIZAREA SERIILOR DE VEGETAŢIE ZONALĂ (SIGMETA): O PRIMĂ APROXIMARE

(Rezumat)

Majoritatea propunerilor pentru regionalizarea fitogeografică a Italiei sunt bazate pe distribuţia florei vasculare. Acest articol propune o nouă subdivizare fitogeografică a Italiei, bazată pe apariţia seriilor de vegetaţie zonală la nivel

de regiuni administrative. În acest scop, datele de prezenţă au fost luate din Harta Seriilor de Vegetaţie din Italia (Blasi, 2010). Ca urmare a unor modificări (adăugare şi fuziune de sigmete) şi excluderi (sigmete azonale şi insule mici), a rezultat o matrice de prezenţă-absenţă alcătuită din 20 regiuni administrative şi 224 serii de vegetaţie, care a fost supusă analizei cluster, ordonării indirecte şi analizei indicatorilor. Regiunile administrative au fost împărţite în 12 unităţi (districte) fitogeografice, dintre care 6 erau alcătuite dintr-o singură regiune. Sardinia este singura regiune care nu are niciun sigmetum comun cu altă regiune. Gradienţii cei mai importanţi care determină compoziţia sigmetum-ului şi regiunea sunt latitudinea şi proximitatea oceanului. Subdivizarea Italiei pe baza seriilor de vegetaţie este similară cu cea obţinută pe baza distribuţiei taxonilor de plante vasculare, daca se ia în calcul o clasificare la nivele ridicate de similaritate floristică în cadrul clustere-lor. Numeroasele unităţi fitogeografice (12) se datorează, cu siguranţă, gradienţilor climatici puternici şi variaţiei geomorfologice pe teritoriul Italiei, însă numărul lor este probabil supraestimat, ca şi consecinţă a redundanţei din nomenclatura sintaxonomică. Alături de flora vasculară, seriile de vegetaţie zonală demonstrează că pot fi utilizate cu succes în delimitarea unităţilor fitogeografice terestre.

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