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SUCCESSIONAL PATHWAY OF MEDITERRANEAN ULTRAMAFIC VEGETATION IN CENTRAL ITALY

ALESSANDRO CHIARUCCI

(Dipartimento di Biologia Ambientale, Università di Siena)

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The main plant communities of ultramafic (serpentine) outcrops of a Mediterranean area in central Italy are described and their successional pathway discussed. Four vegetation stages are distinguished: a) an endemic garigue stage, with high percentage of exposed rocky soil belonging to *Armerio-Alysetum bertolonii*; b) a garigue stage similar to the previous one but with several Mediterranean evergreen shrubs; c) a closed evergreen maquis of Mediterranean type belonging to *Viburno-Quercetum ilicis* subass. *ericetosum*; d) an evolved evergreen forest stage with some deciduous species belonging to the *Viburno-Quercetum ilicis* subass. *ornetosum*. While the pioneer stages are characterised by several endemic serpentinophytes, adapted to the peculiar environmental conditions of ultramafic shallow soils, the more evolved vegetation stages, on the contrary, are typical of Mediterranean environments and do not show any serpentine characterisation.

Introduction

Because of their characteristics, ultramafic soils are highly selective for plant life. The main features of these soils are a low Ca/Mg ratio, usually lower than one, a high content in potentially toxic metals such as nickel, chromium and cobaltum, a low content of nutrients and a heavy microclimate, due to the dark colour and the high permeability (Pichi Sermolli 1948, Krause 1958, Proctor & Woodell 1975, Sasse 1979, Kinzel & Weber 1982, Brooks 1987, Proctor & Nagy 1992). Only species with special adaptations resist such conditions, giving rise to typical plant communities. These features have prompted many studies, both geobotanical and biogeochemical (for reviews see Brooks 1987 and Proctor & Nagy 1992).

Many ultramafic outcrops exist in Italy, in the Alps and along the Apennines (Abbate & Bortolotti 1984, Giannini *et al.* 1971). Tuscan ultramafic outcrops have been subject of geobotanical studies since the description by Cesalpino (1583) of an "*Alysson* growing on black stones". Most of these studies were descriptive of the flora and sometimes of the vegetation (Caruel 1871, Pampanini 1912, Fiori 1914, 1919–1920, Sambo 1927, 1931, Messeri 1936, Cengia Sambo 1937, Corti 1940; Pichi Sermolli 1948, Vergnano 1953; Arrigoni 1974, Corti 1974; Cortini Pedrotti 1974, Marchiori & Tornadore Marchiori 1977; Arrigoni *et al.* 1983). Recently Ferrari *et al.* (1992) investigated the phytogeography of the serpentine flora of the Northern Apennines, Vergnano Gambi (1992) outlined the main problems concerning ultramafic vegetation ecology and ecophysiology in Italy and Chiarucci *et al.* (1994) carried out a phytosociological research on the garigues of all ultramafic areas of Tuscany. Studies on vegetation dynamics, except for some observations, were not performed.

The aim of the present study was to describe the different stages of ultramafic vegetation of a Mediterranean area and analyse their floristic relationships, outlining a dynamic scheme. This kind of investigation was chosen, in first approach, because it can provide a prompt overview of succession when environmental conditions are homogenous (Lepart & Escarre 1983).

The study area

The study area, located near the village of Murlo (Tuscany, Italy; Fig. 1), was recently proclaimed a nature reserve but few preliminary data are available on its flora and vegetation (Chiarucci 1993, Chiarucci *et al.* in press). This area is located in the central part of the basin of the Ombrone River, in a preapennine belt with hilly morphology ranging in altitude from 250 to 500 m. The geological formations in the area include many outcrops of the Ophiolitic complex with serpentinites, gabbrous rock with veins of porfirc and diabasic basalt in pillow structure (Bonechi 1980, Brunacci & Manganeli 1980). The climate is submediterranean, with equinoctial rainfall maxima and moderate summer drought. Climate data for Murlo (Barazzuoli & Salleolini 1993) give a mean annual rainfall of about 900 mm and a mean annual temperature of 13.0°C; the minimum mean monthly temperature occurs in January and is about 5.8°C, and the maximum occurs in July with 22.7°C. The climate diagram according to Bagnouls & Gaussen (1953) and Walter & Leith (1960) is shown in Fig. 1.

The dominant vegetation reflects the features of a transition belt between deciduous oak woods and Mediterranean evergreen woods. The latter stretches inland from the coast along south-exposed valley slopes, sometimes for several score kilometres. More xeric substrates, including ultramafic rocks, favour this penetration.

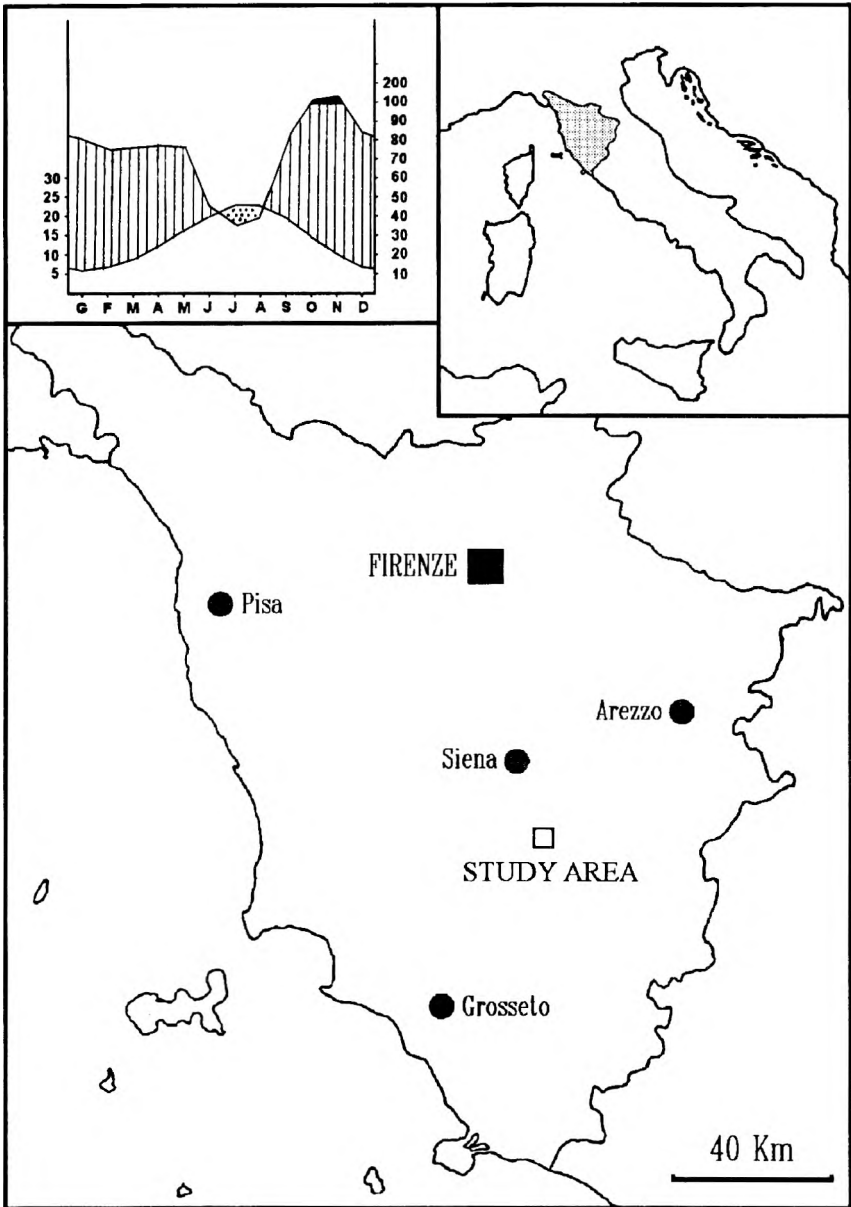


Fig. 1. The study area and the thermopluviometric diagram of the climatic station of Murlo.

Methods

Twenty-seven vegetation relevés were performed in the study area following the method of Braun-Blanquet (1932), endeavouring to cover all types of vegetation present. To detect floristic similarity and species variations among the different types of vegetation, data were processed by multivariate analysis of relevés x species matrices. The Braun-Blanquet cover scale was transformed according to Van der Maarel (1979). For the classification of relevés, cluster analysis, using minimum variance as agglomeration criterion (Orlòci 1978), was applied to a distance matrix constructed on the basis of Euclidean distance. As suggested by Wildi & Orłòci (1990), the square root of the cover values was taken in order to reduce the excessive effect of high ground cover. The ordering of relevés was performed by Principal Components Analysis (PCA) applied to a covariance matrix (Pielou 1969, Orłòci 1978). Patterns of life forms, according to Raunkiaer (1934), were constructed using the value of angular distance among relevés in the ordination plot as new axis. Data processing was performed with the programme package of Wildi & Orłòci (1990).

Nomenclature: Arrigoni (1974) for serpentino-phytes and Pignatti (1982) for other species.

Results

Classification

Cluster analysis (Fig. 2), revealed that the 27 relevés (Table 1) are distributed in two distinct clusters, both of which clearly dividable into two groups.

The first main cluster (relevés 1–15) is differentiated by a great number of species, many of which are serpenticolous or typical of dry and rocky soils. The relevés of the first group (1–9) were performed in garigues, with a high percentage of exposed soil and limited shrub cover. This group is characterised by species, many of which are therophytes, with low frequency and cover. The second group of relevés (10–15) contains nearly all the species that characterised relevés 1–9. Serpentinicolous species are all present, though less abundant than in group I. Shrubs such as *Juniperus oxycedrus* ssp. *oxycedrus*, *Erica scoparia* and *E. arborea*, scarce in the first group, are more abundant here. Another group of shrubs including *Phillyrea latifolia*, *Quercus ilex*, *Arbutus unedo* and *Cistus incanus*, absent in group I, are present in group II. The grass layer cover increases in this group, mainly due to *Bromus erectus*.

The third (16–21) and fourth (22–27) groups of relevés, carried out in markedly different environments, were more homogeneously clustered. These vegetation types are characterised by the overwhelming presence of evergreen woody species appearing in group II, and by the disappearance of the garigue species. In particular, the third group joins relevés performed in closed maquis a few metres high, locally called "forteto", dominated by *Quercus ilex*, *Arbutus unedo* and *Phillyrea latifolia*. *Juniperus oxycedrus* ssp. *oxycedrus* still has significant cover, equalled or exceeded by *Erica scoparia* and *E. arborea*. The grass layer is reduced by the lack of light at ground level. The fourth

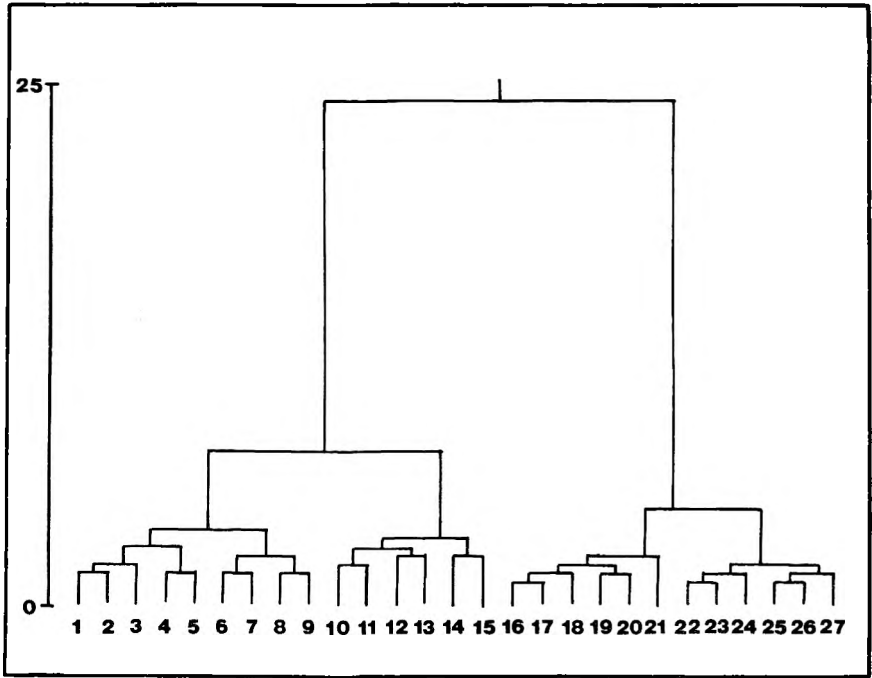


Fig. 2. Dendrogram showing the classification of the relevés.

group represents the most evolved and structured forest stage, dominated by *Q. ilex* and with high tree cover. Shrub cover is reduced and, as in the previous group, the grass layer is minimal. Two deciduous trees, *Quercus pubescens* and *Fraxinus ornus*, are fairly abundant. The only other differential species is *Tamus communis*.

Ordination

In the ordering plot of the relevés (Fig. 3) the first two axes accounted for 43.5% and 12.5% of the total variance respectively; the arrangement of the relevés well corresponds to the groups emerged by cluster analysis. From the integrated information of the two axes the gradient garigue → garigue with shrubs → closed maquis → closed maquis → *Quercus ilex* woodland emerges. The ordering pattern, based on species composition, can therefore be explained in terms of increasing structural complexity. This is confirmed by the good fit ($R^2 = 0.95082$; $p < 0.0000$) of the multiple regression analysis (Fig. 4) of the PCA angular distance values with respect to the ground cover of grass, shrub and tree layers. Figure 5 confirms that the relevés gradient was linked with variation in community structure, showing the life form changes in the vegetation pathway. Chamaephytes show a decrease in percentage due to the increase of other life forms in group II, and drop to zero in group IV; their

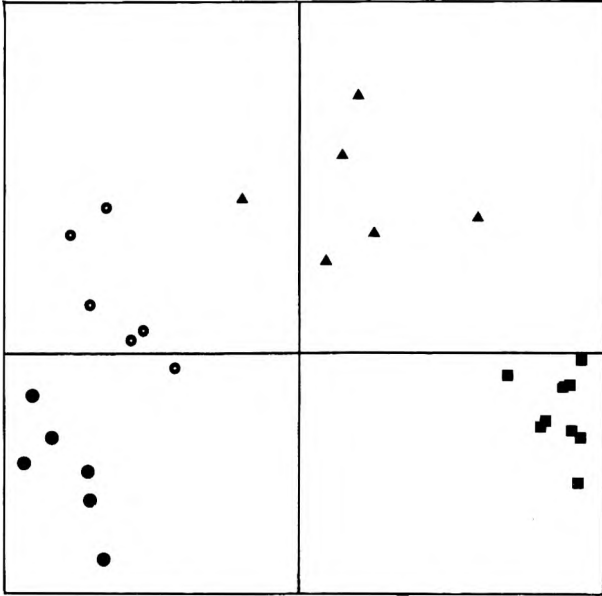


Fig. 3. PCA ordination plot of the relevés. Quadrats: *Armerio-Alysetum bertolonii* garigues; triangles: garigues with shrubs; circles: evergreen maquis (*Viburno-Quercetum ilicis* subass. *ericetosum*); points: evergreen woods (*Viburno-Quercetum ilicis* subass. *ornetosum*).

$$\text{PCA angle} = 93.578 + 1.605 \text{ tree cover} + 1.771 \text{ shrub cover} - 0.565 \text{ grass cover}$$

$$R\text{-SQ} = 0.95082 - p < 0.0000$$

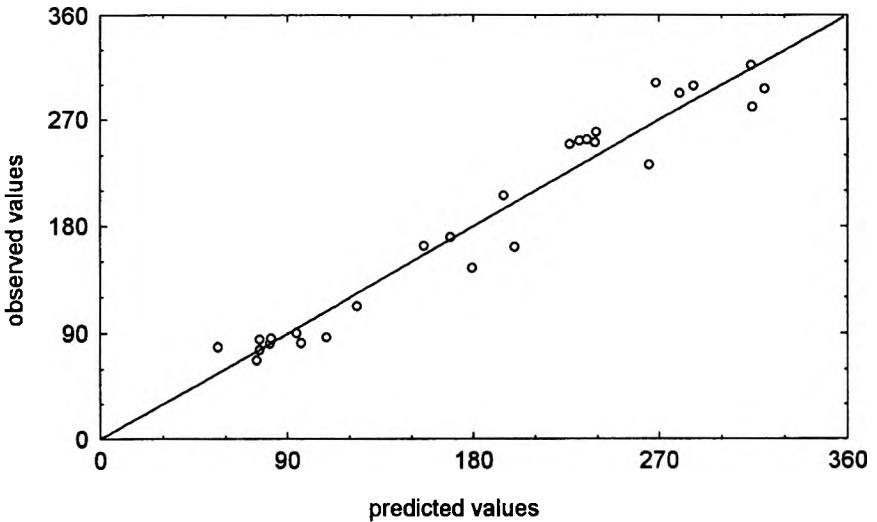


Fig. 4. Multiple regression of the PCA angular distance values among the relevés with respect to the cover of grass, shrub and tree layers.

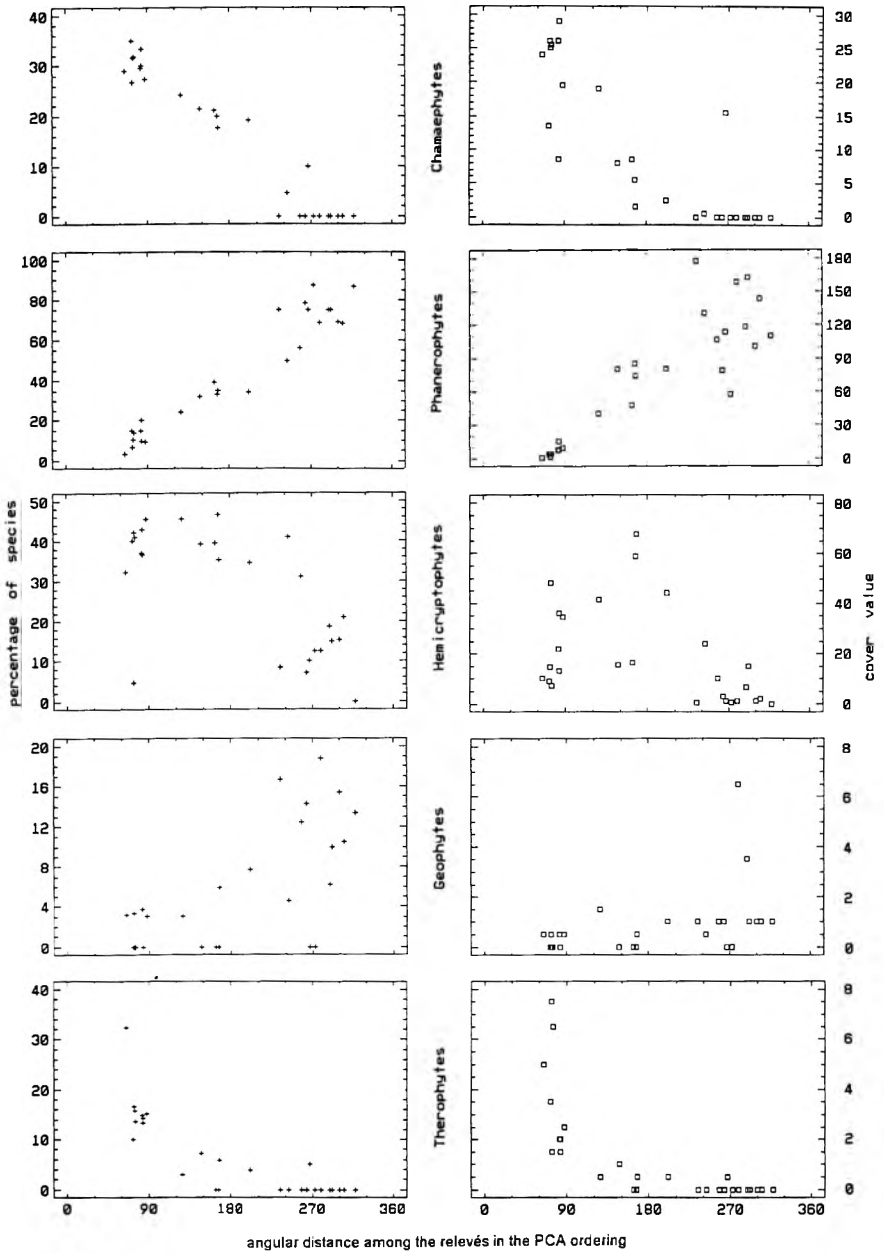


Fig. 5. Patterns of Life form variations (+ = number percentage; □ = ground cover) with respect to the angular distance values among the relevés.

cover shows an even steeper drop. Phanerophytes show a constant increase in percentage of species and ground cover. Hemicyptophytes trend is less clear because their percentage is practically constant in groups I and II, decreasing, with two exceptions, in groups III and IV; cover is not regular but seems to increase in group II, as already observed. Geophytes are scarce but increase in percentage in the more evolved stages due to the decrease in the total number of species; their cover is always extremely low, except in group IV, due to the abundance of *Ruscus aculeatus*. Therophytes show a similar pattern to chamaephytes, both in percentage and cover.

Discussion

Coenoses similar to the garigues of group I have been described by the Raunkiaer method, by Messeri (1936) and Pichi Sermolli (1948). Their relevés were used by Ernst (1974) to describe *Alysetum bertolonii* Ernst 1974, belonging to *Violetaea calaminariae* Br.-Bl. et Tx. 1943. Since that study had many shortcomings, Arrigoni et al. (1983) described the same vegetation type, from Monte Ferrato, as *Armerio-Alysetum bertolonii* Arrigoni, Ricceri et Mazzanti 1983. This association, characterised by the serpentine endemics *Alyssum bertolonii*, *Armeria denticulata*, *Centaurea aplolepa* ssp. *carueliana*, *Stachys recta* ssp. *serpentinii*, *Thymus acicularis* var. *ophiolicus* and *Euphorbia nicaeensis* var. *prostrata*, was assigned to *Festuco-Brometea* Br.-Bl. et Tx. 1943. Chiarucci et al. (1994) defined two subassociations: *typicum*, growing in the inland areas, and *euphorbietosum spinosae* Chiarucci Foggi et Selvi 1994, in the more Mediterranean areas. They assigned the relevés of Murlo to a marginal form of the latter subassociation.

Open scrubs, to those of group II (10–15) and characterised by *Juniperus oxycedrus* ssp. *oxycedrus* and *Erica scoparia* were reported by Pichi Sermolli (1938). This author regarded them as dynamic stage, successive to the *A. bertolonii* communities, observing that *J. oxycedrus* is the most significant woody species, followed by *E. scoparia*. In our relevés the importance of the latter is comparable to that of *E. arborea*. This vegetation type represents a transition between an evolved form of the *Armerio-Alysetum*, and a well structured scrub. Arrigoni et al. (1983) pointed out the importance of *Bromus erectus* and *Brachypodium rupestre* grasslands in serpentine soil evolution and shrub diffusion. Pichi Sermolli (1948) also recorded *Bromus erectus* grasslands with shrubs in the upper Tiber Valley. In this study, such a vegetation was not found, although grass cover increases from garigue to garigue with shrubs, with *Bromus erectus* playing the main structural role.

The vegetation of groups III and IV is characterised by the dominance of evergreen woody species and an almost complete lack of deciduous species. This contrasts with other *Quercus ilex* woods of the Sienese hills, which have a mixture of evergreen and deciduous species (De Dominicis 1973; De Dominicis & Casini 1979). The true *Quercus ilex* woods, consist almost exclusively of species of *Quercetalia ilicis* finds, in Tuscany, its optimum only near the coast (Pignatti & Pignatti 1968, De Dominicis & Barluzzi 1983). The closed maquis of group III is similar to the evergreen maquis and woods described by several authors along the southern coast of Tuscany (Pignatti & Pignatti 1968; Arrigoni et al. 1985;

De Dominicis *et al.* 1988) and in particular by Marchiori & Tornadore Marchiori (1977) in the ultramafic hills near Livorno. As observed by the latter authors, this vegetation belongs to *Viburno-Quercetum ilicis* (Br.-Bl. 1936) Rivas-Martinez 1974 subass. *ericetosum* Mol. 1936. Evergreen woods, with structure determined by frequent cutting and a near absence of deciduous species, typically belong to this *syntaxon* (Molinier 1937, Braun-Blanquet 1952).

Since it was well differentiated by *Fraxinus ornus* and *Tamus communis*, with respect to the previous group, group IV can be ascribed to *Viburno-Quercetum ilicis* (Br.-Bl. 1936) Rivas-Martinez 1974 subass. *ornetosum* Allier & Lacoste 1980. Similarities also exist with the *Orno-Quercetum ilicis* Horvatić (1956) 1958 but, because of its floristic resemblance with group III, the subassociation rank is preferable. Another differential species, abundant in this group, is *Quercus pubescens* which in Mediterranean environments is favoured with respect to *Q. ilex* in sites with deeper and moister soils. Comparison of these *Q. ilex* woods with those studied by De Dominicis (1973) evidences lower percentage of hemicryptophytes and higher percentage of woody species.

The following successional pathway may be inferred from the present data and in agreement with Pichi Sermolli (1948): the *Armerio-Alysetum bertolonii* garigues are stable communities in sites with high soil erosion, but represent the last degradation stage on flat substrates that could host more developed soil. The colonisation of *Erica scoparia*, *E. arborea*, *Phillyrea latifolia*, *Arbutus unedo*, *Quercus ilex* and especially *Juniperus oxycedrus* ssp. *oxycedrus*, allows the passage to a transitional shrubby garigue. The importance of *Erica arborea* in the structure of low maquis was also noted by Allier & Lacoste (1981) in calcifuge series in Corsica. On the present substrates, however, it seems much less important than *Juniperus oxycedrus* ssp. *oxycedrus*. Garigue with shrubs can evolve into a closed maquis in which *Arbutus unedo* has an important role, as observed by Pignatti & Pignatti (1968) and Allier & Lacoste (1981) in the dynamics of calcifuge evergreen woods on other substrates. When cut the forteto regenerates, if burned it degenerates into garigue and if left to develop it evolves into *Quercus ilex* woodland in which deciduous species such as *Q. pubescens* and *Fraxinus ornus* become established. According to Allier & Lacoste (1980), these woods, belonging to *Viburno-Quercetum ilicis ornetosum*, represent a stage very close to the climax in Mediterranean France. The *Quercus ilex* woodland can return to forteto with cutting, but only regresses to garigue with heavy burning (Pignatti & Pignatti 1968).

It remains to be determined whether this successional model is really that occurring in nature, and on what time-scale it develops, or, as observed by Carter *et al.* (1987) for the Keen of Hamar serpentine (Scotland), if the complete erosion of some areas impedes vegetation evolution. For this purpose, permanent plots were established for long term studies aiming at precise measure in vegetation variations and determining the relationship of these changes to soil evolution.

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SAŽETAK

SUKCESIJA MEDITERANSKE SERPENTINSKE VEGETACIJE U SREDIŠNJOJ ITALIJI

Alessandro Chiarucci

(Odjel za biologiju okoliša, Sveučilište u Sieni)

Opisuju se glavni tipovi vegetacije na serpentinitima mediteranskog dijela središnje Italije i prikazuje se njihova sukcesija. Utvrđena su četiri vegetacijska stadija:

- a) endemičan garig na izrazito stjenovitoj podlozi, koji pripada zajednici *Armerio-Alysetum bertolonii*;
- b) garig sličan prethodnom, ali sa rijetkim vazdazelenim mediteranskim grmljem;
- c) vazdazelena makija mediteranskog tipa, koja pripada zajednici *Viburno-Quercetum ilicis* subass. *ericetosum*;
- d) vazdazelena šuma sa nešto listopadnih elemenata, koja pripada zajednici *Viburno-Quercetum ilicis* subass. *ornetosum*.

Pionirski stadiji vegetacije okarakterizirani su sa nekoliko enemičnih serpentinfita, prilagođenih na osebuje uvjete života na plitkim serpentinskim tlima. Suprotno tome, razvijeniji vegetacijski stadiji tipični su za mediteransko područje i ne pokazuju nikakva serpentinska obilježja.

Dr. Alessandro Chiarucci
Dipartimento di Biologia Ambientale
Università di Siena
Via P.A. Mattioli 4
I - 53100 Siena (Italy)