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Life forms, life strategies and ecological indices of bryophytes for bioindication in wood areas: a case of study in the "Bosco della Ficuzza, Rocca Busambra, Bosco del Cappelliere e Gorgo del Drago" Oriented Nature Reserve (West Sicily)

Abstract

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Life forms, life strategies and ecological indices of bryophytes which live in evergreen and deciduous *Quercus* woods as well as in a *Pinus halepensis* artificial system within the "Bosco della Ficuzza, Rocca Busambra, Bosco del Cappelliere e Gorgo del Drago" Oriented Nature Reserve are analysed and compared. The study highlights that in the same local climatic conditions the *Quercus* and *Pinus* trees select different bio-ecological types in the bryophyte communities. They appear to be especially useful to detect physionomic-structural differences in the woods, integrating the information provided by the ecological indices.

Key words: Bryophytes, life forms, life strategies, bioindication, Sicilian woods.

Introduction

As bryophyte life forms and life strategies make it possible to bring together unrelated taxa on base of adaptive traits, they are known as functional types which provide better information of habitat conditions than species composition (Gimingham & Birse 1957). For this reason they have been studied by several authors in very different environments ranging from polar to tropical ones, to high-altitude (alpine and Mediterranean) habitats, to deserts (e.g. Longton 1988; Nakatsubo 1994; Frey & Kürschner 1991a, 1991b; Kürschner 1999; Kürschner & al. 1999; Puglisi & al. 2013a, 2013b, 2014).

In this work life forms, life strategies and ecological indices of bryophytes which live in evergreen and deciduous *Quercus* woods as well as in a artificial arboreal system within the "Bosco della Ficuzza, Rocca Busambra, Bosco del Cappelliere e Gorgo del Drago" Oriented Nature Reserve were analysed and compared. We wanted to evaluate the effects of the change in dominant tree species on adaptive ecological characters of bryophytes within the same forest area. The aim was to understand if at similar altitudes and in the

same local climate conditions, bio-ecological types can provide further specific information, other than that of ecological indices, which express the climate and substrate requirements of taxa in their distribution range. Namely we wondered if life forms and life strategies, since their selection in a community mostly depends on the microenvironment types, can provide indication on physionomic-structural conditions of woods.

The Study area

The nature reserve "Bosco della Ficuzza, Rocca Busambra, Bosco del Cappelliere e Gorgo del Drago ", located in western Sicily, covers a total area of 7,397.49 hectares. After the great regional parks, it is the largest protected area of the island.

Morphology and hydrography of the area are significantly influenced by the presence of the great limestone massif of Rocca Busambra. In fact, it is the natural watershed of three important river basins of western Sicily: Belice Sinistro, San Leonardo and Eleuterio.

The reserve is part of the Apennine-Maghrebian chain and the geomorphological landscape is quite varied, including limestone formations, but also shales, clays, marls and quartzarenites (Gianguzzi & La Mantia 2004).

With reference to the climate the area is characterized by the following termotypes and ombrotypes: mesomediterranean (T = 13-16 ° C) with upper dry (P = 450-600 mm), lower sub-humid (P = 600-800 mm) or upper sub-humid (P = 800-1000 mm) ombrotypes; supramediterranean (T = 8-13 ° C) with upper sub-humid (P = 800-1000 mm) or lower wet (P => 1000 mm) ombrotypes (Gianguzzi & al. 2004).

Inside the reserve, different aspects of forest vegetation occur. The north side of the Rocca Busambra hosts: *Quercus ilex* L., *Q. suber* L., *Q. virgiliana* (Ten.) Ten., *Q. leptobalanos* Guss. and also the endemic *Q. cerris* var. *gussonei* Borzì woods.

Afforestation measures introduced mainly *Fraxinus angustifolia* Vahl., *Eucalyptus globulus* Labill., *Pinus halepensis* Mill. and *Castanea sativa* Mill.

The area is almost entirely subject to grazing activities.

Material and methods

The study focused on three different forest communities located in four sites in the Reserve. In particular, the surveys were conducted in two *Quercus ilex* woods, at Cima Cucco and Pizzo Nero, two *Q. leptobalanos* woods at Cima Cucco and Casa del Fanuso and at last in an artificial arboreal system with *Pinus halepensis* at Piano della Tramontana, on the northern slope of Rocca Busambra (Fig. 1).

The sites chosen are all located between 900 and 1100 m a.s.l. and have mesomediterranean upper sub-humid climate. The lithologic substrate ranges from Numidian Flysch of Casa del Fanuso to limestone-dolomite substrates of the other sites.

At each site the bryophyte flora was studied in three sample areas of about 150 m^2, away from forest edges, paths and water bodies.

For bioindication indices we referred to Hill & al. (2007), as regards the light, temperature, water, pH of the substrate and its content of nitrogenous salts. For each site, the mean

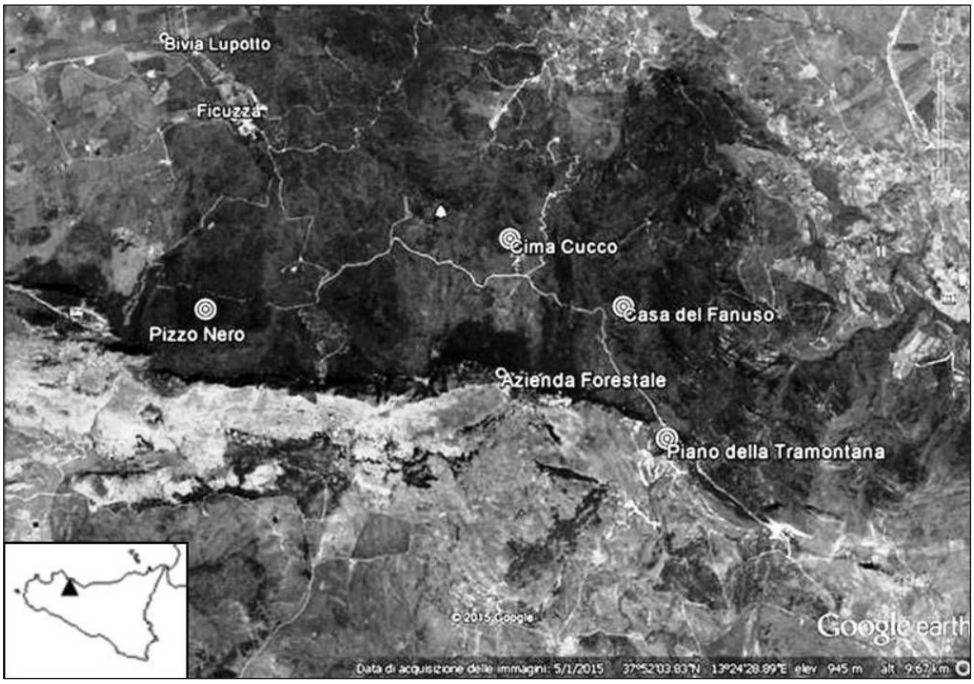

Fig. 1. Localization of the study sites.

values of indices ofthese five major ecological factors were calculated to draw radar diagram. Also life forms data have been drawn by Hill & al. (2007), while life strategies data (*sensu* During 1979, 1992) are those reported by Dierßen (2001).

In order to carry out synthesis evaluations life forms, short turf and tall turf were joined in the main category Turf, while "Mats, rough" and "Mats, smooth" have been grouped together in the category Mats.

Similarly, with reference to the life strategies, colonists and pioneer colonists were gathered in the category Colonists (C) and perennials, perennials competitive, stress-tolerant perennials and long lived shuttel were joined in the category Perennials (P).

The nomenclature of bryophytes, reported in Appendix 1, follows Ros & al. (2007) and Ros & al. (2013), while that of tracheophytes follows Giardina & al. (2007).

Results

Altogether 58 taxa were found (10 liverworts and 48 mosses) in the five studied sites (Table.1).

Bryophyte flora shows diverse consistence and taxa composition in different sites. The oak wood of Pizzo Nero has the richest flora (31 taxa), while the deciduous oak wood of Cima Cucco is among the studied sites one that has the lowest number of species (16). The number of taxa present in the artificial pinewood is rather high (20).

Table 1. List of taxa collected in the study sites.

	Dominant tree species				
	Pinus halepensis	***Quercus ilex***	***Quercus ilex***	***Qercus leptobalanos***	***Qercus leptobalanos***
	Locality				
Taxa	**Piano della Tramontana**	**Cima Cucco**	**Pizzo Nero**	**Cima Cucco**	**Casa del Fanuso**
Musci					
Aloina ambigua (Bruch & Schimp.) Limpr.	+				
Barbula unguiculata Hedw.	+				
Bartramia pomiformis Hedw.			+		
Brachythecium rutabulum (Hedw.) Schimp.	+	+		+	
Bryum dichotomum Hedw.	+				
Dicranella howei Renauld & Cardot	+		+		
Didymodon insulanus (De Not.) M.O.Hill					+
Didymodon luridus Hornsch.			+		
Didymodon sinuosus (Mitt.) Delogne			+		
Didymodon tophaceus (Brid.) Lisa	+				
Encalypta ciliata Hedw.			+		
Encalypta streptocarpa Hedw.		+			
Eurhynchium striatum (Hedw.) Schimp.		+			
Fissidens taxifolius Hedw.			+	+	
Fissidens viridulus var. *incurvus* (Starke *ex* Röhl.) Waldh.	+				
Grimmia lisae De Not.	+				+
Habrodon perpusillus (De Not.) LIndb.		+	+	+	
Homalothecium sericeum (Hedw.) Schimp.		+		+	+
Hypnum andoi A.J.E.Sm.		+			
Hypnum cupressiforme var. *lacunosum* Brid.	+	+	+	+	+
Hypnum cupressiforme Hedw.		+			
Hypnum cupressiforme var. *filiforme* Brid.				+	
Isothecium alopecuroides (Lam. *ex* Dubois) Isov.			+		
Leptodon smithii (Hedw.) F.Weber & D.Mohr		+	+	+	+
Leucodon sciuroides (Hedw.) Schwägr.	+	+	+	+	+
Nogopterium gracile (Hedw.) Crosby & W.R.Buck		+		+	
Orthotrichum affine Schrad. *ex* Brid.	+	+	+	+	+
Orthotrichum diaphanum Schrad. *ex* Brid.	+		+		
Orthotrichum lyellii Hook. & Taylor	+	+	+	+	+
Orthotrichum striatum Hedw.	+				
Orthotrichum tenellum Bruch *ex* Brid.	+				
Oxyrrhynchium praelongum (Hedw.) Warnst.			+		
Polytrichum juniperinum Hedw.			+		+
Pterigynandrum filiforme Hedw.		+	+		
Ptichostomum capillare (Hedw.) Holyoak & N. Pedersen	+	+	+	+	+
Racomitrium aciculare (Hedw.) Brid.			+		
Rhizomnium punctatum (Hedw.) T.J.Kop.					+
Rhynchostegiella litorea (De Not.) Limpr.	+				
Rhynchostegiella tenella (Dicks.) Limpr.			+		
Rhynchostegiella teneriffae Dirkse & Bouman				+	

Table 1. continued.

Syntrichia laevipila Brid.	+	+	+	+	+
Syntrichia ruralis (Hedw.) F.Weber & D.Mohr		+			
Syntrichia virescens (De Not.) Ochyra	+				
Thamnobryum alopecurum (Hedw.) Gangulee		+	+		
Tortella nitida (Lindb.) Broth.			+		
Tortella squarrosa (Brid.) Limpr.		+			
Tortula inermis (Brid.) Mont.	+				
Zygodon rupestris Schimp. *ex* Lorentz		+	+	+	
Hepaticae					
Fossombronia angulosa (Dicks.) Raddi					+
Frullania dilatata (L.) Dumort.		+	+		
Lejeunea cavifolia (Ehrh.) Lindb.					+
Lophocolea heterophylla (Schrad.) Dumort.					+
Metzgeria furcata (L.) Dumort.					+
Porella obtusata (Taylor) Trevis.			+		
Radula complanata (L.) Dumort.			+		
Reboulia hemisphaerica (L.) Raddi					+
Scapania compacta (A. Roth) Dumort.			+		

No liverwort was found in deciduous oak woods at Cima Cucco as well as in the pinewood.

High diversification was observed between the five floras, as it is shown in the dendrogram of Fig. 2. The highest similarity is found between the floras of *Quercus ilex* and *Q. leptobalanos* woods at Cima Cucco. The distance factor in this case seems to have a greater incidence than the dominant tree species on the floristic diversity. The similarity between these two floras, however, does not reach 50%. The oak forest of Pizzo Nero is then linked to this cluster with a similarity of 30.1%.

The flora that differs most is that of artificial pine forest that though having a high species number, no less than that of almost all other sites, shows a similarity of only 23.4% compared to the whole group of oaks.

In the graph of Fig. 3, which takes into account the main life forms, the categories that have the highest incidences are Turfs and Mats both in the areas dominated by native oaks and in the pinewood. However, significant differences are observed between the areas. The life form Mats, that usually prevails in sites rather humid and with good lighting (Kürschner 2004), has a stronger presence at Cima Cucco especially in deciduous but also in evergreen oak woods. The Turf which together with the Cushions dominate in dry areas have significantly higher relative abundance in the pinewood.

Dendroid species, which live in sites with high moisture levels (Gimingham & Birse 1957), and that, as well as the weft, are very sciaphilous, are little represented in the studied woods. Similar results are observed by analyzing the incidences of life forms on different substrates, as shown in Fig. 4. In fact the Mats are always prevalent on bark, rock and soil in oak woods, while in pinewood the Cushions (followed by turfs) prevail on the bark, the turfs are the most abundant on other two substrates.

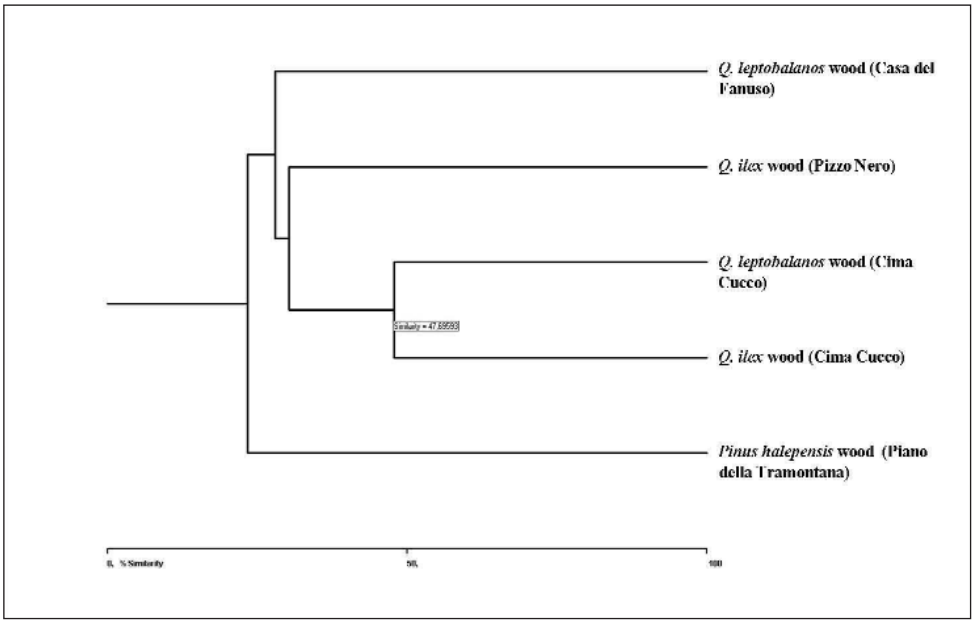

Fig. 2. Similarity and classification of floras of study sites.

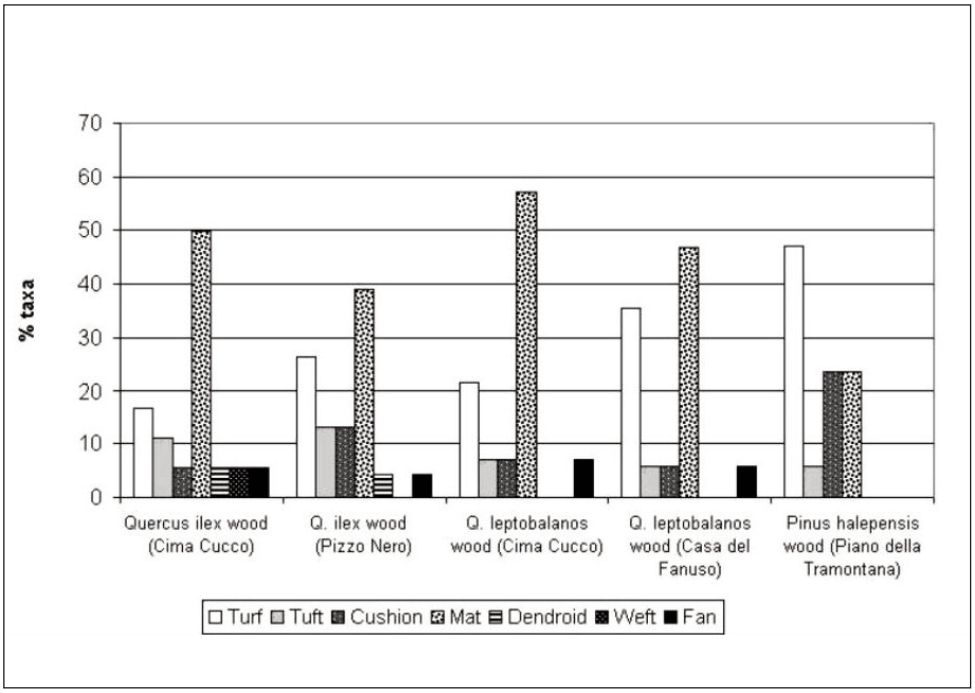

Fig. 3. Percentage incidence of life forms.

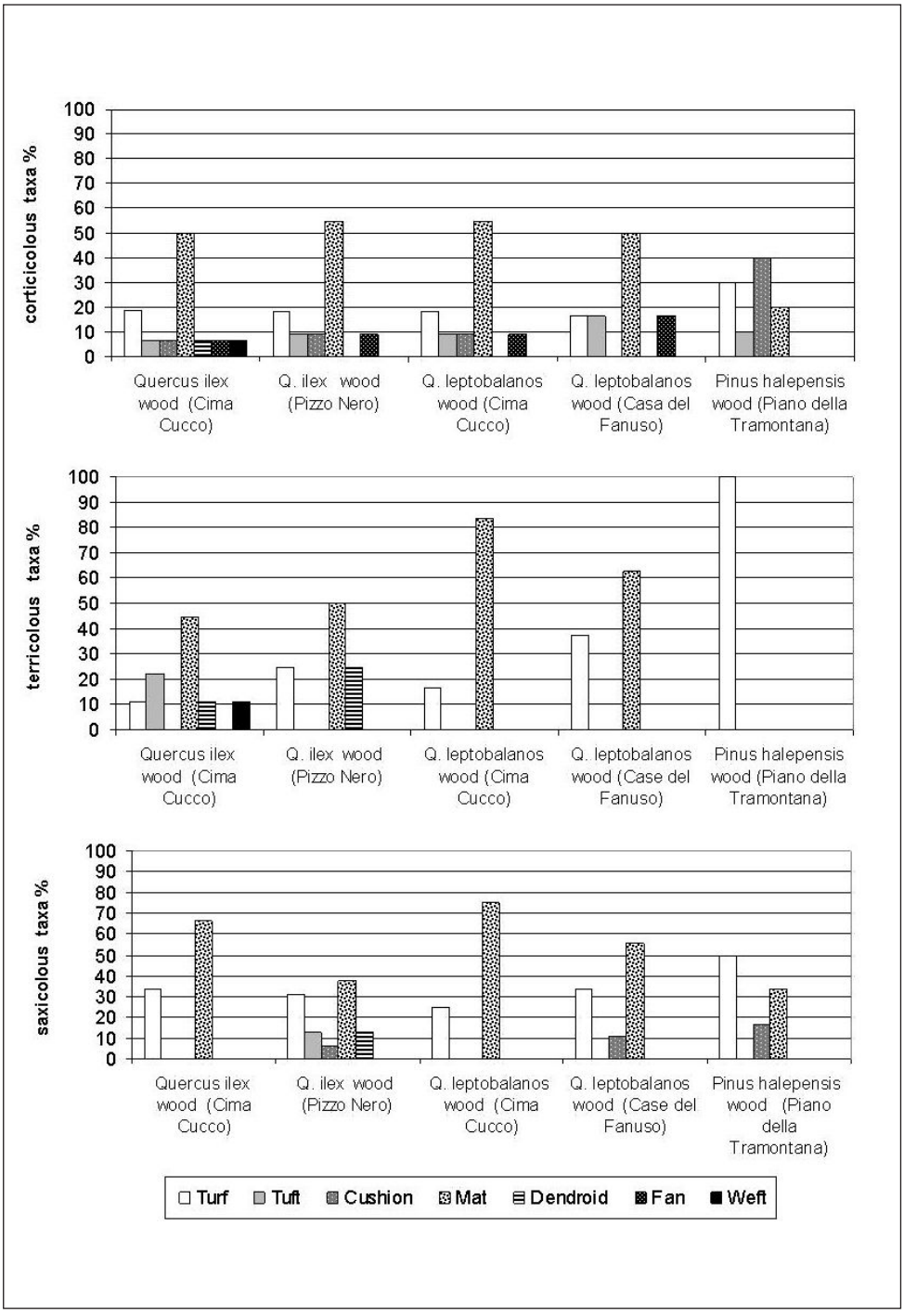

Fig. 4. Percentage incidence of life forms on bark, soil and rock.

With regard to life strategies, in the graph of Fig. 5 in which all colonizing species were joined between them and likewise all the perennial species, it is observed that the Perennials have a higher percentage than the Colonists in all four oak woods while the Colonists are the most represented in the pine forest reaching 75%.

The same result is obtained by taking into account the flora on different substrates, as shown in Fig. 6. The Colonists, in fact, are always dominant in the pinewood, on the trunks of trees, on the ground and on boulders and this character contrasts with the condition of the oak wood floras where Perennial species are always prevalent in all substrates.

Although, as was noted above, the bryophyte floras show a low floristic similarity (always less than 50%) in the different sites, the diagram constructed on the basis of the average values of the indexes of bioindication not show a significant ecological differentiation (Fig . 7). In fact, all floras have a mesophotophilous, mesoterm, mesophilous, rather oligotrophic and almost neutrophilous connotation.

The only differences concern the pinewood and deciduous oak woods of the Casa del Fanuso. In the first, bryophytes show a slightly greater nitrophily, in the second they indicate a weakly acidophilic condition of the substrates and an environment a bit cooler.

Discussion and conclusions

The study shows that within the same protected area in about the same altitudinal and climatic conditions, but in different types of forest vegetation, diverse bryophyte floras with different incidence of bio-ecological types are selected.

Among the analyses conducted, the one based on indices of bioindication provides a

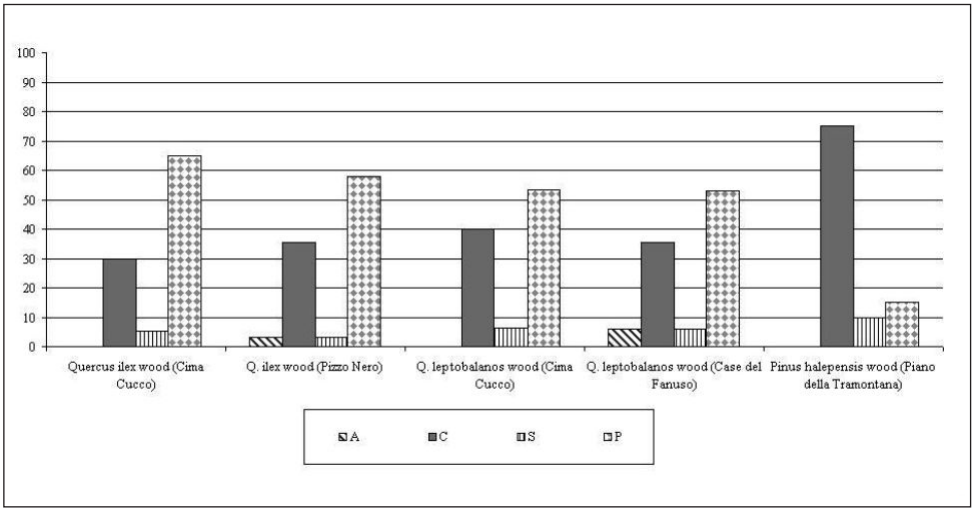

Fig. 5. Percentage incidence of life strategies.
A: annuals; C: colonists and pioneer colonists; S: short-lived species; P: perennials, perennials competitive, stress-tolerant perennials and long lived shuttle.

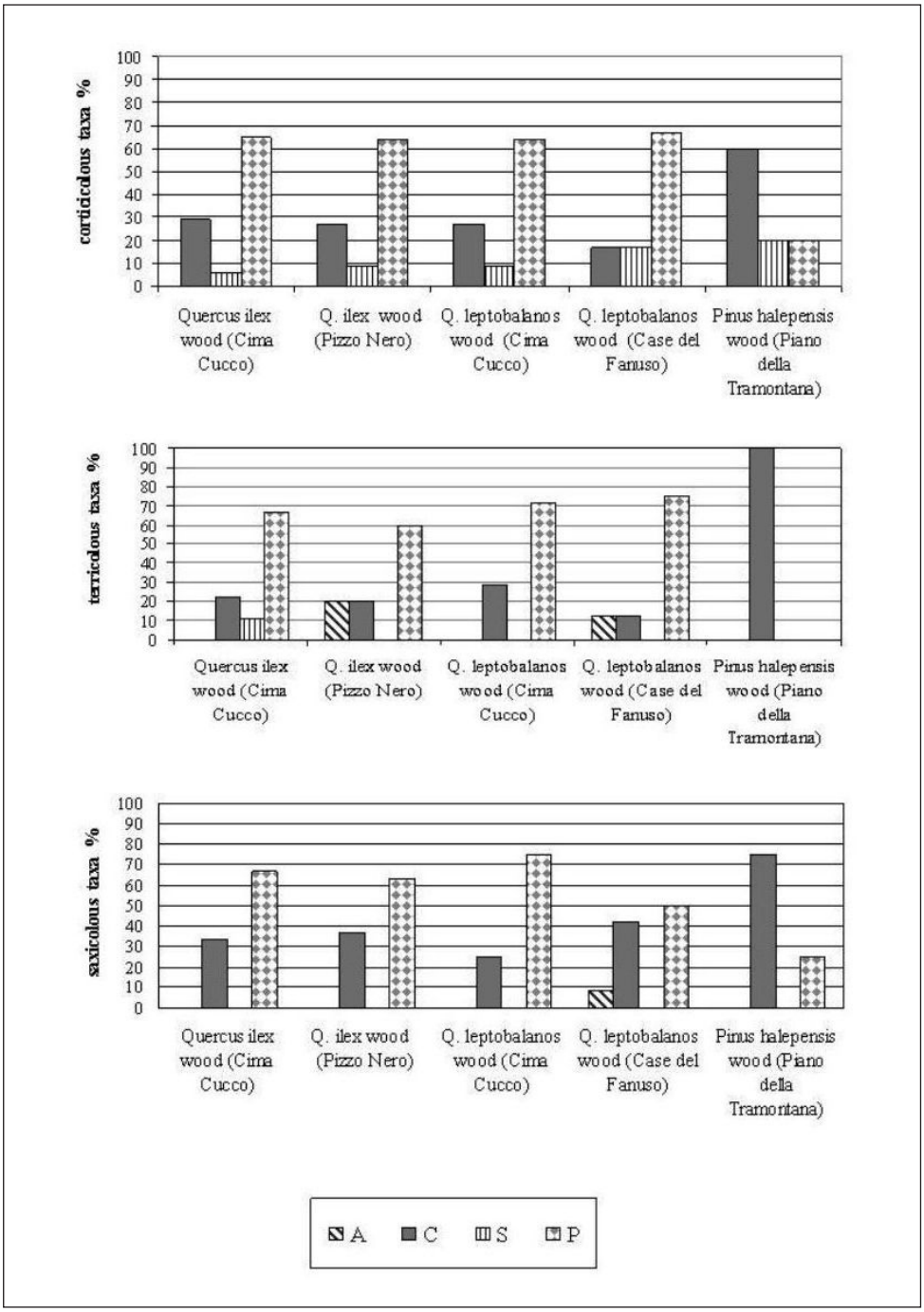

Fig. 6. Percentage incidence of life strategies on bark, soil and rock (Abbreviations for life strategies are given in the caption of Fig. 5).

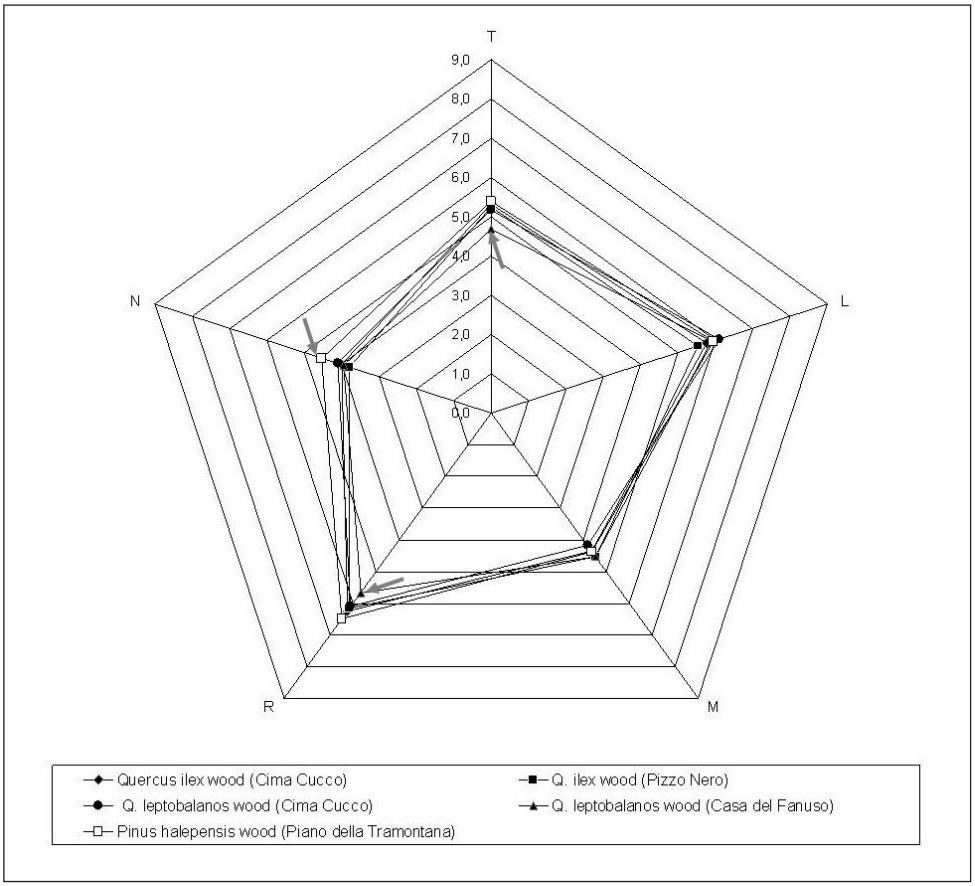

Fig. 7. Radar diagram based on the average values of bioindication indices at the study sites.

profile ecologically quite uniform of these floras. The only detected differences concern the pinewood and deciduous oak woods of Casa del Fanuso. The slightly higher nitrophily of the flora in the former can be explained in greater frequentation of animals, as the area is adjacent to an intensively grazed grassland. The slightly greater acidophily of Casa del Fanuso flora can be related to a different lithological nature of the site.

The analysis of the life forms and life strategies highlighted more sharply the difference between the wooded areas dominated by native tree species and artificial system. In the latter bryophyte flora is highly modified and the distribution of the life forms and life strategies highlights in all substrates the presence of poorly developed communities constituted by colonies which have the growth form best suited to drought conditions and lighting rather high. The eco-physiological character of the pines, remarkably heliophilous, results in a low density of trees and hence an open cover; this enhances the stressful conditions of habitat corticicolous and saxicolous. Furthermore, the accumulation of needles to the soil determines the maintenance of

rather bare soils. These conditions together with the attendance of grazing animals make the pinewood habitat unsuitable for perennial species.

In conclusion, the present study further confirms the validity of the indexes of bioindication to characterize the environment with reference to the main ecological factors, but stresses especially the importance of bio-ecological types for acquiring useful information to understand the overall environment status. This study, in fact, suggests that these types, depending on microenvironment conditions on the different growth substrates, are able to point to the physionomic-structural differences of the woods. It does not seem, however, that they can highlight the seasonal variations that characterize deciduous than in evergreen forests.

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