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The Mediterranean Ecosystem

Abstract

Pignatti, S.: The Mediterranean Ecosystem. — *Bocconea* 16(1): 29-40. 2003. — ISSN 1120-4060.

Definition of the Mediterranean ecosystem based on climate, characterized by an arid period in summer. Main composition of the flora and relationships with the flora of the region with Mediterranean type vegetation in W.Australia. Adaptations to fire. Man – Vegetation relationships: Man as a factor of evolution – Vegetation as food reserve. Coevolution. Weeds of Mediterranean origin invading other continents.

Introduction

The Mediterranean ecosystem can be defined mainly on the basis of climate. It is a warm-temperate climate with annual average temperatures of 14-18 °C and generally without monthly averages below zero throughout the year; rainfall is in general between 400-1200 mm or more, but always with summer drought. In this sense plants are exposed to a period of severe stress during the warm months, lasting for (2)3-5 months. An important environmental factor under these conditions is the high frequency of fire: vegetation often presents the particular adaptations which are typical in fire prone ecosystems. Such environmental conditions occur in five different regions of the world (Di Castri & Mooney 1973): in the true Mediterranean region, in southern California, central Chile, the Cape Province in South Africa and the temperate portions of Western and South Australia. The aim of this lecture is to emphasize the particular character of the Mediterranean ecosystem, in comparison with the conditions of the other Mediterranean type ecosystems.

Five Mediterranean type ecosystems

In general the floras of the regions with Mediterranean climate can be considered as very rich ones, indeed a comparison only on the numerical basis in this moment is not possible. In fact, the limits of these regions are not unambiguous and the total number of species results much different if geographical or political boundaries are considered. A further problem is that much of the biodiversity is concentrated in the mountains, which from the eco-

logical point of view not always can be considered as belonging to the true Mediterranean region. In addition the surfaces of the different areas are extremely different: from about 50.000 km² in Chile to 70.000 in South Africa, to more than 1,000.000 in W.Australia (here boundaries are very questionable) and possibly 5,000.000 for the true Mediterranean, including the inland sea. The totals of the floras can be estimated as follows:

- Central Chile	3.000
- S. California	4.000
- Cape Province	7.000
- SW. Australia	9.000
- Mediterranean	20.000

The endemic component is completely different in the five regions: about 20-30% in Chile, California and the Mediterranean and a very high figure (up to 85%) in the other areas. Despite of the above mentioned difficulties we try to give some data dealing with the South-Western portion of W.Australia (Green 1985) and the Mediterranean basin, the two regions which seem more comparable as to species number and surface. The species in common are very few and probably all introduced by man. Several genera are in common such as: *Clematis*, *Ranunculus*, *Hydrocotyle*, *Limonium*, *Samolus*, *Juncus*, *Scirpus*, *Carex*, *Schoenus*, *Triglochin* and a few others; most of these examples belong to aquatic groups with world-wide distribution. A comparison of the families shows that a large number of them exists only in Australia (*Biblydaceae*, *Brunoniaceae*, *Cephalotaceae*, *Gyrostemonaceae*, *Tremandraceae*, *Xanthorrhoeaceae*) or are centered in Australia with few species in surrounding areas (*Centrolepidaceae*, *Dilleniaceae*, *Droseraceae*, *Goodeniaceae*, *Myrtaceae-Leptospermoideae*, *Stylidiaceae*) or have gondwanan (Australia – S. Africa) distribution (*Proteaceae*, *Restionaceae*). No representatives of these families occur in the flora of the Mediterranean basin.

On the contrary the only example of a family occurring in the Mediterranean and lacking in SW Australia, at least among the typical representatives of the Mediterranean flora are the *Cistaceae*.

Some particular cases:

- *Epacridaceae* / *Ericaceae* — traditionally considered two closely related but clearly distinct families: *Epacridaceae* only in Australia, *Ericaceae* in the other continents (one species in Australia); in some recent treatments *Epacridaceae* are included in *Ericaceae*.
- *Myrtaceae* — widely distributed in the tropical and subtropical belt, in the Mediterranean area only 1 species (*Myrtus communis*); the tribe *Leptospermoideae* mainly in Australia with large genera (*Eucalyptus*, *Melaleuca*, *Calothamnus*, *Darwinia* etc., over 1000 species), and some representatives in Polinesia, SE-Asia, South Africa and South America.
- *Proteaceae* — Most genera are endemic in Australia, a minor group in South Africa; few species in equatorial Africa and South America.

Groups with a very high number of species in the SW-Australian flora are *Proteaceae* (750 species), *Acacia* (420), *Myrtaceae* (1000); in the Mediterranean flora *Caryophyllaceae*, *Ranunculaceae*, *Boraginaceae* and *Brassicaceae* range between 800-

2200 species. A difficulty of such comparisons can be explained with the example of *Droseraceae*: there are 47 species occurring in the region of SW-Australia with Mediterranean climate; in the Mediterranean basin only 3 species of *Drosera* occur, but they are not living in the Mediterranean vegetation and can be hardly considered as Mediterranean species. The Mediterranean flora has many families and genera in common with the Californian one and on the other side the southwestern Australian flora is strongly related to the South African flora (gondwanan element). Central Chile has scarce floristic affinities with the other Mediterranean type ecosystems; its flora is related to the neotropical flora and has very little in common with the northern or to the gondwanan flora.

Summarizing, the flora of the Mediterranean region consists in a high number of species, but the frequency of endemics is lower than in Western Australia. This seems to be the consequence of the different biogeographical history of both regions. The flora of Australia has had a very long period (44 million years) under more or less isolated conditions as an island continent. Many plant families important in the present Australian vegetation have derived from ancestral members of the gondwanan flora which occurred in the ancient southern landmass (Gondwana) prior to the Tertiary. They are presently surviving in Australia and in the Cape Province and some of them occur in the southern portion of South America. Many of these ancestral groups were never present in the equivalent northern super-continent of Eurasia. In contrast the Mediterranean area has been in contact with the much more extensive landmass of the northern hemisphere and has been influenced by climatic changes and species migrations which were part of the history of the more connected northern landmass (Pignatti 1978). The Mediterranean region was open to exchange biota with the far east, the north of Africa and most of Europe. In late Tertiary there have been periods of rapid changes by vulcanism, orogenesis, the drying up during the Messinian and dramatic climatic changes. The glacial periods of the Quaternary greatly influenced the region exposing a large part of the sea floor and the more southern areas providing refuge for the forest floras forced south from the areas covered by glaciers. The vulcanism and orogeny produced geographical relief which increased habitat diversity. These geological forces also produced relatively young, nutrient rich soils which contrast with the old nutrient-depleted Australian soils.

Mediterranean vegetation

The most representative vegetation in the Mediterranean basin is the evergreen broadleaved forest, dominated by a dozen of tall shrubs or trees with moderately sclerified leaves; the colour of this vegetation, observed from some distance, is deep green and for this reason the common name is *macchia* (ital.) or *maquis* (french), meaning "spot" (Rikli 1943). The names in Spanish: *chaparral* or *matorral* have a different origin. The dominant species is mostly an evergreen oak: *Quercus ilex*, locally substituted by *Q. rotundifolia*, *Q. coccifera*, *Q. calliprinus* or *Q. suber*. *Maquis* vegetation in mature condition is a dense evergreen forest but occurs frequently as a high shrub formation (2-5 m and up to 9 m). Intermingled with the *maquis* are small areas of open vegetation with subshrubs (*chamae-*

phytes, 20-50 cm) or perennial and annual herbs. This vegetation, which is mostly the consequence of fire, is locally called garriga (spanish) or garrigue (french).

The maquis vegetation is generally dominated by a single species, mostly an evergreen oak; the shrub layer is composed of several species while the herb layer is only sparsely developed. Some climbers are also present. In general this vegetation can be considered as a climax but remains with low diversity (at maximum 20-25 species on plots of 100-500 m²). In the evergreen forests of W. Australia, on the contrary, the upper canopy is composed of many species of *Eucalyptus* and a few *Banksia*. A sharp distinction can be observed between climax vegetation (*Quercetea ilicis*) and secondary vegetation after frequent fires (*Cisto-Lavanduletea*; *Tuberarietea*). The latter vegetation is mostly composed of annuals and may be very rich in species (30-40 species in 10 m², in some cases even up to 100 species on 100 m²).

Life forms

The main character of the Mediterranean flora, was indicated by Raunkiaer (1934) with his analysis of life forms: in the tropical flora it is a prevalence of phanerophytes, in the temperate and cool climates hemicryptophytes are prevailing and in the arid interzone (the Mediterranean included) a large number of therophytes occur. In fact the analysis of therophytes frequency (data from Pignatti 1982) in the regions of Italy (Fig. 1) shows a clear concentration of this life form in the Mediterranean area. Therophytes are 22-24% in the temperate part of Northern Italy and in the Alps. This number increases to 26-29% in the mountain part of the peninsula, to 30-34% along the Tyrrhenian coast which has a marked Mediterranean character and reaches 37-39% in the Mediterranean regions (Sardinia, Sicily and Puglia). In the Mediterranean type vegetation of W.Australia, native therophytes are rare (Table 1, data from Pate & Beard 1984). Indeed, this appears a more complicate problem: in the Mediterranean vegetation (Table 2) therophytes are concentrated in the fire

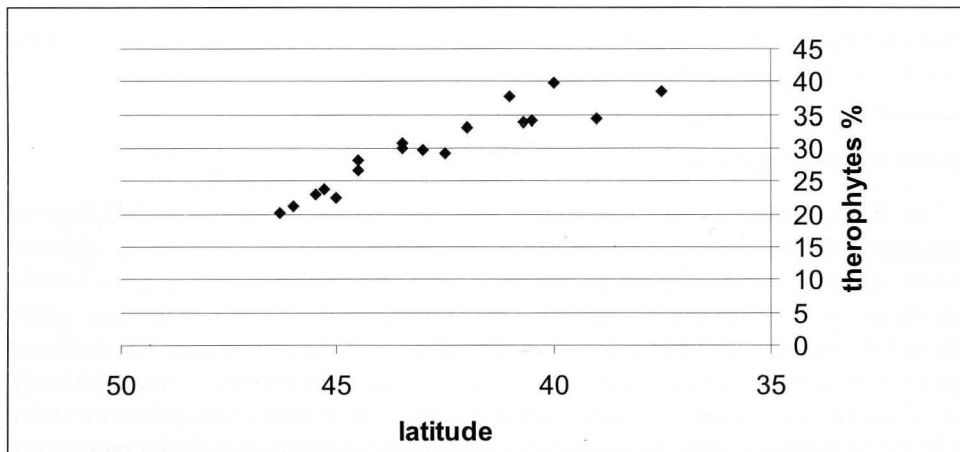


Fig. 1. Increase in the percentage of therophytes at lower latitudes in Italy.

prone associations of the garrigue (up to 97 % in the *Tuberarietum*) and almost lacking in the climax forest (*Quercetum ilicis* 3 %). Consequently, also the presence of therophytes cannot be considered as a useful approach for a quantitative comparison among the floras of the different regions.

Table 1. Percentages of therophytes in the regions of Italy.

Friuli-Vg.	21,1
Veneto	20,1
Trentino	23,9
Lombardia	23,1
Piemonte	22,4
Liguria	26,7
Emilia-Romagna	28,3
Toscana	30,7
Marche	30
Umbria	29,7
Lazio	33,1
Abruzzo	29,2
Molise	30,5
Campania	33,9
Puglia	37,8
Basilicata	34,1
Calabria	34,3
Sicilia	38,5
Sardegna	39,9

Table 2. Percentages of therophytes in the mediterranean type ecosystem of SE Australia.

<i>Eucalyptus mallee</i>	2.8%
Kwongan medit.	3.1
Kwongan subarid	3.3

Fire ecology, grazing

In the Mediterranean flora the most widespread adaptations are dealing with summer drought, burning and grazing. Summer is in general a period when life processes are quiescent. Annual species complete the life cycle in spring and during summer only seeds survive; perennials often lose their leaves in summer or, if evergreen, are strongly reducing photosynthesis. The leaf form is relatively uniform in *Quercus* sp. pl., *Arbutus unedo*, *Laurus nobilis*, *Phillyrea* sp. pl., *Myrtus communis*, *Pistacia lentiscus* (the latter with paripennate leaves). These leaves have the same anatomical structure as the leaves of most circumtropical or cool temperate evergreen trees: moderately sclerophyllous, often hairy

below and hypostomatic, corresponding to the oleoid leaf (following De Lillis 1995) and with other adaptations to reduce transpiration.

During the dry period fires are frequent. In general fires are considered a catastrophic event, but under certain conditions vegetation seems to take an advantage of fire. Burning of plant material causes acceleration of nutrient recycling (Kutiel & Naveh 1987) and for some species a direct stimulation of seed germination by heat or smoke components. In species within the Mediterranean shrub vegetation there is a large number (*Juniperus*, *Rosmarinus*, *Thymus*, *Satureja*, *Micromeria*, *Helichrysum*, *Myrtus*, *Pistacia*, *Pinus*, *Cistus monspeliensis*) containing resins, terpenes and other volatile substances which may easily assist the spread of fire. Several communities are strongly adapted to these conditions and occur regularly after fire: communities of the *Tuberarietea* and *Cisto-Lavanduletea* occur only on habitats where fires are frequent. The consequence of fire is in general to produce in vegetation a condition of statistical disorder, whereas species composition is not greatly changed, at least when fire remains a more or less sporadic event. Data from Languedoc (Trabaud & Lepart 1980), from the Tyrrhenian coast and from the submediterranean vegetation near Trieste (Feoli & al. 1981) demonstrate that immediately after fire vegetation entropy is increasing. This is a consequence of the more or less complete destruction of subaerial phytomass: competition for space and light is lower and quantitative relationships among species become more equilibrated; the situation is probabilistic and can be described as a condition of higher entropy. In the case of Trieste, observations have been continued from a fire in 1968 up to the present. During more than 30 years after fire, species composition remained more or less unchanged and the succession consisted only in the change of dominance within the community (from *Calluna vulgaris* to *Cistus salvifolius*, followed by a new expansion of *Calluna*). The process is very slow but after 30 years the pristine condition appears completely recovered.

The consequence of grazing was investigated by Naveh & Whittaker (1979). In Israel the final vegetation is characterised by a relatively low level of entropy (Fig. 2); by grazing entropy increases progressively, but when grazing pressure becomes very strong, then entropy declines again. A linear correlation between grazing pressure and entropy in vegetation does not seem to exist. In fact, a limited grazing activity is causing an increase of entropy, i.e. low values of order, and this seems a consequence of the mechanical impact on vegetation: cattle and sheep pick up plant material and produce small gaps in the herb layer, and the same is caused by the hooves; in the gaps new plants, mostly belonging to alien species, can germinate and are revealed by the increasing entropy as a factor of disorder. The dung of grazing animals is rich in nutrients, and creates new niches which can be colonised by alien species. When grazing pressure becomes stronger, on the contrary, a severe selection occurs, and only palatable species are selected; at the end only poisonous or spiny species remain and entropy value is again declining. It is difficult to consider this as an increase of order, but in fact it is, at least from a statistical point of view.

A first story: Evolution by reduction

In the Mediterranean ecosystem plant communities have a very different level of biodiversity. The climax vegetation is relatively species poor whereas a high number of species

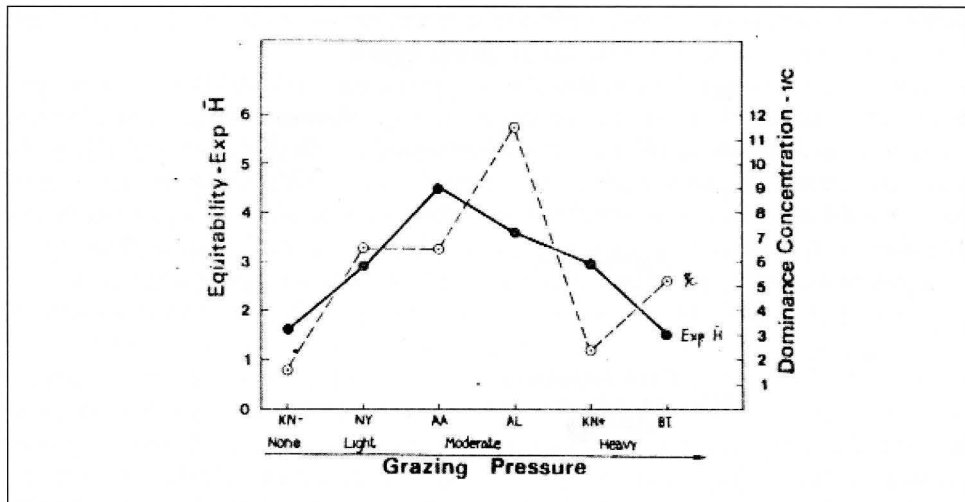


Fig. 2. Relationships between grazing pressure and (H) equitability of vegetation (data from Naveh & Whittaker 1979).

is concentrated in secondary vegetation. In southern France (Pignatti 1983, 1988, on data from Braun-Blanquet 1952) the evergreen forest has only 69 species belonging to 58 genera and the vegetation of the garrigue is five to six times richer (Table 3). The situation is not different in other Mediterranean vegetation complexes.

Table 3. Percentages of therophytes in the mediterranean vegetation (Italy).

<i>Quercetum ilicis</i>	< 3 %
<i>Cisto-Lavanduletum</i>	42
<i>Tuberarietum</i>	> 97

The model of evolution by reduction (Fig. 3) may offer an explanation for this condition as proposed by Pignatti (1979). It is based on some general features which can be observed in many polymorphic groups of the Mediterranean flora:

- some are suffrutescent (Chamaephytes with stems woody at base), other are perennial herbs and annuals;
- Chamaephytes have in general a very local distribution range and occur on natural habitats; perennial herbs have larger ranges and annuals are mostly widespread;
- the reduction of life-span is accompanied by the progressive transition from natural to semi-natural and finally to synanthropic habitats;
- the reduction of life-span is accompanied by the progressive increase in polyploidy.

Life reduction, expansion of the geographic range, invasion of synanthropic habitats and polyploidy develop more or less in parallel. It seems that evolution in this case

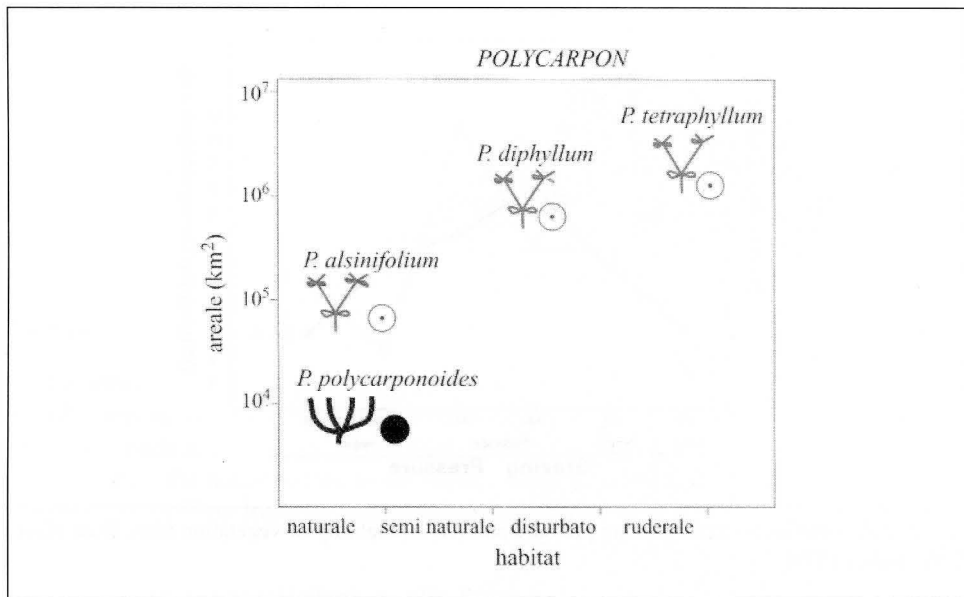


Fig. 3. Model of evolution by reduction in the Mediterranean flora (Pignatti 1999).

occurred mainly under the influence of man and implied the diffusion over large areas and invasion of new habitats created by man.

Man as an agent of evolution seems a very doubtful hypothesis, but in the Mediterranean basin man as *Homo erectus* has been present since at least one million years and the use of fire is demonstrated since at least 400.000 years. At the end of the Pliocene the warm temperate region around the Mediterranean was covered by climax-like forest vegetation (Fig. 4). An evergreen forest similar to the present time *Quercetum ilicis* (with relatively low species number) is documented by fossil records from this time. Plant biodiversity was concentrated in marginal habitats as mountain regions or coastal cliffs. The expansion of man caused a general impact on the forest vegetation: open spaces were cre-

Table 4. Floristic diversity of the Mediterranean vegetation (Pignatti 1988).

	Southern France (Braun-Blanquet, 1952)				Barcelona (Bolos, 1962)			
	genera	species	ass.		genera	species	ass.	
Evergreen forest	58	69	2		58	66	2	
Macchia	65	78	2		60	68	2	
Garriga		235	435	28		171	286	10

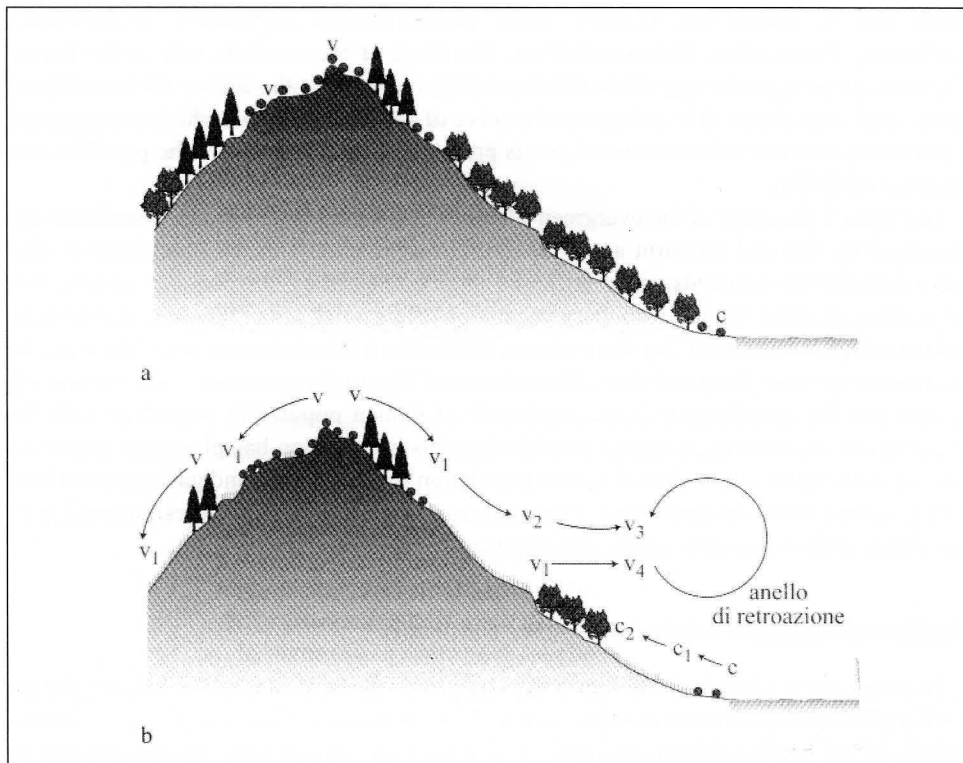


Fig. 4 – Modification of the plant cover and evolution of the flora in the Mediterranean areas. Species of marginal (v) and coastal (c) habitats invading free niches after fire (Pignatti 1999).

ated and the species of marginal habitats had the chance to expand and move into these areas. The invasion of open spaces was a powerful factor of evolution and new genotypes have been selected. In this process species with short life cycle and with adaptations to nutrient rich soils had an advantage and expanded over large geographic areas. Consequently the Mediterranean flora became enriched in Therophytes and the center of biodiversity shifted to secondary vegetation. These reflections can give an explanation for the conditions indicated above, i. e. a very elevated number of species concentrated in secondary vegetation and relatively low numbers of endemics.

The second story: Coevolution man / vegetation

A second important story of the Mediterranean ecosystem is the coevolution between plant and man. The evergreen forest offers little food to man: the fruits of *Arbutus* (only for a short time), pods of *Ceratonia*, some young shoots of *Ruscus* and *Tamus*, and a few berries. On the contrary many species of the short-cycle herbs occurring in the secondary vegetation are edible. The flora of degraded areas following repeated fires is rich in wild cereals (*Hordeum*, *Avena*, *Secale*), legumes (*Cicer*, *Lupinus*, *Vicia*, *Lathyrus*, *Pisum*) and

seeds rich in edible oils (*Linum*, many *Brassicaceae*), vegetables (*Rhagadiolus*, *Cichorium*, *Foeniculum*, *Valerianella*) etc. The flora of the semiarid belt in the Fertile Crescent, at the eastern edge of the Mediterranean region, was the source for ancestors of many cultivated plants. It is an important reserve of genomic material, which can represent a patrimony and has to be conserved, but is presently at risk, because of the possible concurrence of OGM.

In Figure 5 the cycle of the evergreen Mediterranean forest is indicated: woodlands are destroyed by fire and on burnt areas the garrigue vegetation appears; this changes after some decades into a maquis and later can be again colonized by *Quercus ilex*, and the forest is restored. After fire the secondary vegetation offers a rich nourishment to human population which is "attracted" by these places. Otherwise a denser human population can be the reason for more frequent fires. The scheme of Figure 5 represents a self-stimulating system and the consequence is the expansion of human population connected with the reduction of forest areas. It seems possible that this coevolution has played an important role, stimulating the expansion of human population first as hunters and gatherers and later with primitive forms of agriculture. The arid areas of Mesopotamia to Palestine and Egypt have been probably centers of this development.

Mediterranean plants expand over other continents

In comparison with other Mediterranean type ecosystems it can be pointed out that no similar phenomena occurred in other regions. The abundance of annual species is characteristic of the Mediterranean area and no forms of agriculture have been developed in South Africa, Western Australia or in California and Chile in former times. Consequently the Mediterranean flora after geographical discoveries had the chance to expand over other continents and occupy empty ecological spaces with synanthropic annuals. Floristic exchanges among the continents in the last centuries developed mainly in one direction. The Mediterranean is the main source exporting floristic elements: *Briza*, *Cichorium*,

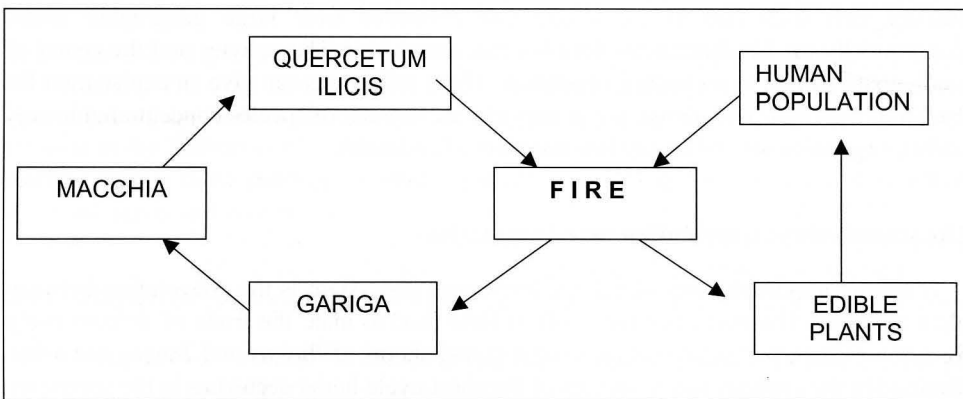


Fig. 5. The self-stimulating system connecting fire ecology and human society in the conditions of late Palaeolithic.

Cirsium, *Convolvulus*, *Echium*, *Erodium*, *Euphorbia*, *Foeniculum*, *Galium*, *Hypochoeris*, *Lamium*, *Medicago*, *Picris*, *Plantago*, *Rumex*, *Trifolium* and other Mediterranean weeds are frequently invading areas of SW.Australia, South Africa, Chile and California. On the contrary only few species from the extra-european Mediterranean type ecosystems had the possibility to migrate into the Mediterranean basin. Presently there are no weeds of SW.Australian origin in the Mediterranean. Many species expanded from North America to Europe (e.g. *Robinia*) but outside the true Mediterranean region. Some elements came from South America and from South Africa, but mostly colonizing open spaces, sea shores or waste places. Apparently the massive migration of peoples of Mediterranean origin in other continents was accompanied by similar migration of Mediterranean plants.

Conclusions

The flora of the Mediterranean basin is composed by a very high number of species, but remains clearly behind other Mediterranean type ecosystems as to frequency of endemics. These conditions are partly dependent from the different ancestral stocks for each area, and partly related to different geological and biogeographic history.

Land degradation due to clearing and overgrazing is a general problem since millennia, and destocking and reforestation appear necessary to obtain a permanent rehabilitation. In parallel, a strategy of nature conservation is urgently needed. Indeed, conservation has not to be directed only to the protection of endemics and climax-like communities. The synanthropic vegetation encompasses a large portion of the plant biodiversity, in some cases related with economically important plants, and special procedures are to be experimented for its conservation.

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