

Classifying Mediterranean Ecosystems in the Mediterranean Rim Countries and in Southwestern U.S.A.¹

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Methods of classifying ecosystems, in particular forest ecosystems, which represent the most evident vegetation structures, have developed in a very different manner in European and Anglo-saxon countries. It is of interest to compare the methods used in the countries bordering the Mediterranean Sea and in Mediterranean California. We shall not discuss again the physiognomic and climatic analogies existing between both regions (cf. Di Castri and H. Mooney 1973), and shall only try to retrace the development of the methods of classifying ecosystems in both regions.

In the circum-mediterranean area, the study of vegetation started very early, but since the beginning of the present century it has taken two clearly different directions :

- Physiognomic studies of plant communities - the global study of vegetation landscapes and of their relationships in space, following especially the works of Flahault (1897) and Gaussen (1926).

- Phytosociology - the analysis of plant associations based essentially on floristic relevés, and seeking also to define the ecological and dynamic relationships existing between the various associations, a methodology initiated by Braun-Blanquet (1932). Throughout the 20th century, both methods, originally considered as difficult to reconcile, have in fact been the basis of all attempts at classifying ecosystems, though other techniques were elaborated all over the world: ecological groupings, quantitative studies, transect methods, theoretical models.

In California, as in the whole United States, methods of classifying ecosystems have nearly always been founded on physiognomy. There has been very little change between Cooper's studies (1922) and the recent synthesis by Barbour and Major (1977); the interpretations and the vegetal communities described remain physiognomic and are mostly defied in relation to dominant species. It should be emphasized that the methods of field study, even using relevés (quadrat or linear), are extremely diverse in the United States, practically each author using his own particular method. American, especially Californian,

¹Presented at the Symposium on Dynamics and Management of Mediterranean-type Ecosystems, June 22-26, 1981, San Diego, California.

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Abstract: Methods of classifying ecosystems have developed differently in Europe and America. Individualization of bioclimatic zones and of altitudinal levels proved most valuable, particularly the role of edaphic factors. This methodology can be associated with the vegetation series concept, that is, a succession of community types which, within a given altitudinal level and bioclimatic zone, and for specific edaphic conditions, leads to establishment of the climax community. Man's impact in these theoretical schemas can be directly considered. The methodology is open to numerous applications.

phytogeographers have often engaged in sometimes quite sophisticated ecophysiological or autoecological studies, which, in spite of their obvious interest, can not be used as classification methods for ecosystems.

For some ten years, phytogeographers of the Mediterranean countries in the Old World have tried a more synthetic approach to the problems raised when defining or classifying ecosystems, together with a more practical analysis of the problems, which could easily help in ecological planning or management. Purely physiognomic methods allow us to apprehend but a small part of the ecological facts, and still, in a very artificial manner. In Morocco, for example, the ecosystem "sclerophyllous forest with *Quercus rotundifolia*" that corresponds to an homogeneous physiognomic unit can be found between 500 and 3000 m altitude, under annual precipitation varying between 500 and 2000 mm and with mean temperatures ranging between 5 and 17° C. In this case, a classical phytosociological approach provides valuable complementary information by distinguishing in this whole, several syntaxonomic units characterized by floristic criteria as well as specific and edaphic requirements.

However, it is quite obvious that in the Mediterranean countries of the Old World, strictly physiognomic and phytosociological methods are now exhausting their scope of application. Nevertheless, in spite of its constraining character (numerous relevés are necessary together with an excellent knowledge of the flora), the phytosociological method has made it possible to go very deeply into the analysis and classification of great ecosystems, to determine their respective relationships and to establish ecological or dynamic analogies between geographically disjoined structures. Most of these results could not be obtained by a purely physiognomic method, and it is to be regretted that this type of approach is only just beginning in North America (Looman 1980; Campbell 1980).

It has been shown recently (Barbero and Quezel 1981) that the phytosociological method remains one of the best means of approaching planning or zoning problems on a small scale (cf. infra) provided that a more detailed conception of vegetation structures is adopted taking into account the heterogeneity of stations from a geomorphological, geopedological and climatic point of view. This technique

gives a preponderant place to relevés that are often limited but correspond to homogeneous ecological criteria. Therefore, one of the simplest and most significant solutions, to classifying ecosystems is to establish correlations between ecological and dynamic approaches, the analysis of vegetation structures being made through numerous phytosociological relevés (Braun-Blanquet 1952 ; Godron *et al.*, 1968).

The major interest of the method is to provide a large sum of information with many possible applications, but also to render the results obtained by different authors compatible from the point of view of typology and ecological and dynamic characterization as well as from the point of view of analytical interpretations.

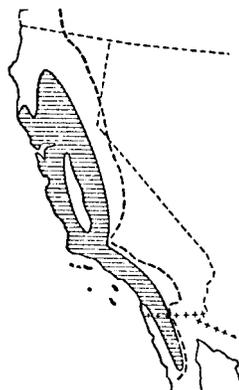
THE ECOLOGICAL APPROACH

The ecological approach relating to classification methods for ecosystems at a small scale in the Mediterranean countries cannot be but a global one. No doubt that at this stage the major ecological factors are connected with the climate, since all the Mediterranean areas in the world are essentially, and even exclusively, defined by this type of character. But climatologists and bioclimatologists of the Old World, as well as those of California, are far from having the same idea of the mediterranean climate. Though in the Old World most ecologists or biogeographers are agreed in making the limits of the mediterranean climatic region coincide, at least approximately, with those of the



Limits of Mediterranean Isoclimatic Area (DAGET, 1977); Black : Limits of the Mediterranean Region (ASCHMANN, 1973).

Hachured : True Mediterranean Climate (ASCHMANN, 1973); Packed line : Limits of the California floristic Province (RAVEN & AXELROD, 1977).



floristic Mediterranean region, the same does not hold true concerning California, as appears from interpretation of limits usually acknowledged for both units by climatologists (Aschmann 1973) and biogeographers (Raven & Axelrod 1978).

The climatic criteria

The criteria established in order to define the Mediterranean climate are alas ! not evident, though certain characters such as summer drought are unanimously admitted. It seems that De Martone (1927) was the first to define the mediterranean climate as a temperate climate with an undistinguishable winter, pertaining to the sub-tropical zone and characterized by a cold temperate (average temperatures for the coldest month $> 5^{\circ} \text{C}$) and humid season, and by a hot and dry season (average temperatures for the hottest month $> 20^{\circ} \text{C}$). Let us mention the definitions given by Koppens and Geiger (1936), Gaussen (1954), Trewartha (1954). The results obtained concerning the delimitation of the Mediterranean climatic region, though different, are more or less similar. The criteria acknowledged by North American climatologists, in particular Aschmann (1973), in defining the Mediterranean climate in California are distinctly more restrictive (annual rainfall between 275 and 900 mm out of which at least 65 % occurs in winter, and average monthly temperature 7.1°C), thus contracting the limits of the Mediterranean region in the Old World, position contradictory to the observations concerning vegetation structures. Only one climatic criteria has been admitted by all authors when defining the Mediterranean climate: the presence of a dry period within the hot season, that is to say, the existence of a period when the vegetation needs more water for its survival and development than the supply it receives. Thus, a climate is considered to be of the Mediterranean type when it fulfills the following conditions summer is the driest season; there is a period of effective drought.

The bioclimatic criteria

Water balance is unfortunately a quite complex problem requiring delicate apparatus and experiments. Theoretically, the results obtained after Thornthwaite coefficients (1948) constitute the best method. They are generally used, especially in English-speaking countries, and a global approach to the problem in California is made by Major (1977). This method is also practised in the Mediterranean countries in the Old World, but it has been the subject of various critics, and finally it does not seem to be more accurate than other empirical methods. In the Mediterranean rim countries the coefficients defined by Emberger (1930) and Bagnouls and Gaussen (1953) are generally used by biologists and bioclimatologists. The most comprehensive attempt is represented by the bioclimatic map of the Mediterranean zone, and its analogues in the world, published by U.N.E.S.C.O. (1963). From the thermal criteria standpoint,

Bagnouls and Gaussen are excluding from the Mediterranean climate the zones with a monthly average temperature under 0° C; American authors have a more restricted position. This restriction certainly explains the numerous confusions and doubtful classifications of the Mediterranean climate, leading to its limitation to juxta-littoral parallel strips, with mild winters. This does not correspond to any biogeographic reality and leaves out vast zones where flora and vegetation are still unquestionably Mediterranean. If we admit that there are no limits to thermal minima when individualizing the Mediterranean bioclimates, we can then distinguish a whole scale of ecologically evident thermal variants (Emberger 1939).

The bioclimatic zones

In the same way, all the bioclimatologists working on the Mediterranean bioclimate have also defined, in relation with increasing humidity, diverse zones for which the terms mostly used are: arid, semiarid, subhumid and humid (Emberger 1930; Thornthwaite 1948). These facts have recently permitted Daget (1977) to define an isoclimatic Mediterranean area corresponding to the whole north tropical territories of the Old World characterized by a Mediterranean type bioclimate. For example, Emberger's bioclimatic coefficient ($Q_2 = 2000 P / M^2 - m^2$) in which P is the annual rainfall in mm, M the average maxima of the hottest month, m the average minima of the coldest month, is a quite classic concept. The values of P are of course decisive, and some authors (Le Houerou 1971) tried to use P and not Q₂ for delimiting bioclimatic zones. Presented hereafter is the hierarchization and its schematic equivalents generally admitted in the Mediterranean region.

Bioclimatic types :	Q ₂	P (in mm and for the cool variant)
perarid	< 10	< 100
arid	10 to 45	100 to 400
semiarid	45 to 70	400 to 600
subhumid	70 to 110	600 to 800
humid	110 to 150	800 to 1200
per-humid	> 150	> 1200

In each of these bioclimatic types it is possible to distinguish thermal variants, defined in relation with the values of m (senso Emberger). The generally admitted limits (Daget 1977) are the following :

The combination of the bioclimatic zones and their climatic variants make it possible to establish a diagram—the climagram—(Emberger 1933) now classic in Mediterranean phytogeography.

Altitudinal levels

Following the works of Flahault (1901), Gaussen, (1926), Quezel (1974), Ozenda (1975), it is now

Variant	Values of m
very hot	> 10° C
hot	7 to 10° C
temperate	3 to 7° C
cool	0 to 3° C
cold	-3 to 0° C
very cold	-7 to -3° C
extremely cold	-10 to -7° C
icy	< -10° C

conventional to distinguish in the Mediterranean region a schematic altitudinal arrangement of species and vegetation types corresponding essentially to thermal criteria. The following levels are generally distinguished:

- an Infra-Mediterranean level corresponding in western Morocco only to the Macaronesian zone with Argania spinosa and Acacia gummifera;
- a Thermo-Mediterranean level, extending all over the circum-Mediterranean area, made up of sclerophyllous formations with Olea-Ceratonia, Pistacia lentiscus, Pinus halepensis, Pinus brutia and Tetraclinis articulata;
- a Meso-Mediterranean level mostly constituted by sclerophyllous forests of Quercus ilex and Q. rotundifolia in western and central Mediterranean, and of Q. calliprinos in eastern Mediterranean. In this level Pinus halepensis and Pinus brutia forests are paraclimax ;
- a Supra-Mediterranean level which is the elective domain of deciduous forests within the humid bioclimate, replaced in subhumid and even semiarid bioclimates and in southern Mediterranean by an upper-Mediterranean level dominated by sclerophyllous oaks ;
- a Mountain-Mediterranean level, grouping essentially highlands coniferous formations (Cedrus, Pinus nigra and the Mediterranean firs) ;
- an Oro-Mediterranean level, often made up of grazed greens of thorny xerophytic garrigues with sparse arborescent Juniperus ;
- an Alti-Mediterranean level hardly distinguishable but on the Atlas or the Taurus, where only scattered dwarfed Chamaephytae can develop.

Sythetic climagrams

In the countries bordering the Mediterranean, the distinguishing of bioclimatic zones and altitudinal levels proved to be most valuable in defining and classifying ecosystems. Botanists and forest people can thereby individualize plant groupings, the ecological requirements of which can easily be represented on a climagram. The studies carried on for some ten years have shown that this state of facts is generally found and that each climatic forest association nearly always corresponds to one or several divisions of the climagram. This was confirmed in particular in Greece (Barbero and Quezel 1976) in Mediterranean Anatolia (Akmann, Barbero and Quezel 1978, 1979), in Lebanon (Abi-Saleh 1978) and in Morocco

(Achhal et al. 1980). We should not overlook the role of edaphic factors, which are of particular importance to evidence secondary divisions within the great bioclimatic systems. The results obtained with this method in Crete (Barbero and Quezel 1980) are particularly suggestive.

In Mediterranean California, phytogeographers and ecologists have never considered this approach; they did not proceed further than a global physiognomic approach of great systems. Let us note, however, that Whittaker (1951) and Whittaker and Niering (1965) have proposed an altitudinal zonation of vegetation based upon relevés, which at least permits a comparison with the above-mentioned conceptions of European authors or with the more recent diagrams established by Rundel et al. (1977) in the Sierra Nevada forests.

THE DYNAMIC ASPECTS

The first synthetic interpretation of the dynamics of this vegetation is probably that given by Braun-Blanquet in his work on the Quercus ilex forests of Languedoc. There he adopted the concept of "vegetation series" as previously defined, particularly by Flahault (1897), and placed it within the phytosociological context. This notion of "dynamic series" is of ever-increasing importance in phytosociology at the present, since it constitutes a major connecting element in any attempt to interpret the development of vegetation. A vegetation series may be seen as a succession of community types which, within a given region, in a given altitudinal level and bioclimatic zone and for given edaphic conditions, leads to the establishment of the climax community. The succession can be either progressive or regressive, reversible or irreversible according to the case in point. The more classic schema of succession in the Mediterranean-type ecosystems with humid or sub-humid climate and at the mesomediterranean level is the following : annual grassland → perennial grassland → scrubs → pre-forest formations → climatic forest. Some of these terms should be explained:

- under the name of "scrubs" are grouped dense structures made up of erect, 30 to 200 cm high chamaephytes for which the term "matorral" is also currently used instead of "maquis" or "garrigue" which have a more restrictive connotation (Tomaselli 1976) ;

- under the name of pre-forest are defined structures mainly composed of Phanerophytes with still abundant Chamaephytes on azonal soils and susceptible to develop naturally into typical forest formations ;

- under the name of forest we mean here dense, usually climatic formations with Phanerophytes on mature (zonal) soils and with a generally herbaceous lower stratum.

It should be noted that this schema is only valid for humid and subhumid bioclimates, yet without their dynamic variables "very and extremely cold". Under the semiarid climate (from cool to very hot), the succession, except for meso- or mi-

croclimatic compensations, comes to a standstill with pre-forest formations, mostly with Pinus halepensis, Pinus brutia or Tetraclinis articulata, but sometimes also with sclerophyllous or deciduous oaks. Moreover, under arid bioclimate as a whole, and also under the cold, very cold or extremely cold variables of other bioclimates, succession hardly proceeds further than the stage of scrubs (matorral or steppe) or that of pre-steppic forests when human action is still weak. Let us state that the pre-steppic forest consists of widely scattered and generally not well grown trees among which Juniperus species often play an important part ; practically no significant accompanying forest species can be found in the lower stratum.

Under the conditions described above – the same geographical region, the same altitudinal and bioclimatic zones, the same edaphic conditions and substrata – only one vegetation series can occur. Conversely, for a given region, even if relatively small, if these same criteria vary, different vegetation series can be distinguished. From this viewpoint, the example of Lebanon is particularly significant (Abi-Saleh 1978).

Vegetation dynamics and man's action

In the above-described theoretical schemas and classifying systems, man's impact has not been directly considered; no need to recall its drastic impact on the totality of the circum-mediterranean ecosystems (Pons and Quezel 1980). Cattle breeding and cultivation began in the Near-East more than 10,000 years ago; they extended in Crete or Greece towards 8000 B.P. and in western Mediterranean around 7000 B.P. In spite of its importance human action on Mediterranean vegetation did not bring any catastrophic modifications, until the 19th century. The situation was entirely modified towards the first half of last century, essentially owing to the breaking off from traditional exploitation techniques (mechanization), to the considerable increase of population and to new habits of modern society. It is quite obvious that any attempt to interpret and classify Mediterranean ecosystems should attach the utmost importance to these events.

A particularly important problem in the vegetational dynamics and evolution is that of fire, and it seems difficult not to evoke it here considering the particular part assigned to it by numerous authors in the countries with a Mediterranean climate (Hanes 1971 ; Le Houerou 1973 ; Naveh 1974).

In the Mediterranean French region, several works allow us to propose a seemingly quite realistic schema concerning the role of fire in the "garrigue languedocienne" (Trabaud 1980). This dynamic schema is consistent with the recent conceptions of numerous authors regarding the dynamic significance of "matorrals". But in California, phytogeographers and ecologists think that "chaparrals" generally constitute climax groupings for which an evo-

lution into forest structures cannot be considered. We have previously (1979) presented our point of view about the question. However, let us recall that some authors (Patric and Hanes 1964) consider the possibility, at least locally, of an evolution of chaparral into forest. No doubt, a study carried out on the basis of the above-described model would make it possible to determine their dynamic potentialities.

METHODS OF CLASSIFYING ECOSYSTEMS AND THEIR APPLICATIONS

This methodology is not purely analytic or descriptive ; it opens directly on numerous applications. The major ones will be presented here.

Cartography

Instead of a simple physiognomic representation of vegetation, dominant species or vegetal associations, cartography allows us to establish "series of vegetation" and it leads thus to a cartography of potential structures showing not only the vegetational dynamics but also its ecological significance in relation with climatic, altitudinal or even edaphic criteria. This technique makes it possible to estimate in a fairly precise manner the forest or agronomic potentialities and to propose, on the basis of a simple field experimentation, management solutions forest techniques, choice of species for re-afforestation, delimitation of re-afforestation areas, and best utilization of soils. In California, where an analysis of the different methods utilized has just been made (Calwel 1977), it has proceeded no further than a representation of the prevailing forest trees or of the major physiognomic vegetation structures, generally delimited thanks to air or satellite photographs.

Analytical methods and biological indicators

The various methods of numerical analysis have been used very early by phytoecologiste in the Mediterranean countries of the Old World as well as in America mostly from phytosociological relevés and for miscellaneous purposes. These methods allow us to confirm (in most cases) or to invalidate the conclusions derived from the interpretation of vegetational structures. But they also make it possible to evidence a whole series of species or groups of species indicating ecological or dynamic criteria. According to the floristic and ecologic characters in a given region (Barbero and Quezel 1981) and for each dynamic series of vegetation, stability, change or compensation indicators (Ammer 1976) can easily be defined, which are also related to such and such climatic or pedologic factors : they are bioclimatic indicators.

Ecological zoning

The ecological zoning is widely practised in Europe (Long 1974) and in North America (Mc Harg 1971) ; it is considered as absolutely necessary to any serious realization of management planning. The above described method of classifying ecosystems, combined with cartography techniques and with the help of biological indicators can lead to concrete propositions of zoning on a small or medium scale. The ecological zoning must essentially take into account the following points:

- the ecological diversity of the environment, which can easily be apprehended thanks to the phytoecological methods just described ;
- the edaphic potentialities, which must be properly defined according to the objects aimed at (new cultivation of land, establishment of a productive forestry, extension of pasture land) ;
- the search for biological indicators which may bring valuable information : bioclimatic indicators such as the phenology (blossoming) of certain species with the prospect of a mesoclimatic zonation; potentiality indicators in order to define the environmental capacity and how to improve it (re-afforestation, pastoralism, biomass, etc ... ;
- estimation of the biological and economic value of vegetation structures, with a view to protecting soil, development of marginal areas and the way for man to exploit them without neglecting preservation problems with regard to ecosystems as well as the genetic capital.

This approach, which constitutes the logical and practical issue of any attempt at classifying ecosystems, seems to be the only means to reveal the real potentialities and utilization limits of vulnerable ecosystems.

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