Fire and Vegetation in the Mediterranean Basin

HENRY N. LE HOUEROU
Plant Ecologist
Plant Production and Protection Division
FAO—Rome

FOREWARD

FIRE together with overbrowsing and overgrazing has always been considered as the major enemy of the Mediterranean forest.

Fire and overbrowsing were closely related. There is evidence that, since at least the Iron Age, 2,600 years ago, shepherds and farmers periodically burned the forest to get more and better pasture and cropland (Barry, 1960; Dugrand, 1964). These processes started probably even more than 4,000 years ago in southwestern Asia.

Heavy fire hazards are not restricted solely to the Mediterranean Basin; they are also important in the forest lands of all the regions having a Mediterranean type of climate (i.e. California, Central Chile, South Africa, South and South-West Australia). These regions have Mediterranean-like types of vegetation with vicarious species and plant communities. The same applies to arid and semi-arid land savannas in Africa and, as a rule, where ever there is a long dry season.

The reason for the high susceptibility of the Mediterranean forest to burn is certainly due to the climate, the Mediterranean climate being characterized by a long dry summer season with high temperatures and low air moisture which is particularly favourable to fires.

The longer the dry season, the heavier the damages.

Dry and rainy years, as they are understood here, do not refer to total amount of rainfall, but rather to summer rains, according to their amount and distribution pattern. This refers to biologically dry or rainy years. Winds and air moisture are also of well known importance in the start and magnitude of fires. Fire has little practical importance in other types of vegetation besides forests and shrublands, although stubble burning is sometimes the origin of many forest fires, especially in developing countries.

The size of the areas burned each year vary widely. For instance, in Algeria only 1,600 ha were burned in 1929, whereas 169,000 ha burned in 1881, 141,000 ha in 1902, 138,000 ha in 1913 and 119,000 ha in 1919 (Boudy, 1948). In south eastern France and Corsica, between Marseille and the Italian border, the minimum since 1956 was 3,430 ha in 1963 and the maximum was 73,700 in 1970 (R. and R. Molinier, 1971). The average surface burned yearly, excluding Corsica, was 30,000 ha for 1962, 64, 65 and 70, but only 2,300 ha for 1961, 63, 66, 66, 68, 69 (Chautrand, 1972). In Corsica the area burned was 1,038 ha in 1959 and 30,900 ha in 1971 (R. and R. Molinier, 1971).

THE MAGNITUDE OF THE PROBLEM

General

In the European Mediterranean countries, forest represents 20 to 30 percent of the total land surface (Table 1). Tables 1 and 2 are an attempt to interpret official statistics in terms of ecology and to match these statistics based upon administrative limits, within the limits of the Mediterranean vegetation. Consequently, they are not absolute and should therefore only be considered as orders of magnitude. Table 3 is an attempt to show the relative importance of the various Mediterranean and submediterranean vegetations; it has been computed from numerous and often contradictory sources. Even for countries like France or Algeria, where fire occurrence has been carefully studied for long periods of time, these tables do not give

TABLE 1. IMPORTANCE OF FOREST LAND IN THE MEDITERRANEAN COUNTRIES

Countries	Total Forest land including Shrubland 10^3 ha	Afforestation Rate % of total country area	Mediterranean Forest and Shrubland 10^3 ha	Percentage of Mediterranean Forest in the country Forest land
France	13,022	24	2,030	15.6
Spain	26,818 (1)	49	16,049	59.7
Italy	6,146	20	3,320	54.0
Yugoslavia	8,812	34	800 ?	10.0 ?
Greece	2,608	20	1,568	60.1
Portugal	2,500	28	1,250 ?	50.0 ?
Turkey	18,273	23	5,500	30.0
Israel	104	5.0	Total	100.0
Syria	440	2.3	"	
Cyprus	173	18.5	"	100.0
Lebanon	95	9.1		
Jordan	67	0.7	"	100.0
Egypt	2	0.0..	"	100.0
Libya	501	0.3	"	100.0
Tunisia	840	5.1	"	100.0
Algeria	3,050	1.5	"	100.0
Morocco	5,300	12.0	"	100.0

TABLE 2. IMPORTANCE OF FIRES IN THE MEDITERRANEAN AND SHRUBLAND (ESTIMATES)

Countries	Average number of fires per year	Average area burned 10^3 ha/year	Area of average fire ha	Percentage of Mediterranean forest and shrubland burned every year	Periods of reference
France	1,260	38.0	30.0	1.9	1960–71
Spain	1,200	31.0	25.8	0.2	1960–71
Italy	1,800	19.0	10.8	0.6	1960–71
Greece	522	8.3	15.9	0.5	1965–70
Yugoslavia	300 ?	1.2 ?	4.0 ?	1.5 ?	1963–66
Israel	330	3.3	10.0	3.1	1963–66
Turkey	518	7.3	14.0	0.04	1963–66
Cyprus	56	1.1	19.2	0.6	1963–66
Tunisia	50	6.0	120.0	0.7	1903–45
Algeria	300	40.0	133.0	1.3	1853–1945
Morocco	60	2.5	41.6	0.04	1924–45
Totals	6,120	157.7	25.9	—	—

TABLE 3. MEDITERRANEAN AND SUB-MEDITERRANEAN FOREST AND SHRUBLAND TYPES
ESTIMATED APPROXIMATE SURFACES: 10^3 HA

Countries	Mediter-ranean *Abies*	*Pinus laricio*	*Fagus silvatica F. orientalis*	Deciduous oaks *Q. pubescens Q. toza etc.*	*Castanea sativa*	*Cedrus libanotica c. brefifolia*	*Juniperus thurifera J. excelsa*	*Quercus faginea*	*Pinus pinaster* var *mesogeensis*	*Quercus suber*	*Quercus ilex*
Tunisia	—	—	—	—	—	—	—	25	2	127	83
Algeria	1	0.1	—	—	—	30	1	67	12	440	676
Morocco	5.5	—	—	14	—	115	31	10	15	367	1345
Portugal	—	—	—	40	45 ?	—	—	100	100	690	360
Spain	1.3	340	360	700	163	—	—	266	1200	339	2800
France	—	50	30	670	135	—	—	—	50	100	400
Italy	1.6	67	420	770	244	—	—	—	—	85	2500
Greece	364	145	234	1034	28	—	—	—	—	—	—
Turkey	1482	2946	2982	4538	183	256	385	—	—	—	—
Syria	10	—	—	—	—	15	—	—	—	—	—
Lebanon	1	—	—	—	—	2	—	—	—	—	—
Jordan	—	—	—	4	—	—	—	—	—	—	—
Israel	—	—	—	5	—	—	—	—	—	—	—
Cyprus	—	4	—	—	—	1	—	—	—	—	—
Libya	—	—	—	—	—	—	—	—	—	—	—
Totals	1866.4	3552.1	4026	7775	798	419	417	468	1379	2148	8164

TABLE 3. (CONT'D)—MEDITERRANEAN AND SUB-MEDITERRANEAN FOREST AND SHRUBLAND TYPES
ESTIMATED APPROXIMATE SURFACE: 10^3 HA

Countries	*Q.coccifera Q.callipri-nos*	Evergreen Maquis or Garrigue	*Pinus hale-pensis P.brutia*	*Cupresus semperv. c.dupre-ziana c.atlantica*	*Pinus pinea*	*Tetra-clinis articu-lata*	*Cerato-nia Olea*	*Juniperus phoenicea*	*Argania spinosa*	*Stipa tenacis-sima* steppes	Totals
Tunisia	3	—	340	0.1	—	30	70	425	—	650	1755
Algeria	41	—	843	0.1	—	161	100	600	—	3000	5972
Morocco	—	—	65	8.5	—	740	500	200	700	1500	5616
Portugal	—	—	100	—	20	—	—	—	—	—	1435
Spain	16	10070	1300	—	238	—	—	62	—	578	18433.3
France	300	300	80	—	5	—	2	—	—	—	2092
Italy	—	—	130	—	45	—	—	—	—	—	4262
Greece	743	—	528	5	—	—	—	—	—	—	3081
Turkey	590	823	3220	10	—	—	—	73	—	—	17488
Syria	63	—	70	—	—	—	—	—	—	—	158
Lebanon	43	—	5	1	12	—	—	11	—	—	75
Jordan	21	3	0.2	—	—	—	0.1	8	—	—	36.3
Israel	35	—	30	—	—	—	—	—	—	—	70
Cyprus	—	52	116	—	—	—	—	—	—	—	173
Libya	1	—	5	0.5	—	—	50	150	—	500	706
Totals	1856	11248	6832	25.2	320	931	722.1	1529	700	6228	61353.6

an exact idea of the phenomenon. For instance, the percentage of forest burned every year in south eastern France is 1.87 as an average (1961–70). In a zone covering more than 500,000 ha—Corsica, Provence and Côte d'Azur—the so called "Red Belt," the area burned averages 4 percent per year (Uhlen, 1972; Chautrand, 1972; Seigue, 1972; Poudou, 1972; Degos, 1972; R. and R. Molinier 1971 and 1972). This means that each piece of forest is burned every 25 years as an average within this "Red Belt."

In many places of south eastern France, Corsica, Sardinia, Sicily, and north eastern Algeria, 10 percent of the forest or shrublands are burned every year. Taking into account the fact that several countries of the Near East or Portugal were not considered here, one may assume that fire annually destroys close to 200,000 ha per year of the Mediterranean forest and shrubland. The damage is a minimum loss of $50 million per year including fire fighting and prevention, but not counting the damage due to resulting erosion, decreased fertility, silting of dams and reservoirs, floodings, etc. Of these damages, about ¾ are located in the western Mediterranean where the afforestation rate is about 10 times higher than in the eastern Mediterranean (Turkey and Greece excepted).

What burns, when and why

What:—Fire occurrence per unit area is 3 times higher in privately owned forests than in public and state managed ones (Susmel, 1973).

Pine forests are particularly vulnerable. Aleppo pine (*Pinus halepensis*) forests cover huge areas in France, Italy, Greece, Turkey, Tunisia, Algeria, Spain. They pay the highest tribute to fire. In Greece, for instance, Aleppo pine represents ⅓ of the burned areas (Casamajor, 1971). This is almost in the same proportion in Spain, France and Italy. Other coniferous species such as Umbrella pine (*Pinus pinea*), Maritime pine (*Pinus pinaster*), Laricio pine (*Pinus laricio*), are also very susceptible as well as cedar forest. Then comes the evergreen oaks and maquis; Holm oak (*Quercus ilex*), Cork oak (*Quercus suber*), Spiny oak or Kermes oak (*Q. coccifera* and *Q. calliprinos*), which often constitute degraded forests of the Maquis or

"Garrigue" types (Chapparral, Matorral, Encinal). The less susceptible types are the deciduous oak or beech forests of (*Quercus pubescens*, *Q. pyrenaica*, *Q. faginea*, *Fagus silvatica* and *F. orientalis*) and the fir forests (*Abies pinsapo*, *A. cilicica*, *A. cephalonica*, etc.). These less susceptible types are not typical Mediterranean vegetation but transitional types where there are relatively high summer rains.

When:—*The peak season* of fire occurrence is summer (45–65%): July, August, September (October) either in Italy, France or Spain. This corresponds also to the peak season of tourism and drought. There is a small recurrence of fires in spring: February-March-April (20–35%)

Fires generally occur in daytime. About 80 percent occur from 9 AM to 6 PM and most of them (about 70%) occur between 11 AM to 5 PM. (Aronica and Bertini, 1971; Servicio de Incendios Forestales, 1971; Susmel, 1973).

Why:—*The causes of fires* may vary from country to country, and from province to province within each country. For the Mediterranean as a whole, Susmel (1973) has reached the following conclusions computed from various sources:

	Numbers %	Areas %
Lightning	1.6	2.4
Railways	1.9	2.1
Carelessness	42.2	40.4
Malignity	14.6	10.3
Unknown	29.4	30.2
Various	10.3	10.4

In southeastern France A. Astier (1972) gives the following figures:

Malignity and/or on purpose	30%		
Carelessness (non tourists)	25%	Unauthorized garbage deposits	10%
Tourists (picnics, smokers)	25%	Unknown	10%

Aronica and Bertini (1971) give the following for Toscany, Ligury, Lombardy 1953–66:

	Numbers	%	Area ha	Area %
Lightning	80	0.2	3,700	1.0
Railways	150	0.5	3,800	1.0
Malignity	3,100	10.7	54,000	14.0
Carelessness	9,700	33.4	110,000	30.0
Various and Unknown	16,000	55.2	205,000	54.0
TOTAL	29,030	100.0	376,500	100.0

In Europe (France, Spain, Italy, Greece) carelessness refers mainly to tourism, picnics and burning cigarettes thrown from cars and trains. From sample surveys it has been calculated that in the area of the Bouches-du-Rhône only, and during an average summer day, 12,000 to 15,000 burning cigarettes are thrown from cars and trains (R. and R. Molinier, 1971). Even though the chances that a fire might start from a cigarette are 1/1,000, one can understand why a good many of the fires start along the roads and railway networks.

Abandoned bottles, acting as lenses on the litter, are a non-negligible cause. In Spain where the trains are still often steam-powered, railways are responsible for 5 percent of the fires.

In developing countries or in less developed areas in otherwise developed countries, burning pastures is still an important cause, for instance in Corsica, parts of Italy, Greece, Spain, Turkey and Algeria. Boudy (1948) gives the following percentages for Algeria and Tunisia:

	Algeria %	Tunisia %
Carelessness (mainly from pasture burning)	40 – 50	55 – 60
Malignity	20 – 25	38 – 40
Unknown	30 – 35	10 – 15

In Algeria during the pre-independence war, which lasted from 1954 to 1962, large areas of forests, mainly Aleppo pine, were burned, often by napalm bombing.

Trends:—In countries like France where detailed and reliable statistics over 50 years or more are available, it is possible to detect some trends which also seem applicable to other countries like Spain and Italy. The number of fires has increased rapidly since the second world war, owing mainly to a sharp increase in tourism. In the Calanque-Ste Baume area, east of Marseilles in France, for instance, the 5-year total amount of fires increased from 1,000 in 1961–65 to 18,000 in 1966–70. In the same area the total surface burned increased from 700 ha in 1951–55 to 21,000 ha in 1961–65 and decreased to 13,000 ha in 1966–70. This means that the number of fires has increased sharply whereas the total surface burned remained stable or decreased since 1966, owing to increasingly efficient fire control systems. Consequently, the area burned per fire decreased sharply: from 28 ha to 7 ha (Astier, 1972).

However, this is not true everywhere. In Tuscany (Italy) the increase during 1970–71 in respect to 1961–69 was 56 percent in numbers, 75 percent in acreage and 42 percent in surface per fire (Susmel, 1973). Generally speaking, in Spain, Italy and Greece the number of fires increased very fast whereas the area burned in each fire remained almost stable from 1961 onwards (Susmel, 1973). In some parts of France, i.e. in the southwestern maritime pine forests of Landes de Gascogne (1,420,000 ha), fires have been almost curbed during the last 20 years (See data below).

Landes de Gascogne

Period	Total area burned ha	Average per year ha	Percentage burned each year
1945 – 48	166,000	41,000	2.8
1950 – 65	33,000	2,200	0.1
1971	–	889	0.06

However, since this is not a Mediterranean zone and since most areas are reafforestations of *Pinus pinaster* and the accessibility is good, this is a particularly easy situation for fire prevention (Siloret et Itey, 1972).

THE MEDITERRANEAN VEGETATION

General

To understand the repartition or "chorology" of the Mediterranean vegetation, it is classified according to ecological criteria: Bioclimatology and edaphology (mainly soil pH and moisture).

Bioclimatology

Using the criteria set up by Emberger and his school of phytogeography and plant sociology, we can divide the Mediterranean climates as follows into eight types:

1,200 < R (1)	Mediterranean	per humid climate
800 < R < 1,200	"	humid climate
600 < R < 800	"	sub-humid climate
400 < R < 600	"	semi-arid climate
300 < R < 400	"	arid climate upper
200 < R < 300	"	" " middle
100 < R < 200	"	" " lower
100 < R		desert climate

Each one of these climate types is subdivided into eight sub-types according to average daily minimum temperature of January (coldest month see chart next page):

9 < m (2)	Very warm winters—No frost
7 < m < 9	Warm winters—Frost very rare
5 < m < 7	Mild winters—5–10 days frost
3 < m < 5	Temperate winters—10–20 days frost
1 < m < 3	Cool winters—20–30 days frost
−2 < m < 1	Cold winters—30–60 days frost
−5 < m < −2	Very cold winters—60–120 days frost
m < −5	High mountains—More than 120 days frost

We are thus left with theoretically 64 sub-types of Mediterranean climates. In fact, they are less as some combinations are impossible or, at least, practically never occur.

These criteria are not arbitrary but designed to match with phytogeographic and agronomic facts. They can be expressed more clearly with graphs showing the distribution of the climax types of vegetation in respect to these climatic criteria (see Figs. 1–4).

Types of Forest and Shrubland (dominant species) and Bioclimates in the Western Mediterranean

1. Cushion-like Spiny xerophytes (high mountains)	(B h)
	C h
	D h
	(E h)

		A	B	C	D	E	F	G	H
	m \ R	1,200 <	800–1,200	600–800	400–600	300–400	200–300	100–200	< 100–
a	9	+	+	+	+	+	+	+	+
b	7 – 9	+	+	+	+	+	+	+	+
c	5 – 7	+	+	+	+	+	+	+	+
d	3 – 5	+	+	+	+	+	+	+	+
c	+ 1 – 3	+	+	+	+	+	+	+	+
f	– 2 – + 1	+	+	+	+	+	+	+	+
g	– 5 – – 2	+	+	+	+	+	+	+	–
h	< – 5	?	?	+	+	+	?	?	–

(1) R = Average rainfall in mm.

(2) m = average daily minimum of the coldest month (January) °C.

2.	*Fagus silvatica, Abies pinsapo*		A g
	A. maroccana, A. numidica, A. nebrodensis		B g
	A. cilicica, A cephalonica etc.		
3.	*Pinus laricio*		C g (h)
	Juniperus thurifera		D g (h)
4.	*Cedrus libanotica*		B g (f)
			C g (f)
			(D g f)
5.	*Deciduous Oaks:*	*Q. faginea*	Abc d e f
			Bbc d e f
	Q. conferta	*Q. pubescens*	A e f
	Q. cerris	*Q. toza* (= *Q. pyrenaica*)	B e f
	Q. macedonica		Bbc d e f
			Abc d e f
6.	Evergreen Oaks:	*Q. suber*	Bbc d e f
			Cbc d e f
			(Dbc d e f)
		Q. ilex	Bc d e f
		Q. coccifera	C c d e f
		Q. calliprinos	D c d e f
7.	*Pinus halepensis*		C c d e f
			D c d e f
			E c d e f
			F c d e f
8.	*Tetraclinis articulata*		D a b c d (e f)
			E a b c d (e f)
9.	*Argania spinosa*		D (a) b c d
			E (a) b c l
			F (a) b c d
			G (a) b c d
10.	Olive – Carob		B (a) b c d
	Ceratonia siliqua, Olea europea		C (a) b c d
			D (a) b c d
			E (a) b c d
11.	*Poterium spinosum*		B a b c d
			C a b c d
			D a b c d
			E a b c d
12.	Red Juniper		D a b c d e f
	Juniperus phoenicea		E a b c d e f
			F a b c d e f
			C a b c d e f
			(H)
13.	Esparto – Lygeum, White Sage		E a b c d e f
	Stipa tenacissima		F a b c d e f
	Lygeum spartum		G a b c d e f
	Artemisia herba alba		

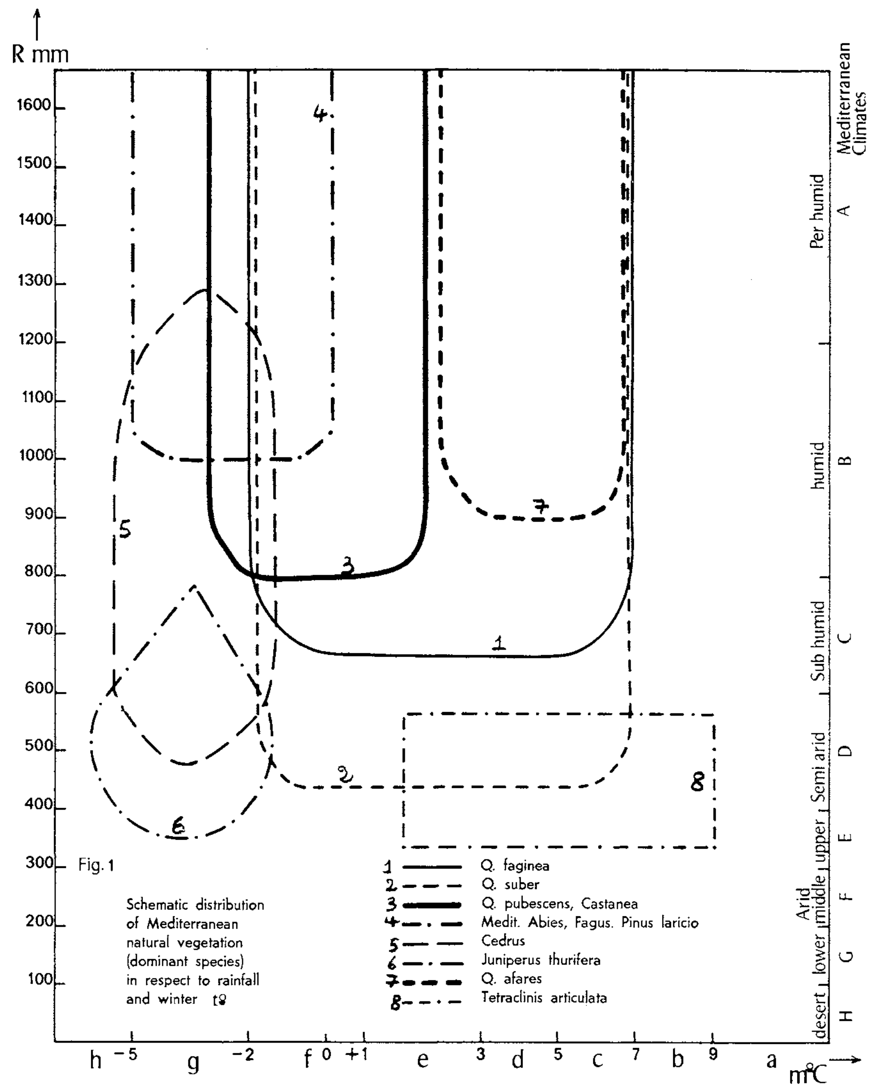
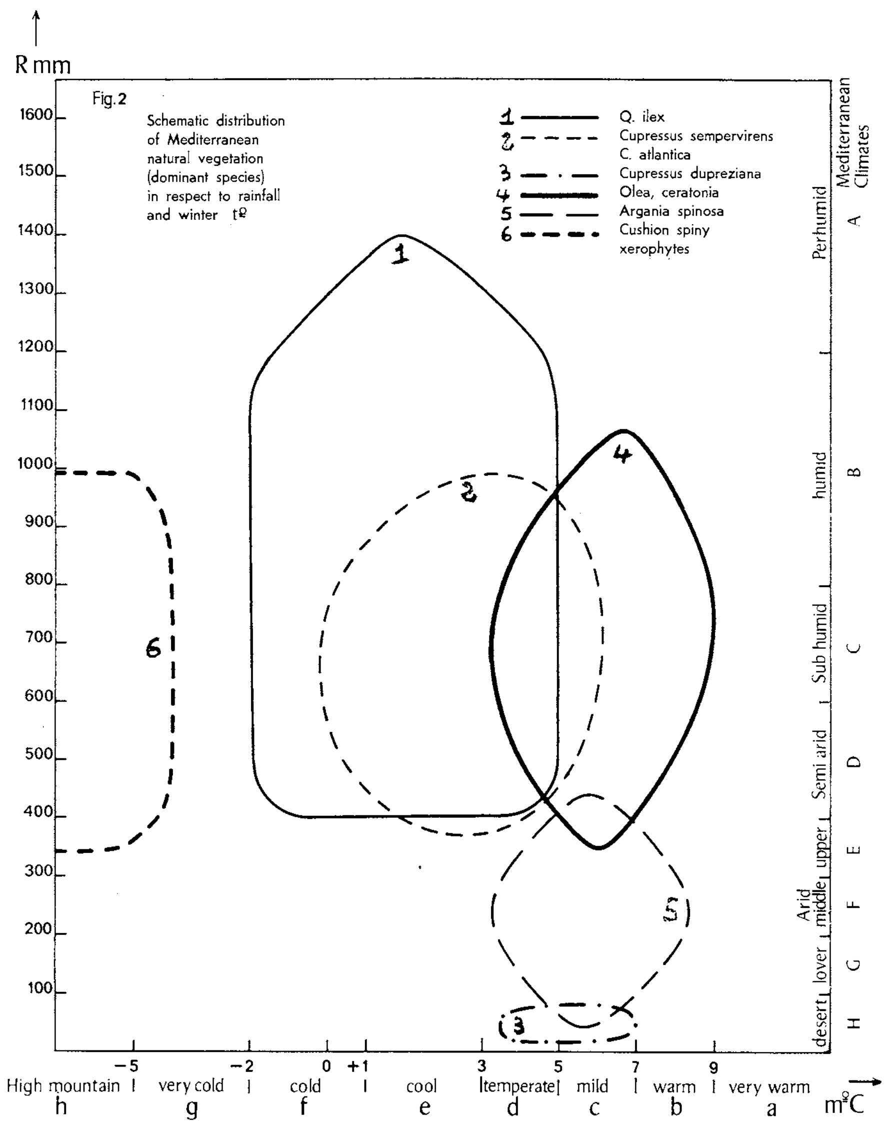


Fig. 1

Schematic distribution of Mediterranean natural vegetation (dominant species) in respect to rainfall and winter t°



R mm
Fig. 2
Schematic distribution of Mediterranean natural vegetation (dominant species) in respect to rainfall and winter t°
1 Q. ilex
2 Cupressus sempervirens
C. atlantica
3 Cupressus dupreziana
4 Olea, ceratonia
5 Argania spinosa
6 Cushion spiny xerophytes
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
Perhumid
humid
Sub humid
Semi arid
Arid upper
middle
lover
desert
Mediterranean Climates
A
B
C
D
E
F
G
H
−5
−2
0
+1
3
5
7
9
High mountain
very cold
cold
cool
temperate
mild
warm
very warm
h
g
f
e
d
c
b
a
m°C

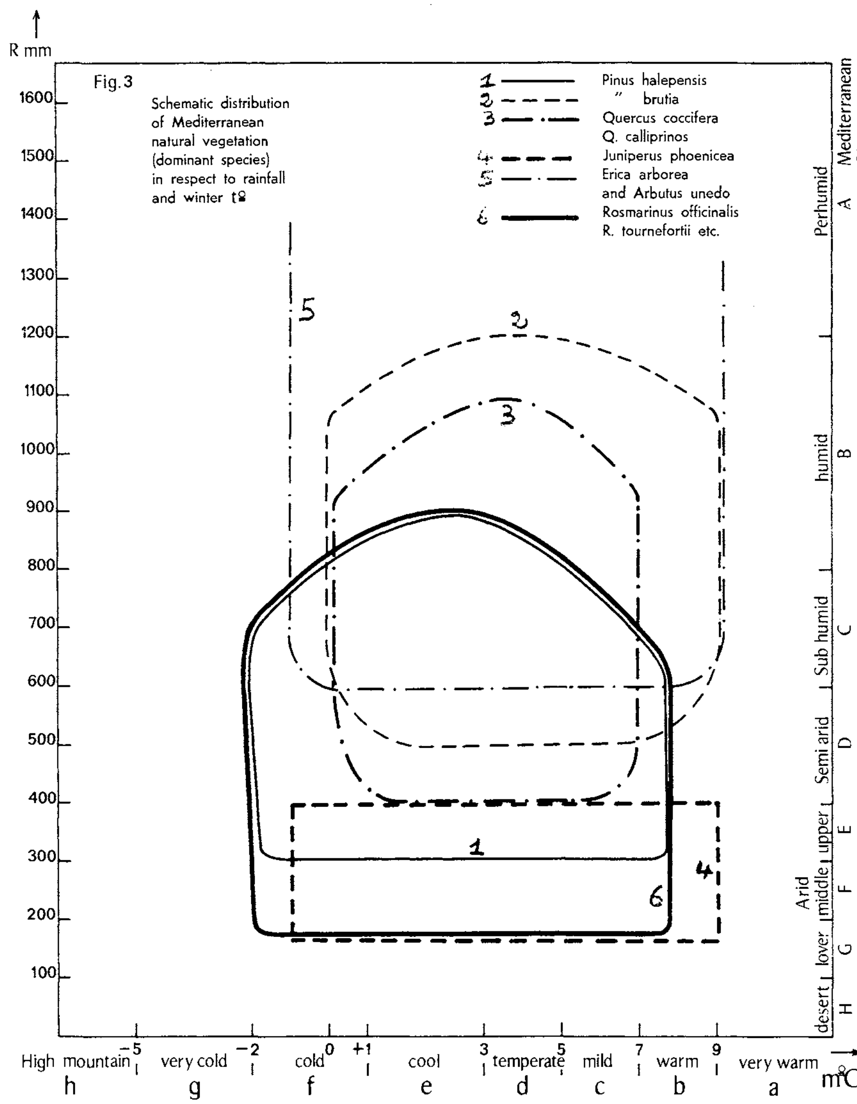
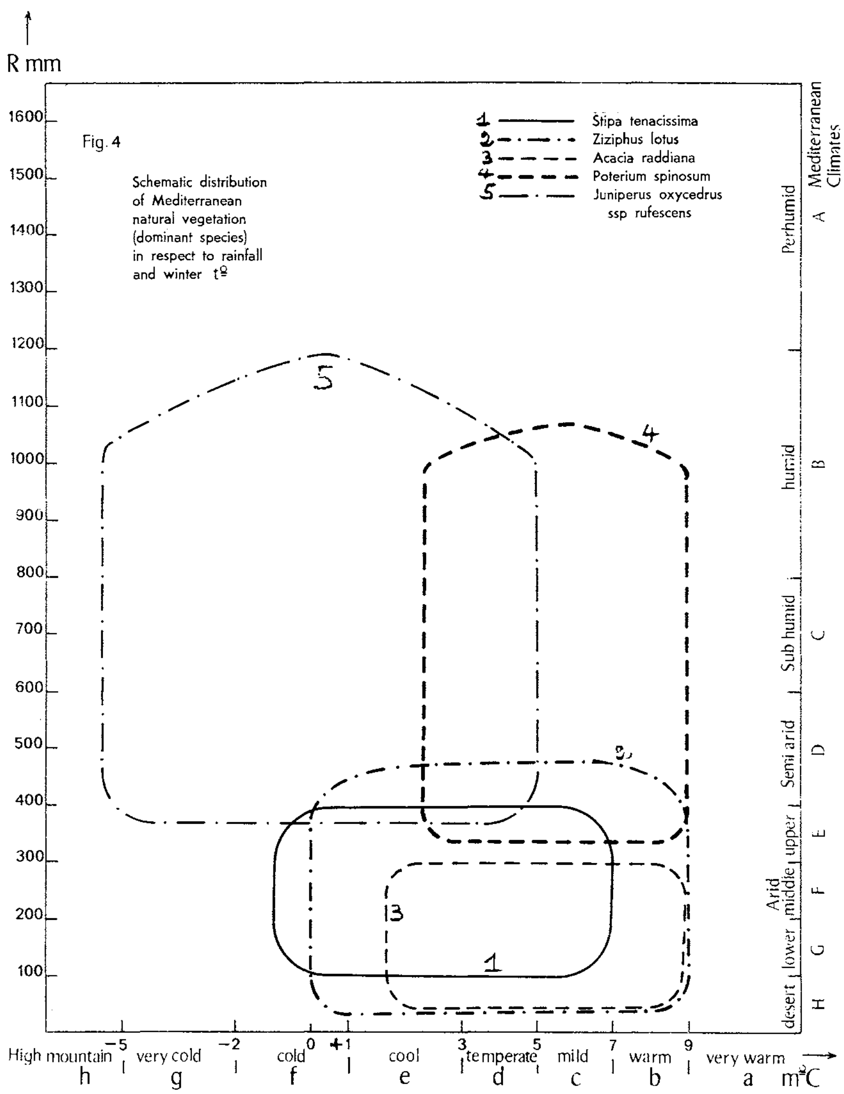


Fig. 3 Schematic distribution of Mediterranean natural vegetation (dominant species) in respect to rainfall and winter t°


R mm
1600
1500
1400
1300
1200
1100
1000
900
800
700
600
500
400
300
200
100
Fig. 4
Schematic distribution of Mediterranean natural vegetation (dominant species) in respect to rainfall and winter t°
1 Stipa tenacissima
2 Ziziphus lotus
3 Acacia raddiana
4 Poterium spinosum
5 Juniperus oxycedrus ssp rufescens
Perhumid A
humid B
Sub humid C
Semi arid D
Arid upper E
middle F
lower G
desert H
Mediterranean Climates
High mountain h
very cold g
cold f
cool e
temperate d
mild c
warm b
very warm a
m°C
−5
−2
0
+1
3
5
7
9

Graphs (Figs. 1–4) show the climatic distribution of dominant species—i.e. as dominant types of vegetation and not as individuals.

Types of vegetation according to edaphic factors

In forest vegetation the main edaphic factors are pH and soil moisture. Soil pH depends to a large extent on the substratum. Generally speaking, igneous, metamorphoric rocks and sandstones will give neutral or acid forest soils, whereas limestones and marls (very common in the Mediterranean) will produce neutral to basic soils.

Some forest types are linked to more or less acid soils such as:

Quercus faginea	*Pinus laricio* (pro parte)
Quercus afares	*Pinus pinaster* (pro parte)
Quercusc suber	*Arbutus unedo*

Some types are slightly or not affected at all by pH such as:

Fagus silvatica	*Abies sp.*	*Juniperus thurifera*
Cedrus libanotica	*Q. pubescens*	*Juniperus phoenicea*
Quercus ilex	*Pinus halepensis*	

Some are linked, or very tolerant, to basic calcareous soils such as:

Quercus coccifera	*Ceratonia siliqua*	*Tetraclinis articulata*
Q. calliprinos	*Stipa tenacissima*	*Rosmarinus officinalis*

Classification according to soil moisture available during the growing season would roughly follow the bioclimatologic order given above, where the forest types are classified by increasing aridity (except for No. 1 Spiny high mountain xerophytes). In fact, rainfall, soil moisture, winter temperatures are all linked to orographic factors. Rainfall and soil moisture increase with altitudes up to 2,000–2,500 m, whereas winter temperatures are inversely related. The rainfall gradient is of the magnitude of 5–8 percent increase per 100 m of elevation. Rainfall distribution is also affected by orography as summer rains increase with elevation. The temperatures gradient is of about 0.5 °C per 100 m of elevation (Le Houérou, 1959, 1969).

THE ROLE OF FIRE IN VEGETATION DYNAMICS

General

This topic is an extremely complex one. Numerous works have been devoted to this complexity around the Mediterranean, especially in southern France and North Africa where vegetation surveys and mapping have been very intense for more than 50 years. This complexity is due to many reasons:

—The vegetation types are very numerous, probably around 10,000 or more, for the western Mediterranean only (about 1,000 for a small country like Tunisia only).
—The effect of fire is not always clearly understood since other factors interfere with it: overgrazing, overbrowsing, unrational cutting, clearing and all sorts of mismanagement.
—The effect of fire itself depends upon various factors such as:
  a) The way in which vegetation burns in a given type of vegetation, quickly or slowly, at ground level, or at canopy level, etc.; which in turn depends on the wind velocity during the burning, etc.
  b) The fire rotation itself. In some places fire occurs once in a century, in others once every 20 or 30 years and even in some parts once every 10 years or more. Consequently, the effect of fire depends a great deal upon the fire frequency.
  c) The season when fire occurs can also effect reseeding and regrowth of many species according to the phenological stage of each species when the burning takes place. These effects have been studied very little, and experimental studies are scarce and a rather new area of research in the Mediterranean (less than 10 years): see the work of Trabaud in southern France.

The pyrophytes

To my knowledge the above word was created by Kuhnholtz-Lordat (1939) to designate *those plants in which multiplication or reproduction is stimulated by fire*. These are different from *anthracophytes* which occupy the bare ground left after a forest fire, and are often annual nitratophytes and have nothing to do with fire itself but only with its effects on soil (release of nutrients and mineralization of nitrogen from the organic layers).

One may consider several types of pyrophytes (Kuhnholtz-Lordat, 1939, 1958; Trabaud, 1970).

Passive pyrophytes:—These withstand fire owing to especially thick bark (cork oak), or relatively little susceptibility to burning (deciduous oaks, Tamarix, Atriplex, for instance), or which escape the effect of burning by their sub-terranean organs like the rhizomes of *Pteridium aquilinum.*

Active pyrophytes with vegetative response to fire:—These respond by vegetative growth which is stimulated by fire such as:

Quercus coccifera	Shoots from underground stump, suckers
Tetraclinis articulata	" " " " no "
Juniperus phoenicea	" " " " " "
Arbutus unedo	" " " " " "
Erica arborea, E. multiflora	" " " " " "

Active pyrophytes whose seed propagation is stimulated by fire:—Pines belong to this species, especially the Aleppo pine, whose cones burst often when burning, sending the seeds away at a distance of several meters, enabling part of them to escape from burning. Also many species of the Cistaceae family seem to have the same reaction, such as:

Cistus albidus	*Cistus libanotis*	*Cistus sericeus*
" *monspeliensis*	" *salviifolius*	" *laurifolius*
" *crispus*	" *ladaniferus*	" *populifolius*
" *parvifolius*	" *villosus*	*Halimium halimifolium*, etc.

These species are often encountered as pure stands with high ground cover in areas where fire occurrence is frequent.

The effect of fire on the seed physiology is not clearly understood and would require experimental studies.

The case of Kermes oak (Q. coccifera):—*Q. coccifera* is a typical evergreen sclerophyllous pyrophyte which covers huge areas, probably over 2 millions hectares, in southern France, Spain, North Africa and Italy and, under the sub-species *Calliprinos,* in Libya, Crete, Cyprus, Greece and Near East. Although it could be a small tree 3–5 m high under natural conditions, it is rarely so due to repeated burning, mainly to improve grazing. It is usually a very intricate shrub of 0.5–1.5 m high with rigid branches and hard spiny, holly shaped leaves. It is usually in the shape of a brush-like short carpet distributed on a pattern of patches covering a few square meters each. In these patches, ground cover approximates 100 percent whereas the shallow soil is almost bare in between.

Kermes oak occurs on various sorts of limestone in the semi-arid to humid Mediterranean climate ($400 < R < 1{,}200$ mm) with winters from warm to cool ($0°C < m < 9$). It is much more thermophillous than Holley oak (*Q. ilex*) ($-2 < m < 5$). It covers all sorts of limestone, usually very shallow, and is therefore a very important plant for erosion control. Liacos and Moulopoulos (1967) in Greece as well as Long, Fay, Thiault and Trabaud (1964 and 1967) in France, have shown that young sprouts of this oak are quite palatable and nutritious fodder, as graziers have been known for centuries.

Kermes oaks have been in equilibrium for centuries with periodical burnings of the pyro stable vegetation as a kind of fire pseudo climax; but, when fires are too frequent, it may be killed leaving the ground to short, open swards of *Brachypodium ramosum*. *Q. coccifera* has the double ability or regrowth after burnings, both by shoots from stocks and suckers from the roots. Its root system is very powerful, although rather superficial and finds ways to develop between crevices, diaclases, and all sorts of rock fractures of limestone outcrops. Its spiny hard leaves and rigid short branches make a good protection against overbrowsing and, hence, its periodical burning by shepherds. However, seedlings are very rarely observed which means that the species propagates primarily by vegetative reproduction stimulated by fire.

The regressive succession in southern France may be synthesized as follows (from Barry, 1961; Molinier 1968, 1971, and others); see following "Sequence" diagram.

Arbutus unedo:—This ericaceae (as well as *A. andrachne* in the Near East and *A. pavarii* in Eastern Libya) is an evergreen broadleaved more or less sclerophyllous shrub, 1–4 m high, and very common in the Mediterranean maquis. It occurs on acid soils or on "terra rossa" where the calcium carbonate has been more or less leached. It corresponds to sub-humid-humid bioclimates with rainfalls over 600 mm and from cool to warm winters ($0 < m < 9$).

As a pyrophyte, *Arbutus unedo* is characterized by extremely vigorous regrowth of shoots from the stock (but no suckers) during the growing seasons consecutive to fires or cuttings. As a consequence, it is often able to eliminate or weaken most of its competitors in the

FIG. 5. Normal aspect of high, dense, arborescent matorral, unburned for 30–50 years. Dominant species: *Quercus ilex* and *Pinus halepensis.*

FIG. 6. Similar, contiguous vegetation 1½ years after burning. All trees were killed—*Q. ilex* and *Arbutus unedo* sprout from stumps.

course of a few years after a fire. Contrary to the Kermes oak, *Arbutus* is a self-reseeder.

Erica arborea shows about the same ecology and biological characteristics in respect to fire as *Arbutus*, but usually occurs in more more humid conditions and more acid soils. *Arbutus unedo* is often the dominating species in the burned forest or maquis of *Q. ilex*, *Q. suber* or *Q. faginea.*

Sequence

				Stages
		Primeval forest of *Quercus ilex*		A
		↓		
	Limestones	Shales marls	Siliceous rocks non-calcareous soils	
	↓	↓	↓	
Periodical burning	Q. coccifera	Rosmarinus officinalis	Q. suber	B
	↓	↓	↓	
Frequent burning	Cistus albidus	Dorycnium suffruticosum	Arbutus unedo Erica arborea	C
	↓	↓	↓	
Very frequent burning	Brachypodium ramosum	Brachypodium phoenicoides	Helianthemum guttatum	D

THE MAIN DYNAMIC SEQUENCES IN THE WESTERN MEDITERRANEAN VEGETATION

***Cedrus libanotica*—Sequence:**—*Cedrus* forests may be called "pyrolabile" because of their sensitivity to burning; they occur in high mountains of North Africa and the Near East, between 1,500 and 2,500 m, where the rainfall reaches 600 mm or more and where daily average minimum temperature in January lie between —2 and —5 °C. Average snow cover varies from 20 to 120 days.

The characteristic species of the cedrus forest are (Schoenenberger, 1970; Quezel, 1956; Le Houérou et Claudin, 1973, Emberger, 1939):

FIG. 7. Same place as Figure 6. On patches of shallow soil chalky limestone outcropping ground cover is very low 10–20 percent. Annuals are scarce. *Arbutus unedo* sprouting from stump. All *Pinus halepensis* trees are dead; seedlings of Pinus are scarce (0.1 per m^2).

Acer monspessulanum	*Taxus baccata*
Acer obtusatum	*Ilex aquifolium*
Daphne laureola	*Paeonia corallina*
Berberis hispanica	*Viola munbyana*,
Amelanchier ovalis	*Prunus prostrata*. etc.

Burnings of this type of forest results in two different types of vegetations.

A) In the higher altitudes, the forest is replaced by spiny xerophytic communities similar to those of the nearby high mountains zone; they cover 60 to 100 percent of the ground and are interspread with grasses and grass-like species.

FIG. 8. Same place as Figure 6. Patches of deeper soil (20–50 cm)—Ground cover is high (≥ 90%) Seedlings of *Cistus albidus* ≃ 1 year old, are abundant (10–100 per m^2). Seedlings of Pinus, ≃ 1 year old, are fairly abundant (5 per m^2).

Aa) *Spiny xerophytes:*

Erinacea anthyllis	*Alyssum spinosum*	*Juniperus communis*
Bupleurum spinosum	*Cytisus balansae*	*Arenaria pungens*
Pseudocytisus mairei	*Cytisus purgans*	*Rhamnus alpina*

Ab) *Grasses and grass-like speciess*

Catananche montana	*Festuca aurasiaca*	*Phleum phleoides*
Dianthus caryophyllus	*Festuca ovina*	*Koeleria splendens*
Dianthus balbisii	*Armeria plantaginea*	*Koeleria vallesiana*, etc.
	Armeria alliacea	

Fig. 9. Same vegetation other nearby place. *Background:* High dense; arborescent matorral of *Quercus ilex* and *Pinus halepensis* remained unburned for 40 years. *Foreground:* 2½ years after burning *Arbutus unedo* is sprouting very vigorously from stump and covers 50–60 percent of the ground.

Fig. 10. Same place as Figure 9. Structure of the vegetation 2½ years after burn. *Q. ilex* sprouts from stem and stump—70 percent of *Pinus halepensis* were killed. Vigorous sprouts of *Arbutus unedo,* 1–1.5 m high. Covering 50–60 percent of the ground.

FIG. 11. Close-up view of Figure 10; 0.1 seedling of Pinus $\simeq$ 2 years old per m².

B) *In the lower altitudes*, the sequence includes the following stages:

Stages	A	*Cedrus* Forest	C	Grasses and grass-like swards—*Thymus*, *Bromus* sp. pl., *Ampelodesmos mauritanicum*, *Poa* sp. pl., *Helianthemum* sp. pl., *Teucrium chamaedrys*, etc.
	B	*Quercus ilex* *Juniperus oxycedrus* Maquis		

***Quercus faginea* Series:**—*Q. faginea* forests may also be qualified as pyrolabiles; they occupy high rainfall areas in North Africa, Portugal and Spain. The rainfall is always over 800 mm, and almost always over 1,000 mm. Winters are mild to cold ($O < m < 7$); soils are always neutral to acid and usually deep.

Q. faginea itself is a big deciduous tree, 10–20 m high, and similar in shape and leaves to *Q. robur* or English oak.

A) *In well developed forests*, the dominating species are (Quezel, 1956; Debazac, 1959):

Q. faginea	*Hedera helix*	*Cytisus triflorus*	*Tamus communis*
Galium ellipticum	*Sanicula micrantha*	*Melica minuta*	*Stellaria holostea*
Myrtus communis	*Potentilla micrantha*	*Erica arborea*	*Brunella vulgaris*
Vinca media	*Lysimachia cousiniana*	*Viburnum tinus*	*Ruscus hypophyllum*

Q. faginea is very sensitive to burning; almost all the trees are killed when a fire of some intensity occurs (Debazac, 1959). This is why *Q. faginea* forests are restricted in acreage in respect to the area they could ecologically cover. Burning of *Q. faginea* leaves the ground to the passive pyrophyte cork oak *Q. suber* (Quezel, 1956). Although this has been overlooked by most of the Mediterranean ecologists and phytogeographers, I certainly agree with Quezel when he states that *Q. suber* is not a climax in North Africa but a fire stage in the *Q. faginea* sequence. This fact is still more obvious when comparing the areas of distribution and the ecological profile of both species.

B) In the *Q. suber* stage, the major species are:

Q. suber	*Calycotome villosa*
Phillyrea media	*Myrtus communis*
Erica arborea	*Pistacia lentiscus*
Smilax aspera	*Pteridium aquilinum*
Daphne gnidium	*Cytisus triflorus*
Galium ellipticum	*Arbutus unedo*
Cistus stlviaefolius, etc.	

C) When the cork oak forest or maquis itself is too often burned, it leaves the ground to a more or less thick maquis, 1–4 m high, which is dominated by true pyrophtyes such as:

Arbutus unedo	*Lavandula staechas*	*Cistus salviaefolius*
Myrtus communis	*Daphne gnidium*	*Halimium halimifolium*
Phillyrea media	*Erica arborea*	*Helianthemum tuberaria*
Calycotome villosa	*Cistus monspeliensis*	

Debazac (1959) has published a series of observations of post-burning vegetation in *Q. faginea* and *Q. suber* forests of northwestern Tunisia. These are summarized as follows:

Stage A—9 months after burning:
Annuals cover 100% of the ground, mostly:

Vicia sativa	35%	Ground Cover	*Medicago soleirolei*	10%	G.C.
Trifolium campestre	5%	" "	" *murex*	10%	" "
" *jaminianum*	5%	" "	*Cynosurus polybracteatus*	5%	" "
Hypochoeris aetnensis	5%	" "	*Briza maxima*	5%	" "
Trifolium ligusticum	5%	" "	*Fumaria capreolata*	5%	" "

Shrubs cover 10–15%

Erica arborea	5%	G. C.	*Cistus monspeliensis*	5%	G. C.
Myrtus communis	5%	" "	*Quercus suber*	5%	" "

This is in agreement with the observations of Trabaud (1970) and mine as well in which the first stage after burning is dominated by more or less nitrophilous annuals. Then, progressively, shrubs tend to dominate again.

Stage B—Two years after burning, shrubs already occupy 40 percent of the ground cover:

Shrubs: 80% G.C.

Arbutus unedo	20%	G. C.	*Cistus salviaefolius*	5%	G. C.
Quercus suber	5%	" "	*Genista ulicina*	1%	" "
Daphne gnidium	1%	" "	*Cystisus triflorus*	5%	" "
Cistus monspeliensis	5%	" "	*Calycotome villosa*	5%	" "

Annuals cover only 10–20%

Stage C—Ten years after burning:

Trees: Q. suber 45% G.C.

Arbutus unedo	60%	G.C.	*Erica arborea*	15%	G. C.
Calycotome villosa	5%	" "	*Phillyrea media*	5%	" "
Cytisus triflorus	5%	" "	*Daphne gnidium*	5%	" "
			Myrtus communis	5%	" "

These observations on the vegetation of northwestern Tunisia are in perfect agreement with ours in northeastern Algeria, with those of Zeller (1958) on the cork oak forests of northeastern Spain and with those of Sauvage (1961) on the same type of vegetation in Morocco. R. and R. Molinier reach similar conclusions for France. We can, therefore, synthesize the sequences as follows:

Stages	Types of Vegetation	North Africa	N.E. Spain France Italy	
A	*Primeval forest*	Q. faginea	Q. ilex	— Burning
		↓	↓	
B	*Open forest or high matorral*	Q. suber	Q. suber	— Burning
		↓	↓	
C	*Maquis, high matorral*	Arbutus unedo Erica arborea Calycotome, Myrtus, etc.		— Burning
		↓		
D	*Low matorral, "Lande"* Halimium sp. plur. Genista sp. plur. Ulex sp. plur.	Cistus villosus Cistus albidus Cistus monspeliensis		Cistus laurifolius Cistus ladaniferus Cistus populifolius

		Cytisus sp. plur.	Cistus crispus ↓	Cistus salviifolius — Burning
E	*Erme*		Asphodelus microcarpus Urginea maritima Pteridium aquilinum Helianthemum guttatum Helianthemum tuberaria	

***Quercus ilex* forest** (**usually coppice**) **Rainfall 600–800 mm:**— In high rainfall areas, humid and sub-humid Mediterranean climate with rainfalls over 600–800 mm, the sequence on siliceous material is as indicated above, resulting in cork oak open forest and then maquis. On calcareous soils the sequence is different. I give as follows an example I have studied near Narni, Italy and located 70 km north of Rome at the foothills of the Appenine chain.

coordinates: X = 12.5° E; Y = 42.5 N : Z = 300
Elevation ≃ 300 m
Rainfall ≃ 850 mm
Mean minimum T° of January ≃ + 0.5°C
Substratum soft and marly limestones
Soil: Loamy red Mediterranean (Terra rossa) 5 to 50 cm deep

A) 12–18 months after a severe burning. (September 1971).
Layer I: All trees of *Q. ilex* and *P. halepensis* were dead. (Height 4–8 m).
Layer II: Height 0.5—1.5 m—Ground cover 30%
Shrubs were sprouting from the stock:

Q. ilex G. C. < 5%	*Arbutus unedo* G. C. 25%
Pistacia lentiscus < 5%	*Spartium junceum* < 5%
Phillyrea media < 5%	*Erica arborea* < 5%
Q. pubescens < 0.1%	*Satureja sp.* < 5%
Erica multiflora < 5%	*Pistacia terebintus* < 1%

Layer III : Height 0.1 — 0.5 m — Ground cover 80%

Cistus albidus G. C. 30%	*Rubia peregrina* G. C. 10%	*Senecio sp.* 5%
" *salviifolius* G. C. 10%	*Pinus halepensis* 1–5 seedlings per sq. m	*Medicago sp.* pl 20%
" *Smilax aspera* < 10%	*Osyris alba* < 5%	*Satureja sp.* 5%
Lotus sp. 5%	*Dorycnium sp.* 5%	*Vicia sp.* 5%

B) Place similar to the above 2½ years after burnings (August 1971)—less intense burning.

Layer III : Height 0.1 — 0.5 — G. C. 10%
Pinus helapensis (70% dead)
Q. ilex (100% alive, sprouting from the stem)

Layer II: Height 1–2 m — G. C. 60%

Arbutus unedo G.C.	30%	*Q. ilex* G. C.	5%	*Coronilla emerus*	5%
Erica arborea	5%	*Pistacia lentiscus*	5%	*Erica multiflora*	1%
Q. pubescens	1%	*Phillyrea media*	5%		

Layer III : Height 0.1 — 0.5 — G. C. 10%
Seedlings of *P. halepensis* 0.1 per sq. m

Cistus salviaefolius	1%	*Carex halleriana*	1%
" *albidus*	1%	*Satureja sp.*	1%

C) Same type of place as above (B) but not burned

Layer I : Coppice 4–8 m high, 30–40 years old (minimum) G. C. — 100%

Q. ilex G. C.	85%	*Erica arborea*	1%	*Lonicera implexa*	1%
Juniperus oxycedrus	5%	*Pinus halepensis*	5%	*Rubia peregrina*	1%
Arbutus unedo	1%	*Q. pubescens*	1%	*Asparagus acutifolius*	1%
Pistacia lentisus	1%	*Spartium junceum*	1%		

Layers II and III : Practically nothing, thick litter and patches of *Hedera helix.*

The above sequence shows that after burning the soil is covered by more or less nitrophilous annuals which is in agreement with Debazac (1959) and Trabaud (1970). Nearly 3 years after burning the primary vegetation reestablishing itself. This, again, is in agreement with Debazac (1959) and Trabaud (1970), but it would not necessarily have to be so if the burnings were regularly repeated at short intervals of, say, 10 years or less, in which case the vegetation would be changed into a *short pyrophytic vegetation.*

D) The garrigue, on shallow-eroded limestone, with Kermes oak and/or *Cistacea*, *Leguminosea* and *Labiacea* which usually constitute the most degraded stage of the sequence and is called "Tomillares" in Spain, "Phrygana" in Greece, "Batha" in Israel, etc., where the small chamaephytes of the following genera play a major role:

Cistaceaes:	*Leguminoseae:*	*Labiaceae:*
Helianthemum	*Genista*	*Satureja*
Fumana	*Ulex*	*Thymus*
Cistus	*Spartium*	*Lavandula*
Halimium	*Coronilla*	*Teucrium*
	Argyrolobium	*Rosmarinus*
	Various families	
Globularia	*Buxus*	*Posterium spinosum*
Euphorbia	*Helichrysum*	(Eastern Mediterranean only)
Erica	*Phagnalon*	*Brachypodium ramosum*

Lower rainfall areas ($400 < R < 800$ *mm*):—The sequence is similar to that of *Pinus halepensis* (see hereunder pages 269, 270) with the following stages:

Stages	Limestones	Shales marls
A —	Primeval forest of *Quercus ilex*	
Burning ↓ B —	High Garrigue of *Q. coccifera* *Pistacia lentiscus* *Phillyrea*	↓ High Garrigue of *Spartium junceum* *Dorycnium suffruticosum*
Burning ↓ C —	Low Garrigue of *Rosmarinus officinalis* *Erica multiflora*	↓ Sward (Erme) of *Aphyllantes monspeliensis* and *Thymus serpyllum*
Burning ↓ D —	Sward (Erme) of *Brachypodium ramosum* *Asphodelus sp. pl.* and *Labiateae*	↓ (Erme) Sward of *Brachypodium phoenicoides*

Aleppo pine forests:—Aleppo pine occupies 2.8 million hectares in the western Mediterranean whereas the closely related *Pinus brutia* occupies nearly 4 millions in the eastern Mediterranean (Turkey, Cyprus, Syria, Greece, Creta).

As said before, the Aleppo pine is considered a pyrophyte, its seed propagation being favoured by the burst of the cones during or after the fire. As the trees are usually completely burned, or killed, by fire, their heliophilous seedlings find favourable conditions to early growth in the sunshine on bare burned soils, where competition is less severe and nutrients are abundant. This probably explains why the Aleppo pine covers such large areas in the typical semi-arid and sub-humid Mediterranean climates.

The Aleppo pine forests occurred in the past centuries down to the border of the present desert (Le Houérou 1968, 1969). Vestigial trees may still be found in very few places where rainfalls do not amount to more than 200 mm yearly (Le Houérou, ibid.). As a dominant forest tree, it is, however, at present restricted to areas receiving between 300 to 800-900 mm of rainfall, that is to say in arid, semi-arid and sub-humid Mediterranean climates.

I shall divide the Aleppo pine forests here into 3 sequences:

Arid—Semi-Arid—Sub-Humid

1. *Arid* (R < 400 mm)

The Arid Aleppo pine forest is characterized by the presence, and often the dominance, of:

Juniperus phoenica	*Rhamnus lycioides*	*Helianthemum sp. pl.*
Stipa tenacissima	*Rosmarinus officinalis*	*Olea europaea*
		(Le Houérou, 1969)

The sequence is

Stages				
A	Primeval Forest	*Pinus halepensis* *Juniperus phoenicea*	Burning + Grazing	
		↓		
B	Garrigue	*Juniperus phoenicea* *Rosmarinus officinalis* *Cistus libanotis*	Burning + Grazing	
		↓		
C	Steppic Garrigue	*Rosmarinus officinalis* *Cistus libanotis* *Stipa tenacissima*	↘	— overgrazing + burning
		↓	↓	
D	Steppe	*Stipa tenacissima* *Artemisia herba alba*	*Poterium spinosum* (East Mediterranean)	— overgrazing + burning
		↓	↓	
E	Steppe	*Artemisia herba alba* *Poa bulbosa*	*Artemisia herba alba* *Poa bulbosa*	— overgrazing
		↓	↓	
F	Erme	*Paganum, Thapsia,* *Poa*	*Poa bulbosa* *Peganum harmala*	

2. Semi-Arid (400 < R < 600 mm)

The semi-arid Aleppo pine forest is characterized, in addition to the above species, by the presence of:

Quercus ilex	*Juniperus oxycedrus*
Pistacia lentiscus	*Phillyrea media*

Ampelodesmos mauritanicum, and other species which are absent in the arid type forest (Le Houérou, 1969; Alcaraz, 1969).

The sequence is:

Stages			
A	Primeval Forest	*Pinus halepensis* *Quercus ilex*	Burning + Grazing
		↓	
B	Garrigue	*Q. ilex* — *Juniperus oxycedrus*	
		↓	

FIG. 12. Same place as Figure 9. Effect of fire on *Quercus ilex.* Branches were killed; vigorous sprouts grow from the stem (epicormic shoots) and the base of the main branches.

FIG. 13. Differential effect of fire on two contiguous trees of *Quercus ilex* and *Pinus halepensis: Quercus* is regrowing—*Pinus* is dead.

C	Open Garrigue	*Juniperus oxycedrus* *Cistus villosus* *Rosmarinus officinalis*	
D	Woody Pseudo Steppe	*Rosmarinus officinalis* ↓ *Cistus villosus* *Ampelodesmos mauritanicum* ↓	*Poterium spinosum* (East Mediterranean) — overgrazing
E	Erme — Sward	*Poa bulbosa-Ferula-Thapsia*	*Poa bulbosa*

3. *Sub-Humid* (600 < R < 800 mm)

In addition to the above mentioned species, this type differs from the semi-arid by the presence of:

Pistacia terebinthus	*Arbutus unedo*	*Staehelina dubia*..	*Cytisus triflorus*
Colutea arborescens	*Viburnum tinus*	*Genista tricuspidata*	*Crataegus azarolus*, and others

The sequence is close to the one examined above for the *Q. ilex* forests.

Tetraclinis articulata forests:—*Tetraclinis articulata* is a small tree, 5–10 m high, growing in the semi-arid (400 < R < 600) Mediterranean climate of North Africa where it occupies close to one million hectares, of which ¾ are located in Morocco. Its ecology is similar to that of the Aleppo pine with the exception that *Tetraclinis* is less resistant to cold and is more demanding for air moisture than Aleppo pine.

The sequence is often the following (Le Houérou, 1969; Alcaraz, 1969):

Stages			
A	Primeval Forest	*Tetraclinis articulata* *Ceratonia siliqua* *Olea europaea* ↓	Burning
B	Garrigue	*Tetraclinis articulata* *Quercus coccifera* and *Chamaerops humilis* ↓	Burning + Browsing
C	Open Garrigue	*Quercus coccifera* and *Chamaerops humilis* ↓	Burning + Browsing
D	Degraded brush-like Garrigue	*Chamaerops humilis* and/or *Artemisia herba alba* and *Asphodelus microcarpus*	

CONCLUSIONS

The Mediterranean vegetation is very sensitive to fire owing to the nature of the climate. Man burned the forest for several thousands of years in search for better pastures and cropland. At present, fire destroys about 200,000 ha yearly of forest and shrubland in the Mediterranean, causing a $50 million annual loss. This is why the Mediterranean vegetation is dominated by pyrophytes; we, therefore, do not know what really is the "climax" vegetation. Some species which are extremely susceptible to fire (for instance *Laurus nobilis* which burns like gasoline) are now very rare and may even have totally disappeared. What was their role in the Mediterranean vegetation prior to man's interference?

Some points are very clear due to the very numerous vegetation surveys, mainly in the western Mediterranean (the bibliography amounts to several thousand articles).

Fire affects vegetation: in its structure—in its composition—in its productivity.

The non-burned forests, or at least those which have not been burned for 50–100 years or more, have a very simple structure with only trees, lianas and herbs.

When fire occurs periodically, the structure becomes more complex and includes trees, tall shrubs, low shrubs, herbs and forbs. Whenever fire occurs very often, the structure becomes again simpler with only low shrubs, herbs and forbs (annuals and perennials The most degraded stages become very simple with only a herb-layer.

The effect of fire on the botancial composition is also rather clear. The number of species and the proportion of annuals increases with the frequency of fires. The productivity of the vegetation decreases inversely with the frequency of fires for two main reasons: a) Pyrophytic vegetation is potentially less productive than non-pyrophytic, and b) The soil erosion following frequent fires decreases water availability and fertility and consequently productivity.

Finally, as Kuhnholtz-Lordat (1939, 1945, 1952, 1958) pointed out, the basic fact is fire periodicity and intensity in respect to fire resistance of the various species which enables, or not, any given species to reproduce and propagate.

Fire is practically unused in modern management of forests, shrublands or grasslands within the Mediterranean.

However, Liacos, in Greece, (see paper in these Proceedings) has experimentally shown that prescribed burning can be used with benefit in the management of such fire sensitive vegetations as Aleppo pine forests.

LeHouerou (unpublished) used it also in Tunisia in the management of tall fescue sown grasslands.

Other experiments on fire and vegetation are underway in southern France since 1966 (see Trabaud, 1970 a and b in these Proceedings.)

The same Trabaud has developed in Montpellier a new and very original method for objectively assessing fire hazards in vegetations. This method makes it possible to map the flammability of the various Mediterranean vegetation types. These large scale maps (1/20.000) are already being successfully used by firemen in southern France in planning fire-fighting. However, unfortunately, no scientific paper has yet been published on this methodology (Trabaud, personal communication).

These recent experiments and studies have already brought about a much better understanding of the phenomena involved.

One may, therefore, hope that the causes and effects of fire on the Mediterranean vegetation will soon be more clearly understood as well as fire behaviour in various types of vegetations and climatic conditions.

Wildfire could then be mastered. One may furthermore hope that prescribed burning will soon be used for prevention of wildfires and vegetation management. However, this will still certainly need much experimental and psychologic action in order to convince those who are responsible for forest management in the Mediterranean.

International cooperation such as carried out for so many years by the Tall Timbers Research Station has already helped enormously in the understanding of this very complex subject.

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GLOSSARY

Primeval forest: Little degraded or disturbed forest, not necessarily the climax.

Matorral: Chaparral: evergreen sclerophyllous broad leaved shrubby vegetation. Oaks often dominant.

Maquis: High dense matorral, usually occurring in high rainfall areas and on deep, more or less acid soils.

Garrigue: Low, open mattoral, very often on limestone or degraded "Terra Rossa," shallow soils, edaphically dry.

Erme: Low herbaceous more or less open vegetation with a very marked seasonal development rythm, usually constituted of unpalatable dominant species like *Asphodelus, Peganum, Ferula,* Thistles, etc.

Tomillares, Phrygana, Batha: Low open garrigue, very degraded with dominant chamephytes: *Thymus, Helianthemum, Fumana, Globularia* etc.

Vicarious: Physiognomically and ecologically similar vegetations made up of spices having a similar shape and biology but taxonomically different and occurring in distant areas having similar climate for instance Mediterranean Basin and California.

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