Changes and disturbances of forest ecosystems caused by human activities in the western part of the mediterranean basin

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Abstract

The development of socio-economic activity over the past ten years in the Mediterranean region has induced severe changes in the main natural forest ecosystems.

In the *northern Mediterranean*, rural depopulation has accelerated since the end of the second World War, particularly since the establishment of Common Market agricultural policies, and led to an under-utilization of species causing a strong *biological resurgence of the forest*, even at high altitudes. This means that, at the present time, the extension of *expansion model* coniferous forests is favored by their capacities for spatial, biological and ecological selection. Along with this, the under-utilization of sclerophyllous (*resistance model*) and deciduous (*stabilization model*) oak coppices has led to the establishment of new forest structures and architectures which are notably different from the main climatic groups defined up to now by phytosociological and synchronic methods. Two new forms of disturbances have appeared:
- increasingly important wild fires have replaced disturbances caused by burn beating and are at the origin of the very *strong spatial and temporal heterogeneity* of current forest species.
- In addition, the geographical continuity of the main groups of same-aged sclerophyllous and deciduous species, due to their non-use over the past ten years, has accelerated a *phytosanitary imbalance* by an increase in the action of *pests*.

In the *southern Mediterranean*, particularly in North Africa, demographic pressure and grazing have widely disturbed the main forest ecosystems which show a continual regression of their surface. Many forest tree species with a low spatial and biological selection, such as Mediterranean firs and black pines (*Pinus nigra* subsp. *mauritanica*), are threatened with extinction, as are the deciduous oak forests which, considering the climatic stress and edaphic constraints, are permanently in a state of imbalance. Human disturbances induce a complete modification of structures and architectures tending towards the installation of *simplified forest models* (trees-grasses) where tree regeneration is nearly impossible. The sclerophyllous coppices well-adapted to stress are also threatened by shorter and shorter cutting cycles and by the high usage of tree canopies for grazing.
- The forest understory structures have witnessed a decrease in their characteristic sylvatic species and the *matorralization* of most of the forests can be seen by the replacement of typical forest groups by *preforest groups* (*Tetraclinis* forests, Aleppo pine forests).

- New geopedological constraints linked to the removal of the surface soil layer combined with regular climatic stress (duration of drought periods) strongly decrease the *resilience* of these ecosystems which are under continual pressure (*unbalanced models*).
- In diverse regions, particulary in semi-arid bioclimates, hyperdegradation affects the shrub cover which disappears for a time in favor of perennial grasses (*forest steppization*): *Andropogon* div. sp., *Ampelodesmos*, *Stipa* div. sp.

In all bioclimatic groups, the increase in grazing pressure throughout the southern Mediterranean ecosystems can even lead to the total disappearance of perennial species from the ecosystem with the exception of the dominant tree. Regardless of the altitude or ecosystem, invasive therophytes are then the only plants to occupy the understory and indicate hyperdegradation (*forest therophytization*).

Introduction

The Mediterranean forests are fragile natural ecosystems already greatly disturbed by a multitude of different utilizations whose origins date back to the beginning of the Neolithic period. The disturbances varied in frequency and intensity throughout the ages in relation to human demography, which determined how their area progressed or regressed (Quézel & Barbero 1989).

Until the beginning of the Industrial Age, forests in the Western part of the Mediterranean region were used by man in basically the same way in the north and in the south, but, during the last quarter of the 19th century, the northern Mediterranean peoples became aware of the importance of restoration and instigated large reforestation operations. However, the true divergence between the utilization of forests in the north and south dates from the end of World War I and, since that time, a radically different development can be observed:

A. in the north, the concentration of farming in the plains linked to mechanization caused an initial phase of abandonment of farmlands and the spectacular development of high forests and stands of conifers such as *Pinus halepensis*. Nevertheless, coppices were still traditionally used for communal wood cutting and garrigues for grazing. This situation continued until the end of World War II (Barbero & Quézel 1989). Following this date, two distinct periods can be seen:

a. the first is linked to the generalized use of fossil fuels, which caused coppices to be left uncut, and to rural depopulation, already significant at the end of World War I, which increased at least in France and Italy.

b. the second is the result of the more recent Common Market agricultural policies (P.A.C.) which accelerated the disappearance of small farms in the 1960s and thus led to the abandonment of rural areas, which were rapidly recolonized by vegetation (Barbero & Quézel 1989). This tendency towards rural depopulation increased during the next decade with agricultural quotas and inevitably brought about a positive development of forested areas.

B. in the southern Mediterranean, however, forests represent an environment which has always been used by man for survival, and there has even been an intensification of the use of forest resources far beyond their regenerative capacities over the past decades due to the high demographic growth in these countries. These forests are used either directly for fuel or lumber, or indirectly as grazing lands for animals for example in the 'dehesas' type system (sylvo-pastoral system with sparce *Quercus* and perrenial grass layers) in some countries such as Spain (Joffre 1987) or for grains and leguminous cultivation planted under the forest canopy where the herd uses the remaining culms and plants after harvest (silvo-pastoral agricultural system).

Structural characteristics of mediterranean forest ecosystems

The classic concept (Braun-Blanquet 1936; Rikli 1943) was to consider that sclerophyllous oak forests with *Quercus, Ceratonia* and *Olea* and pine forests with *Pinus halepensis, P. mesogeensis* and *P. pinea* were the only typical Mediterranean forests. In fact, this concept has changed considerably as currently (Abi-Saleh, Barbero, Nahal & Quézel 1978) Mediterranean forests are considered to be those forests subject to a Mediterranean bioclimate, which is in turn subdivided in several bioclimatic groups depending on the value of Emberger's pluviothermic coefficient (1936, 1955) as well as the duration of summer drought (Nahal 1981), which represents a regular, but variable phenomenon related to the Mediterranean climate type.

The bioclimatic particularities are also reflected in the pedogenesis of the main Mediterranean edaphic complexes with, for example, typical brown forest soil in the humid and subhumid bioclimates of the northern Mediterranean, fersiallitic brown soils, especially in subhumid bioclimates forests, and red fersiallitic soils in the semi-arid and particularly in arid bioclimates.

The intense degradation due to human occupation of most forests since the Neolithic period caused a significant erosion of Mediterranean forest soils, disturbing their geochemical cycles and accentuating the high ecological constraints most of the forest species are subject to, whether for dissemination or for maintenance. Therefore, the recognition of the relationship between soil and substrate (geopedology) is a necessary step in the evaluation of the effect of constraints on the ecophysiology of major forest species.

Finally, disturbances of varying frequencies and intensities linked to the action of man and herds, but also to irregular natural phenomena (pests, wind-fallen wood, wild fires) are, among others, the essential historical factors defining the state of forest structures and architectures (Tomaselli 1981).

From the point of view of their present day value, forests or, more precisely, wooded struc-

tures correspond to three dynamic groups of differing significance in the Mediterranean basin (Fig. 1).

(1) actual sclerophyllous forest formations which represent relatively stable ecosystems, despite an ever-present anthropic activity, with a flora containing characteristic species linked to these ecosystems on mature soil. Except in special ecological situations, they constitute climatic plant communities and ends of successional series. Forest mesosclerophyllous species, such as *Viburnum tinus, Phillyrea latifolia, Osyris quadripartita*, characterize these formations.

(2) pre-forest formations, by far the most common, represent in fact two distinct groups. In per-humid and sub-humid bioclimates, they are essentially composed of plant communities which are highly man-influenced, making up transitory phases in a succession towards true forests where mesoxerophyllous species dominate: *Phillyrea angustifolia, Rhamnus* sp.,
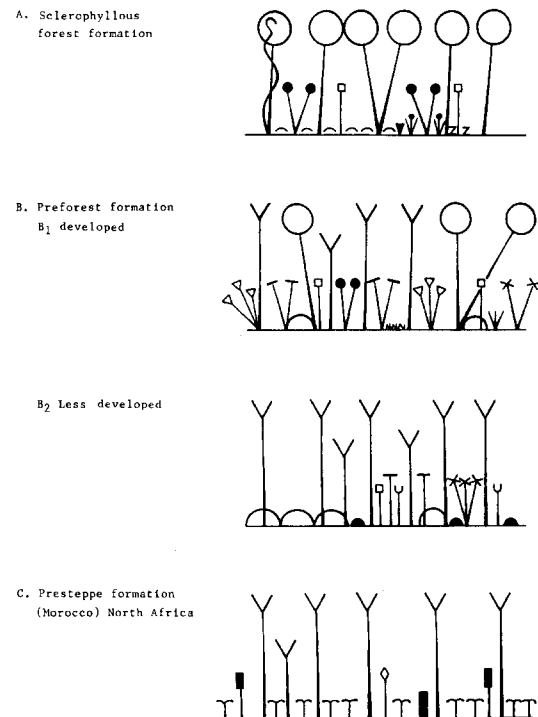

Fig. 1. Characterization of three Mediterranean forest groups. (For all figures, legends after Fig. 4).

Pistacia terebinthus, Arbutus unedo. However, in semi-arid bioclimates as well as in particular ecological situations in the other types of bioclimates (permanent formations, or especially edaphic climax), they represent communities more of the wooded matorral type, blocked under current ecological conditions where xerosclerophyllous species thrive: *Quercus coccifera, Pistacia lentiscus, Chamaerops humilis.*

(3) finally the pre-steppe forest formations (Abi-Saleh, Barbero, Nahal & Quézel 1976), widely distributed in southern Spain and North Africa, are open tree formations whose herb layer contains almost no pure forest species, but are invaded by perennial species with an affinity for steppe environments whose soils are not highly developed and which are often truncated at the surface. Presteppic formations can be divided into two groups. In an arid and occasionally a lower semi-arid bioclimate, they develop especially in temperate and warm thermic variants and are thus in contact with steppe formations conditioned by hydric constraints. This situation can be observed primarily in southwestern Morocco, where, for certain biogeographic and historical reasons, a very particular flora survived which forms forests with *Acacia gumifera* and *Argania spinosa.* On the other hand, in cold, very cold, and extremely cold thermic variants, this vegetation with trees occupies the highest altitude, where it comes into contact with high-altitude steppic formations. Under this thermic stress, a particular vegetation with *Juniperus* sp. and *Ephedra* sp. arises, which is well-represented in the Maghreb (Quézel & Barbero 1981), but poorly known. In situations of periodic climatic stress and over-utilization by man, this vegetation cannot develop.

Dynamic characteristics of forest models

It is possible to distinguish three general models of actual spatial occupation from the point of view of the response functions of the principal biological components of the main Mediterranean forest ecosystems to climatic stress, geopedological constraints and natural or anthropozoogenic disturbances (Barbero & Quézel 1989).

The expansion model

This model is essentially represented by conifers such as *Pinus halepensis, P. mesogeensis, P. sylvestris, Cedrus* and, to a lesser extent, some races of *Pinus nigra* (*P. clusiana* in Spain) which feature a good biological selection coupled with an early fertility (10 years, on average), a high production of seeds which resist pests and other predators. Within the model (Table 1), two large categories can be distinguished:

(1) The generalist Conifers. They are characterized by protein-rich light-weight seeds little subject to attacks by parasites which guarantee a high rate of survival in different types of environments. These conifers can adjust their stands to favorable and unfavorable trophic conditions as well as to stational and general climatic stress due to an excellent ecological selection. In addition, the adaptation of seeds to anemochory is an essential factor in their high spatial selection. The Aleppo pine (*Pinus halepensis*), *P. sylvestris* and *Cedrus atlantica* can be added to this group.

(2) The opportunist conifers. The dissemination capacity and thus the spatial selection is always well-marked in this group, but it is limited by the ecological requirements of these species (water requirements for seedlings, incompatibility with calcareous soils). Here the following trees can be mentioned: *Pinus mesogeensis, P. pinea,* and also *P. nigra* whose ecological selection capacity is less strong than that of the generalist conifers.

These conifer stands are well-adapted to climatic stress as, for example, for the Aleppo Pine in the western Mediterranean basin, the length of the summer drought period can vary from 1 to 6 months depending on the bioclimate. The pine forests can also withstand all types of edaphic

Table 1. Expansion model.

Generalist Conifers (*Pinus halepensis, Cedrus atlantica*).
Opportunist Conifers (*Pinus mesogeensis, P. clusiana, P. pinea*).

Good biological selection:	– Early fertility (at 10–15 years old). – High regular production of cones per individual and seeds per cone. – Light-weight resistant seeds, thick cuticle, high in protein.
Good ecological selection:	– Development on all substrate types (limestone, silica, marls) and in all geopedological structures (lithosoils, rendzinas, rankers, brown forest soil) in full sunlight. – High resistance to hydric stress (1 to 6 months) (early stomatal blockage).
Good spatial selection:	– Wind pollination essential factor in dissemination.
Interspecific competition:	– Low compared to sclerophyllous and deciduous leaved species. – High colonization of presteppe and preforest environments and competition by exploitation.
Stands:	– Essentially preforest in nature, rapid growth, high biovolume occupation, large spatial-temporal heterogeneity of structures and architectures, the youngest are composed of highly inflammable and combustible species.
Disturbances:	– Rapid recovery of environment after cutting or fires by seeds and stump-resprouting for some components. Four or five decades are necessary to reconstitute a typical pine preforest. Resilience nonexistent if the species associated with the pine forest are not stump sprouting, average if they are stump sprouting and contribute to the dynamic acceleration. Increase in floristic richness and diversity if disturbances are irregular on the same plot, decrease if they are regular and frequent.

constraints, from lithosolic soils, protorankers and protorendzinas to the most developed soils where the main limiting factor to their expansion is competition with better-adapted deciduous trees (Abbas *et al.* 1985, 1986).

The strong spatial selection shows the high heterogeneity of stands and thus the age classes, which demonstrates the excellent dynamism of this model where mechanisms of competition by exploitation play an important role. Young individuals have a rapid growth and thus a high production of biovolume which guarantees a good interspecific competition in dense stands of shrub lands where 'r' strategy species with a high resprouting ability dominate.

From the point of view of resistance to disturbances, these expansionist conifers are well adapted both to human activities (recolonization after cutting, compatibility with understory graz-

ing) and to natural occurrences (good regrowth after fires by regeneration from seed-bearing stands left undamaged or from windfallen wood which creates open canopies favoring the stand's uneven aged distribution) (Abbas, Barbero & Loisel 1984).

This particularities are at the origin of the large spatio-temporal heterogeneity of structures and architectures according to the following models:
(1) young stands:
  a) from recent colonizations in sites which have undergone repeated disturbances by fire which was able to eliminate almost all of the stump sprouting species by its regularity. *Cistaceae, Fabaceae* and *Lamiaceae* dominate in the understory. After fires, there is no resiliency as the ecosystem is entirely destroyed, but the environment's recovery speed is high due to the large

regeneration by seeds from the initial members of the stand.

b) from recent colonization by *Pinus* installed after fires but whose structures are dominated by stump sprouting species: Pine forests with kermes oaks, *Rhamnus* div. sp., *Pistacia*, *Myrtus*, *Osyris*. After disturbances, there is an average resiliency and the recovery speed is very high. These two groups are composed of highly inflammable and combustible species which are thus very vulnerable to fires.

(2) developed stands:
where disturbances by fires are not apparent and deciduous trees can resprout from stumps or from seeds spread by ornithochory. In these communities, species whose inflammability is low or non-existant are present which makes selective clearing necessary for their management.

Resistance model

Except for certain conifer stands such as *Tetraclinis* forests, this model (Table 2) contains most of the sclerophyllous deciduous trees (*Acacia, Argania, Pistacia* div. sp., *Rhus* div. sp., *Olea, Ceratonia, Quercus* div.sp.). They are characterized by a high ecological selection and thus a strong ability to adjust to summer drought lasting from 1 to 6 months depending on the bioclimate. At least some of them, such as the holly Oak (*Quercus ilex*), also show a high climatic plasticity of the thermic type. *Quercus rotundifolia* in Morocco, for example, occupies most of the bioclimatic groups from semi-arid to perhumid and their variants from extremely cold to temperate and even hot (Barbero, Quézel, Rivas-Martinez 1981). This adaptation to climatic stress is associated with survival potential after disturbances, particularly on substrates ranging from jointed parent rocks on limestones, dolomites and siliceous rocks to typical brown forest soils. These adaptative particularities can probably be paralleled with the high polymorphism of these stands (Yacine 1987).

The biological selection of these species is average. In fact, the generation time is long and four to six times higher than that of the preceding model (fertility age: 40 to 60 years on average). Moreover, seed production is irregular and long-distance seed spreading is low and animal-dependant. Most of the grains are also subject to predation and attacks by parasites.

These features explain the low spatial selection of these sclerophyllous stands. The installation of young individuals is generally produced by birds within the undisturbed stands of the preceding expansionist model.

However, once it is achieved, the interspecific competition capability of these K strategy species whose life-span is long (several centuries) gives them the ability to entirely replace *Pinus* species. Comparative studies of production of old stands of *Pinus halepensis* (Abbas 1986) and *Quercus ilex* (Miglioretti 1987) demonstrate the increasing advantage of the *Quercus ilex* strategy with age.

Resistance to disturbances is optimal and naturally results from the high capacities for ecological selection of these species when they are installed.

Whether human-induced (clear cutting of coppices and high forests, pruning for cattle food) or caused by wild fires or wind-fallen wood, these disturbances provoke an extremely rapid resprouting and guarantee a rapid occupation in biovolume.

This resprouting ability (Miglioretti 1987) is all the more noticeable when the edaphic constraints are strong and the disturbance is repeated. These disturbances, (Fig. 2) whose frequency and intensity have varied in space and over time, condition a very high geographic heterogeneity of the structure and architecture of Mediterranean sclerophyllous stands. It can be seen in the homogeneous physiognomy of landscapes in fire damaged zones where the root system has a strong response to disturbances (Kummerow 1981) or in forested areas with short rotation periods (coppices) where a dominant species occupies the space (*Quercus coccifera, Q. ilex*) or in undisturbed vegetation where tall sclerophyllous forests currently comprise exclusive sclerophyllous

Table 2. Resistance model.

Sclerophyllous oaks (*Quercus ilex, Quercus rotundifolia*) *Ceratonia siliqua, Olea oleaster, Argania*, etc. or Conifers (*Tetraclinis articulata*).	
Average biological selection:	– Late fertility (at 40–60 years old). – Irregular acorn production. – Heavy-weight seeds with relatively thin cuticle averagely rich in water.
Ecological selection:	– Installation on evolving soils (rendzinas, brown rankers) in forest and preforest structures. – High resistance to hydric stress (1–6 months) and thermic stress depending on species (*Quercus rotundifolia*).
Low spatial selection:	– difficulties in seed spreading (barochory).
Interspecific competition:	– High compared to preforest conifers which are eliminated from the stands. – Low compared to deciduous species with better height growth.
Stands:	– High spatial and temporal heterogeneity of often mosaic structures and architectures directly linked to disturbances from the lithosoils where stumps remain in plate due to high intensive disturbances to the brown forest soils where disturbances are older (80 years or more). – Reconstitution of sclerophyllous forest stands in preforest groups. – Low architectural heterogeneity of evolved stands and high floristic richness (few forest species) due to shade.
Disturbances:	– Very rapid recovery of environment after cutting or fires by stump sprouting. – Sprouting increases along with increased repetition of disturbance. – Resilience is high for some ecosystems (*Quercus coccifera* oak forests, *Chamaerops* shrubland) and average for others (*Quercus ilex* oak forests – 70 to 80 years depending on site). – Adaptative strategies of sclerophyllous species and regularity or irregularity of disturbances have created sclerophyllous landscapes which occupy all the successional stages due to a remarkable adaptation to stress and constraints (low trophic requirements). – Irregular disturbance is a factor in the increased floristic and architectural diversity and richness. It leads to the substitution of mesophilous sclerophyllous species by xerosclerophyllous species. – Regular disturbances simplify stratification and diversity and cause a selection to occur in the specific initial pool by favoring dominant species.

forest species (*Viburnum tinus, Phillyrea media, Ruscus aculeatus*) and liana (*Smilax aspera, Lonicera implexa*).

The resistance model is thus by far the best one adapted to stress, constraints and disturbances, particulary to fires (from burn beating to wild fires) which by their repetitive nature have favored the installation of other sclerophyllous species in these ecosystems, such as *Pistacia, Phillyrea, Arbutus* or R strategy brush such as *Cistus, Calycotome, Ulex* and *Rosmarinus*.

Depending on the adaptative strategies of most of the members of the sclerophyllous forests in regard to disturbances (Margaris 1981) and in the consideration of the current development of their structure in undisturbed situations, the problem of secondary extension of sclerophyllous stands can be raised, at least in the northern Mediterranean. This is essentially due to anthropozoo-genic disturbances which have favored sclero-phyllous species over deciduous species. This hypothesis can be supported by palynological
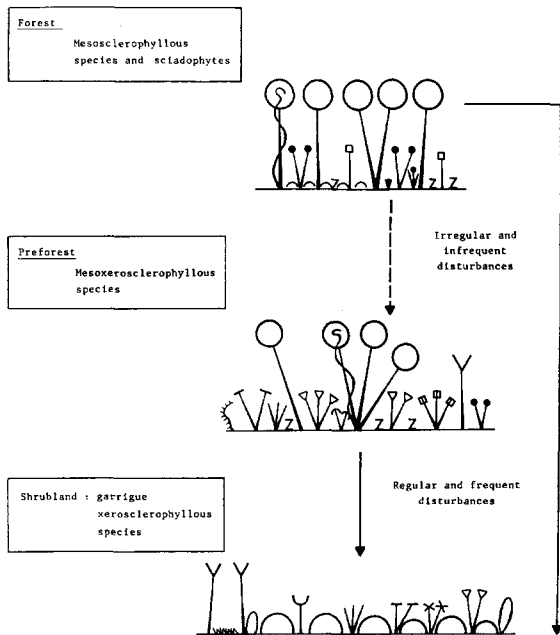
Fig. 2. Effects of regular and irregular disturbances on Quercus ilex forests.

studies (Pons 1981) as well as pedoanthracological studies (Thinon 1978) which reveal that the extension of sclerophyllous species occurred along with the development of human activity, particulary the destruction of *Quercus pubescens* and *Quercus faginea* forests located on shallow soils. It is also confirmed by the production balances on the level of mixed stands of *Quercus pubescens* and *Q. ilex* (Miglioretti 1987). In the same stations as *Quercus ilex*, *Q. pubescens* invests in height and diameter growth through early natural pruning, while *Q. ilex*, which produces numerous branchlets and a high leaf biomass, is rapidly dominated.

After disturbances in sclerophyllous stands, resilience is high or average depending on the stand and recovery speed is high due to the extraordinary capacity to resprout from stumps while, as we have seen above, the generation time is very long.

Stabilization model

This combines forest species with a low biological selection who have the highest fertility age

(Table 3). As in the preceding model, seed production is high, but irregular and there are many obstacles to spreading their heavy diaspores. Animals transport them in an irregular fashion. Parasites and predation are high and, once installed, young seedlings are less resistant than those of sclerophyllous species in open plots.

Ecological selection of this model is low, as seen by the bioclimatic requirements of the main species which remain confined to subhumid, humid and per-humid bioclimates in stations where drought periods can last from 1 to 3 months, but which are often compensated by the trophic quality of the substrates (deep soils with a good ionic and hydric balance). The adaptation to extreme constraints is thus not very marked.

Low biological and ecological selections thus limit the extension of the characteristic stands of these species, such as the deciduous oaks (*Quercus pubescens*, *Q. faginea*, *Q. canariensis*, *Q. afares*) as well as conifers such as the Mediterranean fires (*Abies pinsapo*, *A. marocana*, *A. numidica*) and different Mediterranean races of *Abies pectinata*.

Most of these species belong to the K type and invest in long lives and a continual biomass production spread out over several centuries, giving them a good capacity to compete in mixed stands, as well as in association with sclerophyllous species.

On the stand level, they have a low spatial heterogeneity, but a high architectural heterogeneity (vertical stratification) and mechanisms of competition by interference are particularly strong. In the absence of disturbances, this model shows a high homeostasis.

However, resistance to disturbances is much less well marked than previously. If most of the constituent species of these stands reseed or resprout following irregular disturbances, they are not at all comparable to sclerophyllous species. Moreover, this model is poorly adapted to regular disturbance cycles of high frequency and intensity (fires, cutting).

These characteristics can explain the replacement of deciduous species by sclerophyllous species in different parts of the northern Mediter-

Table 3. Stabilization model.

Deciduous oaks (*Quercus pubescens, Q. faginea, Q. canariensis, Q. afares*).	
Low biological selection:	– Very late fertility (at 70–80 years old).
	– Irregular acorn production.
	– Very heavy seeds, rich in water with a very thin cuticle.
Low ecological selection:	– Almost exclusive installation on brown forest soils.
	– Regereration in understory or in preforest ecosystems with deciduous *Sorbus, Acer, Fraxinus.*
	– Low resistance to hydric (1 to 3 months) and thermic stress.
Low spatial selection:	Difficult seed spreading (barochory).
Interspecific competition:	High compared to preforest conifers (*Pinus sylvestris*) and sclerophyllous oaks (low sprouting, but better height and diameter growth, competition by interference).
Stands:	Low spatial heterogeneity of structures.
	High architectural heterogeneity and high specific richness in forest species.
Disturbances:	– Slow recovery of environment after cutting and fires, low sprout production. Low resilience. 90–100 years or more to reconstitute potential ecosystem.
	– Species disappear if disturbances are highly frequent and strong, replacement by sclerophyllous species if disturbances occur. Irregular disturbance is a factor which increases the overall floristic richness and decreases the richness of forest species.

ranean region due to high anthropozoogenic activity and not necessarily due to climatic changes. Nevertheless, this model presents an optimal protection against wild fires. This is due to the very complex stratification of mature stands: major and minor tree layer; important, less dense brush layer; reduced herb layer. In addition, most of the constituent species of this model are not readily inflammable or combustible.

After repeated disturbances, resiliency is low and recovery speed is average, which represent obstacles to the spatial extension of this model coupled with the fact that the generation time is much longer than that of sclerophyllous species.

Evaluation and development of forested areas

It is not an easy task to exactly evaluate the surface area currently occupied by forests in the Mediterranean region. An initial evaluation was made by the F.A.O. (1963), but it should be used with caution as the surfaces were evaluated for countries as a whole, even if part of their surface area was not included in the Mediterranean climate; in addition, forests and maquis-garrigues were included together. A second evaluation made by the F.A.O. (1976) and resynthesized by Le Houerou (1980–1981) theoretically took into account the portions in each country subject to a Mediterranean climate, but the bioclimatic criteria used were problematic as they only included zones receiving more than 400 mm annual rainfall, which entirely excludes arid tree formations, which should not be excluded from the Mediterranean bioclimate and placed in the category of 'steppes and deserts'. One of the present authors (Quézel 1985) approximately estimated these surfaces based on bioclimatic criteria and the data are shown in Table 4 along with the total surface area of each country.

This table makes possible to compare the North African forests with those in northern

Table 4. Surfaces of countries, part of countries included in the mediterranean region and forested areas. Note: surfaces are in thousands of km^2.

	Total surface	Mediterranean surface (Quezel 1985)	Mediterranean surface (Le Houerou 1980)	Forested and garrigues areas (Le Houerou 1980)	% of forested mediterranean area (Le Houerou 1980)
Portugal	91	70	56	31	55
Spain	505	400	317	92	29
France	551	50	87	42	48
Italy	300	200	117	34	29
Lybia	1759	100	31	5	17
Tunisia	164	100	81	5.3	6.5
Algeria	2387	300	92	24	26
Morocco	727	300	137	51	37

Mediterranean countries. The values shown should be considered with caution, but they are at least interesting as an initial approximation. Again it should be emphasized that maquis and garrigues are included in the stated surfaces, except for some countries. Thus, due to criteria used by the different national organizations, it is necessary to add the often significant surface areas of 'diverse garrigues and maquis' to the evaluations indicated above. This is particularly the case for Spain (100 000 km^2).

Nevertheless, this evaluation is instructive as it very clearly illustrates the highly different situations which exist between the northwest and the southwest Mediterranean where the percentages of wooded areas can be estimated at approximately 35% and 6% respectively. These values are somewhat overestimated for North Africa, in Algeria and Morocco particularly, as large matorral-type grazing lands and wooded areas where only trees are present, the other layers having been removed, are included in the forest statistics. The trees are definitely threatened in the long run by hyperdegradation which strips the stumps.

The history of the development of the forest canopy in the western Mediterranean region is currently fairly well-known and phytogeographers are able to define the potential distribution area of the main species, i.e. the areas they are likely to occupy in relation to ecological and biogeographic criteria, without any human intervention. In fact, this means evaluating the situation which should have existed seven or eight thousand years ago, before the action of man became important.

The civilizations which preceded the Christian era extensively mistreated the North African forests whose degradation continued until the 16th century with diverse fluctuations due to wars and major epidemics. The relative stagnation of the populations combined with the progressive installation of a type of land management based, as Kunholtz-Lordat demonstrated as early as 1949, on the rational sharing of space between farmlands (ager particulary of grains in North Africa), pasture lands (saltus) and forests (sylva) greatly contributed to the creation of a certain stability in the main Mediterranean landscapes. This stability lasted until the middle of the 19th century. By this time at least half of the forests had been destroyed (Quézel 1976).

In fact, from this period, a clear discrepancy appears between the two sides of the Mediterranean due to a very different utilization of space: the predominance of grazing in the south and agriculture in the north. The harm caused by deforestation on the part of the European countries led to the large reforestation projects carried out during the last quarter of the 19th century. The difference between the north and the south has steadily increased following the rural depopulation caused by industrialization in Europe, as well as by the wars in the 20th century.

North Africa (Maghreb)

Two examples make it possible to clearly grasp this recent development. First of all, though unfortunately far less than the current reality, Boudy (1948) estimated the difference between forested areas and potential sites of the main forest species in the Maghreb, which well illustrates the already important regression of the north African forests at that time (Tables 5a and 5b).

In terms of total surface, forested areas represented approximately 4 100 000 hectares in 1948 (approximately 3 300 000 in 1973) compared to 13 500 000 potential hectares in Morocco and 2 300 000 compared to 7 000 000 hectares in Algeria in 1948, i.e. less than 30% for both countries.

We were able to obtain the following estimate from forest reports of surface areas currently de-

forested per year in Morocco (Benabid in lit.) (Table 6).

These values clearly show the regression of the forest assets in Morocco. For all of North Africa this can be estimated at 3% per year on average,

Table 5b. Mean decrease of forested areas in Morocco (in 1000 ha).

	Decrease per decade
1960 ≃ 4000	
1965 ≃ 3800	− 1%
1970 ≃ 3580	
1975 ≃ 3200	
1980 ≃ 2850	− 2%
1985 ≃ 2330	
1990 ≃ 1900	− 4%

Table 5a. The regression of North African forests (in thousands of hectares, according to BOUDY (1948)).

Species	Climatic surface area	Actual surface area (1948)	% of decrease
ALGERIA			
Pinus halepensis	1290	600	54
Pinus pinaster	13	13	0
Tetraclinis articulata	521	130	75
Juniperus phoenicea	502	300	57
Cedrus atlantica	128	30	71
Quercus suber	1192	440	62
Quercus rotundifolia	1807	600	67
Deciduous Oaks	82	60	27
Other Deciduous Species	157	10	94
Secondary Species (*Olea − Ceratonia −* etc.)	1296	100	92
MOROCCO			
Pinus halepensis	150	65	56
Pinus pinaster	30	15	50
Tetraclinis articulata	860	740	60
Juniperus phoenicea	900	200	78
Cedrus atlantica	456	115	75
Juniperus thurifera	327	31	91
Other Conifers	30	14	52
Quercus suber	530	367	76
Quercus rotundifolia	2437	1345	37
Deciduous Oaks	50	24	52
Argania apinosa	2128	700	67
Olea-Lentiscus Formation	3624	500	86

Table 6. Annual estimations of deforested areas in Morocco.

Observed cleared land	6000 ha/year
Legal and illegal cutting	15000 ha/year
Fires	3000 ha/year
Representing:	
Quercus suber	600 ha/year
Quercus rotundifolia	450 ha/year
Diverse conifers	320 ha/year
Tetraclinis articulata	420 ha/year
Argania spinosa	170 ha/year
Secondary species	140 ha/year
Cedrus atlantica	18 ha/year
Overall total	24000 ha/year

which demonstrates the alarming nature of the situation and the threat of extinction which weighs on some species: *Pinus nigra mauritanica*, *Abies marocana*, *A. numidica*, etc.

Mediterranean France

In Mediterranean France (Table 7), however, the estimate of the development of surfaces in hectares of the major forest species in the Provence-French Riviera and Languedoc-Roussillon regions (1904–1907 & 1973–1984) shows a marked progression of most species which can be seen in an increase of 222730 hectares in 80 years, excluding matorrals.

This simple comparison clearly demonstrates the fundamental differences between the current situation in the northern and southern Mediterranean, even if some countries, such as Spain, are actually in a middle position due to their socio-economic situation. This divergent evolution between the northern and southern countries can be seen in the estimate published by Le Houerou (1981) which illustrates the current state of transformations in land use (Table 8). It should be noted that this estimate was made for all the surface areas of the countries considered, not only the Mediterranean regions, which causes a certain disproportion between the surface areas indicated in table 8, particulary for the northern Mediterranean countries. These values demonstrate the significant increase in forested areas (forests and secondary matorral stages) accompanied by a decrease in farmlands in all European countries, while the reverse is true for North Africa. Currently, particulary in Algeria, the change in agricultural policy has caused deforestation to accelerate. The regression of forested areas has been estimated at 20% on average for a decade.

Effects of human-induced disturbances on the main forest ecosystems

On a large scale

The effects of disturbances and lack of disturbance are greatly responsible for the current state of the western Mediterranean forest ecosystems.

Direct and irregular actions, such as illegal tim-

Table 7. Current National Forestry institute totale (1978–1984 Languedoc-Roussillon) and (1973–1978 PACA) of main Mediterranean forest species compared to Daubree's Statistice (1904–07).

	Languedoc – Roussillon		French Riviera		Mediterranean France		Evolution
	1904–1907	1978–1984	1904–1907	1973–1978	1904–1907	1973–1984	
Deciduous Oaks	55975	105896	166982	230618	222957	336514	+ 113557 ha
Quercus ilex	157377	140156	125681	83009	283098	223165	− 59893 ha
Quercus suber	5800	5000	37730	33632	43530	38632	− 4898 ha
Pinus silvestris	6850	13510	73432	229397	80282	242907	+ 162625 ha
Pinus halepensis	9197	18824	124551	161043	133748	179867	+ 46119 ha
Pinus pinaster	20950	15963	72822	43009	93772	58972	− 39800 ha
					857327 ha	1080057 ha	+ 222730 ha

Table 8. Transformation of land use (km^2).

	Forest areas			Farmlands		
	1965	1976	%	1965	1976	%
Portugal	31 650	36 410	+ 15	43 320	36 000	− 16.9
Spain	131 600	153 330	+ 16.5	207 090	206 590	− 0.2
France	119 050	145 760	+ 22.4	210 670	187 300	− 11.1
Italy	59 840	63 130	+ 5.5	154 540	123 480	− 19.1
Tunisia	6 740	5 300	− 18.8	44 060	44 100	+ 0.1
Algeria	25 490	24 240	− 4.9	62 610	71 100	+ 13.6
Morocco	53 020	51 640	− 2.1	70 660	78 300	+ 10.8

bering and random cutting, should be distinguished from direct and regular actions, such as the utilization of coppices with a variable rotation cycle depending on the species and the need. These direct actions can be opposed to regular indirect actions, such as grazing in forests and burn beating, and to irregular indirect actions, such as wild fires.

Regular disturbances (Table 9) lead to the complete transformation of ecosystems in their floristic composition by sorting which occur among the initial species and by only maintaining species adapted to the disturbance among the dominant types. The same feature exists for the architec-

tures with an obvious simplification of the stratification:

(1) monospecific *Quercus ilex* coppices with a shrub understory composed of *Phillyrea media* maintained by 20–25 year cutting cycles which have eliminated the poorer sprouting capacities associated species.

(2) monospecific *Quercus pubescens* or *Q. canariensis* coppices with a perennial grass understory (*Brachypodium pinnatum*, *Festuca* agg. *rifana*, *yvesii* and *Helictotrichon*) favored by common fires, used for grazing and cut every 30 to 40 years.

In these communities the effects of regular dis-

Table 9. Development of floristic richness (S) and diversity (D) as a function of disturbances (in Mediterranean France).

	S and D	Grazing		Burn bearing	Felling
		intensive	extensive →		
Regular disturbance		↗t↘	t↘ ↗H	↗t↘	↗t↘
	Healing	zero	rapid	rapid	rapid
	S and D	Infrequent fires		Highly frequent fires	Irregular sample felling
Irregular disturbance		↗		↘ t↗ H↘ slow or rapid depending on the existing biological	↗
	Healing	rapid		material	rapid

t: therophytes   H: hemycryptophytes
↗ increase   ↘ decrease   → same

turbances (timbering, burn beating which lead to the disappearance of some species such as *Acer* and *Sorbus*) can generally be seen by the rapid, but temporary, development of therophytes and anthracophytes (Table 9a, b, c). This exogenic addition momentarily increases the floristic richness and diversity of the communities (Godron *et al.* 1981). However, if the frequency and intensity of the disturbance decreases, the ecosystem rapidly recovers its initial composition:

– high resprouting of holly oak after cutting
– high vegetative regeneration of *Brachypodium pinnatum* helped by burn beating.

The recovery speed of the environment is rapid.

Irregular disturbances (Table 9), such as cutting to create fire blocks or wild fires, have varied consequences:

Depending on the frequency, in deciduous potential forests they result in a more or less marked exogenic addition of sclerophyllous species, *Rhamnus alaternus*, *Phillyrea*, *Osyris*, *Juniperus oxycedrus* and *Cistus*, *Ulex* and different perennial *Poaceae*: *Brachypodium*, *Bromus* and even by therophytes if the effect of the degradation is strong. Here again, there is an increased floristic richness and diversity with, however, for high frequency disturbances, the substitution of ethological types by other types. Irregular disturbances are a factor of spatio-temporal heterogeneity of stands with the installation of mosaic and spot structures.

In ecosystems where sclerophyllous species dominate (Fig. 2), random cutting and irregular wild fires have modified the phenomenon of density dependant retroactions due to shade which played a major role in the installation of simplified stratification of the initial ecosystem.

Relatively infrequent irregular disturbances can be seen by a dual phenomenon:

(1) regression of mesophilous sclerophyllous species such as *Viburnum tinus*, *Phillyrea media*, *Ruscus aculeatus*, *Rubia peregrina*
(2) progression of heliophilous sclerophyllous species occupying open spaces: *Rhamnus alaternus*, *Pistacia terebinthus*, *Osyris alba*, *Jasminum fruticans*, *Juniperus oxycedrus*.

Irregular disturbances lead to the installation of

mosaic structures and to an increase in the floristic diversity and richness of stands.

Irregular and high frequency disturbances lead to the complete transformation of the initial ecosystems prior to their disappearance.

As a result of repeated fires, the sclerophyllous forest has clearly undergone a 'matorralization' (increase in cover and diversity of shrub species) due to the resistance of some key species which have replaced the potential sclerophyllous oaks: *Quercus coccifera* in the northern Mediterranean, *Chamaerops humilis* in the southern Mediterranean, *Erica arborea* and *Erica scoparia* in the sections occupied by cork oak forests (Tomaselli 1981).

In zones where no stump-spouting biological material exists, shrub or chamaephyte r strategy species occupy these space: *Calycotome*, *Ulex*, *Genista*, *Adenocarpus*, *Lavandula*, *Thymus*, *Stoehelinia*, *Dorycnium* (Barbero, Bonin, Loisel, Quézel, Miglioretti 1987).

Frequent irregular disturbances results in a decrease in the floristic diversity and richness due to the continuation of certain adapted species and the deterioration of the environment's geochemical balance.

On a small scale in the Southern Mediterranean

The effects of anthropozoogenic disturbances on the forest ecosystems are directly linked to their permanence, their frequency and their intensity. All these factors should thus be studied within each bioclimatic group in relation to climatic stress, geopedological constraints and also the biological aptitude of the ecosystem's main constitutive species. The consequences of these effects on the perception of Mediterranean forests (Perelman 1981) have been studied in the northern and southern Mediterranean.

Matorralization of forest groups (Fig. 3)
Matorralization can be found throughout southern Spain and North Africa in humid and subhumid bioclimates with a generalized invasion of forests by sclerophyllous species from preforest
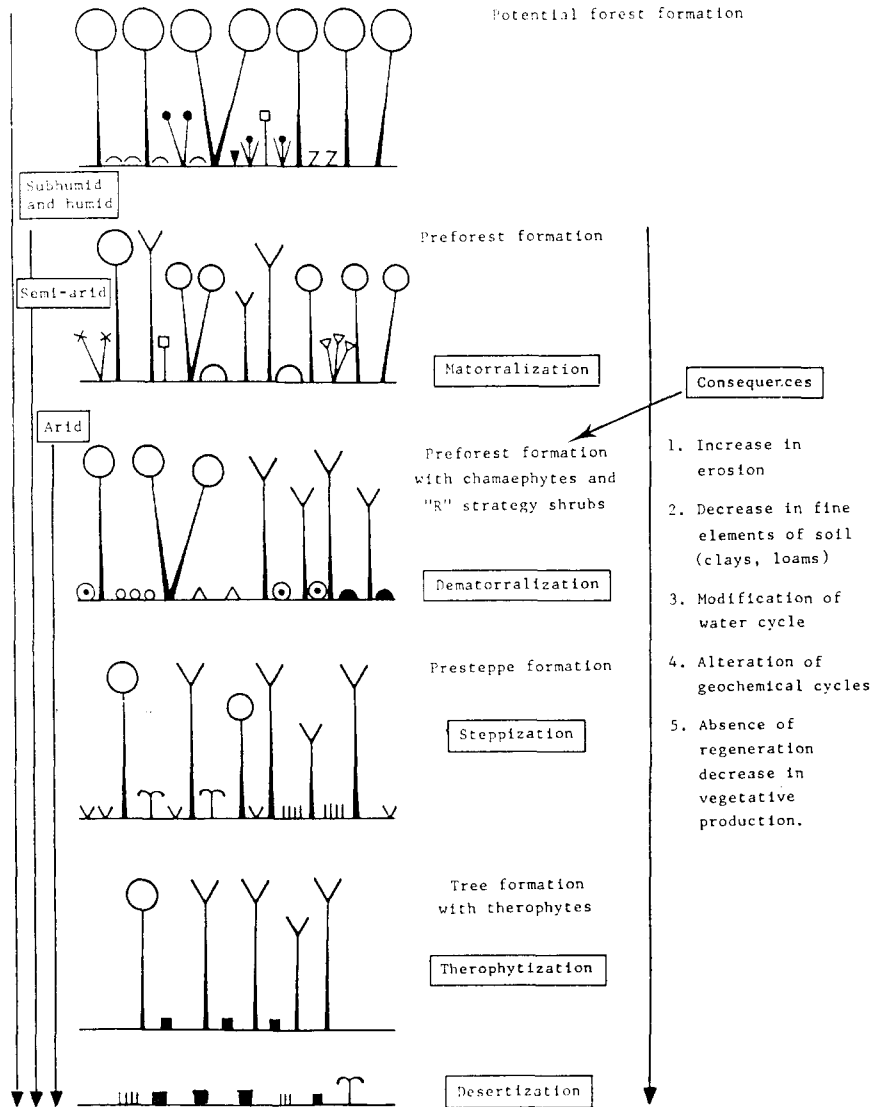
Fig. 3. Process of degradation of sclerophyllous forests in North Africa.

edges and borders, such as *Rhamnus* sp., *Pistacia* sp., *Rhus* sp., *Juniperus* sp., *Osyris* sp. which resist stress and constraints (Cornell & Statyer 1977). These species are spread by edible berries, usually eaten by birds, which allows them to recolonize gaps left after disturbances by the initial ecosystem.

In these communities, which have been remodeled by disturbances, other elements are also present, such as *Pinus* and *Cedrus* at higher altitudes, which regenerate in gaps in holly oak forests. Preforest ecosystems also come into

being for the duration of the disturbance.

In semi-arid and arid bioclimates, the transformation of already matorralized forests can be seen by the replacement of species (*Pinus halepensis* replaces *Tetraclinis* whose stumps were either over-demanded or removed and were thus eliminated from the initial ecosystem in some parts of eastern Morocco), or by the modification of primary matorrals of these forests where new shrubs which are better-adapted to the increase of constraints due to soil erosion can develop.

Presteppic Groups: Ephedraidic matorrals

with *Retama, Coronilla ramosissima, Polygala balansae, Ephedra* are also formed, as well as matorrals with soft cotton-like leaved species (*Cistus* ssp., *Rosmarinus*), matorrals with spiny-leaved species (*Ulex, Genista, Calycotme*), and xerophyte matorrals in patches on upper forest borders (*Cytisus balansae, Erinacea pungens, Alyssum spinosum, Genista lobeli*).

In arid, semi-arid and particulary in infra-Mediterranean zones, the extension of succulent cactus-like *Euphorbia* into presteppic forests is a characteristic phenomenon (*Euphorbia echinus, E. baumeriana*).

Dematorralization of preforest groups (Fig. 3)
Currently in some regions of North Africa, tree stumps are uprooted from forest matorrals and new shrubs develop. This process of replacing primary matorrals by secondary matorrals ultimately results in a dematorralization.

Two phases can usually be found in the North African forests:
(1) the first consists in the replacement of stump-sprouting species by high shrubs which resprout little if at all (*Cistaceae, Cistus clusii; Fabaceae, Genista pseudoretamoides*) and can in turn be replaced.
(2) the second represents the actual dematorralization with the installation of constitutive chamaephytes such as *Lamiaceae* in patches, *Lavandula marocana, L. atlantica, L. dentata, Corydothymus capitatus*) and, more rarely, *Fabaceae* (*Genista pilosa, Coronilla minima*), or Cistaceae (*Helianthemum* and *Fumana*).

All of these species with a high level of renewal respond to several selection criteria (spatial, ecological and particularly biological) by a high production of very resistant seeds capable of remaining dormant for several years (Boulay 1985). These biological characteristics guarantee a good recovery of chamaephytes after long drought periods which can destroy the vegetative systems of many perennial species in semi-arid and arid climates.

Dematorralization of preforest groups results in: either the installation of secondary matorrals when the shrub systems composed of R strategy species have replaced stump-sprouting shrubs, or the direct installation of chamaephyte communities.

On the level of secondary matorrals, the new occupants of dematorralized preforest territories are:
(1) r strategy species whose rapid growth gives them an optimal control of the space, as seen by the generally poor floristic richness of these communities;
(2) species of high ecological plasticity, particulary those with a capacity to resist hydric stress and large thermic variations and thus to adapt their floral biology to the different types of Mediterranean climates where they can be found. Usually they are spiny plants, such as *Carduus, Carduncellus, Centaurea, Cynara* or toxic species such as *Peganum* or *Hertzia*.

Considering the great pressure acting on forests in the Maghreb today, the response of forest communities to dematorralization will depend on several factors:
− short duration of hydric stress
− good edaphic fertility
− frequency of disturbances due to uprooting
− biological characteristics of the species and their capacity for vegetative renewal: runners, resprouting, etc.

Steppization (Fig. 3)
An ultimate stage in the degradation leads to the steppization of forests where an appropriate vegetative material exists.

Poaceae-based Steppization: *Stipa* ssp., particularly *tenacissima; Aristida; Lygeum*, etc.

Asteraceae-based Steppization: *Artemisia, Launaea*

Scrophulariaceae-based (*Antirrhinum ramosissimum*) or *Lamiaceae*-based Steppization (*Micromeria, Thymus algeriensis, T. pallidus*, etc.) spread over the soil.

Many of these shrubs make up an understory in more or less wooded communities and become perennial by regular seeding. They slow down the growth of some woody species already in place by spreading toxins or limit the installation of other, more highly competitive plants.

Thus long periods of low floristic richness develop which represent dominance-level cycles (Escare, Houssard, Debussche 1983).

Therophytization

The lower cover of the preceding communities accentuates the effects of soil erosion and uprooting of chamaephytes and hemicryptophytes. The permanence of grazing in these critical situations further amplifies the withdrawal of vegetation.

Apart from sparsely growing trees which remain in place due to their deep roots, all of the forest ecosystems, no matter what their development stage, undergo therophytization linked with a generalized invasion by annual species.

These 'r' strategy species (therophytes: Poaceae, Asteraceae are favored by short generation periods which allows them to occupy the soil during the brief periods advantageous to their vegetative activities in all the bioclimatic groups and their variants. The forest ecosystems become much more banal as relatively rich floristic structures establish themselves which have nothing to do with the initial structures.

In North Africa, several tens of thousands of forest hectares have already been therophytized and the trees found there are veritable living fossils destined to disappear during the next decades.

This is also true in the cedar forests of the Grand Atlas and the Aurès, the *Argania* forests in the Sous, the *Tetraclinis* forests of eastern Morocco, the pine forests of the Tel Atlas and the holly and cork oak forests of the Rif. In addition, these relic forests are still included in forest statistics which hides the acceleration of the regression of the forest cover throughout North Africa. They no longer suppress erosion whose intensity is more and more important in the Maghreb.

This phenomenon has disastrous consequences:
- the disappearance of fine soil material and disturbances in geochemical cycles, or even a total dysfunction;
- a decrease in vegetative production and photosynthetic activity as well as the modification of oxygen and carbon dioxide cycles due to the vast surface areas involve;

- complete deregulation of the water cycle, particularly the resupplying of the water tables;
- worsening of the socio-economic situation.

Effects of lack of disturbance on northern mediterranean forest ecosystems

These effects can be seen by an extraordinary biological resurgence affecting the forest species, structures and architectures.

As we have indicate above, the phenomenon of older and more recent rural depopulation and the non-use of most of the forests have led to this development which also concerns the establishment of several thousand hectares of secondary shrubland.

Development of forest canopy (Table 10)

It is clearly discernible and rapid for expansion model forest structures.

Two examples taken in Provence for the Aleppo pine (+ 33 610 ha in 10 years despite fires) and the Scots pine (+ 21 313 ha in 10 years) demonstrate this evolution.

The outstanding growth of the Aleppo pine has two main causes:
(1) the abandonment of grazing in sclerophyllous shrublands which are stump-sprouting: maquis and garrigues, and the regeneration of the pine which is no longer subject to grazing.
(2) the installation of *Pinus* on secondary shrublands or grasslands resulting from the abandonment of zones cultivated in terraces.

Table 10. Recent development (last decade) of forest cover in Provence.

	1973–1978	1988	Development
Deciduous Oaks	230 618	235 000	+ 4 382 ha
Quercus ilex	83 009	89 368	+ 6 359 ha
Quercus suber	33 632	45 987	+ 12 355 ha
Pinus silvestris	229 397	250 710	+ 21 313 ha
Pinus halepensis	161 043	194 653	+ 33 610 ha
Pinus pinaster	43 009	36 965	− 7 044 ha

The extension of the Scots pine primarily results from:

(1) the non-use of *Buxus* and *Genista cinerea* formations in grazing lands.

(2) the colonization of secondary shrublands composed of *Genita cinerea* installed on ancient farmlands occupied by grasslands;

(3) the altitudinal extension of *Pinus sylvestris* on territories formerly used for transhumance, but currently abandoned.

The extension of the stabilization model in areas where rural depopulation is oldest, is also remarkable (Table 10). The development of deciduous oaks occurs in the following way:

(1) colonization by oaks of formerly cultivated lands which are included in high coppice zones

(2) replacement of older Aleppo pine and Scots pine high forests by *Quercus pubescens* on abandoned lands left undisturbed for many years.

(3) substitution of sclerophyllous oaks by pubescent oaks in mixed forests which yields a better production, diameter and height growth (Miglioretti 1987).

Deciduous oak forests have increased in Provence from 166982 ha in 1904–1907 to 230618 ha in 1978 while sclerophyllous oak forests decreased from 163411 ha to 116641 ha. However, during the last two decades sclero-phyllous oaks have widely progressed in preforest formations (Table 10) (more than 6359 ha for the holly oak; more than 12355 ha for the cork oak).

This biological resurgence accompanied by a high secondary matorralization (Barbero & Quézel 1989) and by the progression of highly combustible and inflammable preforest structures has resulted in an increase in the frequency of fires and amount of surface area burned (Barbero, Loisel & Quézel 1989). Paradoxically, these fires are a factor of regeneration of the biological and floristic diversity, particulary of species making up the initial stages of succession series which appear to be threatened with extinction in different parts of their territory.

Consequences on structures and architectures

The temporal development of deciduous oak forests (Table 11) generally used as grazing lands (tree-grass-animal system) and the aging of coppices leads to the establishment of complex forest ecosystems with a vertical organization characteristic, and even typical of Central European forests.

In addition, along with the growth of oaks which constitute the major tree layer, the process of animal dispersion and wind pollination have favored the installation of lower tree (*Sorbus*,

Table 11. Temporal evolution of Mediterranean *Quercus pubescens* sequence structures in the absence of disturbance in the coppices of the Gardiole de Rians (Var) State Forest.

Quercus pubescens coppices with	*Brachypodium pinnatum* and *Bromus erectus*	Oak forest with *Hieracium murorum, Hieracium prenanthoides, Solidago virga aurea.*	Oak forest with *Ombelliferae, Chrysanthemum corymbosum, Lathyrus latifolius.*	Oak forest with Geophytes, *Fritillaria, Polygonatum, Crocus*
Floristic richness and diversity	Burn bearing 30 years			
	f	M	F	F
Structure duration	30 years	50 years	70 years	90–100 years and more
Architecture	Tree-grass	Tree-grass, some shrubs, *Lonicera, Juniperus, Phillyrea media*	Complex shrub architecture, *Lonicera, Coronilla, Cytisus, Daphne laureola*	Diversified architecture: Tree layers: major, shrub, non-continuous minor, grassland.
Fertility and soil-substrate	f	M	F	F

Acer, Fraxinus) and shrub (*Coronilla, Cytisus, Cotoneaster, Rhamnus, Evonymus, Ligustrum*) layers.

The effects of a lack of disturbance are also visible in the herb layer. Thus the aging of coppices where the graminoid-types are dominant in the herb layer (*Brachypodium pinnatum, Bromus erectus, Poa nemoralis*) and changes in light intensity resulting from the development of canopies initially result in the installation of new ethological types characterized by the dominance of spatulate-leaved species: *Hieracium* div. sp., *Solidago, Serratula, Campanula*, then, secondly, in the mineral enrichment of the soils by wide-leaved malacophyllous species: *Anthriscus, Chaerophyllum, Peucedamum, Heracleum, Chrysanthemum, Primula, Mercurialis*. In sites with a good hydric balance, geophytes develop: *Neottia, Polygonatum, Fritillaria, Corydalis*, etc.

In pure sclerophyllous oak forests where the process of substitution of holly oak by the pubes-cent oak has become impossible due to low light intensity (Table 12), and when no disturbance intervenes (Barbero, Loisel 1983), temporal development occurs by a regression of xerosclerophyllous species (*Jasminum, Pistacia, Rhamnus, Osyris*) and the continuation of mesosclerophyllous species which make up the high shrub layer (*Phillyrea media, Viburnum tinus*), as well as the low shrub layer (*Ruscus aculeatus, Rubia peregrina*). In sites where the leaf litter is transformed slowly by microflora and fauna (Poinsot-Balaguer 1976), the installation of hemisaprophyte *Orchidaceae* usually occurs (Fig. 4) (*Cephalenthera, Epipactis, Orchis, Plantanthera*), while in more humid sites with a good mineralization diverse deciduous oak forest species develop in the shrub or herb layer (Miglioretti 1987; Sirabella 1988). In very old high forests (150 years old and older), the development of the architecture of holly oaks favors light penetration and makes the regeneration of trees from the pubes-

Table 12. Temporal evolution of *Quercus ilex* sequence structures towards mediterranean pubescent oak forests in the absence of disturbance (Gardiole de Rians, Var).

	Kermes oak forest with holly oak	Mixed *Quercus ilex* and *Pinus* forest with liana-type species	Preforest structures	Metastable and resistant forest structures	Stabilized forest structures
			50 years	80–100 years	200 years
	Cocciferetum	*Clematido-Pistacietum*	*Viburno-Quercetum ilicis*	*Epipactido-Quercetum ilicis*	*Lathyro-Quercetum pubescentis*
Floristic diversity and richness	Xerosclerophyllous species		Mesosclerophyllous species		Sciadophytes and mesosclerophyllous species
	f (if disturbance by fire)	F	M	f	F
Structure duration	(if disturbance by fire)				
	F	M (20 years)	M (50 years)	F (80–150 years)	F (200 years)
Soil-substrate energy and productivity		High radiation	Medium radiation	Low radiation in understory	Medium radiation in understory
	f	f	M	M	F
	Lithosols with pockets of terra rossa	Protorendzina	Young rendzinas	Evolued rendzinas young brown forest soils	Mediterranean brown soils

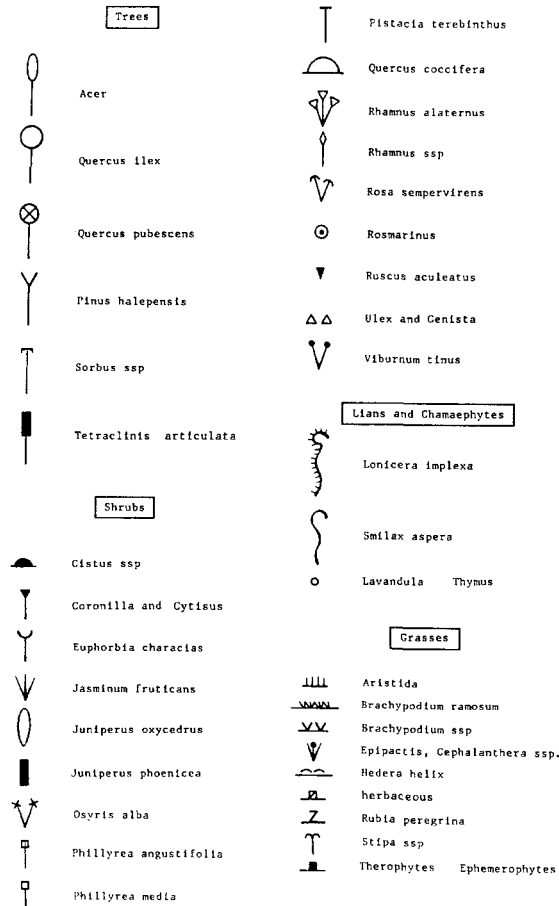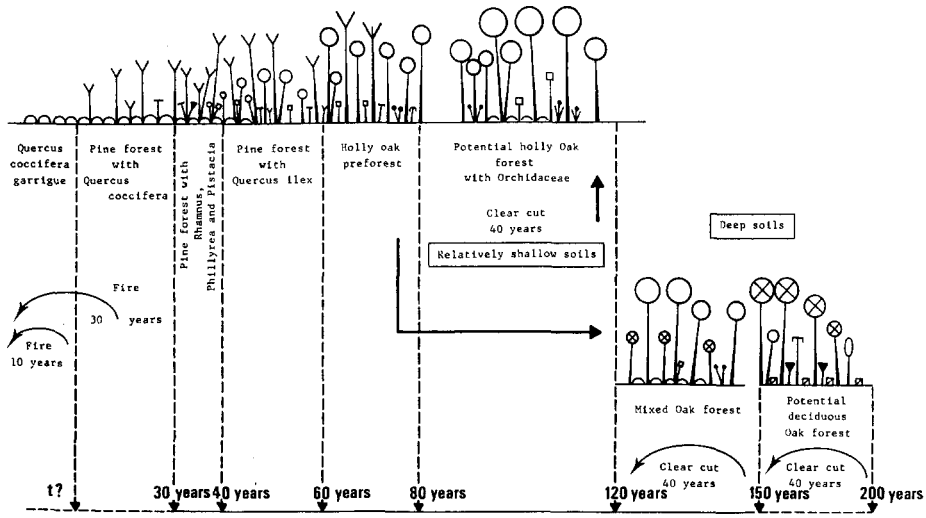(f) weak, (M) medium, (F) strong or long

Fig. 4. Temporal development with or without disturbance for a sequence of sclerophyllous and deciduous forest and preforest ecosystems.

cent oak forest possible in the understory (Fig. 4): *Quercus pubescens, Sorbus aria, Sorbus torminalis* always along with *Viburnum tinus, Phillyrea media* and possibly prefigures the structural and architectural characteristics of older Mediterranean potential pubescent oak forests whose representative stands are known in Mediterranean France (Valbonne in the Gard region; St. Baume in the Var region).

Phytosanitary consequences of non-use

The non-use of forest ecosystems and their almost total geographic continuity resulting from their extension forced some species, such as *Pinus*, to adjust to an interspecific competition for which they are poorly adapted.

This led to modifications in their phytosanitary balance. It has been suggested that, in addition to the cold periods in 1956 which disturbed the biological equilibrium of *Matsucoccus feytaudi* in the Maures Mountains, the transformation of pine forest structures and their non-management could explain the extension of pests which reduced the area occupied by *Pinus mesogeensis* from 72 822 ha in 1904–1907 to 43 009 in 1978 and 36 965 currently in Provence.

In the same way, the geographic continuity of large blocks of Scots pine would be the reason for the current explosion of the *Lophyres* population. Also, the existence of major untimbered holly oak and pubescent oak coppices of the same age would encourage the extension of leaf roller populations in the absence of geographic barriers. The same holds true for extended matorrals whose continuity is subject to strong climatic constraints (Fuentes *et al.*, 1981).

Conclusions

The western Mediterranean forests represent a fragile natural ecosystems due to the regular climatic stress whose duration varies from 1 to 6 months depending on the bioclimate and to the high geopedological constraints which accentuate the effects of human-induced disturbances.

These forests can be divided into three main groups (forest, preforest, and presteppe) which demonstrate the action of severe ecological conditions on the major components of the forest ecosystems.

Three main models can be found which take into account the characteristics of ecological, spatial and biological selection as well as the response to both natural and human induced disturbances:

- the expansion model composed primarily of conifers from the genera *Pinus* and *Cedrus*;
- the resistance model composed of sclerophyllous species whose response to anthropozoogenic influences is optimal.
- the stabilization model represented by deciduous species covering forests which are well preserved and protected from certain types of disturbances, such as fires, but vulnerable to intensive and random timbering.

The effects of disturbances on floristic richness and diversity and the forest ecosystem's structures and architectures were evaluated according to their type.

In the Maghreb forests, a spectacular regression of forested surfaces is occurring due to an acceleration of matorralization, steppization and therophytization depending on the bioclimate. Following the intensive rural depopulation in the northern Mediterranean and despite severe fires, forested surface area has continually increased and shows a dual development:

- a spectacular progression of forests of the expansion model linked to the rural decline at the end of World War II;
- a remarkable progression of forests of the stabilization model in areas where rural depopulation is older and where coppices have not been used for over 50 years.

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