# Site quality and stand structure in *Pinus halepensis* forests of north Greece

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*Summary*

*Pinus halepensis* forests depend partly on the relatively adverse drought conditions prevailing in the area and on human management through the centuries. A major and decisive factor for the establishment and maintenance of these forest ecosystems is fire, which defines their expansion. The degradation of these forests as a consequence of constant pressure by natural and human-caused fires, grazing and clearance, has led to the formation of scrub associations of the Cisto–Micromerietea. The phytosociological study of the area and the analysis of the vegetation table showed the existence of three site quality types I, II and III. The structure of stands in these site types is mostly even-aged, occurring after a fire, in age classes 10–20, 25–35, 40–50 and 60–80 years. The biggest mean diameter, total basal area and mean dominant height of the overstorey, occurred on the more soil-fertile site type I.

## Introduction

*Pinus halepensis* Mill. is an exclusively Mediterranean species. It prefers regions with a high mean annual temperature and is adapted to prolonged summer droughts (Quezel, 1986). Its distribution in Greece coincides with values lower than 5 on Emberger's diagram (1959). Therefore, *P. halepensis* may be considered as species of climate index for regions of Greece having Mediterranean climate. In Greece *P. halepensis* forests occur in Peloponnisos (Pe), Sterea Ellas (StE), Epirus (SPi), Chalkidiki (NE), E. Thessalia (EC), the W. Aegean islands (WAe) and the Ionian islands (Ioi) (Figure 1). *P. halepensis* forests take up an area of 32 737 ha, that is 13.3 per cent of the Greek forests. Particularly in N. Greece *P. halepensis* forests occur only on the Chalkidiki Peninsula. *P. halepensis* is distributed in the plant formation of evergreen, broadleaved scrubs from the coast up to 800 m elevation, with a maximum elevational limit of 1050 m on Kilini Mt and Chelmos Mt in Peloponnisos (Basiotis, 1972). *P. halepensis* grows in the Oleo–Ceratonion zone and especially in the Oleo–Lentiscetum zone, as well as in the Quercion ilicis zone and especially in the Adrachno–Quercetum ilicis zone, in which it finds its optimum growth in the Chalkidiki

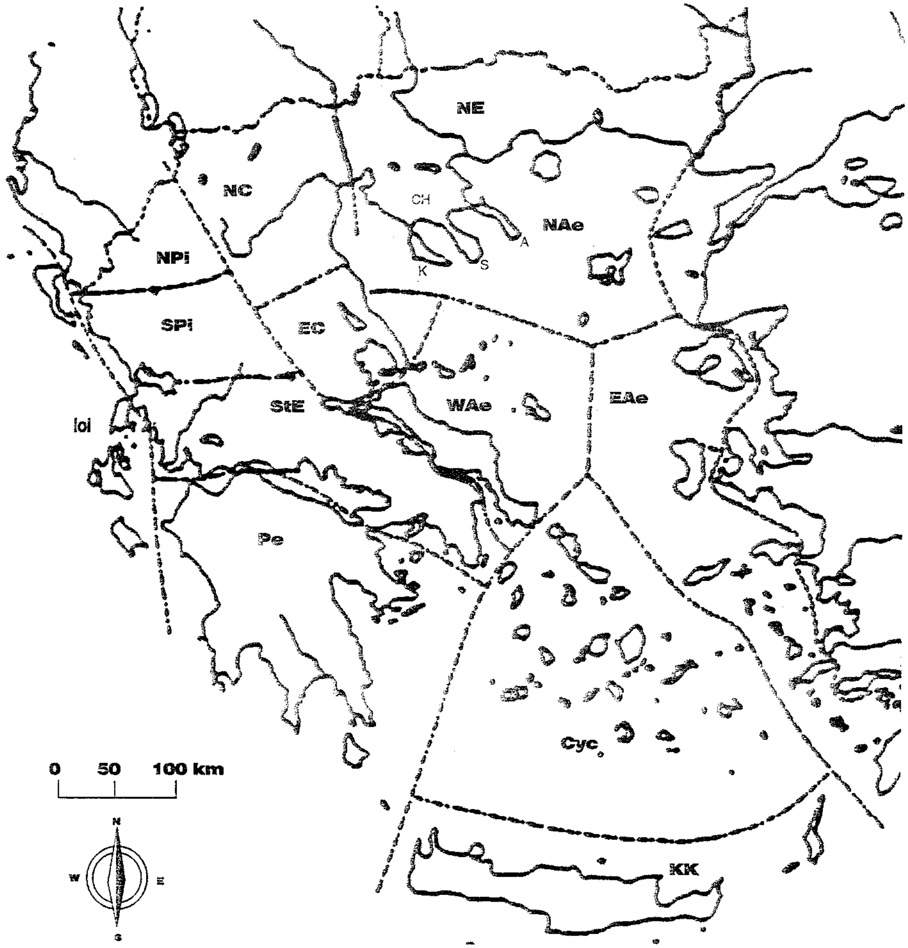


*Figure 1.* Phytogeographical divisions of Greece according to Flora Hellenica. Cyc = Cyclades, EAe = East Aegean islands, EC = East Central, Ioi = Ionian islands, KK = Kreta and Karpathos, NAe = North Aegean islands, NC = North Central, NE = North East (CH = Chalkidiki, K = Kassandra, S = Sithonia, A = Athos), NPi = North Pindus, Pe = Peloponnisos, SPi = South Pindus, StE = Sterea Ellas, WAe = West Aegean islands (Strid, 1986).

Peninsula. It prefers marls, soft or hard limestone as well as serpentine rocks. The forest communities of *P. halepensis* in Greece are a continuation of those of southern France and Ligouria of northwestern Italy, since these communities have their eastern distribution boundaries in Greece (Papaioannou, 1935; Lavrentiades, 1961; Dafis, 1973, 1987; Pavlidis, 1976; Raus, 1979; Athanasiadis, 1986; Iatrou, 1986; Konstantinidis, 1990; Paola *et al.*, 1991; Tsitsoni, 1991).

There is no doubt that *P. halepensis* is self-perpetuating in Greece, although this is questioned for Skiathos (Economidou, 1969) and for Cephallonia (Knapp, 1965). However, only the communities of *P. halepensis* in rocky, coastal areas can be regarded as natural. These communities grow in adverse ecological conditions (Emberger summer drought index <5 and maximum mean temperature 30.4°C, Tsitsoni, 1991) and oligotrophic soils. In these sites coverage by trees is sometimes interrupted by shrubs and herbs and *P. halepensis* is often the only tree that occurs on these sites.

A historical review reports that artificial reforestation in Greece has taken place on a great scale during the last century. However, *Pinus brutia* and *Pinus maritima* were preferred, among other things, for their wider hypsometrical and ecological range and the higher resistance of young seedlings in adverse conditions during the first years of growth (Quezel, 1986; Dafis, 1987). The main reason for using these species in reforestation is their higher growth rates and their straight logs, in comparison with *P. halepensis*. However, since *P. halepensis* is a constant natural member species of the evergreen, broadleafed scrub associations, investigation of the origin of the existing forests is worth while.

The aim of this work is to study:

1 the site quality conditions of the region and to distinguish the site quality types (based on floristic composition) which appear in *P. halepensis* forests in Greece;
2 the structure and the stand productivity of the *P. halepensis* forests in every site type.

## Study area

The research was conducted at the state and community forests of Kassandra Peninsula in North Greece which is located 60 km south-east of Thessaloniki at 25° 30′ E and 40° N. It is the first of the three peninsulas of the Chalkidiki Peninsula from the west to the east. It has an area of 35 000 ha where the *P. halepensis* forests occupy 40 per cent (Tsitsoni, 1991). The northern part of the peninsula is flat with slight hilly elevations in the western part and mostly with rocky coasts. On the contrary, in the southern part there are alternating hilly elevations with an average height of 150–200 m (maximum of 334 m). According to the climatic data from the meteorological station of the Forest Service, the climate of the area is of the Mediterranean type with mild winters and dry hot summers (Balafoutis, 1977). The mean annual rainfall reaches 560 mm, while the mean annual air temperature goes up to 16.5°C. The ecologically dry period begins in the middle of April and lasts until the middle of September (Tsitsoni, 1991). According to the climatic classification of Koeppen (Critchfield, 1974), the climate of the study area is recorded as the special climatic type Csa and it becomes identical to the type of the intense mid-Mediterranean ($75 < x < 100$; $x$ = number of biological dry days during dry period, according to the method of Bagnouls-Gaussen) character of bioclimate of Greece (Mavrommatis, 1980). According to the climatic diagram of Emberger (1959) this peninsula belongs to the subhumid Mediterranean climatic zone (index <5).

In general, the climate of the area, as shown by the floristic analysis (Tsitsoni and Karagiannakidou, 1992), is favourable for the growth of *P. halepensis*. Moreover, it is known that *P. halepensis* is found in climates with an average minumum temperature of the coldest month above −3°C (Quezel, 1986). Geologically, the peninsula belongs to Axios zone. Petrologically, it shows a relative homogeneity since the dominant rocks are marls, cobble sand, marl limestone and only the area of Paliouri cape is occupied by basic pyrogenic rocks (Mountrakis, 1985).

## Materials and methods

In order to study the phytosociological conditions of the region and distinguish the site types, 110 sample plots of 300 $m^2$ each (Dafis, 1969; Athanasiadis, 1986) were selected in an attempt to cover the whole spectrum of the region. The vegetation analysis was based on phytosociological records according to the standard method of Braun-Blanquet (1964). The distinction of the site types was performed with the assistance of plant-index groups as they are described by Ellenberg (1956, 1963, 1979) and Ponita *et al.* (1977). The nomenclature and classification of the taxa mentioned are according to Flora Europea, and therefore the names of the taxa authors have been omitted for practical purposes (Tutin *et al.*, 1964–1980).

In order to have a more complete ecological interpretation of the site types, soil samples from 39 soil profiles were also selected and examined thoroughly, with regard to mechanical analysis, estimation of the total nitrogen, organic matter, pH, calcium carbonate, field capacity and permanent wilting point (Zagas, 1994; Papamichos and Alifragis, 1995).

In order to study the stand structure, after the distinction of the site types, 49 sample plots of 500 $m^2$ (Dafis, 1969; Athanasiadis, 1986) were taken. These plots were allocated among the three site types: 20, 13 and 16 plots in the I, II and III site types, respectively. In every plot all trees were numbered, measured for their diameter and height and classified according to the IUFRO system (Leibundgut, 1966). The data were analysed statistically to define the mean stem per site type and age class.

For the best representation of the existing situation of the stand structures, profiles of stands in every site quality type and age classes were taken (Dafis, 1966; Dafis and Jahn, 1975; Zagas, 1990; Gkanatsas, 1993). These profiles show the horizontal and vertical structure in strips of 5 m wide and 10 m long. The projection of the crown of trees was measured by plumb line and aligning poles, while the height of the trees was measured by altimeter (Haga).

## Results

The plant index groups found in the *P. halepensis* forests by the comparative processing of Table 1, showed the existence of three site quality types I, II and III. The structure of stands in these site types is mostly even-aged occurring after a fire. Even-aged stands are distinguished in age classes (10–20, 25–35, 40–50, 60–80 years). The irregularity noticed, concerning the number of stems (Table 3), is attributed to the lack of systematic tending as well as to random factors such as grazing, illegal felling and clear-cutting.

### *Site type I*

*Spreading–physiognomy* This type mainly occurs in north, north-eastern and north-western exposed slopes with very deep soil, consisting of clay up to sandy-clay. In the overstorey *P. halepensis* is dominating, while in the understorey shrubs of *Quercus ilex* and *Fraxinus ornus* dominate. The herbaceous vegetation consists of mesophytic species with medium ecological range, appearing in relatively good sites with characteristic species mainly those to be found in the alliance Quercion ilicis. In this type differential woody species are *Quercus ilex*, *Fraxinus ornus*, *Cercis siliquastrum*, *Hedera helix*, *Colutea arborescens*, *Thymus sibthorpii*, etc. (Table 1).

*Soil* The forest soils, in the Mediterranean climate, of site type I are deep and have an almost constant content of clay at all depths, so they are characterized as heavy soils. They are relatively rich in organic matter, whereas the content of N is medium so the C:N ratios indicate medium-velocity decomposition. The pH is alkaline because there is a high content of calcium carbonate (Table 2).

*Stand structure* In Table 3 the changes of the structural data between the age classes 40–60 and 60–80 are shown. The mean diameter has a normal increase but the small difference between the age classes 40–60 and 60–80 is due to the higher density of trees in the overstorey of 60–80. The basal area increases greatly in proportion to the age; that means there is a very good increase of stands. The mean height of the overstorey increases impressively between the age classes 40–60 and 60–80. The situations of stands in age classes 40–60 and 60–80 are shown in Figures 2a and 2b respectively.

### *Site type II*

*Spreading-physiognomy* It mostly appears in mid-hillsides and depressions. In the overstorey the *P. halepensis* is dominating while in the understorey the characteristic species of the class and association mentioned in the site type I dominate. Differential woody species here are *Arbutus unedo*, *Arbutus andrachnae*, *Lonicera* species, *Erica arborea*, *Thymus capitatus* (Table 1). The herbaceous vegetation consists of xero-mesophytic species with a greater ecological range appearing in mesotrophic range sites.

*Soil* The forest soils, in the Mediterranean climate, of site type II are deep, sandy-clay and sandy-clay loam with a small proportion of skeletal material. They are relatively rich in organic matter whereas the content of N is medium, so the C:N ratios indicate medium-velocity decomposition. The pH is alkaline because there is a high content of calcium carbonate (Table 2).

*Stand structure* In this site type three age classes were distinguished in even-aged stands. The stands of sample plots were classified and statistical analysis was carried out. The data for the mature stands of the age class 60–80 in site type

*Table 1:* Phytosociological table of *Pinus halepensis* woods in Kassandra, developed in the site quality types I, II and III [Climax constancy I (1–20%), II (21–40%), III (41–60%), IV (61–80%), V (81–100%)]

| | Site types | | | | Site types | | |
|---|---|---|---|---|---|---|---|
| | I | II | III | | I | II | III |
| *Pinus halepensis* | V | V | V | | | | |
| Species of Cisto–Micromerietea | | | | | | | |
| *Brachypodium retusum* | III | IV | IV | *Ononis spinosa* ssp. *antiquorum* | | | |
| *Cistus incanus* ssp. *creticus* | III | IV | II | *Thymus sibthorpii* | I | – | – |
| *Anthyllis hermaniae* | II | IV | II | *Sarcopoterium spinosum* | – | I | I |
| *Erica manipuliflora* | I | I | III | *Teucrium polium* | I | I | I |
| *Dorycnium hirsutum* | I | III | – | *Acinos alpinus* | – | I | I |
| *Cistus monspeliensis* | I | I | III | *Thymus capitatus* | – | I | II |
| *Cistus salvifolius* | I | I | III | *Fumana thymifolia* | – | – | I |
| *Dorycnium pentaphyllum* | I | II | I | *Micromeria juliana* | – | – | I |
| *Hypericum monbretii* | I | II | – | *Hypericum empetrifolium* | – | – | I |
| | | | | *Cytinus hypocistis* | – | – | I |
| Species of Quercetea ilicis | | | | | | | |
| *Pistacia lentiscus* | V | V | V | *Piptatherum miliaceum* | II | II | I |
| *Quercus coccifera* | V | IV | V | *Calycotome villosa* | – | I | II |
| *Asparagus acutifolius* | V | IV | V | *Arbutus andrachne* | – | II | – |
| *Quercus ilex* | V | I | I | *Pistacia terebinthus* | II | I | I |
| *Smilax aspera* | IV | V | V | *Rosa sempervirens* | II | – | I |
| *Rubia peregrina* | IV | IV | IV | *Cercis siliquastrum* | II | – | – |
| *Phillyrea latifolia* | IV | IV | IV | *Erica arborea* | I | II | I |
| *Arbutus unedo* | I | V | I | *Carex distachia* | I | I | I |
| *Lonicera etrusca* | II | IV | II | *Olea europea* var. *sylvestris* | I | I | I |
| *Lonicera implexa* | II | IV | II | *Laurus nobilis* | I | I | I |
| *Myrtus communis* | III | II | I | *Prassium majus* | – | – | I |
| *Ruscus aculeatus* | III | – | I | *Rhamnus alaternus* | – | – | I |
| *Clematis flammula* | II | II | I | *Salvia triloba* | – | – | I |
| Species of Querco–Fagetea | | | | | | | |
| *Brachypodium pinnatum* | II | IV | I | *Cornus mas* | I | I | I |
| *Fraxinus ornus* | III | – | – | *Melica uniflora* | I | I | I |
| *Quercus pubescens* | III | II | I | *Silene italica* | I | I | I |
| *Rosa canina* | II | – | I | *Campanula spathulata* | I | I | I |
| *Hedera helix* | II | – | – | *Buglosoides purpurocaeruleum* | I | I | I |
| *Teucrium chamaedrys* | I | III | – | *Colutea arborescens* | I | – | – |
| *Brachypodium sylvaticum* | I | II | I | *Cornus sanguinea* | I | I | – |
| *Tamus communis* | I | II | – | *Poa nemoralis* | I | – | I |
| *Crataegus monogyna* | I | I | I | *Coronilla emerus* ssp. *emeroides* | I | – | – |
| *Cotinus coggygria* | I | I | I | *Stellaria media* | – | I | – |
| *Ligustrum vulgare* | I | I | I | *Clematis vitalba* | – | I | I |
| *Pyrus amygdaliformis* | – | I | I | *Cyclamen hederifolium* | – | – | I |
| *Vicia tenuifolia* | I | I | I | *Prunus spinosa* | – | – | I |
| *Luzula forsteri* | I | I | I | | | | |
| Other species | | | | | | | |
| *Carduus pycnocephalus* | II | III | I | *Convolvulus cantabrica* | I | I | I |
| *Carex flacca* ssp. *serrulata* | II | III | I | *Trifolium campestre* | I | I | I |
| *Carex otrubae* | II | I | I | *Bellis perennis* | I | I | I |
| *Spartium junceum* | II | – | I | *Psoralea bituminosa* | I | I | I |
| *Rubus ulmifolius* | II | – | I | *Aremonia agrimonoides* | I | I | I |
| *Astragalus monspessulanus* | I | II | II | *Galium aparine* | I | I | I |
| *Oenanthe pimpinelloides* | I | II | I | *Viola arvensis* | I | I | I |
| *Trifolium repens* | I | I | I | *Carex distans* | I | I | I |
| *Brachypodium distachyon* | I | I | I | *Calamintha nepeta* | I | I | I |
| *Origanum heracleoticum* | I | I | I | *Hieracium praealtum* | I | I | I |
| *Dactylis glomerata* | I | I | I | *Leontodon tuberosus* | I | I | I |
| *Sonchus asper* | I | I | I | *Pteridium aquilinum* | I | – | I |

*Table 2:* Soil characteristics in *Pinus halepensis* forests in Kassandra peninsula

| | | | Texture (%) | | | | | | | | | Moisture constants | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Site type | Horizons | Depth (cm) | Sand | Silt | Clay | Classifications | pH | $CaCO_3$ (%) | Organic matter (%) | N (%) | C:N | Field capacity (%) | Wilting point (%) |
| | A1 | 1–11 | 41.9 | 12.3 | 45.8 | SCL | 7.61 | 13.98 | 4.21 | 0.18 | 14:1 | 21.84 | 16.66 |
| I | $A_3$ | 12–51 | 18.7 | 46.2 | 37.1 | CL | 7.76 | 17.90 | 2.50 | 0.13 | 11:1 | 24.59 | 18.54 |
| | B/C | 52–91 | 28.2 | 29.6 | 42.2 | C | 8.23 | 18.06 | 1.05 | 0.05 | 12:1 | 20.57 | 9.25 |
| | $A_1$ | 1–8 | 59 | 18.8 | 22.2 | SC | 7.63 | 13.88 | 4.38 | 0.16 | 16:1 | 25.14 | 15.57 |
| II | $A_3$ | 9–31 | 42.6 | 30.2 | 27.6 | SCL | 7.96 | 11.47 | 3.21 | 0.12 | 15:1 | 24.17 | 13.70 |
| | B | 32–49 | 46.7 | 20.8 | 32.5 | SCL | 8.21 | 20.80 | 1.21 | 0.05 | 14:1 | 22.70 | 13.20 |
| | B/C | 50–79 | 40.9 | 29.2 | 29.9 | SCL | 8.26 | 15.48 | 1.01 | 0.05 | 12:1 | 24.10 | 14.10 |
| | $A_1$ | 1–10 | 53.5 | 16.2 | 30.3 | SCL | 6.37 | | 3.35 | 0.11 | 18:1 | 20.50 | 10.00 |
| III | $A_3$ | 11–31 | 54.4 | 7.3 | 38.3 | SC | 6.04 | | 1.80 | 0.08 | 17:1 | 20.25 | 10.80 |
| | (B) | 32–53 | 46.7 | 13.5 | 39.8 | SC | 6.44 | | 1.17 | 0.06 | 16:1 | 20.90 | 11.50 |

SCL, sandy-clay loam; CL, clay loam; SC sandy clay; C, clay.

*Table 3:* Structural data in the three site types in different age classes

| Site type | Age class | | | Total | Overstorey | Middlestorey | Understorey |
|---|---|---|---|---|---|---|---|
| I | 40–60 | $n$ ha$^{-1}$ | | 460 | 225 | 225 | 10 |
| | | d.b.h. | Mean | 29.35 | 34.04 | 25.07 | 20 |
| | | | s.d. | 10.16 | 9.75 | 8.55 | – |
| | | G | | 46.41 | 29.49 | 16.48 | 0.44 |
| | | H | Mean | 16.13 | 17.18 | 15.24 | 7.50 |
| | | | s.d. | 3.87 | 3.23 | 4.24 | – |
| I | 60–80 | $n$ ha$^{-1}$ | | 585 | 380 | 155 | 50 |
| | | d.b.h. | Mean | 30.51 | 35.86 | 23.35 | 12 |
| | | | s.d. | 13.42 | 12.45 | 8.08 | 3.52 |
| | | G | | 50.99 | 42.97 | 7.41 | 0.61 |
| | | H | Mean | 16.72 | 19.38 | 13.58 | 6.20 |
| | | | s.d. | 5.08 | 3.13 | 3.08 | 1.54 |
| II | 60–80 | $n$ ha$^{-1}$ | | 527 | 200 | 280 | 47 |
| | | d.b.h. | Mean | 23.32 | 34.43 | 17.40 | 9.16 |
| | | | s.d. | 13.75 | 12.05 | 9.49 | 7.44 |
| | | G | | 29.82 | 20.81 | 8.59 | 0.41 |
| | | H | Mean | 13.05 | 17.20 | 11.14 | 5.66 |
| | | | s.d. | 4.79 | 2.99 | 3.36 | 3.14 |
| III | 10–20 | $n$ ha$^{-1}$ | | 620 | 420 | 200 | – |
| | | d.b.h. | Mean | 17.85 | 19.05 | 15.35 | – |
| | | | s.d. | 7.97 | 5.15 | 11.71 | – |
| | | G | | 18.57 | 12.82 | 5.75 | – |
| | | H | Mean | 11.03 | 12.57 | 7.80 | – |
| | | | s.d. | 3.41 | 2.85 | 1.88 | – |
| III | 40–50 | $n$ ha$^{-1}$ | | 473 | 306 | 140 | 27 |
| | | d.b.h. | Mean | 24.93 | 31.21 | 14.19 | 9 |
| | | | s.d. | 15.32 | 15.25 | 5.68 | 4.76 |
| | | G | | 31.68 | 28.92 | 2.55 | 0.21 |
| | | H | Mean | 12.35 | 15 | 8.05 | 5 |
| | | | s.d. | 4.61 | 3.42 | 1.45 | 0.81 |

$n$ ha$^{-1}$, number of trees per hectare; d.b.h., breast-height diameter in cm; G, basal area in m$^2$ ha$^{-1}$, H, height in m; s.d., standard deviation.

II, are given in Table 3 while the profile of this situation is shown in Figure 3c.

*Site type III*

*Spreading–physiognomy* It appears in hillsides with mostly steep south, south-eastern and south-western exposed slopes. In the overstorey *P. halepensis* dominates while in the understorey the characteristic species of the class and alliance mentioned above dominate with differential woody species of site type II, *Erica manipuliflora*, *Cistus salvifolius*, *Cistus monspeliensis*, *Calycotome villosa* (Table 1). The herbaceous vegetation consists of xerophytic species which appear in acid and degraded soils, mainly in ridges and southern exposed slopes.

*Soil* The forest soils, in the Mediterranean climate, of site type III are moderate shallow, rich in skeletal material in all horizons sandy-clay and sandy-clay loam. They are poor in organic matter whereas the content of N is medium and the C:N ratios (>15–17:1) indicate that the availability of

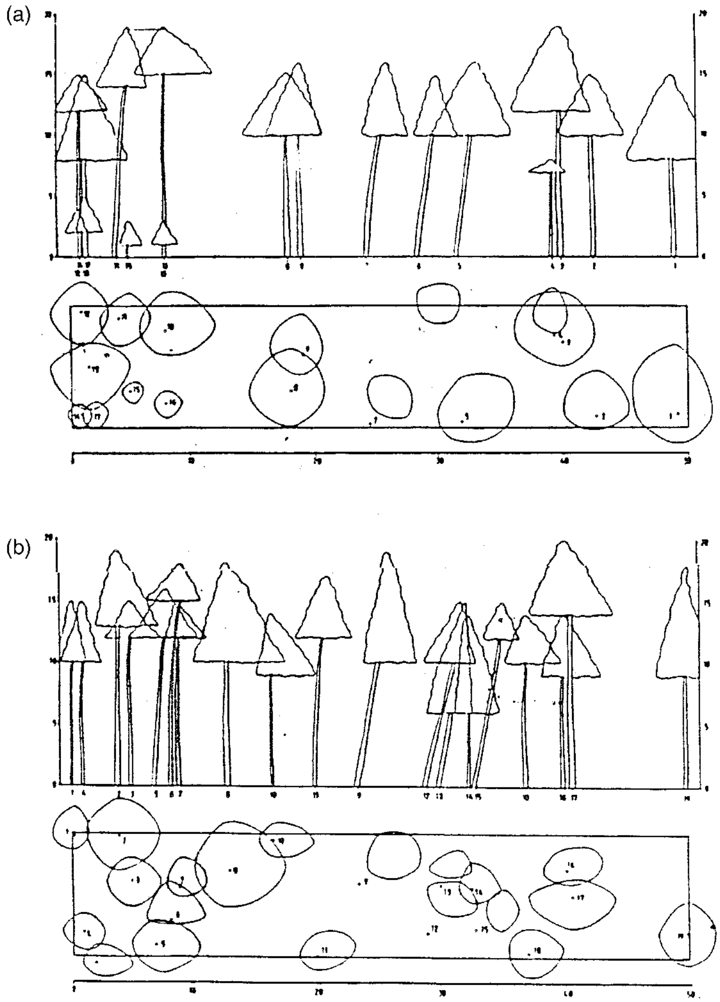


*Figure 2*. Stand profile of the site quality type I in *Pinus halepensis* woods in Kassandra, Chalkidiki. (a) Age class 40–60. (b) Age class 60–80.

N in particular may be limiting (Alexander, 1989). The pH is slightly acid because of the lack of calcium carbonate (Table 2).

*Stand structure* The data for the stands of the age classes 10–20 and 40–50 are given in Table 3 and the profiles of these situations are shown in Figures 4e and 4f respectively.

The most frequent structures of *P. halepensis* forests stands in the study area are shown by the profiles of stands in Figures 2, 3 and 4. Figures 2a and 2b illustrate associations of *P. halepensis* burnt many years ago, about 1940 or 1950, and they correspond to the vegetation unit of site type I. These associations are less heterogenous from a floristic viewpoint and appear in north and north-eastern aspects. Their floristic composition, concerning the prevailing species, becomes more similar to that of *Quercus ilex* associations. Even if the Quercion ilicis species are often mixed up with those of Querco–Fagetea, this is not true for the accompanied species (Lavrentiades, 1961; Tsitsoni, 1991).

Figure 3c illustrates stands of the site type II,

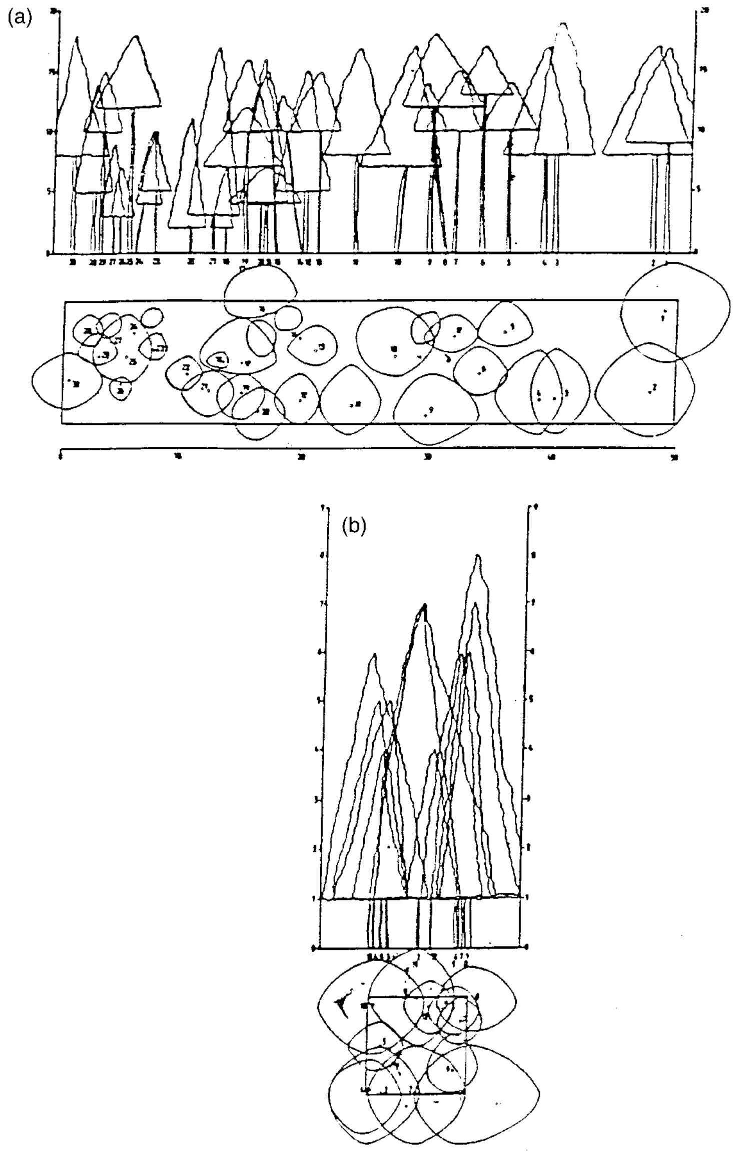


*Figure 3.* Stand profile of the site quality type II in *Pinus halepensis* woods in Kassandra, Chalkidiki. (a) Age class 60–80. (b) Thick young stands without shrubby understorey.

which appear in any aspect, mainly in depressions in the ground and middle hillsides. The data of structure present the normal increase of the age 60–80 (Table 3).

Figure 3d shows young stands; the shrubby understorey is entirely absent, whereas the herbaceous vegetation is significantly limited or has vanished.

Figures 4e and f illustrate areas which have suffered by fires recently (1977, 1981). In Figures 4e and f, the regenerated associations of these forests are often rich but heterogeneous from a floristic viewpoint. Usually, they appear in poor soils, in west, south-western aspects and species of the Cisto–Micromerietea class are often presented with species of Quercetalia ilicis. These

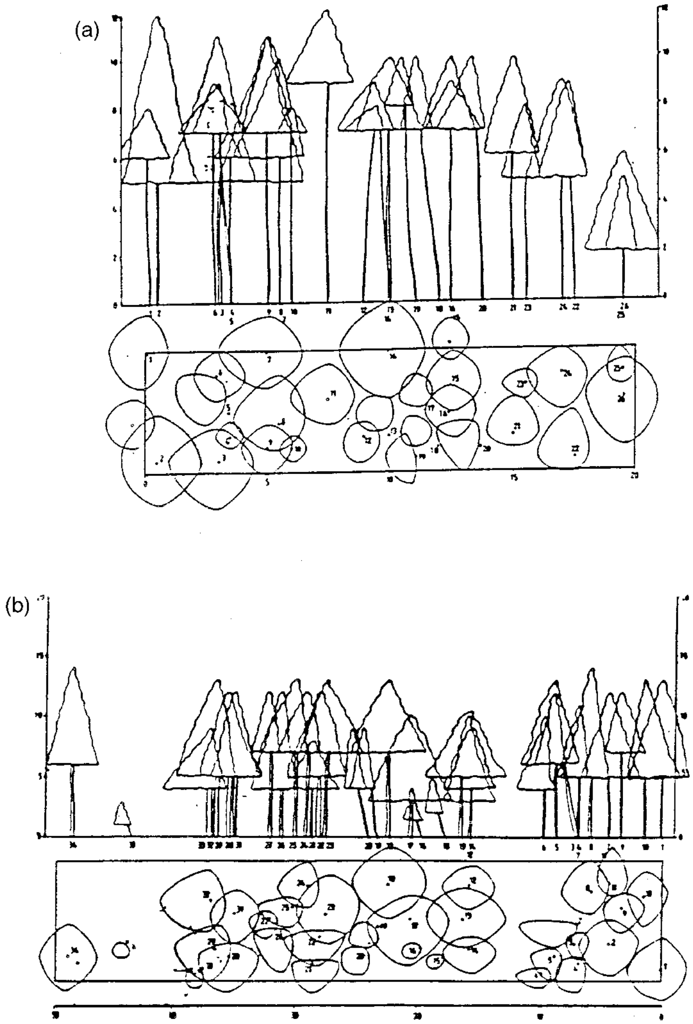


*Figure 4.* Stand profile of the site quality type III in *Pinus halepensis* woods in Kassandra, Chalkidiki. (a) Age class 10–20. (b) Age class 40–50.

communities correspond with the site type III. The data of structure in age classes 10–20 and 40–50 are shown in Table 3. The mean diameter, basal area and height increase proportionally to the age, except the mean diameter in middlestorey because of the relocation of these individuals within the storeys.

## Discussion

The formation of maquis, which is mainly met under the scattered stands of *P. halepensis* in this area, belongs to the Quercetea ilicis class and more specifically to the alliances of Oleo–Ceratonion and Quercion ilicis (Braun-Blanquet, 1936). From the above alliances the Oleo-Ceratonion mainly occurs along the coast reaching 100–150 m, whereas the Quercion ilicis alliance grows inland over 100 m, where from the characteristic species of Oleo-Ceratonion alliance, *Olea europaea* var. *sylvestris* appears more frequently while *Ceratonia siliqua* is absent. According to Rechinger (1943) and Pavlidis (1976), this species is also absent from the other two peninsulas of

Chalkidiki, Sithonia and Mount Athos and appears mostly in southern Greece and islands. Of the characteristic species of the class Quercetea ilicis and order Quercetalia ilicis, *Pistacia lentiscus*, *Smilax aspera*, *Quercus coccifera*, *Phillyrea latifolia*, *Rubia peregina*, etc. are the most frequently appearing species (Table 1). Of the characteristic species of Quercion ilicis alliance, *Asparagus acutifolius*, *Lonicera implexa*, *Piptatherum miliaceum*, *Arbutus unedo*, *Quercus ilex*, *Pistacia terebinthus* and *Rhamnus alaternus* occur most frequently.

The results of Table 1 in comparison with the results of Lavrentiades (1961) in the same area, appeared as follows: In the alliance Quercion ilicis two associations were distinguished by Lavrentiades. The first association Quercetum galloprovinciale (Braun-Blanquet, 1936; Braun-Blanquet *et al.*, 1951), which has a high homogeneity, appears in the present research area in the form of two subassociations. In the areas of the peninsula where the soil is deep, humic and covered by vegetal relics, the first subassociation occurs similar to the subassociation pubescentetosum (Braun-Blanquet, 1936; Braun-Blanquet *et al.*, 1951) of the Mediterranean coasts and corresponds to the vegetation unit of the site type I. On the hills of the south part of peninsula there is the second subassociation similar to the subassociation of ericetosum (Molinier, 1937) of the Mediterranean coasts of France with the dominant species *Arbutus unedo* and *Erica arborea*. This subassociation shows a great homogeneity, attains a height of 3–4 m and corresponds to the vegetation unit of the site type II.

The second association is the man-made association Calycotomo–Cistetum, which is a degraded stage of the Quercetum galloprovinciale (Braun-Blanquet, 1936) as a result of the wildfires. It is characterized by the presence of many thermophillous species and by the absence of shade-grown species and it occurs along the western and eastern coasts of the southern part of the peninsula, having as dominant species the most characteristic ones such as *Calycotome villosa* and *Cistus monspeliensis* (Table 1). This association corresponds to the site type III.

Very often, in the Kassandra peninsula, between the zones of *P. halepensis* forests and wheat farms, as well as in areas covered by maquis vegetation, which were clear-cut and abandoned, phases of various species of *Cistus* (*C. monspeliensis*, *C. salvifolius*, *C. incanus* ssp. *creticus*) appear. Within these phases there are individuals of *Quercus coccifera*, *Pinus halepensis*, *Rubus ulmifolius*, *Thymus capitatus*, *Thymus sibthorpii*, etc. Probably, these phases constitute a dynamic stage of evolution towards the maquis plant community (Lavrentiades, 1961).

Konstantinidis (1990) in *P. halepensis* forests in the second Peninsula of Chalkidiki, Sithonia, distinguished the following five associations: (1) Pinetum halepensis – Manipuliflorae; (2) Cisto – Ericetosum arboreae; (3) Cocciferetum; (4) Oleo – Lentiscetum; (5) Andrachno – Quercetum ilicis. The first two associations correspond to the site type III. The woody species of the third association correspond to the site type I.

Athanasiadis and Gerasimidis (1985) in Peloponnisos-Greece, classify the *P. halepensis* even-aged stands in the subassociation Myrtus communis–Pinus halepensis cocciferetosum in which they distinguished the following two phases: (1) Myrtus communis–Pinus halepensis cocciferetosum, Juniperosum phoeniceae; (2) Myrtus communis–Pinus halepensis cocciferetosum, Cistosum salvifoliae. The characteristic species of the second phase correspond partly to the characteristic species of the vegetation unit of site type III.

Raus (1979), in the alliance Quercion ilicis and the *P. halepensis* zone in E. Thessalia distinguished the following three associations: (1) *Erica manipuliflora*; (2) *Cistus salvifolius*; (3) *Thymus sibthorpii–Cistus creticus*. The first association corresponds to the site type III concerning the characteristic species.

Trinajstic (1990), in the forest vegetation of island Brac in Dalmatic coasts, distinguished the following two associations in *P. halepensis* forests: (1) Erico – Cistetum cretici pinetosum halepensis; (2) Querco ilicis – Pinetum halepensis. The characteristic woody plants of the first association correspond to the woody plants of site type III. The second association corresponds relatively to the site type I.

The soils of this area may be characterized as Rendzinas, in other words AC or (ABC) soils, characterized by the presence of strong grainy or angled structure and heavy mechanical composition. These soils belong to the category VERTISOLS according to the American soil taxonomy

(Hatzistathis, 1976). The soil research has also verified the close relationship between soil and vegetation. Wherever the demanding species appear, the soils are characterized by a higher availability of nutrients and better natural conditions. Moreover, the numbering of the forest types (I, II and III) describes at the same time an ecological series with a decrease of nutrients. Under Greek soil conditions the sites I and II have deep soils and the site III has moderate shallow soils. With respect to the content of organic matter the site qualities I and II are rich, whereas III may be characterized as poorer. The pH rates of the *P. halepensis* zone soils, where the present research was carried out, range from 8.26 to 6.04. The moisture constants are relatively satisfactory particularly for this drought-tolerant species which resists long-lasting drought periods even 6 months long (Table 2). Compared with the results of Papamichos and Alifragis (1986) in *P. halepensis* forest of Strofilia in Peloponnisos (South Greece) and Magini (1955), in *P. halepensis* forests in Italy, the same rates of pH and calcium carbonates were measured.

## Conclusions

The floristic regeneration ability of recent *P. halepensis* associations in the study area is the outcome of a constant pressure by natural and human-caused fires and the uninterrupted grazing through centuries. The fire and grazing are acknowledged more and more as not only temporary factors with disastrous influences, but also as basic elements of Mediterranean ecosystems for their growth (Naveh, 1973, 1975, 1991; Raus, 1979; Paola *et al.*, 1991). By this means, the shrub storey, which consists mainly of Quercion ilicis species, has been transformed, in respect to the natural dynamic succession. Consequently, the communities of *Pinus halepensis* forests were maintained at the expense of *Quercus ilex* and *Quercus pubescens*, forests which used to cover the entire peninsula. This is concluded because very often, within the existing wheat fields, over-aged individuals of *P. halepensis* and *Quercus pubescens* were found, which are considered as remains of forests pre-existing in the area (Lavrentiades, 1961). This conclusion is also supported by the expressed opinion (Barbero and Quesel, 1976), that in central and southern Greece the pine forests in Oleo–Ceratonio constitute the climatic-dependent association, while in Quercion ilicis the pine forests are of secondary origin.

The broadleaved, evergreen shrubs, which can survive through the effects of the two above mentioned factors, could be able to form forests, the structural and floristic differences of which would be important for the current shrubby communities. On the other hand, maquis is a combination of species exposed to grazing and fire, which can survive man-made effects, and moreover it is able to occupy zones of degraded or destroyed vegetation. In this vegetation of the over-grazed limestone areas, the formed evergreen communities cannot be recognized as regular in the range of communities, according to their dynamic evolution; for that reason they are grouped in accordance to their dominant species (Raus, 1979).

The structure of stands in these site types is mostly even-aged, occurring after a fire, in age classes 10–20, 25–35, 40–50 and 60–80 years. The evolution of the structural parameters in the three site types in *P. halepensis* forests appeared as follows:

1 *Diameter*: The greatest mean diameter of the overstorey was measured in the more fertile site type I.
2 *Basal area*: It was related to site quality and age of the stand, so the greatest total basal area was measured in site type I and the age class 60–80.
3 *Height*: The highest mean total height, for the same age class in the three site types, was measured in site type I.

Concerning the silvicultural purpose, this should be the creation of a forest, biologically healthy and ecologically managed for use of multiple purposes (timber production, recreation, resin production, apiculture, soil protection, water flow regulation etc.). In the area of Kassandra, the young to middle-aged stands are not being cultivated. The cultivation should be included in the management plans, aiming for the creation of even-aged stands or group selective ones with regular succession of ages.

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