

## Structure and development patterns analysis of the *Ostrya carpinifolia* pure and mixed stands in the western part of Nestos valley

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### Abstract

The study was conducted in *Ostrya carpinifolia* (pure and mixed) stands in the slopes of the western part of Nestos valley (in the region of Xanthi). In order to analyze the structure and the development patterns of our stands, 41 plots were established, trees were cut, increment cores were taken, and stem analysis was conducted in 3 couples of dominant (competitive) trees. The main results of this research indicate that a) *O. carpinifolia* (pure and mixed) stands origin, initiation, development patterns, structure and spatial distribution were strongly affected by anthropogenic disturbances. b) The development patterns and structures (today) of *O. carpinifolia* structural types were also affected by three other important factors: the growth ecology of each species, their regeneration mechanisms and the quality of the site. c) *O. carpinifolia* and *F. ornus* trees, until the age of 80 - 100 years old, dominate in the upper storeys, exhibiting similar height growth patterns, whereas *C. orientalis* trees usually are stratified in the lower storeys. d) The site sensitivity classification of the three main species, in *O. carpinifolia* mixed stands, is as follows *O. carpinifolia*>*F. ornus*>*C. orientalis*. This site sensitivity difference between the main species of our mixed stands has a significant effect in the formation of their structure. We observe a gradual alteration of the species contribution, in the total basal area of the stand, in relation to site quality. e) *O. carpinifolia* trees maintain a high sprouting capacity in medium ages (around 50 years old), whereas the most vigorous 30 years old stump sprouts, have high growth rhythms that are greater than those which had the seed origin standards in the first 30 years of their lives. f) The main silviculture objective is to convert almost all stands in seed origin stands. Furthermore, forest practice must favor multiple species mixed stands. Their composition must be determined in relation to site quality.

**Key words:** *Structure, anthropogenic disturbances, development patterns, Ostrya carpinifolia, Fraxinus ornus, Carpinus orientalis, site sensitivity, growth, sprouting capacity.*

### 1. Introduction

Descriptions of stand structure provide useful tools for management of forest resources (O'Hara and Milner 1992). In an ecological silviculture the term forest structure include the description of species mixture, the age and dimensions distribution of trees and the spatial, horizontal and vertical forest diarthrosis (Smiris 1992). According to Oliver and Larson (1996) "Stand structure is the physical and temporal distribution of trees and other plants in a stand. The distribution can

*be described by species; by vertical or horizontal spatial patterns; by size of living and/or dead plants or their parts, including the crown volume, leaf area stem, stem cross section, and others; by plants ages; or by combinations of the above"* Also mention that "Stand development is the part of stand dynamics concerned with changes in stand structures over time".

The possible variations in stands structures are almost infinite (Smith et. al. 1997). Oliver (1992) mentions that although stands occur in many structural patterns, however, we can find similar patterns in many parts of the world.

Numerous scales related variables affect the composition of vegetation, the development patterns and the structure in forest stands. Some of these factors are the disturbance history of the stands (the initiating and secondary disturbances), the distribution (and the species) of the seed trees after disturbances, the species ecology, the regeneration mechanisms of the different species and the quality of the site (Lorimer 1980, Kelty 1986, Deal et al. 1991, Smiris 1995, 1999, Oliver and Larson 1996, Milios 2000).

Man with his activities (acting as anthropogenic disturbances) shaped the structure and has influenced the development patterns of many forest ecosystems affecting many of the above mentioned factors.

In my country the destruction of forests started thousands years ago as the price paid to civilization (Tsoumis 1992). In the last centuries the damages were greater than in the past because of the ottomans occupation. These conditions created by this occupation lead to the population of mountain areas. This change of residence caused a degradation of the forests due to land clearing, burning, cutting, overgrazing and other human disturbances. The last 20 - 30 (Smiris 1995) years, (or in the last 70 - 80 in our case) an inverse process started, as the population left the mountains, resulting in a decreased level of pressure in the forests.

Size and age analysis in combination with disturbance history and growth rates reconstruction of individual trees has often been used to provide information about the history of forest development and the regeneration (in the past and present) patterns in a forest stand ( Stewart 1989, Agren and Zackrisson 1990, Arista 1995, Abrams et. al. 1995).

*Ostrya carpinifolia* is a sub - Mediterranean species of south Europe, extending from southeastern France, Italy, Balkan peninsula to Anatolia, Syria and Transcaucasia (Athanasiadis 1986, Tutin et. al. 1990, Strid and Tan 1997). It is a usual constituent of our deciduous forest and scrublands, growing often in limestone. We can also find it in open coniferous forest and in macchie on dry rocky slopes (Strid and Tan 1997).

In the present study, **the main objectives are:** a) to analyze the **structure** of *O. carpinifolia* stands, or groups (pure and mixed) in the slopes in the western part of Nestos valley (in the region of Xanthi) b) to analyze their **development patterns** c) to relate local **anthropogenic disturbance** regime to stands age and size structure d) to reconstruct and examine **growth**

**rates of interacting** (competitive) individual trees and e) to use this information to **suggest silvicultural alternatives for the management** of these stands.

## 2. Study area

The study was carried out in the western part of Nestos river valley. This area is located at the south of central Rhodope mountains in the northwest of Xanthi region which lies in North - east Greece, an area close to the Bulgarian border. Our stands are located in the Pascalia public forest and in particular at northfacing slopes between the abandoned villages Kastanoto and Aerico. The elevation ranges between 500 to 850 m. The climate is humid with harsh winters, the yearly precipitation averages 872 mm, and the mean annual temperature is 11.7 °C. This data come from the meteorological station of Echinosa a village about 50 kilometers away from our area due to the absence of a meteorological station in Nestos valley. The climatic conditions in Echinosa are close to our climate, because of many similarities between the two areas. Geologically, the study area belongs to marbe - calcitic - dolomitic series of Rhodope massif (Dimadis and Zachos 1986).

The area has been inhabited since the ancient times. In the beginning of the twentieth century (1912 - 1923), war events and population movements shaped the structure and influenced the development patterns of our stands. The population of the two villages (Kastanoto and Aerico) was dramatically reduced, as a result of the difficult social conditions. The Aerico was entirely abandoned in the period 1930 - 40 and the Kastanoto in 1960 - 70. Since 1912 - 23 many fields have gradually been abandoned and the intensity of grazing and illegal cuttings have been reduced.

The Pascalia public forest consists mainly of mixed stands (and a few pure). It's main forest species are: *Quercus pubescens*, *Quercus dalechampii*, *Quercus conferta*, *Fagus sp.*, *Carpinus orientalis*, *Ostrya carpinifolia*, *Fraxinus ornus* and *Castanea sativa*. Apart from these there are also the: *Cornus mas*, *Corylus avellana*, *Juglans regia*, *Tilia tomentosa*, *Acer monspessulanum*, *Acer campestre*, *Acer hyrganoum*, *Acer platanoides*, *Acer pseudoplatanus*, *Crataegus monogyna*, *Juniperus oxycendrus*, *Juniperus communis*, *Betula pendula*, etc. In this forest, in which most trees are sprout origin, a rudimentary management began in the decade 1930 - 40. However, the organized cuttings were few due to the absence of forest roads. The first management plan was conducted in the period 1960 - 70 (Maragos 1998).

## 3. Research method

In order to study stands structure, 21 representative plots of 500 m<sup>2</sup> (20mx25m) and 20 of 100 m<sup>2</sup> (10mx10m) were randomly established. These plots were graded in structural types. Also the regeneration diarthrosis was measured using 20 plots of 4 m<sup>2</sup> (2mx2m). These plots were distributed in 3 site types. Site type A represents the good site qualities, site type B represents the medium and the C site type represents the bad site qualities. This distinction was made using a combination of several methods such as: the height of the predominant trees in each

sample plot (5 trees in a plot of 500 m<sup>2</sup>) in relation to their age, the location of the plot on the slope, the shape of the terrain (concave or convex), the slope steepness, the slope exposure (northern, eastern etc.) and the soil depth (Husch et. al. 1982, Papamichos 1985, Dafis 1986, Matis 1989, Zingg 1984, Philip 1994, Smith et. al. 1997).

For every sample plot the following data were recorded: a) diameter in cm, for trees with a diameter of over 4 cm (breast height), and b) height in meters. In the case of regeneration plots, the number, the species and the height of seedlings and young stump sprouts were recorded.

In two structural types in which almost all the trees are sprout origin, in order to estimate the initial density of *Ostrya carpinifolia* trees in the stands before the cuttings (coppice with standards system), that took place thirty years ago, we counted the number of standards and sprout groups. Also the number of *Ostrya carpinifolia* sprouts (with a diameter of over 4 cm) per group (old stump) were counted.

In each plot of three structural types, **increment cores** for all species were taken (at the stump height), in the main diameter classes, for the seed origin trees. In the case of sprout origin groups of trees, these groups were divided in categories according to the number of sprouts per old stump and the diameter and height of the most vigorous sprout per old stump. For each category some stump groups were selected according to the stratified random sampling method (Matis 1987) and an increment core from only one sprout (per group) was taken. In the plots of the two structural types (mentioned above) an increment core of each standard and of only one sprout (in one sprout group) was taken.

Stump height was preferred (from breast height) for the increment cores, in order to have a more exact estimation of the trees age, because it is closer to the tree base. Basal ages are more useful than breast height ages in stand reconstruction studies, where we are trying to "gain a precise understanding of the total age structure of the stand" (Deal et. al. 1991).

A major problem was that in many cases (mostly in two of our structural types) the growth rings were not visible in the increment cores, so the trees were cut and the age was recorded using a cross sectional disc (in the stump height).

**Stem analysis** was conducted in 3 couples of dominant (competitive) trees in 3 structural types. Two couples consist of a dominant *O. carpinifolia* standard (remainder of the old stand) and an adjacent (most vigorous) *O. carpinifolia* stump sprout from the adjacent sprout group. The third couple consists of a seed origin *O. carpinifolia* tree and a seed origin *Fraxinus ornus* tree. All these trees (in each couple) were competitors, they had almost the same height and their crowns were touching each other. They were selected according to the stratified random sampling method. From each tree, cross - sectional discs were cut and removed from a 0.3 m level, breast height, 3.30 level and at a 2 meter intervals up to the bole. The last disc was collected from the 5 cm - bole diameter. These discs were taken to the Forestry laboratory in order to measure the rings' width with the ADDO instrument (Smiris 1991, Smiris et. al. 1998).

In stem analysis the mathematics formulas of Regent instruments in Xlstem V1.1 were used (Fortin and Labranche 1996).

In the other structural types trees were cut but stem analysis was not feasible because some annual rings were not visible due to small radial growth of trees (in some years) in relation to the wood structure of the species.

Also information was taken from old residents of the nearby villages about the human activities and the vegetation form and composition (in the area) in the previous decades.

Finally in order to have an indicative picture of our stands soil, a soil profile of a representative site was taken in 3 plots (one plot for each site type) and soil samples were analyzed (Alifragis and Papamichos 1995) in the laboratory.

#### 4. Results

##### 4.1. Soil

The soil analysis data are given in table 1.

Table 1. Soil analysis data

| Soil profile | Horizon        | Depth Cm | Org. matter % | Sand % | Silt % | Clay % | Texture | N%   | pH  | Site type |
|--------------|----------------|----------|---------------|--------|--------|--------|---------|------|-----|-----------|
| 1            | 1 <sup>a</sup> | 0-20     | 11.60         | 34.1   | 46.7   | 19.2   | L       | 0.47 | 7.1 | A         |
|              | 2              | 20-40    | 7.50          | 29.8   | 33.5   | 36.7   | CL      | 0.33 | 7.5 |           |
|              | 3              | 40-60    | 7.90          | 30.6   | 41.2   | 28.2   | CL      | 0.35 | 7.5 |           |
|              | 4              | 60-80    | 8.80          | 33.9   | 43.8   | 22.3   | L       | 0.39 | 7.4 |           |
| 2            | A              | 0-11     | 14.76         | 27.4   | 53.5   | 19.1   | SiL     | 0.49 | 7.1 | B         |
|              | B              | 11-35    | 6.98          | 25.1   | 36.3   | 38.6   | CL      | 0.25 | 7.3 |           |
| 3            | A              | 0-18     | 8.58          | 37.2   | 41.7   | 21.1   | L       | 0.32 | 7.4 | C         |

a The soil profile 1 was taken in an abandoned field, as a result there were no forest soil horizons.

##### 4.2. Structural types

Five main structural types were found. These structural types include stands, or smaller formations dominated by *O. carpinifolia*, or stands in which *O. carpinifolia* constitutes one of the main (with respect to basal area) species component.

###### 4.2.1. Site type A

In this site type, one structural type was found.

#### 4.2.1.1 St. type 1. Pure *O. carpinifolia* formations (coppice with standards)

In this type 10 sample plots were established. These pure *O. carpinifolia* formations (small stands) are two aged. Almost all trees are 30 years old stump sprouts, except a few individuals which are 80 - 86 years old. These sprouts, even though they are clustered around old stumps, have straight stems of good form.

The plots dimensions were 10mx10m mainly because of the formations sizes (small stands) and their structure homogeneity. These small stands were initiated in abandoned fields that had very small width and great length. The fields had step like forms in a concave area between slopes with convex terrain. The fields soil, which had been carried over from adjacent areas by the cultivators, has a depth over 70 cm (see table 1).

The initiation of this type coincides with the period of time between 1912 - 1923 in which the war events led the local people to abandon many of their fields. The available growing space was rapidly occupied by *O. carpinifolia* seedlings (the seeds came probably from sparsely scattered individuals). The duration of this invasion is not easy to be estimated because today there is only a small number of old trees. The present structure of these formations is the result of cuttings that took place 30 years ago, under the coppice with standards system. The density of standards (which established immediately after the fields abandonment) is about 40 per hectare. Also the density of the sprout groups (old stumps) is 1440 per hectare and the mean number of sprouts per old stump is 3.94 (st. deviation=1.75). We can conclude that the initial density (before the cuttings) of *O. carpinifolia* was 1480 trees per hectare.

The (present) mean structural type statistics are presented in table 2.

Table 2. Mean stand statistics for st. type 1 in site type A

| Total                  |           |             |          |             |      |                      |
|------------------------|-----------|-------------|----------|-------------|------|----------------------|
| Species                | DBH       |             | Height   |             | N/Ha | B. A.                |
|                        | Mean (cm) | St. Deviat. | Mean (m) | St. Deviat. |      | (m <sup>2</sup> /ha) |
| <i>O. carpinifolia</i> | 7.74      | 2.87        | 12.9     | 2.75        | 5720 | 30.65                |
| Overstorey             |           |             |          |             |      |                      |
| <i>O. carpinifolia</i> | 8.65      | 2.78        | 14.3     | 1.48        | 4200 | 27.21                |
| Middlestorey           |           |             |          |             |      |                      |
| <i>O. carpinifolia</i> | 5.80      | 1.10        | 9.1      | 1.28        | 1480 | 3.39                 |
| Understorey            |           |             |          |             |      |                      |
| <i>O. carpinifolia</i> | 4.00      | 0.00        | 5.5      | 0.00        | 40   | 0.05                 |

The bole distribution in diameter classes is given in figure 1. We observe a fall in diameter distribution in the small diameter classes, this fall is not abrupt due to the existence of growth differences among sprouts. The standards appear in the diameter classes of 25 (10 trees) and 27 (30 trees) cm.

The tree height distribution in height classes (see fig. 1) shows an almost multistorey stand with the maximum trees massing in the 15 m height class. In this case even though the sprouts are 50 - 55 years younger than the standards many of them have almost the same height (17 - 17.5 m).

type A.

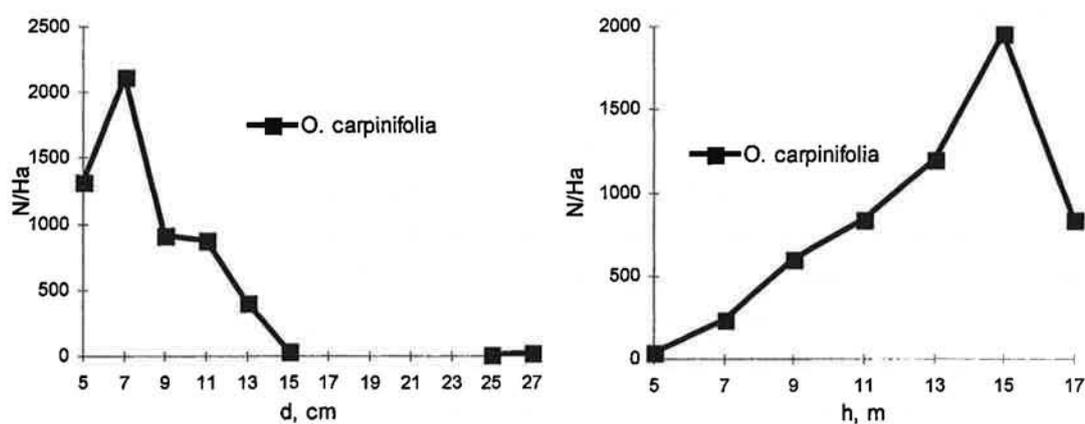


Figure 1. Structure analysis graph of diameter and height classes of st. type 1 in site.

Today a few *Acer platanoides* and *Fraxinus ornus* seedlings and saplings have been established, in openings, under the *O. carpinifolia* canopy.

#### 4.2.2. Site type B

In this site type, three structural types were found.

##### 4.2.2.1. St. type 1. *O. carpinifolia* - *F. ornus* formations (coppice with standards)

In this type 10 sample plots of 100 m<sup>2</sup> were established. *O. carpinifolia* is two aged having exactly the same age structure as in st. type 1 of site type A. Most of the *F. ornus* trees are 40 - 45 years (sprout and seed origin) old except a few which are older (75 - 85 years old, seed origin). However there are two more species in these stands with small participation in the total basal area. *Carpinus orientalis* and *Cornus mas* trees are 40 - 60 ( sprout origin) years old. As in the case of site type A the *O. carpinifolia* sprouts have straight stems of good form.

The plots dimensions were 10mx10m, mainly because of the stands structure homogeneity. These small stands were initiated in the same period (in nearby areas) with the previous st. type of site type A, in the slopes with the convex terrain at the edges of the fields. The years before

the fields abandonment, as a result of the vicinity to the fields, since human activities were extremely intense, these slopes were almost bald of vegetation. Probably there were some *O. carpinifolia* trees that were cut afterwards. We conclude that in this case (also) the stands followed almost the same development pattern as in site type A. The main differences are the slightly different initial stand composition and the fact that in the cuttings that took place 30 years ago (coppice with standards system) only *O. carpinifolia* trees were cut. The density of standards (which established immediately after the fields abandonment) is about 80 per hectare. Also the density of the sprout groups (old stumps) is 1240 per hectare and the mean number of sprout per old stump is 5.48 (st. deviation=3.20). We conclude that the initial density (before the cuttings) of *O. carpinifolia* was 1320 trees per hectare.

The (present) mean structural type statistics are presented in table 3.

Table 3. Mean stand statistics for structural type 1 in site type B

Total

| Species                | DBH       |             | Height   |             | N/Ha | B. A.<br>(m <sup>2</sup> /ha) |
|------------------------|-----------|-------------|----------|-------------|------|-------------------------------|
|                        | Mean (cm) | St. Deviat. | Mean (m) | St. Deviat. |      |                               |
| <i>O. carpinifolia</i> | 6.36      | 2.13        | 8.5      | 1.99        | 6840 | 24.19                         |
| <i>F. ornus</i>        | 6.39      | 3.90        | 7.9      | 2.07        | 760  | 3.34                          |
| Other species          | 4.13      | 0.22        | 6.1      | 0.76        | 160  | 0.21                          |

Overstorey

|                        |      |      |     |      |      |       |
|------------------------|------|------|-----|------|------|-------|
| <i>O. carpinifolia</i> | 7.25 | 2.26 | 9.9 | 1.03 | 3960 | 17.95 |
| <i>F. ornus</i>        | 9.00 | 4.94 | 9.9 | 1.40 | 320  | 2.63  |
| Other species          | -    | -    | -   | -    | -    | -     |

Middlestorey

|                        |      |      |     |      |      |      |
|------------------------|------|------|-----|------|------|------|
| <i>O. carpinifolia</i> | 5.15 | 1.09 | 6.6 | 1.19 | 2840 | 6.18 |
| <i>F. ornus</i>        | 4.50 | 0.53 | 6.4 | 0.83 | 440  | 0.71 |
| Other species          | 4.13 | 0.22 | 6.1 | 0.76 | 160  | 0.21 |

Understorey

|                        |      |      |     |      |    |      |
|------------------------|------|------|-----|------|----|------|
| <i>O. carpinifolia</i> | 4.50 | 0.41 | 3.5 | 0.00 | 40 | 0.06 |
| <i>F. ornus</i>        | -    | -    | -   | -    | -  | -    |
| Other species          | -    | -    | -   | -    | -  | -    |

The younger age group of *F. ornus* consists of a few seed origin trees which were established under small canopy openings and mainly of sprout origin trees (as a result of illegal cuttings).

*C. orientalis* and *C. mas* trees are sprouts, arised from the stumps of individuals which were established probably with *O. carpinifolia* and *F. ornus* trees in the stands initiation stage 80 - 85 years ago. These individuals were cut illegally several decades ago.

Figure 2 presents the bole distribution in diameter classes. We observe a more abrupt fall in the small diameter classes of *O. carpinifolia* distribution (which represent the thirty years old sprouts) than in the case of site type A. This happens because of the worse site conditions than

site type A which delayed the dimensions differentiation. The standards appear in the diameter classes of 19 (40 trees) and 21 (40 trees) cm. The *F. ornus* trees, of younger age group, are distributed in 5 and 7 cm classes and the older trees in 13 and 15 cm classes.

The tree height distribution in height classes (see fig. 2) shows an almost multistorey stand with the maximum trees massing in the 9 m height class. In this st. type (again), even though the sprouts are 50 - 55 years younger than the standards, many of them have almost the same height. The *F. ornus* trees are distributed in the same height classes with *O. carpinifolia* trees having the maximum massing in the 7 m class (younger age group).

type B.

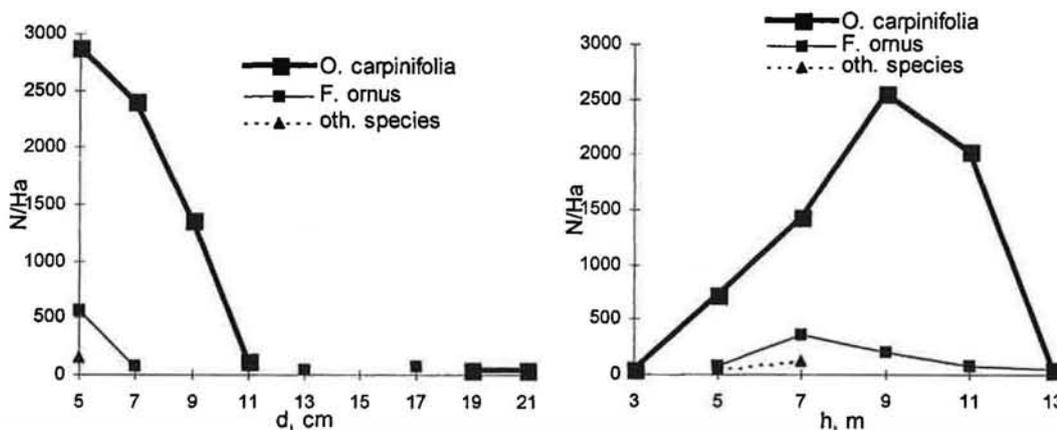


Figure 2. Structure analysis graph of diameter and height classes of st. type 1 in site.

#### 4.2.2.2. St. type 2. *O. carpinifolia* - *C. orientalis* - *F. ornus* - other species formations

In this type 5 sample plots of 500 m<sup>2</sup> were established. These small stands are unevenly aged. The ages of their trees (with a diameter of over 4 cm) is between 35 - 100 years. Most of the *O. carpinifolia* and *C. orientalis* trees are 70 - 85 years old, although there are a few trees which are older (90 - 100 years) and a few which are 35 - 70 years old. Almost the same age structure is found in *F. ornus* trees. The only difference is that, in this case, the younger age group count in a greater number of trees. As far as the other species component is concerned, it consists of *Acer monspessulanum*, *Cornus mas*, *Quercus dalechampii* and *Acer campestre* trees. These trees are unevenly aged too, but most individuals are 75 - 85 years old.

The st. type 2 stands are located in slopes nearby old fields. These fields are closer (than the fields of site type A) to Kastanoto and Aerico villages, consequently after the abandonment due to war events in 1912, some of them, were cultivated (the years after 1923) again by residents of the above villages. The cultivation lasted till 1960 - 70. The facts mentioned above led to st. type 2 initiation and formed its structure.

The (present) mean structural type statistics are presented in table 4.

Table 4. Mean stand statistics for st. type 2 in site type B

## Total

| Species                | DBH       |             | Height   |             | N/Ha | B. A.<br>(m <sup>2</sup> /ha) |
|------------------------|-----------|-------------|----------|-------------|------|-------------------------------|
|                        | Mean (cm) | St. Deviat. | Mean (m) | St. Deviat. |      |                               |
| <i>O. carpinifolia</i> | 11.90     | 2.87        | 9.9      | 1.81        | 400  | 4.70                          |
| <i>C. orientalis</i>   | 6.49      | 2.07        | 6.8      | 2.08        | 784  | 2.86                          |
| <i>F. ornus</i>        | 8.56      | 3.49        | 9.6      | 2.37        | 336  | 2.25                          |
| Other species          | 8.45      | 4.13        | 7.4      | 2.97        | 172  | 1.19                          |

## Overstorey

|                        |       |      |      |      |     |      |
|------------------------|-------|------|------|------|-----|------|
| <i>O. carpinifolia</i> | 12.67 | 2.58 | 10.7 | 1.28 | 300 | 3.93 |
| <i>C. orientalis</i>   | 9.05  | 2.63 | 10.3 | 1.30 | 124 | 0.86 |
| <i>F. ornus</i>        | 9.84  | 3.49 | 10.9 | 1.58 | 224 | 1.91 |
| Other species          | 12.24 | 3.29 | 10.5 | 1.10 | 68  | 0.85 |

## Middlestorey

|                        |      |      |     |      |     |      |
|------------------------|------|------|-----|------|-----|------|
| <i>O. carpinifolia</i> | 9.60 | 2.53 | 7.8 | 0.87 | 96  | 0.74 |
| <i>C. orientalis</i>   | 6.15 | 1.56 | 6.7 | 1.02 | 564 | 1.78 |
| <i>F. ornus</i>        | 6.04 | 1.65 | 7.4 | 0.83 | 104 | 0.32 |
| Other species          | 6.53 | 2.64 | 6.4 | 1.27 | 72  | 0.28 |

## Understorey

|                        |      |      |     |      |    |      |
|------------------------|------|------|-----|------|----|------|
| <i>O. carpinifolia</i> | 9.00 | -    | 4.0 | -    | 4  | 0.03 |
| <i>C. orientalis</i>   | 5.23 | 1.20 | 3.5 | 0.64 | 96 | 0.22 |
| <i>F. ornus</i>        | 5.75 | 0.35 | 3.0 | 0.00 | 8  | 0.02 |
| Other species          | 4.75 | 0.85 | 3.2 | 0.65 | 32 | 0.06 |

In the area that is occupied today by the st. type 2 stands, human activities were extremely intense, as a result these slopes were almost bald of vegetation. According to the trees age structure there were only few sparsely scattered individuals of *O. carpinifolia*, *F. ornus* (sprout and seed origin trees) and *C. orientalis* (mainly sprout origin trees). After the fields abandonment the available growing space was occupied by seed (mostly) origin *O. carpinifolia*, *F. ornus* and other species plants and by sprout origin (from existed old stumps) or/and seed origin *C. orientalis* individuals. After the fields recultivation the human activities were not so intense, especially grazing and cuttings, as a result the stands continue to grow under the small pressure of illegal cuttings. The result of these cuttings is the establishment of the (mainly sprout origin) younger age group of all species.

The structure and the composition of this st. type were intensely modified by forest service cuttings that took place a year ago. Even though, in these cuttings, mainly *O. carpinifolia* trees were removed, *O. carpinifolia* is, still, by far the most dominant species (with respect to basal area) having a basal area of 4.70 m<sup>2</sup>/ha (see table 4).

type B.

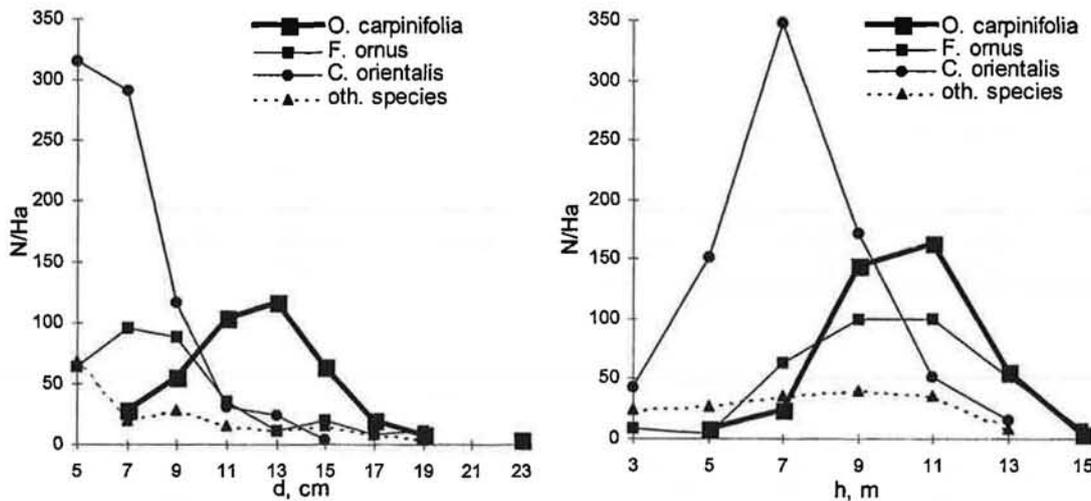


Figure 3. Structure analysis graph of diameter and height classes of st. type 2 in site.

The *O. carpinifolia* diameter distribution (fig. 3) resembles to a normal distribution that is characteristic of an even aged structure. The few younger and older trees are located in the smaller and in the higher diameter classes respectively. The *F. ornus* distribution seems analogous to its age structure having the younger trees in the small classes and the older in the classes which represent the large diameters. This is partly true, since the number of trees present in the small classes is by far larger than the true number of younger trees. This happens because there are significant age differences between the trees inside each diameter class due to growth differences among sprouts of the same stump and to the different trees origin (sprout or seed origin trees). In *C. orientalis* trees we observe a fall in diameter distribution. The other species trees are distributed almost evenly in all classes.

The dissimilar distribution of different species trees with the same age, especially *O. carpinifolia* and *C. orientalis* trees) is the result of a) the fact that most of the *C. orientalis* trees are sprout origin arisen in groups from old stumps and b) the different growth ecology (growth rates) among the species.

The tree height distribution shows a multistorey stand. The *O. carpinifolia* and the *F. ornus* trees dominate in the upper storeys and the *C. orientalis* in the lower storeys. We observe that *O. carpinifolia* trees distribution resembles to *F. ornus* trees distribution. The differences between the two distributions is probably the result of the species different number of trees per hectare and their dissimilar age structure.

#### 4.2.2.3. St. type 3. *O. carpinifolia* - *F. ornus* - other species stands

In this st. type, which occupies an area larger than all the rest st. types together, 10 sample plots of 500 m<sup>2</sup> were established. The stands of this st. type are unevenly aged. Most of the *O. carpinifolia* trees are 70 - 90 years old, although there are many trees which are older (some trees are over 130 years old) and a few which are 35 - 70 years old. Almost the same age

structure is found in *F. ornus* and the other tree species. The only difference is that, in the *F. ornus* case, the younger age group count in a greater number of trees. The other species component consists of *C. orientalis*, *C. mas*, *A. monspessulanum*, *A. campestre* and *Sorbus torminalis* trees. However almost the half of other species trees belong to *C. orientalis* species.

These stands are located in distant to the two villages areas. Even though the illegal cuttings pressure, before the period 1912 - 1923 was intense, there were many sprout and seed origin trees. During the war events, illegal cuttings and grazing were almost stopped, as a result a new age group, mainly of sprout origin and secondly of seed origin trees, was established. After 1923, human activities, as cuttings, restarted with lower tension than before. The result of these cuttings is the establishment of the (mainly sprout origin) younger age group of all species. In this st. type many sprout origin *O. carpinifolia* trees have crooked stems of poor form.

Figure 4 presents the bole distribution in diameter classes (see table 5 for the mean st. type statistics). *O. carpinifolia* has an unsymmetrical normal form distribution. The older trees are distributed in the large diameter classes, the age group of 70 - 90 years old (which include the majority of trees) is represented mainly by the medium classes and the younger trees are distributed in the small diameter classes.

type B.

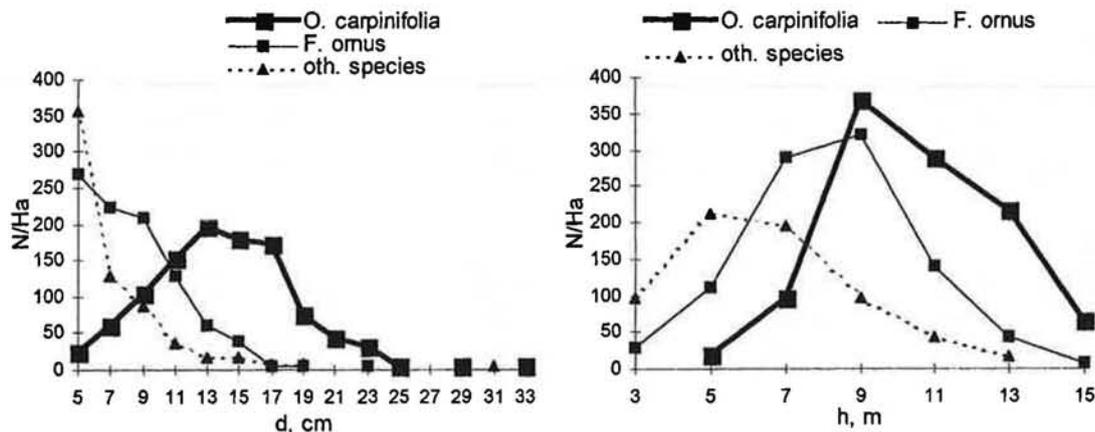


Figure 4. Structure analysis graph of diameter and height classes of st. type 3 in site.

However there are significant age differences between the trees inside smaller (mainly) diameter classes due to growth differences and to the different trees origin (sprout or seed origin trees). In *F. ornus* trees, as in st. type 2, the form of the distribution is the result of a) its unevenly aged structure and b) the significant age differences between the trees inside each diameter class, e.g. many trees of 5 cm class are 60 - 80 years old. In the other species we observe an exponential distribution.

The tree height distribution in height classes (see fig. 4) shows an almost multistorey stand with the maximum trees massing in the 9 m height class. The upper storeys are dominated by *O. carpinifolia*, the lower storeys by the other species and the *F. ornus* trees dominate in the

intermediate storeys and partly in the upper storeys. As in the case of st. type 2 *O. carpinifolia* trees distribution shape resembles to that of *F. ornus* trees.

#### 4.2.3. Site type C

In this site type, one structural type was found.

Table 5. Mean stand statistics for st. type 3 in site type B

##### Total

| Species                | DBH       |             | Height   |             | N/Ha | B. A.<br>(m <sup>2</sup> /ha) |
|------------------------|-----------|-------------|----------|-------------|------|-------------------------------|
|                        | Mean (cm) | St. Deviat. | Mean (m) | St. Deviat. |      |                               |
| <i>O. carpinifolia</i> | 13.67     | 4.34        | 10.1     | 2.22        | 1052 | 17.00                         |
| <i>F. ornus</i>        | 7.96      | 3.06        | 7.9      | 2.24        | 940  | 5.37                          |
| Other species          | 6.77      | 3.52        | 6.2      | 2.35        | 660  | 3.02                          |

##### Overstorey

|                        |       |      |      |      |     |       |
|------------------------|-------|------|------|------|-----|-------|
| <i>O. carpinifolia</i> | 15.50 | 3.92 | 11.5 | 1.52 | 652 | 13.08 |
| <i>F. ornus</i>        | 10.48 | 3.23 | 10.8 | 1.20 | 248 | 2.34  |
| Other species          | 12.74 | 5.75 | 10.5 | 0.96 | 76  | 1.16  |

##### Middlestorey

|                        |       |      |     |      |     |      |
|------------------------|-------|------|-----|------|-----|------|
| <i>O. carpinifolia</i> | 10.76 | 3.15 | 8.0 | 1.05 | 396 | 3.91 |
| <i>F. ornus</i>        | 7.22  | 2.44 | 7.2 | 1.27 | 644 | 2.94 |
| Other species          | 6.57  | 2.38 | 6.7 | 1.32 | 368 | 1.41 |

##### Understorey

|                        |      |      |     |      |     |      |
|------------------------|------|------|-----|------|-----|------|
| <i>O. carpinifolia</i> | 4.50 | 0.00 | 4.0 | 0.00 | 4   | 0.01 |
| <i>F. ornus</i>        | 4.88 | 0.96 | 3.5 | 0.66 | 48  | 0.09 |
| Other species          | 5.00 | 1.09 | 3.7 | 0.49 | 216 | 0.45 |

#### 4.2.3.1. St. type 1. *C. orientalis* - *O. carpinifolia* - *F. ornus* - other species stands

In our study area, stands of this st. type (*C. orientalis* - *O. carpinifolia* - *F. ornus* - other species stands) occupy a small portion of the bad site conditions areas. The rest of the stands (of site type C) mainly consist of *C. orientalis* and secondly of *Q. pubescens* (*O. carpinifolia* component is very small or non existent).

In this type 6 sample plots of 500 m<sup>2</sup> were established. The great majority of trees from all species are 70 - 90 years old except a few *F. ornus* individuals which are younger. Even though *F. ornus* participation in the total basal area is smaller than the 10%, we accept it as a main component of the mixture because its presence is considered to contribute to the formation of the stands ecological conditions.

type C.

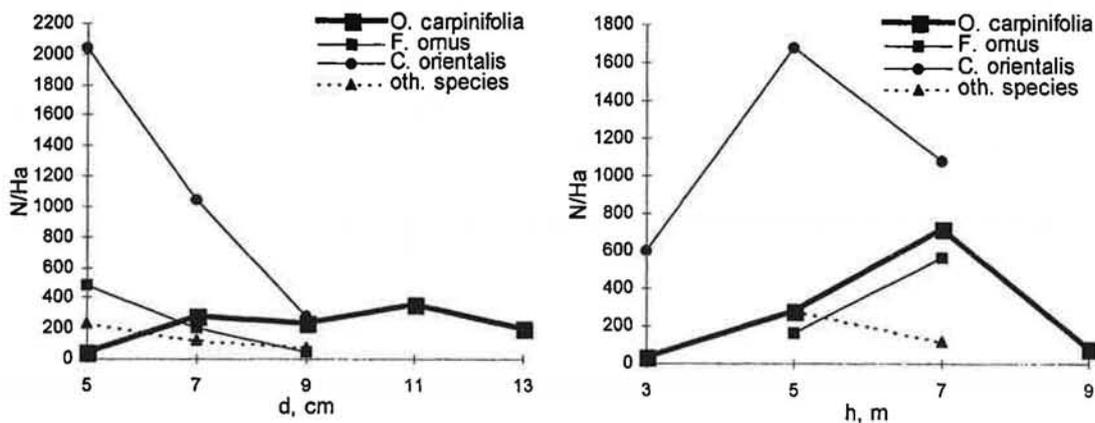


Figure 5. Structure analysis graph of diameter and height classes of st. type 1 in site.

Table 6. Mean stand statistics for st. type 1 in site type C

Total

| Species         | DBH       |         | St. | Height   |             | N/Ha | B. A.<br>(m <sup>2</sup> /ha) |
|-----------------|-----------|---------|-----|----------|-------------|------|-------------------------------|
|                 | Mean (cm) | Deviat. |     | Mean (m) | St. Deviat. |      |                               |
| C. orientalis   | 5.49      | 1.59    |     | 4.9      | 1.44        | 3360 | 8.43                          |
| O. carpinifolia | 9.36      | 2.37    |     | 6.3      | 1.34        | 1122 | 8.18                          |
| F. ornus        | 5.56      | 1.26    |     | 6.2      | 1.00        | 720  | 1.83                          |
| Other species   | 5.68      | 1.45    |     | 4.8      | 1.10        | 438  | 1.18                          |

Overstorey

|                 |       |      |  |     |      |      |      |
|-----------------|-------|------|--|-----|------|------|------|
| C. orientalis   | 6.47  | 1.30 |  | 6.4 | 0.61 | 1278 | 4.37 |
| O. carpinifolia | 10.23 | 1.84 |  | 6.8 | 0.76 | 882  | 7.45 |
| F. ornus        | 5.75  | 1.31 |  | 6.7 | 0.50 | 558  | 1.52 |
| Other species   | 7.25  | 0.96 |  | 6.0 | 0.41 | 162  | 0.67 |

Middlestorey

|                 |      |      |  |     |      |      |      |
|-----------------|------|------|--|-----|------|------|------|
| C. orientalis   | 4.95 | 1.01 |  | 4.2 | 0.69 | 1884 | 3.76 |
| O. carpinifolia | 6.17 | 0.68 |  | 4.1 | 0.38 | 240  | 0.73 |
| F. ornus        | 4.88 | 0.85 |  | 4.6 | 0.48 | 162  | 0.31 |
| Other species   | 4.79 | 0.70 |  | 4.1 | 0.61 | 276  | 0.51 |

Understorey

|                 |      |      |  |     |      |     |      |
|-----------------|------|------|--|-----|------|-----|------|
| C. orientalis   | 4.30 | 0.45 |  | 2.3 | 0.27 | 198 | 0.30 |
| O. carpinifolia | -    | -    |  | -   | -    | -   | -    |
| F. ornus        | -    | -    |  | -   | -    | -   | -    |
| Other species   |      |      |  |     |      |     |      |

The other species component consists of *C. mas*, *A. monspessulanum*, *A. campestre* and *Q. pubescens* trees.

Most of the stands of this st. type are located in slopes close (above) to Kastanoto village. The illegal cuttings pressure and especially overgrazing before the period 1912 - 1923 was extremely intense, consequently these slopes were almost bald of vegetation. During the war

events, illegal cuttings and grazing were gradually reduced and finally stopped. After 1923 the village residents were fewer and human activities removed to other areas richer in vegetation. The stands initiation coincides with this war period. Almost all their trees are sprout origin (except perhaps few *F. ornus* individuals) raised from the existed old stumps. In this st. type almost all *O. carpinifolia* trees have crooked stems of poor form.

The bole distribution in diameter classes is given in figure 5 (see table 6 for the mean st. type statistics). Even though the different tree species have almost the same age and almost all the trees are sprout origin, we observe great differences in their diameter distributions because of their different growth ecology.

The distribution of trees of the same species with the same age in different diameter classes is the result of growth differences between sprout individuals of different stump origin but mainly of competition between the sprouts of the same stump.

The tree height distribution in height classes (see fig. 5) shows a stand with one storey in 5 - 7 m.

In this st. type there are many sprouts with a breast height diameter under 4 cm, having almost the same age as the other trees. However there are some which have younger age. The same phenomenon is observed in st. types 2 and 3 of site type B, though in that cases most of these (mainly sprout origin) trees belong to the younger age group of their st. type.

### 4.3. Regeneration

In some of the fields which were abandoned in the period 1960 -1970 (see st. type 2 of site type B), the present vegetation consists of a few sparsely scattered trees. The forestation of these areas failed until today due to grazing and illegal cuttings as a result of their vicinity to sheep and goat stalls. In these old fields, which belong to site type B, 20 sample plots of 4 m<sup>2</sup> were established in order to study the regeneration composition.

The total regeneration density (see also fig. 6) is 52750 plants/ha, 6750 are *O. carpinifolia* plants, 22000 are *F. ornus*, 9250 are *C. orientalis* plants and 14750 plants belong to other species. The ecological value of this density is limited because most of the plants are stump sprouts or seedlings sprouts, consequently the regeneration composition and density is influenced by the former stand composition and the shepherds cutting habits.

However the interesting points in regeneration diarthrosis are the facts that a) a large number of *F. ornus* plants are seed origin and b) the 5000 plants of the 14750 plants/ha of the other species component are *Quercus sp.* seedlings. The establishment of *Quercus sp.* seedlings is common also in the st. types 2 and 3 of site type B.

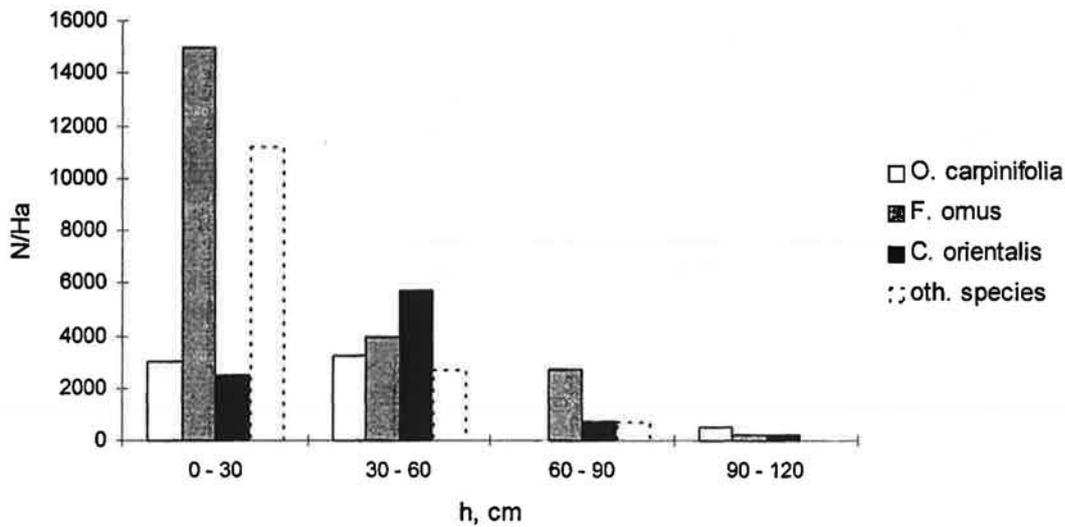


Figure 6. Structure analysis graph of height classes of regeneration in site type B.

**4.4. Stem analysis**

The first two competing couples consist of a *O. carpinifolia* standard and the most vigorous adjacent *O. carpinifolia* stump sprout. These couples come from the st. types 1 of A and B site types.

The two standards are 86 and 85 years old for A and B site type respectively. Both sprouts, established after the cuttings, are 30 years old (see table 7). The sprouts, as we observe in figure 7, had greater periodic annual height increment than the standards, in the duration of their lifes. Today they have almost the same height as the standards (see fig. 7). In this point it must be referred that in both standards (as in most standards) a part of the stem, above the last disc, which collected from the 5 cm - bole diameter, was broken. In order to conduct stem analysis we consider the tip of an adjacent branch as the tip of the tree. So the total heights of the standards and their periodic annual increments (in the last years) in figure 7 are smaller than it would have been if the tips of the trees were not broken.

Table 7. The ages, heights and volumes of trees in the three competing couples

| Couple 1. ( <i>O. carpinifolia</i> trees) site type A |           |                                      |           |                         | Couple 2. ( <i>O. carpinifolia</i> trees) site type B |           |                         |           |                         |
|---|-----------|--------------------------------------|-----------|-------------------------|---|-----------|-------------------------|-----------|-------------------------|
| standard  |           | sprout                               |           |                         | standard  |           |                         | sprout    |                         |
| Age (years)   | Heig. (m) | Vol. (dm <sup>3</sup> ) <sup>a</sup> | Heig. (m) | Vol. (dm <sup>3</sup> ) | Age (years)   | Heig. (m) | Vol. (dm <sup>3</sup> ) | Heig. (m) | Vol. (dm <sup>3</sup> ) |
| 10  | 3.8       | 0.7                                  | 8.8       | 15.9                    | 10  | 2.4       | 0.4                     | 5.3       | 2.2                     |
| 20  | 8.8       | 10.0                                 | 12.7      | 49.8                    | 20  | 5.6       | 3.2                     | 8.9       | 13.3                    |
| 30  | 11.9      | 34.6                                 | 16.3      | 93.6                    | 30  | 8.3       | 15.3                    | 11.5      | 30.3                    |
| 60  | 16.0      | 177.7                                | -         | -                       | 60  | 10.3      | 76.6                    | -         | -                       |
| 80  | 17.0      | 321.1                                | -         | -                       | 80  | 11.2      | 121.2                   | -         | -                       |
| 86  | 17.3      | 361.5                                | -         | -                       | 85  | 11.4      | 125.8                   | -         | -                       |

| Couple 3. Site type B |                        |                         |                 |                         |
|-----------------------|------------------------|-------------------------|-----------------|-------------------------|
|                       | <i>O. carpinifolia</i> |                         | <i>F. ornus</i> |                         |
| Age (years)           | Heig. (m)              | Vol. (dm <sup>3</sup> ) | Heig. (m)       | Vol. (dm <sup>3</sup> ) |
| 20                    | 5.7                    | 2.7                     | 5.3             | 2.7                     |
| 40                    | 8.4                    | 19.3                    | 8.4             | 21.4                    |
| 60                    | 10.2                   | 42.4                    | 10.0            | 58.4                    |
| 80                    | 12.0                   | 89.0                    | 11.6            | 99.7                    |
| 81                    | 12.1                   | 91.2                    | 11.7            | 101.3                   |
| 84                    | 12.4                   | 99.2                    | -               | -                       |

a. 1000 dm<sup>3</sup> = 1 m<sup>3</sup>

This breakage probably happened when the trees were freed by the cuttings and they were susceptible to wind damages.

In both couples, the year before the cuttings, current and mean annual volume increment curves of the two standards (see fig. 8) had almost met. Afterwards the standards had an abrupt increase in their current annual volume increment due to the great amount of released growing space. This increment was small the first year but took the greatest values the second year. The influence of cuttings brought to an end in about 15 years as a result of the increased sprouts competition. Afterwards in the standard of site type B, current and mean annual volume increment curves finally met. A few years later, the competing sprout had higher volume increment than the standard. In the case of site type A the standard maintains its competitive ability taking relatively high current annual volume increment values, higher than these of the competitive sprout.

The sprouts in the two couples in the age of 30 years have high growth rates greater than the rates (which) the seed origin standards had in the same age.

The third couple consists of a dominant *O. carpinifolia* and an adjacent, competing, dominant, *F. ornus* tree. The trees were cut in a st. type 2 of site type B plot.

The *O. carpinifolia* tree is 84 years old and the *F. ornus* tree is 81 years old (see table 7). In figures 7, 8 we observe that the two trees show analogous (almost the same) growth patterns in most years of their lives. However in the last 10 years even though the *O. carpinifolia* tree maintained high values in current annual volume increment the competing tree showed a reduction in the corresponding values. If this trend continues, in a few years the current and mean annual volume increment curves of *F. ornus* tree will meet. Today the two trees have almost the same volume, however the *O. carpinifolia* tree is slightly taller than the *F. ornus* tree.

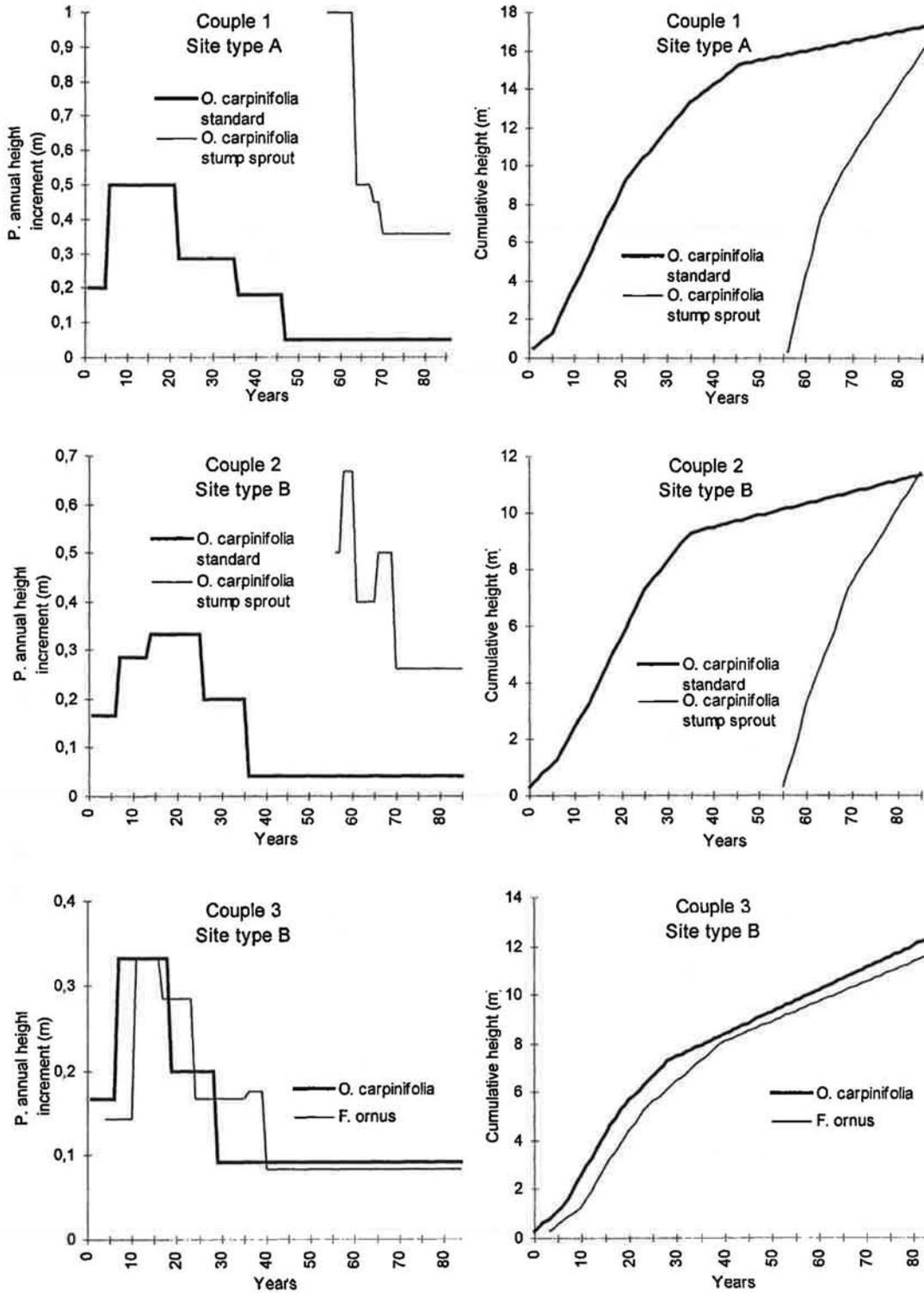


Figure 7. Periodic annual height increment and cumulative curves in the three competing couples.

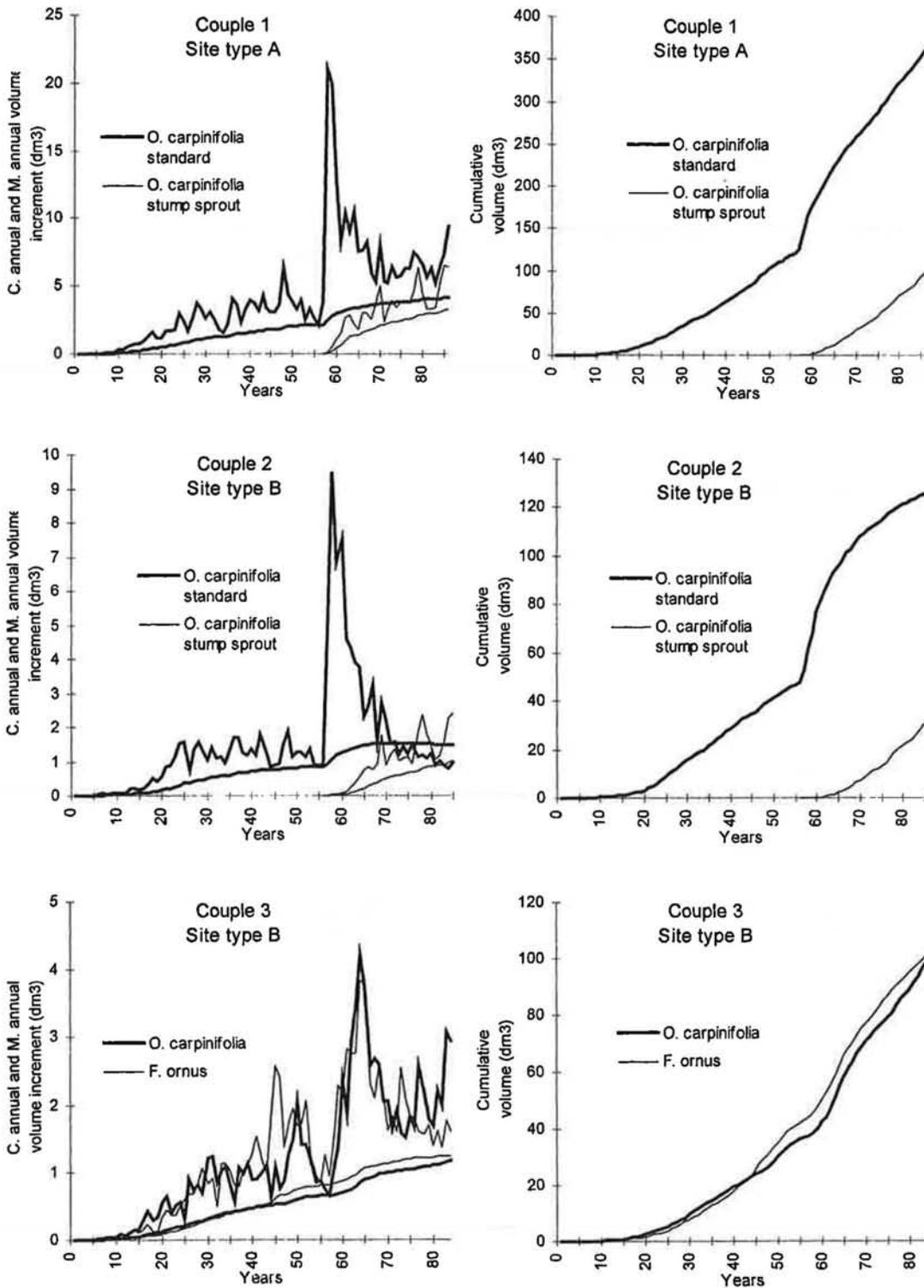


Figure 8. Current annual with mean annual volume increment and cumulative curves in the three competing couples.

## 5. Discussion

Stands origin, initiation, development, structure and spatial distribution were strongly affected by anthropogenic disturbances. Each one of the five different st. types initiated in areas which were occupied by human activities. They were established in the available growing space created after the gradual abandonment of these areas, which coincides with the war events and population movements in the period of 1912 - 1923. The consequent development patterns and structures today were also influenced by human disturbances such as illegal and organized cuttings. Several studies in Greece relate origin, form, and structure of stands, composed by some of our species, to human disturbances. According to Peterman (1999) the form of the small stands mainly consisting of *C. orientalis* and *F. ornus* trees and found in the slopes along Nestos river bed, northern from our study area, is the result of intense grazing and illegal cuttings by people of adjacent villages. Reif and Loeblich (1999) claim that *O. carpinifolia* codominates with *Q. dalechampii* in degraded, by humans, stands found in Pieria, a mountainous area which lies in North - central Greece. Also according to Smiris (1995) the appearance of the *Pinus nigra* - *O. carpinifolia* - *Quercus sp.* mixed stands in north Olympus was partly determined by human activities.

Cutting practices have influenced stands structures all over the world. Marquis (1992) mentions that the small residual stems, left after the clearcut for sawtimber and chemical wood in an Allegheny hardwood forest stand, had a considerable impact on subsequent stand development. According to Seymour (1992) the large scale episodic removals of mature individuals by logging in combination with some natural disturbances have transformed a Maine's *Picea rubens* - *Abies balsamea* "from one dominated by mixed - aged, old growth stands to a forest dominated by younger, more uniform stands". Rackham (1992) explains that some forestry methods in Europe encourage a single species and where this species was desirable for a long period the result was the creation of pure stands at the expense of mixtures and mosaics. In our case a slightly different procedure took place. The preferred species were mainly the *Quercus sp.* and secondly the *F. ornus*. Illegal cutting practices of local people led to an almost total erasing of *Quercus sp.* from our stands due to the use of oak wood as firewood in the past. The density of *F. ornus* trees was, also, reduced and their diameter and height distributions were modified. This happened because (mainly) young stems of *F. ornus* were desirable for various uses, as the construction of the internal walls in the houses of the Nestos river valley villages and the construction of frames which were used in order to dry the tobacco leaves. In the last decades the pressure of illegal cuttings has been reduced and the social conditions have changed, as a result *Quercus sp.* began to reclaim the available growing space. As we mention above, the establishment of *Quercus sp.* seedlings is common in most st. types.

The st. types development patterns and their structures (today) were also affected by three other important factors: the growth ecology of each species, their regeneration mechanisms and the quality of the site.

Development patterns in mixed stands, in most cases, become complex as the number of species in the stand increases (Guldin and Lorimer 1985). In mixed stands, in most cases, a species height stratification is observed as a result of differences in height - growth patterns and in shade tolerance characteristics among species (Larson 1992). Some species, such as *Acer rubrum* and *Betula lenta* in New England (Oliver and Larson 1996) or *Picea sitchensis* and *Tsuga heterophylla* in coastal southeast Alaska (Deal et al. 1991) when grown together exhibit almost the same height growth rates. Most of our st. types are multistoried, *O. carpinifolia* and *F. ornus* trees, which usually dominate in the upper storeys, appear in the same height classes having an almost similar or analogous height distribution. The small differentiations observed are probably the result of the different number of trees per hectare, between the two species, and their slightly dissimilar age structure (usually *F. ornus* younger age group count in a greater number of trees). These facts, in combination with the similar height growth rates of the adjacent, competing, dominant, *O. carpinifolia* and *F. ornus* trees (in couple 3), suggest that, in this area, until the age of 80 - 100 years old, the two species appear in the same height strata having similar height growth patterns. *C. orientalis* trees dominate in the lower storeys, having (in most cases) lower height than the other two species, even though they have almost the same age structure as the others. Many factors (except height growth patterns) such as branch stiffness, shade tolerances, number of stems of competing species, sites, spacing among stems etc. may influence the stratification patterns in evenly aged mixed species stands (Oliver and Larson 1996). In our stands, *C. orientalis* did not have a serious shade problem from the above storeys in the st. type 2 of site type B, mainly because of the spatial distribution of the trees which allow a satisfactory portion of light to reach the trees in the lower storeys. In the st. type of site type C, we have a height distribution of a one storey stand, the *O. carpinifolia* and *F. ornus* trees can not form (even though there are many individuals taller than *C. orientalis* trees) an upper storey which could cause shade in the lower trees.

As far as the diameter distribution of trees is concerned, the differences in growth patterns between species are modified by the competition (for growing space) between the trees of the same (or different) species and the different regeneration mechanisms among individuals. The seed origin individuals exhibit different diameter growth patterns from the sprout origin trees of the same species, sometimes this difference is greater than that between seed origin trees of different species. On the other hand the multiple stems, arising from the same stump, have different diameter growth rates (between each other) because of the intense competition among them. This procedure led to the fall in diameter distribution of the young evenly aged *O. carpinifolia* trees of st. type 1 in site types A and B. The same form of distribution (for the same reasons) is found in *C. orientalis* trees in the st. type of site type C and in st. type 2 of site type B. In the last case there is a number of seed origin individuals, also there are some age differences between trees. However in st. type 1 of site type C, even though *O. carpinifolia* trees are also sprout origin and have the same age as *C. orientalis* trees, they show a different diameter distribution from them because of a) their different growth ecology (*O. carpinifolia* reaches greater diameters for the same age than *C. orientalis*) and b) their different site sensitivity which probably causes the death of the suppressed (with small dimensions) *O. carpinifolia* sprouts.

Species usually grow where they can compete successfully, not where they can grow best (Oliver and Larson 1996). When many species grow together, each species predominates in the environmental conditions where it can compete best (Oliver and Larson 1996). The site sensitivity difference between the main species of *O. carpinifolia* mixed stands has a significant effect in the formation of their structure. We observe a gradual alteration of the species contribution in the total basal area of the stand in relation to site quality. In site type A the *O. carpinifolia* formations (small stands) are pure, in site type B, *O. carpinifolia* dominates, however we have the codominance of *F. ornus* and *C. orientalis* (in st. type 2). In site type C a dominance transition is observed. *C. orientalis* (even though it reaches smaller dimensions than the other species) has the greatest contribution in the total basal area of the stand. The density and the dimensions (the basal area too) of *F. ornus* trees were modified by the illegal cuttings in the past. However *O. carpinifolia* is a more demanding species than *F. ornus* (Ellenberg et. al. 1992, Donita et. al. 1977), *C. orientalis* on the other hand is a component species of degraded ecosystems (Boratynski et al. 1992), also its plant communities are a degraded stage of broadleaved *Quercus sp.* forests (Fukarek 1966, Lausi and Poldini 1966). In conclusion the site sensitivity classification of the three species is as follows *O. carpinifolia*>*F. ornus*> *C. orientalis*.

As we mentioned in the st. types 1 of sites types A and B the age of the *O. carpinifolia* standards is around 85 years, consequently the old stumps from which the sprouts arised 30 years ago, if they had not been cut, today they would be more or less the same age (we assume that stands initiation stage, in the period 1912 - 1923, lasted few years). During the year of the cuttings, even though they had the same with standards age (about 55 years old), they maintained a high sprouting capacity (number of sprouts per stump), considering, that (today) 30 years after the cuttings the mean number of sprouts (with a diameter of over 4 cm) per old stump is 3.94 and 5.48 for the A and B site type respectively. It is certain that the year after the cuttings the mean number of sprouts per stump was by far larger than today. According to Matthews (1989) the sprouting capacity of most species is reduced when stools (living stumps) reach large sizes and hence in order to product shoot stools it is (at most times) necessary to cut trees at an age of not more than 40 years. Nyland (1996) claims that this reduction in sprouting capacity results not only because of the bark thickening over dormant buds at the cambium (some sprouts arise from these buds, other sprouts arise from dormant buds that originate at the pith) but also as a result of the connection breaking between the dormant buds and the pith. Inhibitions due to these two factors increases with tree age and size (Smith 1986). Probably one of the reasons which was responsible for the high sprouting capacity at this age of *O. carpinifolia* was their relatively small stump diameters. The two standards had a stump diameter (at the year of the cuttings) below 17 and 13 cm for A and B site type respectively (these data are derived from the two standards stem analysis). Considering that in the coppice with standards system the reserved for standards trees are usually dominant we conclude that the trees which were cut (from which the sprouts arised), had smaller dimensions.

The two standards, in the competing couples 1 and 2, reacted in the growing space increment, after the cuttings, accelerating their growth rates. This acceleration lasted about 15 years. On the other hand the two sprouts of the same couples retain high growth rhythms, 30 years after

their establishment. These growth rhythms are greater than those which had the seed origin standards in the first 30 years of their lives. This difference (even though sprouts grow faster during early life than seed origin trees) is significant because in the duration of these 30 years these sprouts apart from the intense competition of the adjusted standards, dealt with the competition of the other sprouts of the same old stump. They overcame these difficult growing conditions mainly because of the *O. carpinifolia* ability to tolerate the partial (at least) shading.

As far as the silvicultural alternatives for the management of these stands are concerned the main objective is to convert them in seed origin stands using the appropriate methods for each st. type and site type (see Matthews 1989, Dafis 1989, Nyland 1996, Smith et. al. 1997). As an exception, in small areas (patches) of site type C we must practise the coppice system, in order to enhance the regional fauna biodiversity. This practice, in combination with the different structures of the other st. types, the edges between them and the areas where the vegetation today consists of a few sparsely scattered trees (see regeneration), will create sufficient habitats (food and cover) for the wildlife.

Furthermore, forest practice must favor multiple species mixed stands especially in site type B and prevent *Quercus sp.* to predominate. In the future stands of site type B, the upper storeys, through the appropriate treatments, must consist of *O. carpinifolia*, *F. ornus*, *Quercus sp.* (mainly *Q. dalechampii*), and *Acer sp.* trees. Whereas *C. orientalis* with other species as *C. mas* must form the lower storeys. In site type A the establishment of other site demanding species as *Tilia tomentosa*, *Prunus mahaleb*, *A. pseudoplatanus* or *A. platanooides* etc. must be favored, however *O. carpinifolia* must remain as a main component. In site type C, our future silvicultural goal has to be the creation and maintenance of *Quercus sp.* (mainly *Q. pubescens*) - *C. orientalis* - *F. ornus* - *O. carpinifolia* stands.

## 5. Conclusions

- *O. carpinifolia* (pure and mixed) stands origin, initiation, development patterns, structure and spatial distribution were strongly affected by anthropogenic disturbances.
- The present structures and development patterns of *O. carpinifolia* structural types are also affected by three other important factors: the growth ecology of each species, their regeneration mechanisms and the quality of the site.
- *O. carpinifolia* and *F. ornus* trees, until the age of 80 - 100 years, dominate in the upper storeys exhibiting similar height growth patterns, whereas *C. orientalis* trees usually are stratified in the lower storeys.
- The site sensitivity difference between the main species of *O. carpinifolia* mixed stands has a significant effect in the formation of their structure. We observe a gradual alteration of the species contribution in the total basal area of the stand in relation to site quality. In site type A the *O. carpinifolia* small stands are pure. In site type B, *O. carpinifolia* dominates, however we have the codominance of *F. ornus* and *C. orientalis* (in st. type 2). Finally in site type C a

dominance transition is observed. *C. orientalis* have the greatest contribution in the total basal area of the stand.

- *O. carpinifolia* trees maintain a high sprouting capacity in medium ages (around 50 years old), whereas the most vigorous 30 years old stump sprouts have high growth rhythms that are greater than those which had the seed origin standards in the first 30 years of their lives.
- The main silvicultural objective is to convert almost all stands in seed origin stands. Furthermore, forest practice must favor multiple species mixed stands. Their composition must be determined in relation to site quality.

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