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STRUCTURE ANALYSIS OF A LOWLAND GRAZED *QUERCUS PUBESCENS – QUERCUS FRAINETTO* FOREST IN NORTHEASTERN GREECE

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Abstract

The aim of this study was to analyze the diameter structure of a *Quercus pubescens*-*Quercus frainetto* remnant forest in Northeastern Greece. The main disturbances acting in the study area are illegal cuttings and grazing. Two site types are found in the studied forest as a result of different grazing pressure. In site type A, where the grazing pressure is not as intense as in site type B, there are *Q. pubescens*-*Q. frainetto* degraded stands. Site type B is covered by *Q. pubescens* degraded stands. In each site type, a square plot of 100×100 m was established. Each plot was divided into four square subplots of 50×50 m (I, II, III and IV subplots), where the breast height diameter of all trees having a diameter equal and over 4 cm was measured. For I, II, III and IV subplots, I+II subplot and I+II+III+IV plot Anderson-Darling statistic was used in order to examine in which typical distribution their diameter distribution fits better. This procedure took place for the investigation of diameter structure spatial heterogeneity. Both species, in all plots, present low basal area and do not exhibit large diameters. The main conclusion of this study is that there is a significant spatial heterogeneity in the tree diameter structure. This heterogeneity is a combination of different forms of diameter distributions as well as of differences in basal area in the different plots. In site type B the spatial heterogeneity is more intense than in site type A if the form of the diameter distributions is considered as the main criterion for the heterogeneity assessment. On the other hand, the heterogeneity is higher in site type A if only the differences among the basal areas of subplots of 50×50 m are taken into account. The understanding of the structure of these rare for Greece stands will contribute to the protection and sustainable management of them as well as of analogous ecosystems.

Key words: degraded forest, oak forest, overgrazing, remnant forest, stand heterogeneity.

Introduction

Grazing can degrade a forest ecosystem (Evans 1998, FAO 2011). Anthropogenic disturbances such as grazing and illegal cuttings have affected the stand structures and dynamics of many forests in Greece. According to Milios and Smiris (2001), illegal cuttings and grazing determined the structure of *Fagus sylvatica*-*Quercus dalechampii* sub-mountainous stands in the Rhodope Mountains of Northeastern Greece. Illegal cuttings and grazing shaped the structure of *Juniperus excesla* stands in the central part of Nestos valley in Northeastern Greece (Milios et al. 2007). The same disturbances influenced the structure and regeneration of *Juniperus excesla* stands in Prespa National Park in Greece (Stampoulidis and Milios 2010, Stampoulidis et al. 2013).

In Greece, oak forests are grazed (Bergmeier and Dimopoulos 2008, Papanastasis et al. 2009). In an open coppice oak forest of Northeastern Greece, species composition is strongly influenced by different intensities of grazing. In addition, the contribution of woody species was significantly increased when there was a protection from grazing (Kyriazopoulos et. al 2010). Goats affect negatively the growth of young oak shoots (Papachristou and Platis 2011). Chaideftou et al. (2009) found that grazing decreased the species' richness in the vegetation of a sub-Mediterranean oak forest. Tsitsoni (2003) reported that overgrazing combined with repeated fires can convert oak forests to barren land. However, grazing also affects oak ecosystems in other Mediterranean areas (Pulido et al. 2001, Plieninger 2007, Pardini 2009, Alias et al. 2010).

Quercus frainetto and *Q. pubescens* are common oak species of Greece growing in various elevations in pure and mixed formations (Boratynski et al. 1992, Christensen 1997). However, such lowland forests are very rare in Greece. According to Theodoropoulos (1996), *Q. pubescens* lowland forests in Greece are rare due to the conversion of forests to agricultural land, overgrazing, and illegal cuttings.

One of these rare forests is a degraded grazed *Q. pubescens*-*Q. frainetto* remnant forest found in Northeastern Greece. Milios et al. (2014) analyzed the regeneration of this forest in the context of grazing and referred that its stand structure is heterogeneous without having analyzed diameter structure data.

The aim of this study is to analyze the stand diameter structure as well as to investigate the spatial heterogeneity of diameter structure in this rare forest that is under grazing pressure of domesticated animals. The understanding of the structure will contribute to the protection and sustainable management of them as well as of analogous ecosystems.

Materials and Methods

Study area

The study area is comprised of the remnants of a lowland *Quercus pubescens* Willd.-*Quercus frainetto* Ten. forest located in the southern part of Xanthi region, a few kilometers away from the seashore in Northeastern Greece (41°00′ N, 24°55′ E). It covers an area of approximately 284 ha with a low slope and an altitudinal range of approximately 27 to 70 m (Milios et al. 2014). Around the studied forest there is agricultural land (Batziou et al. 2017). The substratum is tertiary deposits (Schinas et al. 1995). The mean annual air temperature is 15.5 °C and the average annual precipitation is 675 mm (Papaioannou 2008).

The main disturbances acting in the study area are illegal cuttings and grazing. Two thousand one hundred thirty six sheep, 87 goats and 68 horses graze periodically in the area (data from regional district of Xanthi archives).

Two site types are found in the studied forest as a result of different grazing pressure. In site type A, where the grazing pressure is not as intense as in site type B, there are *Q. pubescens*-*Q. frainetto* degraded stands and the soil texture is sandy clay to loam. The trees of the two species, in most cases, are mixed. Site type B is covered by *Q. pubescens* degraded stands. The soil texture in site type B is sandy loam to clay. Moreover, in the area of site type B there is an animal stockyard (Milios et al. 2014).

According to Milios et al. (2014) the stand structure in the studied forest appears heterogeneous. There are areas having sparsely scattered trees, places with rather dense groups of trees, locations covered by *Erica manipuliflora* Salisb., almost bare or bare of vegetation areas, as well as areas covered by grazed ground vegetation. They also mention that the basal area in site type A is about 6.3 m^2/ha while in site type B is approximately 3.8 m^2/ha.

Research Method

In 2006, in each site type, a square plot of 100×100 m was randomly established. Each plot was divided into four square subplots of 50×50 m (I, II, III and IV subplots), where the breast height diameter of all the trees having a diameter equal and over 4 cm was measured. This was made in order to examine the diameter distribution in adjacent areas. For all subplots including the I+II subplot and the I+II+III+IV plot (the sum of the four subplots of 50×50 m creates the plot of 100×100 m) Anderson-Darling statistic was used in order to examine in which typical distribution (triangular, Weibull, gamma, normal, lognormal, exponential, empirical, beta, uniform) their diameter distribution fits better. We used the I+II subplot and the I+II+III+IV plot since the first covers a double area than each of the I, II, III and IV subplots (and integrates I and II subplots), and the later covers a double area than the I+II subplot (and integrates it as well as the I, II, III and IV subplots). This approach was used since we wanted to investigate whether the diameter distribution changes as the area of a subplot is doubled. Sagheb-Talebi and Schutz (2002) have also used subplots which were successively doubled in size in order to study the stand structure of beech stands in Iran. Moreover, the tree basal area was calculated for each subplot of 50×50 m in the two site types. For continuous distributions, Anderson-Darling test can be used to find the distribution that most closely fits the data. The distribution with the smallest value of Anderson-Darling statistic is the one that provides the closest fit (Anderson and Darling 1954). When examining fit statistics for distributions, larger *p*-values indicate higher statistical significance. As a general rule, *p*-values less than 0.05 indicate that the distribution may not provide a close fit to the data. However, a *p*-value is not always available for all tested distributions – taking this into account, we based our decision regarding the best fitted distribution on the value of Anderson-Darling statistic only. This procedure took place for the investigation of diameter structure spatial heterogeneity. In the present study the heterogeneity is considered as a combination of different forms of diameter distributions (resulting in differences in the distributions that fit better to them), with differences in basal area in the different subplots.

Results and Discussion

In total 221 trees were measured in the 100×100 m plot of site type A and 368 trees in the 100×100 m plot of site type B. In figures 1 and 2 the diameter distribution of the subplots and the plot in site type A is presented. In all subplots in *Q. pubescens* and in I, II, I+II subplots and I+II+III+IV

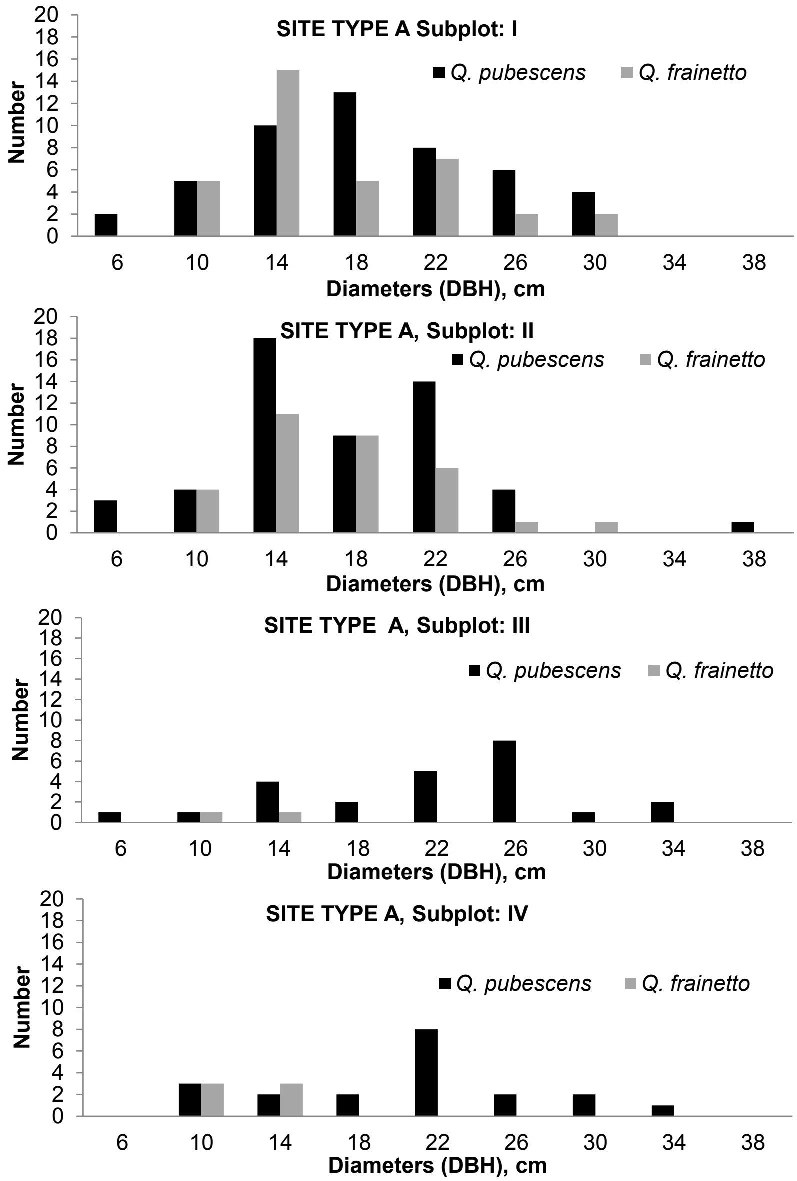

Fig. 1. Diameter distribution of *Q. frainetto* and *Q. pubescens* in subplots I–IV in site type A.

plot in *Q. frainetto*, the most trees appear between the classes of 14 and 26 cm. *Q. pubescens* is the dominant species in all subplots. In III and IV plots the participation of *Q. frainetto* is very small. On the other hand, in the subplots of site type B almost all trees are found up to the class of 14 cm (figs 3 and 4). In site type A, the

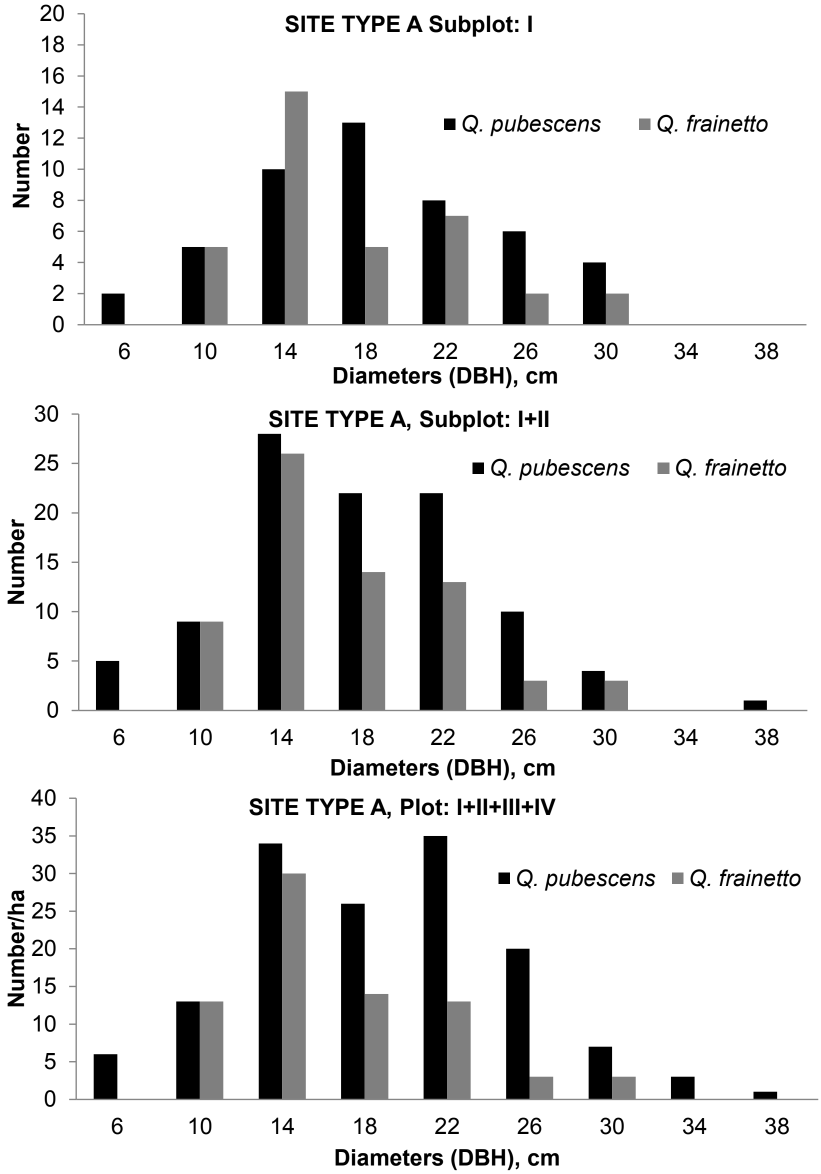

Fig. 2. Diameter distribution of *Q. frainetto* and *Q. pubescens* in subplots I, I+II and in plot I+II+III+IV in site type A.

larger trees of *Q. pubescens* appear in greater diameter classes compared to the largest trees of the species in site type B (figs 1 and 3). Moreover, a multi-stemmed form of adult *Q. pubescens* trees is mainly observed in site type B (Batziou et al. 2017). This was not the result of a coppice silvicultural system. Milios et al. (2014)

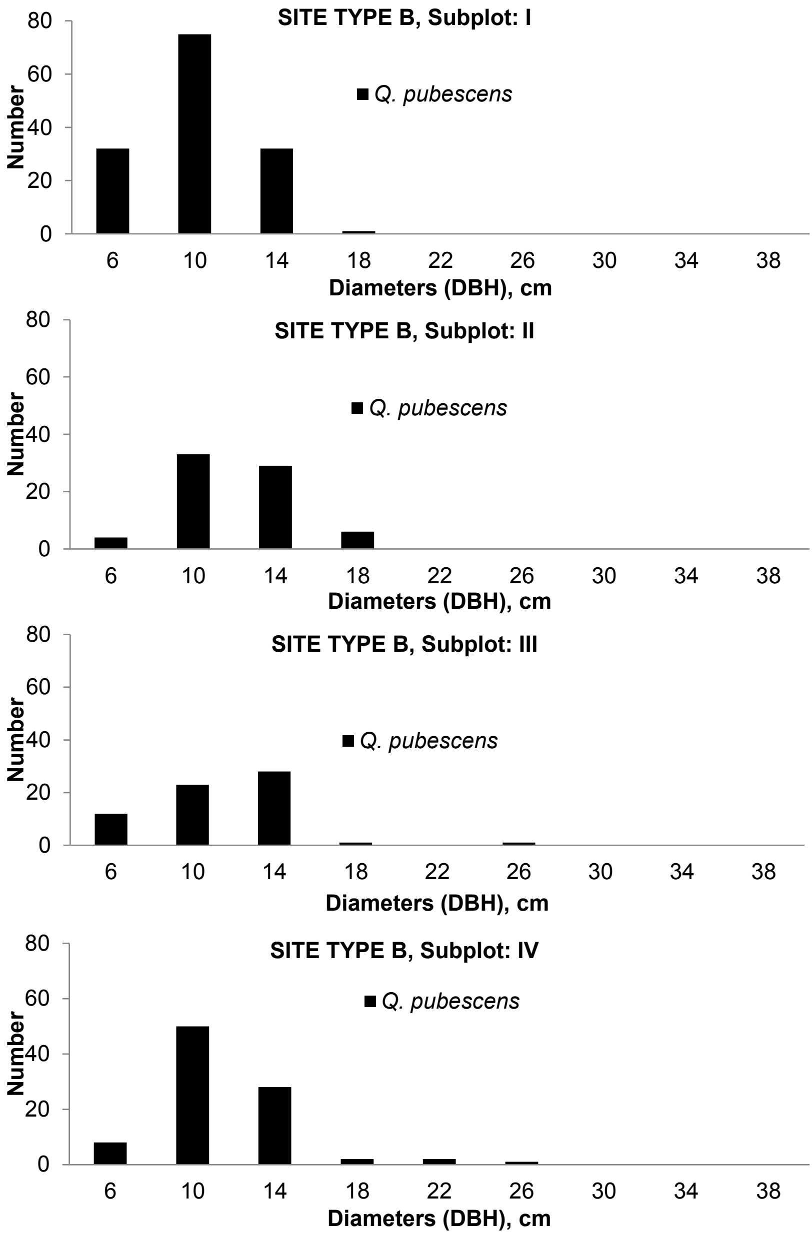

Fig. 3. Diameter distribution of *Q. pubescens* in subplots I–IV in site type B.

reported that in the study area, all examined regeneration plants of the two species with a height equal to or over 20 cm were sprouts. Most of them were multi-stemmed (Batziou et al. 2017). It seems that this multi-stemmed form was retained mainly in the trees of site type B. Moreover, in some trees this form possibly is

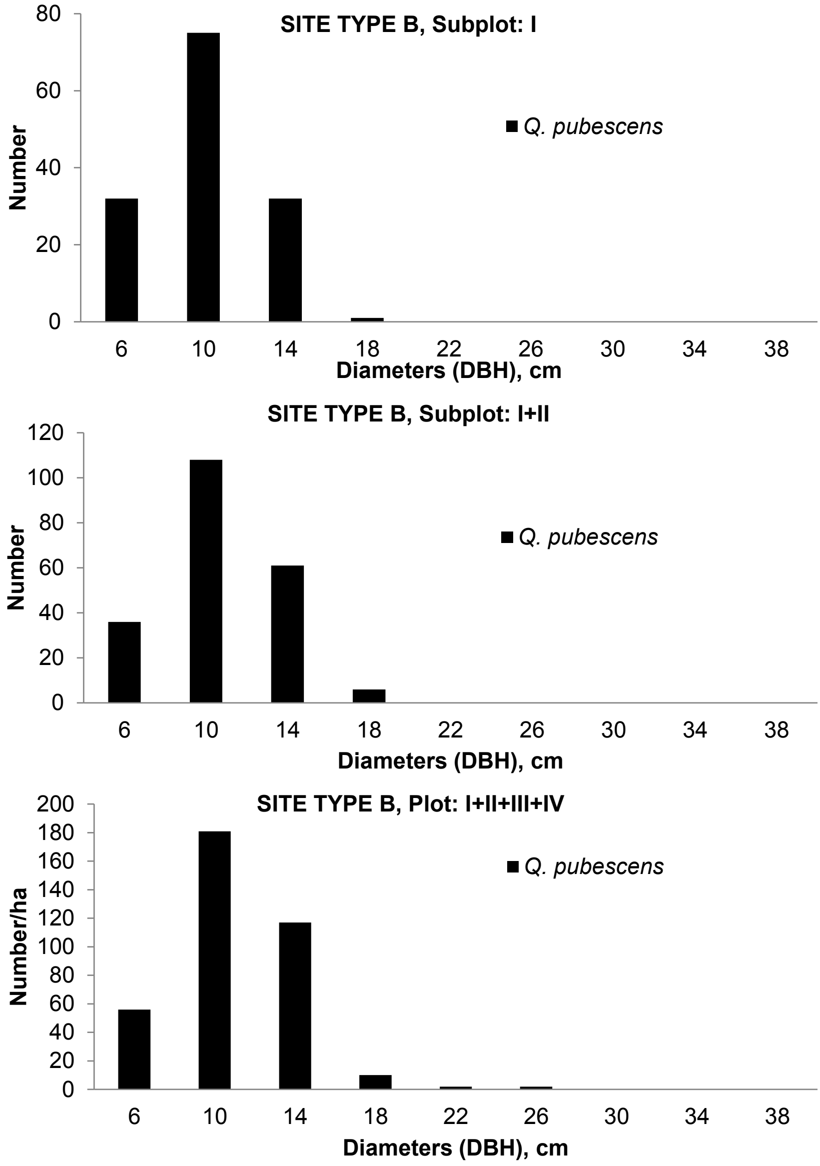

Fig. 4. Diameter distribution of *Q. pubescens* in subplots I, I+II and in plot I+II+III+IV in site type B.

the result of illegal cuttings.

In site type A, in all plots, the basal area is low and *Q. pubescens* exhibits higher basal area than *Q. frainetto*.

In site type A, in two of the subplots (III and IV) triangular distribution fits better in *Q. pubescens* diameter distribution than the others. Moreover, regarding *Q. frainetto* in both subplots, Anderson-Darling statistic could not be applied, since trees of the species appeared only in two classes (of 10 and 14 cm) (Fig. 1). On the other hand, in plot I uniform for *Q. pubescens* and triangular for *Q. frainetto* diameter distribution fit better than the others (Table 1). The corresponding distributions for plot II are exponential and uniform. In addition, there are differences among the basal areas of I, II, III and IV subplots that range from rather significant to strong (Fig. 5). Finally, the distributions that fit better to the diameter distributions of I+II subplot and I+II+III+IV plot are exponential and uniform correspondingly for *Q. pubescens* and triangular in both of them for *Q. frainetto*.

Table 1. Typical distribution that fits better in the diameter distributions in site type A using Anderson-Darling statistic.

Subplots and plot	Species	Typical distribution	A (Anderson-Darling statistic)	*p*-value
I	*Q. pubescens*	Uniform	-0.75	0.999
II	*Q. pubescens*	Exponential	-1.02	0.430
III	*Q. pubescens*	Triangular	-2.52	Not available
IV	*Q. pubescens*	Triangular	0.37	Not available
I	*Q. frainetto*	Triangular	-1.96	Not available
II	*Q. frainetto*	Uniform	-2.05	0.870
III	*Q. frainetto*	-	-	-
IV	*Q. frainetto*	-	-	-
I+II	*Q. pubescens*	Exponential	-0.12	0.240
I+II+III+IV	*Q. pubescens*	Uniform	0.16	0.660
I+II	*Q. frainetto*	Triangular	-2.13	Not available
I+II+III+IV	*Q. frainetto*	Triangular	-1.99	Not available

In the case of site type B in each of I, II, III and IV subplots the distribution that fits better to their diameter distribution is different. In subplot I, it fits the triangular distribution, in subplot II the uniform, in subplot III the normal, and in the subplot IV fits the log-normal distribution. Moreover, in the diameter distributions of I+II subplot and I+II+III+IV plot (Fig. 4) the distributions that fit better are uniform and triangular respectively (Table 2). Additionally, there are basal area differences among I, II, III and IV subplots. However, the total basal area in the subplots of site type B is in the most subplots lower than in site type A (in three of the four subplots) (Fig. 5).

Table 2. Typical distribution that fits better in the diameter distributions in site type B using Anderson-Darling statistic.

Subplots and plot	Species	Typical distribution	A (Anderson-Darling statistic)	*p*-value
I	*Q. pubescens*	Triangular	-1.21	Not available
II	*Q. pubescens*	Uniform	-0.23	0.150
III	*Q. pubescens*	Normal	0.57	0.800
IV	*Q. pubescens*	Lognormal	0.39	0.260
I+II	*Q. pubescens*	Uniform	-1.29	0.926
I+II+III+IV	*Q. pubescens*	Triangular	-1.25	Not available

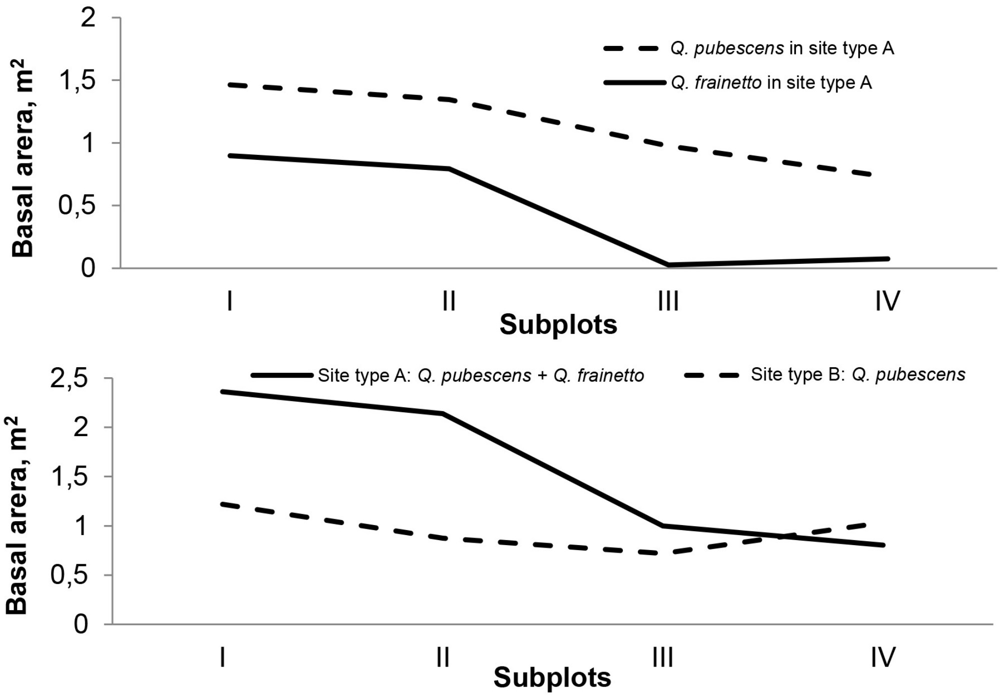

Fig. 5. Total basal area in subplots I–IV in both site types and basal area for *Q. frainetto* and *Q. pubescens* in site type A.

Both site types exhibit diameter structure heterogeneity. In site type B the spatial diameter heterogeneity is more intense than in site type A if the form of the distributions is considered as the main criterion for the heterogeneity assessment, since in all subplots of 50×50 m the distributions that fit better in their diameter distributions differ between each other. On the other hand, the heterogeneity is higher in site type A if only the differences among the basal areas of subplots are taken into account. The differences in basal area between the (sequential) adjacent subplots are greater compared to those of site type B (Fig. 5).

The different intensity of grazing and illegal cuttings led to the observed difference in stand structure heterogeneity. In site type B the intense disturbances resulted in lower basal area and greater differences in the spatial arrangement of trees among the subplots of 50×50 m compared to site type A. Another reason for these differences might have been the rather worse site conditions that possibly exist in site type B than in site type A. Batziou et al. (2017) mentioned that in site type B possibly there is a different soil compaction compared to site type A. On the other hand the greater differences in the basal area between the (sequential) adjacent subplots in site type A compared to that of site type B are probably the result of greater differences in the intensity of illegal cuttings (which reduce the basal area of an area) between adjacent areas in site type A compared to that of site type B. Milios (2000a) referred that the different intensity of grazing and illegal cuttings led to different development patterns and structures in *Ostrya carpinifolia* Scop. stands in the central part of Nestos valley in Northeastern Greece. Similarly, in the same wider area, different timing and (or) intensity of disturbances (like grazing and illegal cuttings) influenced development patterns and structures of mixed stands in the central part of the Rhodope Mountains (Milios 2000b). Smiris (1995) reported that in the northern part of Olympus Mountain in Greece grazing and illegal felling affected development patterns of mixed stands. Even though structural heterogeneity promotes biodiversity (Barnes et al. 1998, Lindenmayer and Franklin 2002), in the present study heterogeneity is so strong that there is a significant forest fragmentation which, in combination with the low basal area of the stands, constitutes a clear picture of degradation. If grazing and illegal cuttings stop the stand diameter structure will differentiate and the forest area will expand. According to Milios et al. (2014) in the studied forest, in the open areas (almost bare or bare of vegetation areas that alternate with areas covered by grazed ground vegetation) the oak regeneration density was 6917 plants/ha in site type A and 2667 plants/ha in site type B. As a result after the stop of grazing the open areas of the forest will be covered by trees (Milios et al. 2014) and the spatial heterogeneity will gradually decrease.

Conclusions

Both site types exhibit diameter structure heterogeneity. This heterogeneity is a combination of different shapes of diameter distributions resulting in differences in the distributions that fit better to them, with differences in basal area in the different subplots. In site type B the spatial heterogeneity is more intense than in site type A if the form of the distributions is considered as the main criterion for the heterogeneity assessment. On the other hand, the heterogeneity is higher in site type A if only the differences among the basal areas of subplots are taken into account.

In the present study structure heterogeneity is so strong that there is a forest fragmentation which, in combination with the low basal area of the stands, constitutes a clear picture of degradation.

The Forest service has to restore this forest.

Acknowledgments

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