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ANALYSIS OF SHADE CONDITIONS OF *PINUS NIGRA* ARNOLD STANDS IN THE ISLAND OF THASOS IN GREECE

Elias Milios and Diamantis Bountis

Department of Forestry and Management of the Environment and Natural Resources, Democritus University of Thrace, Pantazidou 193, 682 00 Orestiada, Greece. E-mail: emilios@fmenr.duth.gr

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Abstract

The aim of the present study was to analyze the shade conditions of *Pinus nigra* Arn. stands in the island of Thasos, which is situated in the northern part of Aegean Sea. Thirty six plots of various dimensions were established in *P. nigra* stands, varying in age and structure. For every plot, the diameter at breast height (DBH) for all trees was recorded and the dominant height in each story was estimated. Moreover in each plot, increment cores were taken, at a height of 1.3 m, in the main diameter classes. Three to fifteen hemispherical photographs were taken in each plot resulting in a total of 240 photographs. The amount of sky visible (V.s. = Visible sky) as a proportion of the whole hemisphere when viewed from a point was used as a measure of shade. For each photograph the V.s. value was calculated. Visible sky is related to the potential of the canopy to transmit incident light and allows comparisons between sites in different locations. The V.s. values in *P. nigra* stands ranged from 0.036 to 0.281. The young stands in stem exclusion stage exhibited the lowest mean V.s. value, while the greatest range of V.s. values (0.042 to 0.281) was observed in stands having old growth structure. The *P. nigra* stands in Thasos exhibit a wide range of shade – light environments as a result of their different and heterogeneous structures in combination with the morphological characteristics and ecology of the species.

Key words: light, stand structure, stand age, old growth, stem exclusion, biodiversity.

Introduction

Pinus nigra Arnold expands from west Asia to south Europe (Athanasiadis 1986). It is an important timber tree that forms forests in the mountains throughout most mainland Greece, as well as in some mountainous island areas (Christensen 1997). *Pinus nigra* is a semi-shade tolerant tree which has the ability to grow in pure stands (Athanasiadis 1986).

Stand structure and stand development in combination with the morphological characteristics and ecology of the component species determine the shade conditions in forests (Dafis 1986, Oliver and Larson 1996). Shade – light conditions in forest stands constitute one of the dominant ecological factors determining the growing space availability and growth rates of plants (Dafis 1986, Oliver and Larson 1996, Milios et al. 2008). Moreover shade – light conditions and their alterations strongly influence the biodiversity in forests (Lindenmayer and Franklin 2002). As a result, the determination of shade conditions created under the canopy of different species in different stand structures and stand development stages contributes to ecological knowledge and superior forest management.

The aim of the present study was to analyze the shade conditions of *P. nigra* stands in the Greek island of Thasos.

Study Area

The study was carried out in the pure *P. nigra* stands in the island of Thasos, which is situated in the northern part of Aegean Sea in Greece. The *P. nigra* stands cover an area of approximately 3617 ha (41^{0}09′ N, 26^{0}03′ E). They are located at elevations from 560 to 1200 m (Eleftheriadis et al. 1982). In the closest meteorological station which lies at an elevation of 3 m, the annual sum of precipitation averages 777.3 mm, and the mean annual air temperature is 15.3^{o}C.

The main parent material is gneiss – schist and crystalline limestone and the forest soils are sandy – clay to clay – sandy (Hlikas and Kontos 1997, Eleftheriadis et al. 1982). The *P. nigra* stands are found in medium productivity sites (Hlikas and Kontos 1997, Eleftheriadis et al. 1982).

In 1985 and in 1989 two severe forest fires took place in the area. The first burned about 900 ha and the second about 800 ha of *P. nigra* forest. As a result of the 1985 *P. nigra* forest fire, no silvicultural treatment took place after 1988. Until then, thinnings and regeneration fellings were applied in the area (data from the Forest Service). The regeneration procedure in most cases was based in the creation of gaps as a result of the felling of one or two adjacent trees having large dimensions.

Research Method

In order to analyze the shade conditions in pure *P. nigra* stands the forest was divided into structural types according to the physiognomy of stands and groups having same density. Two main criteria were used for the separation of structural types; the first was the competition regime among trees and the existence of regeneration or available growing space for regeneration, while the second, which is related to the first criterion, was the dimensions of trees. In order to give names to the structural types, the terms of the development stages proposed by Oliver and Larson (1996) were used.

Oliver and Larson (1996) recognize four stand development stages after a major disturbance if no other disturbance occurs: stand initiation, stem exclusion, understory reinitiation and old growth stage. The same terminology has also been used to classify structures, since each structure is in many cases, though not always, the result of processes occurring in each development stage (Oliver and Larson 1996).

In this study four structural types were determined: Stem exclusion A, Stem exclusion B, Understory reinitiation and Old growth. In the 'Stem exclusion A' structural type, the dimensions of trees are small and there is not any regeneration or herbs in the forest floor, since there is no available growing space. Moreover the trees exhibit differences in height and diameter. The 'Stem exclusion B' structural type has the same characteristics with 'Stem exclusion A' structural type but the trees have larger dimensions and their density is lower. In the 'Understory reinitiation' structural type, an understory of *P. nigra* regeneration plants appears. Moreover herbs and shrubs survive in the forest floor. The understory of *P. nigra* seedlings and small saplings is quite small and thus is visibly distinct from other trees in upper strata. In the 'Old growth' structural type, there are large dimension trees, large, dead standing trees, relative open canopies with foliage in many layers and understory.

During the spring and summer of 2006, 36 plots of various sizes were established in areas having slopes from 0 to 20%. In particular: 10 plots of 25 m^2 (5 m x 5 m) were established in 'Stem exclusion A' structural type stands and groups, 10 plots of 100 m^2 (10 m x 10 m) in 'Stem exclusion B' structural type, 10 plots of 500 m^2 (20 m x 25 m) in 'Understory reinitiation' structural type and 6 plots of 0.1 ha (40 m x 25 m) were established in 'Old growth' structural type. The plots were established using the stratified random sampling method. For every sample plot the diameter at breast height (1.3 m) (DBH) in cm, for trees over 2 cm in DBH, was recorded. In each plot, increment cores were taken (at breast height), in trees of the main diameter classes. In the same trees the height, in m, was recorded for the estimation of the dominant height in each story.

In order to determine the shade conditions hemispherical photography was used. More specifically, the amount of sky visible as a proportion of the whole hemisphere when viewed from a point (=Visible sky), taking values from 0 to1, was used as a measure of shade. A value of 0 means that the sky is completely blocked; while a value of 1 means that the sky is completely visible. 'Visible sky' or 'gap fraction' is related to the light that reaches a point, since it gives a measure of the potential of the canopy to transmit incident light and allows comparisons to be drawn between sites in different locations (Hale 2001).

Two hundred forty points were selected in all plots using the stratified random sampling method. In the 'Stem exclusion A' plots 30 points were selected (3 in each plot), 30 points were selected in the 'Stem exclusion B' plots (3 in each plot), while 90 points were selected in each of the 'Understory reinitiation'(9 in each plot) and 'Old growth' structural types (15 in each plot).

In each point a hemispherical photograph was taken at a height of 1.5 m. The photographs were taken with a Nicon Coolpix 900 digital camera with fisheye lens and a self – leveling mount. All photographs were taken during August 2006 under a clear sky, before sunrise or after sunset. Photos were processed with the Hemiview software (Delta–T Devices 1999, Cambridge, UK). For each photograph the Visible sky (V.s.) value was calculated.

The effect of structural type on V.s. was tested using the Dunnett T3 test, since there was heterogeneity of variances (Toothaker 1993).

Results

In the 'Stem exclusion A' structural type the breast height tree age ranges from 9 to 17 years old, while in the 'Stem exclusion B' structural type there are two major groups of ages. In the first group the trees have an age of between 19 and 25 years and in the second group the age ranges from 53 to 64 years. The 'Understory reinitiation' and 'Old growth' are uneven aged structural types since the breast height ages of trees are distributed more or less uniformly between the ages of 29–92 and 22–88 years respectively.

With the exception of 'Stem exclusion A' structural type, where the height of trees ranges from 4 to 7 m, the other structural types have at least two (and more) strata. In the 'Stem exclusion B', 'Understory reinitiation' and 'Old growth' structural types the height of trees ranges from 6 to 12, 7 to 20 and 7 to 22 m respectively.

The lowest range of diameters is observed in the 'Stem exclusion A' structural type while the highest range is observed in the 'Old growth' structural type (Fig. 1). Moreover the 'Stem exclusion A' structural type exhibits the highest tree density (6080 ha^{-1}) and the 'Old growth' the lowest (622 ha^{-1}). The tree densities in the 'Stem exclusion B' and 'Understory reinitiation' structural types are 2740 ha^{-1} and 790 ha^{-1} respectively. The basal area in the 'Stem exclusion A' structural

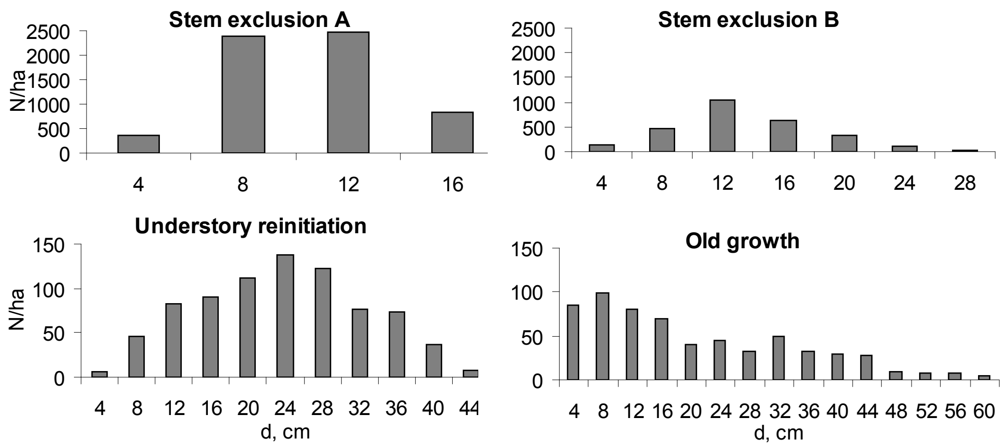

Fig. 1. Diameter distribution of trees in the four structural types.

Table 1. Visible sky values in the four structural types.

Structural types	Visible sky				
	mean	**S. D.**	**min**	**max**	**N**
Stem exclusion A	0.089[a]	0.034	0.036	0.172	30
Stem exclusion B	0.134[b]	0.010	0.117	0.149	30
Understory reinitiation	0.134[b]	0.017	0.099	0.172	90
Old growth	0.148[c]	0.043	0.042	0.281	90

The mean V.s. values are statistically significant different at $P<0.05$ when they share no common letter.

type is 52.66 $m^2.ha^{-1}$ and in the 'Stem exclusion B', 'Understory reinitiation' and 'Old growth' structural types are 40.58, 38.10 and 28.61 $m^2.ha^{-1}$ respectively.

The 'Stem exclusion A' structural type exhibits the lowest V.s. values with a statistically significant difference on average (Table 1), while the 'Old growth' structural type exhibits the highest V.s. values with a statistically significant difference. On the other hand there is no statistically significant difference, on average, between the V.s. values in the 'Stem exclusion B' and the 'Understory reinitiation' structural types.

The lowest V.s. value of *P. nigra* stands, was found in the 'Stem exclusion A' structural type (0.036) and the highest in the 'Old growth' structural type (0.281). The class of 0.060 dominates in the distribution of V.s. values (Fig. 2) of 'Stem exclusion A' structural type, and follows that of 0.100, while in the 'Stem exclusion B' structural type almost all V.s. values appear in the class of 0.140. In the 'Understory reinitiation' structural type the most V.s. values appear in the class of 0.140, but in this case the range of V.s. values is higher than that of 'Stem exclusion B' struc-

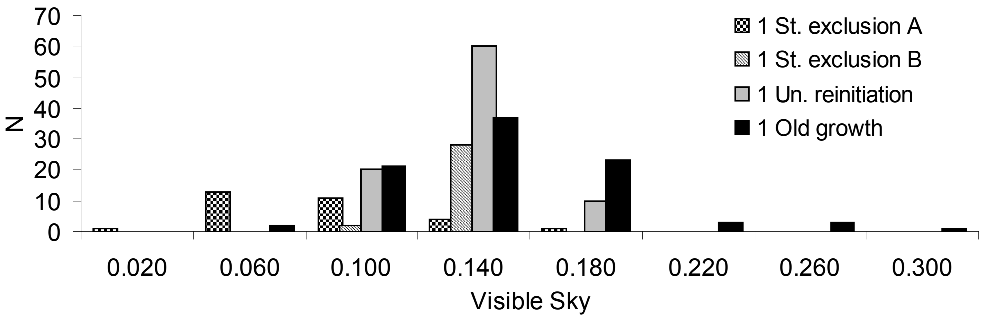

Fig. 2. Visible sky distribution in the four structural types.

tural type. In the 'Old growth' structural type, even though the V.s. values are distributed between the classes of 0.060 to 0.300, most of them are found in the classes from 0.100 to 0.180.

Discussion

The four structural types represent the full array of structures of *P. nigra* stands in Thasos. Only the 'Stem exclusion A' structural type corresponds to the stem exclusion development stage. All the trees were established after the forest fire of 1985 and no other disturbance which led to establishment of trees occurred. In this structural type the V.s. values are the lowest due to the dense canopy of young trees. All the growing space is occupied and there are not any seedlings or saplings in the forest floor.

The other structural types are the result of more than one disturbances. In the 'Stem exclusion B' structural type there are two age groups of trees. The youngest group was established in the growing space that was created as a result of an intense thinning in 1975 (see Eleftheriadis et al. 1982). The V.s. values are higher than those of 'Stem exclusion A' structural type but the growing space probably is also fully occupied, resulting thus in the absence of seedlings and saplings in the forest floor. The 'Understory reinitiation' and 'Old growth' structural types are uneven aged formations that were created by the gradual cutting of trees having large or medium dimensions since the remains of old stumps are still visible. In the case of 'Understory reinitiation' structural type, the cuttings were fewer and after some time the growing space was reoccupied, allowing only the establishment of seedlings that exhibit little growth. Thus, this understory is visibly distinct from other trees in upper strata. In this case, even though the V.s. values are more or less the same with those of 'Stem exclusion B' structural type, seedlings and saplings appear in the forest floor creating an understory. The mechanisms of this phenomenon are not clear. Possibly a higher carbon dioxide concentration near the forest floor in combination to pedogenic processes may create more growing space near the forest floor of the 'Understory reinitiation' structural type stands (see Oliver and Larson 1996). On the other hand, in the 'Old growth' structural type the cuttings led to relatively open canopies with foliage in many layers and understory, resulting in a broad range of V.s. values.

The foliage of *P. nigra* contains shade needles and thus is relatively dense as in other semi – shade and shade tolerant species (see Dafis 1986). The V.s. values found in the four structural types are close to V.s. values of shade tolerant species stands. In a plot of 100 m x 100 m that was established in a low elevation *Fagus sylvatica* stand in northeastern Greece, Papalexandris and Milios (2009) found that the V.s. values ranged from 0.038 to 0.161 (mean 0.089). In Croatia, in the Dinaric *Abies alba – Fagus sylvatica* forests, Jelaska (2004) found that the V.s. values ranged from 0.027 to 0.137 (mean 0.061). In Czech Republic in a *Fagus* *sylvatica* stand, in which the first regeneration felling has taken place, Modrý et al. (2004) found that V.s. values ranged from 0.056 to 0.241 (mean 0.154).

The seedlings in the stands of the semi-shade tolerant species of *P. nigra* in Thasos are found to be established in V.s. values of over 0.099, which are higher than the V.s. values needed for *F. sylvatica* regeneration. Milios and Papalexandris (2008) point out that *Fagus sylvatica* regeneration in low elevation *Fagus sylvatica* stands in northeastern Greece appears even at V.s. values of between 0.033 and 0.076.

More research is needed in many ecosystems under various ecological conditions in order to achieve a better knowledge of the shade conditions in *P. nigra* forests.

Acknowledgments

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