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Study of vertical and horizontal forest structure in Mt. Ainos National Park, Cephalonia Island, Greece

Abstract

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The analysis of the horizontal and internal/vertical structure (profile) of the forest and forested areas of Mt. Ainos National Park on Cephalonia Isl. is presented in this study. The horizontal structure of the forest and forested areas of Mt. Ainos National Park concerned the spatial distribution of the land-cover categories, which have been used in established forestry practices during approximately the last twenty years (1990-2009). The evaluation of the results shows a decrease of the *Abies cephalonica* forest and an increase of the pasture areas through time. A modern vegetation map of the National Park has been produced through this study from satellite data collected in 2009, with the assistance of remote sensing and GIS. The vertical structure of the *Abies cephalonica* forest stand of Mt. Roudi of the National Park was assessed, using data collected in sampling plots. The analysis provided data for important stand density indices that can help authorities in planning sustainable management interventions in the entire forest area.

Key words: forest structure monitoring, forest mensuration, Remote Sensing, Geographic Information Systems.

Introduction

Mt. Ainos National Park was founded in 1962, mainly in order to protect what was left of the once flourishing and magnificent forest, consisting almost entirely of *Abies cephalonica* Loudon (the Cephalonian Fir). The mountain constitutes, according to the International Code of Botanical Nomenclature, the *locus classicus* of the Cephalonian Fir, which is a Greek endemic species. The name *Abies cephalonica* was given by the English botanist J. W. Loudon in 1838, when he classified the Fir from Cephalonia as a new species. Moreover, the whole ecosystem of Mt. Ainos has a significant scientific and aesthetic value, being situated in the heart of Cephalonia Island, right at the center of the island's rich biodiversity.

On Mt. Ainos, *Abies cephalonica* reaches an altitude of 1600 m a.s.l., where it forms the treeline in contact with calcareous rocky slopes with orophilous petrophytic vegetation and

it descends up to an altitude of approximately 600 m. The current upper limit of fir forests on Mt. Ainos are likely to be due to anthropogenic influence rather than to bioclimatic reasons, since the species at issues can be found well above the elevation of 1600 m, as it happens in continental Greece (Peloponnisos, Sterea Hellas).

According to the Dafis' (1973) classification of the forest vegetation in Greece, the fir forest of Mt. Ainos belongs to the beech-fir zone (Fagetalia) with the Abietion cephalonicae alliance, including mainly *Abies cephalonica* forests, and a *Pinus nigra* cluster as well. Recently, the occurrence of *Pinus nigra* subsp. *nigra* Arnold was recorded in the northwestern slopes of Mt. Ainos, at altitude of 1200 m by Efthymiatou-Katsouni & Phitos (2011) and confirmed by our observations.

The study of the structure of the forest allows, on one hand, to gather information on development stages and trends, and on the other, to analyze their potential interactions with wildlife in general (Gatzojiannis 1999a).

In the current study, we present the spatial distribution of the forest and forested areas for the core and buffer zone of Mt. Ainos National Park during the last twenty years (1990-2009). Moreover, a new vegetation map of the National Park was created, basing on a high resolution Geo-EYE orthophotomap of 2009. Finally, the vertical structure of the fir forest stand of Mt. Roudi, in the same National Park, was assessed, by using data collected in sampling plots.

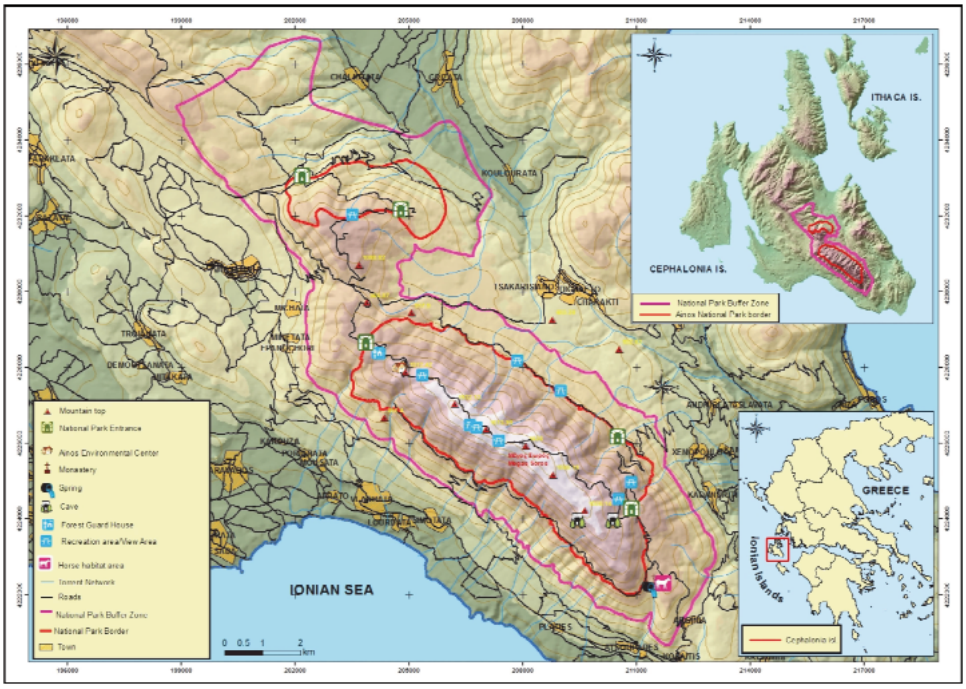

Fig. 1. Study area that includes the core (red line) and buffer zone (violet line) of Ainos National Park on Cephalonia island.

The Study Area

The National Park of Ainos extends to Mt. Ainos and the adjacent Mt. Roudi on Cephalonia Island, Greece (Fig. 1). Mt. Ainos with an altitude of 1628 m is the tallest mountain in the Ionian Islands, whereas Mt. Roudi reaches an altitude of 1125 m.

Besides of the Cephalonia island, *Abies cephalonica* also occurs on Evia Island and in continental Greece, from Peloponnesus to Mt. Olimbos and Mt. Athos. On Cephalonia isl., particularly after the 16th century, extensive woodcutting in the forest of Mt. Ainos-Mt. Roudi, as well as the inability to effectively control and exclude the fires affecting the area, threatened the survival of the Fir forest. As a result, its distribution has been restricted to ¼ the initial one (Y.PE.XO.D.E. 2002). It is possible that the temperature increase in the future, due to global climatic change, may threaten the survival of the Fir forests in the island. It is expected that the temperature increase, predicted in particular for the Mediterranean basin, will have important negative effects on the populations of most conifer species (Körner & al. 2005; Sarris & al. 2007), including *Abies cephalonica*.

In recognition of its significance at European level, the National Park has been designated as a European Biogenetic Reserve, belongs to the "Natura 2000" European Ecological Network of Protected Areas (EEA 2015) and is a Special Protected Zone for the protection of bird species. It has also been declared as a Wildlife Reserve (Michales & Gartsoni 1996). The responsible organizations for its management and administration are the Management Body of the National Park of Mountain Ainos and the Forest Service of Cephalonia.

More than 500 plant species and subspecies have been recorded in the National Park of Mt. Ainos (Phitos & Dambold 1985). Some of them are Cephalonian endemics, such as *Viola cephalonica* Bornm., restricted only to the higher altitudes of Mt. Ainos and *Saponaria aenesia* Heldr. with a wider distribution on the island. Moreover, some Greek endemic plant taxa, such as *Campanula garganica* subsp. *cephalonica* (Feer) Hayek, *Fritillaria mutabilis* Kamari, *Scaligeria moreana* Engstrand, *Scutellaria rupestris* Boiss. & Heldr. subsp. *cephalonica* (Bornm.) Greuter & Burdet, *Thymus holosericeus* Celak., or some rare taxa, such as *Paeonia mascula* subsp. *russoi* (Biv.) Cullen & Heywood etc. can be observed.

In the National Park, more than 100 bird species have been recorded (Handrinos & Akriotis 1997), among them, *Circaetus gallicus* Gmelin, *Buteo buteo* L., *Pernis apivorus* L., *Falco tinnunculus* L., *Athene noctua* Scop., *Alectoris chukar* Gray, *Caprimulgus europaeus* L., *Garullus glandarius* L., *Periparus ater* L., *Turdus viscivorus* L. etc.

The presence of some vertebrates, which can be detected in the area, are: *Podarcis tauricus* subsp. *ionicus* Pallas, *Algyroides moreoticus* Bibron & Bory, *Vipera ammodytes* L., *Erinaceus roumanicus* Barrett-Hamilton, *Talpa stankovici* V. Martino & E. Martino, *Myoxus glis* L., *Lepus europaeus* Pallas, several bat species etc. In the area of the Zoodohos Pigi Monastery, one can observe a herd of semi-wild horses (*Equus caballus* L.).

The climate of Cephalonia is generally of the Mediterranean type, characterized by mild winters with frequent rainfall, frequent sunny days and arid summer. From the existing reports and occasional research by the British Petroleum company (B.P.) of the years 1962-1968 it is known that Mt Ainos consists of: 1) Upper and 2) Lower Cretaceous rocks, aged 80-68 ma. The Upper Cretaceous is subdivided into 5 lithological units, consisting mostly

of pelagic limestones with various fossils, the most characteristic being *Rudistacea*, *Hippuritidae* and *Radiolitidae* (I.G.M.E. 1985; Cestari & Sartorio 1995).

Material and Methods

The horizontal forest structure of Mt. Ainos National Park was studied in the vicinity of the core and buffer zone of the protected area with the use of Geographical Information Systems and Remote Sensing data. Initially, a digitization of land use classes from an orthophotomap derived from the Ministry of Agriculture and dated from 1990 was performed. The following land cover classes were recognized: forest land, shrub land, pasture land, agricultural land and bare land. Following that, a very high resolution satellite image of 2009 (GEOEYE, spatial resolution 0.05 m, four bands) was classified under the same categories as above, representing the current situation of land cover classes in the National Park. A comparison between the two maps revealed the land cover changes in the last 20 years. Using the satellite image of 2009, fieldwork and photointerpretation, a detailed vegetation map was produced. During the fieldwork, some interesting observations were made by the research team about the vegetation of the National Park, concerning the species of *Pinus nigra* subsp. *nigra* Arnold and *Ostrya carpinifolia* Scop.

The study of the vertical structure of *Abies cephalonica* forest was based on the selection of 30 ten-square sample plots 0.01 hectare size (10×10 m), based on a previous study of Politi & al. (2009). In every sample plot the position of each tree, kind of species, diameter at breast height (cm), height (m), crown height (m) and two diameters of crown were recorded, according to IUFRO forest measurement system (Leibundgut 1959; Dafis 1990; Gatzojannis 1999b, 2000; Thanasis 2004). Random sampling was used for the selection of the plots (Matis 1992). Every tree with diameter above 8 cm was measured. Data analysis was done by SPSS 21, SVS (Stand Visualization System), Microsoft Excel and Ecological Methodological software. In each plot the descriptive statistics, given below, were calculated:

– Mean average, standard deviation and standard error of diameter and height.
– Basal area, number of trees per hectare, Stand Deviation Index and Stand Volume.

Table 1. Area (ha) and land use percentage on Mt. Ainos National Park from a forestry point of view between the years 1990 and 2009.

Land use	1990 (Area in ha)	2009 (Area in ha)	1990 Percentage (%)	2009 Percentage (%)
Forest land	2907.5	2701.8	36.94	34.33
Shrub land	4299.2	4174.6	54.62	53.04
Pasture land	457.6	815.0	5.81	10.35
Agricultural land	36.5	15.5	0.46	0.20
Bare land	170.3	164.2	2.16	2.09
Total (ha)	**7871.1**	**7871.1**	**100**	**100**

Results and Discussion

Land use changes between the years of 1990 and 2009 in the core and buffer zone of Mt. Ainos National Park are presented in Table 1.

In Table 1 we can observe a reduction of the area of forest land, shrub land, agricultural land and bare land between the years 1990-2009 per 2.61, 1.58, 0.26 and 0.07% respectively, attributed to human impacts (fires, overgrazing, land abandonment) that the forest has faced in the previous years. On the contrary, pasture land has increased by 4.54%, following the increase in the number of animals in the areas around the National Park. In Fig. 2, land use maps that depicts the changes between the years 1990 and 2009 are presented.

The vegetation map of Mt. Ainos National Park is illustrated in Fig. 3, whereas in Table 2, the area and percentage of each vegetation class of the map is given for the core and buffer zone of Mt. Ainos National Park separately.

According to Table 2, *Abies cephalonica* forest, garrigue vegetation of East Mediterranean area and maquis vegetation occupy the majority of the area of the National park with 33.72, 18.31 and 40.84% respectively. In the core zone of the National Park, apart from *Abies cephalonica*, sixty eight trees of *Pinus nigra* subsp. *nigra* (black pine) were observed. From the measurement of morphometric characteristics of *Pinus nigra* trees, the mean breast height was 23 cm with the maximum of 36 cm and mean height was 17 m with maximum 23 m.

Additionally, in the location of "Melanitsa stream" and "Fagias" of the National Park, a small number, i.e. five individuals of *Ostrya carpinifolia* Scop. (hop hornbeam), a rare species of the Park, were observed.

The *Abies cephalonica* stand of Mt. Roudi is pure by 96,82% and mixed with maquis vegetation by 3.18%. 15% of the diameter of trees ranges from 5-20 to 50-70 cm, 25.5% ranges from 20 to 30 cm and 44.4% from 30 to 50 cm.

In Table 3, typical descriptive statistics of the forest stand of Mt. Roudi of the National Park are presented. From the statistics and tree diameter distribution (Fig. 6) we conclude that the Mt. Roudi stand is of mid-aged condition. The measured stand density equals 1020 trees per ha. The mean height of the stand was determined as equal to 16.9 m, with 24.2 m being the maximum. The mean breast height of the stand was 33.9 cm.

The nonparametric test for the goodness of fit of tree diameters of all the plots with the Kolmogorov-Smirnov tests showed that the dbh distribution of *Abies cephalonica* trees in Mt. Roudi did not follow the normal distribution (p-value = 0.04). The distribution showed a single top curve of bell-shaped form with a slightly right asymmetry and uneven aged structure (Fig. 6).

Conclusions

This study is a contribution to the understanding of the horizontal and vertical structure of forest and forested areas of Mt. Ainos National Park. The creation of a new, detailed vegetation map of the core and buffer zone of the National Park was another accomplishment of this study. The discovery of sixty-eight new trees of black pine in the core zone of the National Park is an indication that the black pine is native in Ainos National Park. The

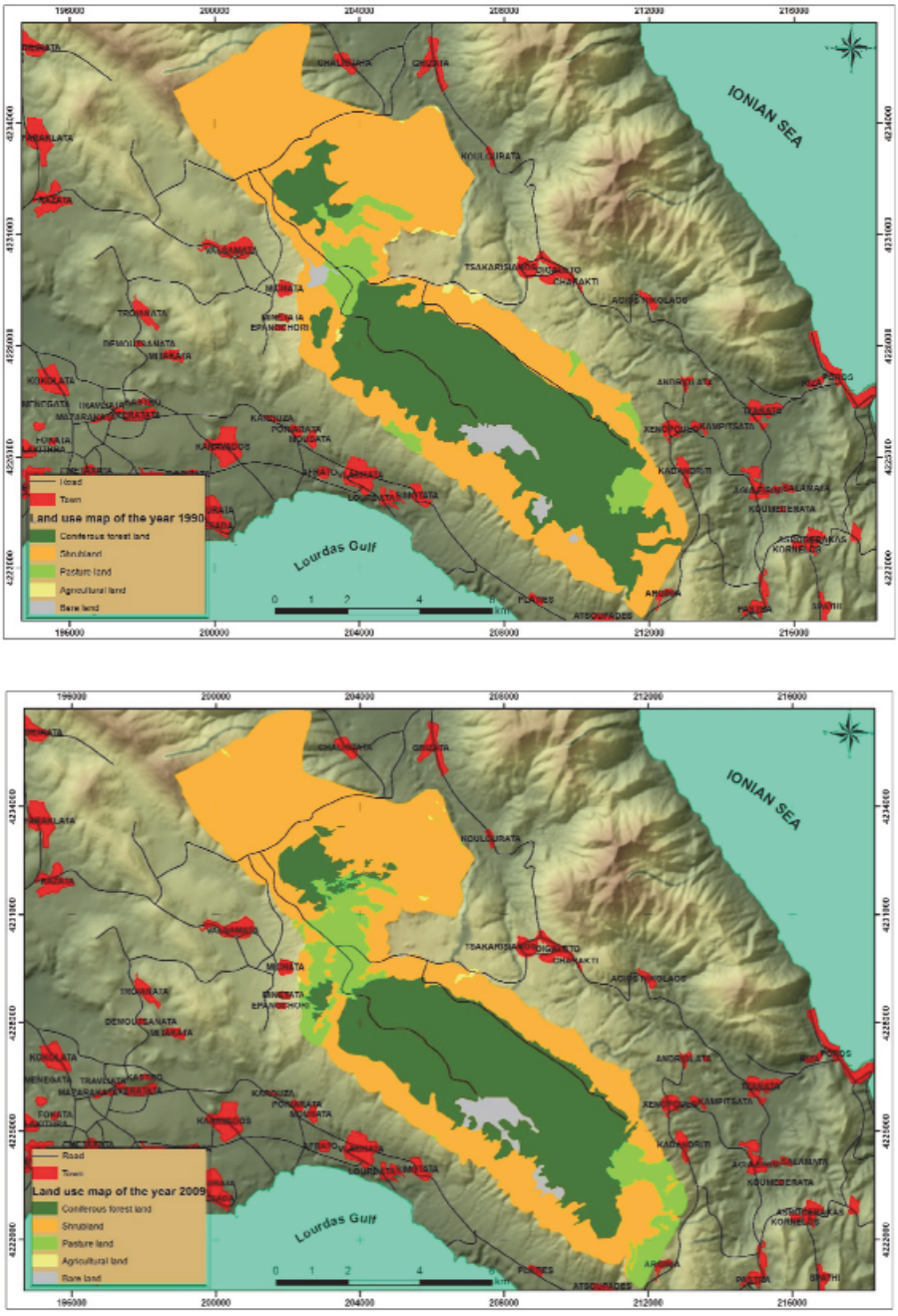

Fig. 2. Land use maps of the core and buffer zone of Ainos National Park in 1990 (above) and 2009 (below).

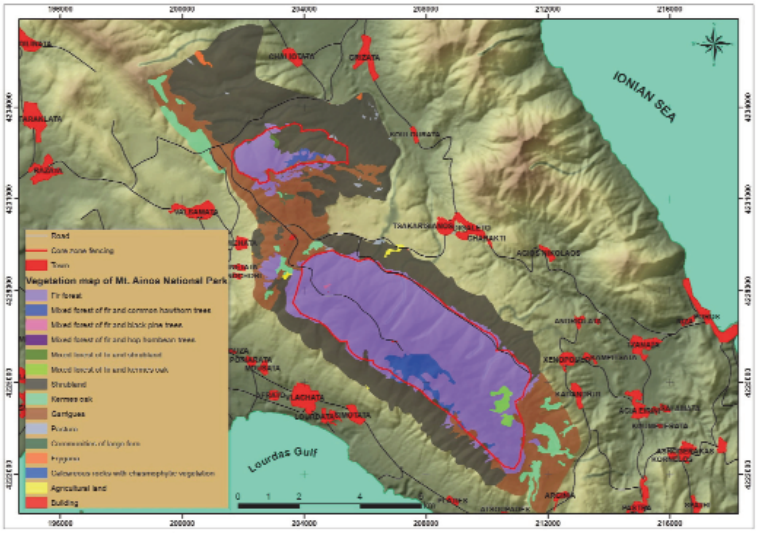

Fig. 3. Vegetation map of the core and buffer zone of Ainos National Park.

Table 2. Contribution of each land-cover type (ha) to the Ainos National Park area from a forestry point of view.

Vegetation class	*Core zone*	*Buffer zone*	*Total*	*Percentage (%)*
Abies cephalonica forest	2440.5	213.4	2653.9	33.72
Abies cephalonica forest mixed with maquis vegetation	6.6	0.0	6.6	0.08
Abies cephalonica forest mixed with *Crataegus monogyna* ssp. *monogyna*	23.7	0.0	23.7	0.30
Abies cephalonica forest mixed with *Ostrya carpinifolia*	0.012	0.2	0.2	0.002
Abies cephalonica forest mixed with *Quercus coccifera*	45.9	0.0	45.9	0.58
Abies cephalonica forest mixed with *Pinus nigra* ssp. *nigra*	1.7	0.096	1.8	0.02
Garrigue vegetation	54.3	1387.3	1441.6	18.31
Maquis vegetation	232.7	2981.6	3214.3	40.84
Quercus coccifera forest	0.0	274.4	274.4	3.49
Phrygana vegetation	0.0	13.3	13.3	0.17
Pteridium aquilinum communities	0.0	6.9	6.9	0.09
Pastureland	0.2	23.6	23.8	0.30
Buildings	1.1	3.7	4.8	0.06
Calcareous rocks with chasmophytic vegetation	146.7	0.0	146.7	1.86
Agricultural land	0.0	13.2	13.2	0.17
Total (ha)	**2953.4**	**4917.7**	**7871.1**	**100**

Fig. 4. *Pinus nigra* subsp. *nigra* tree in the core of Mt. Ainos National Park.

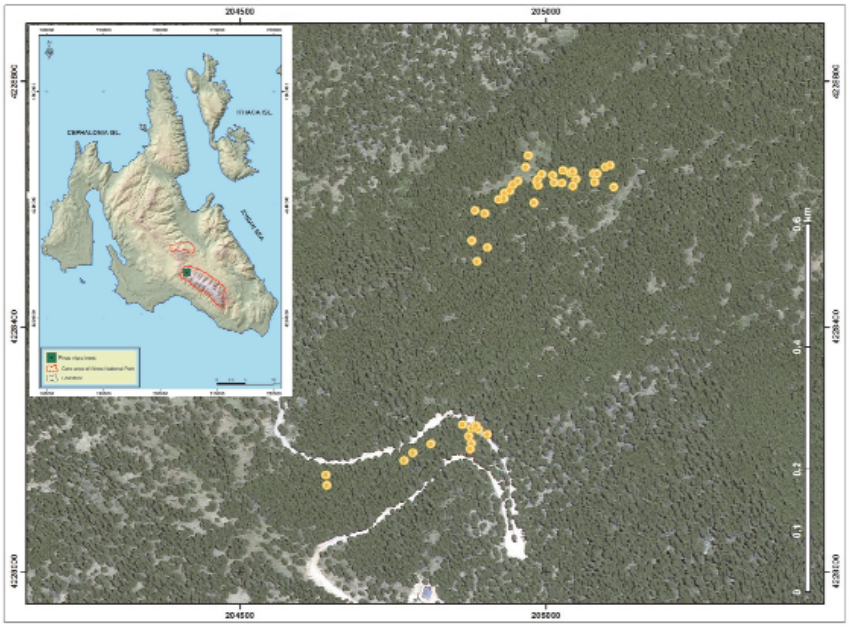

Fig. 5. Distribution of *Pinus nigra* subsp. *nigra* in the core area of the National Park of Mt. Ainos (yellow dots).

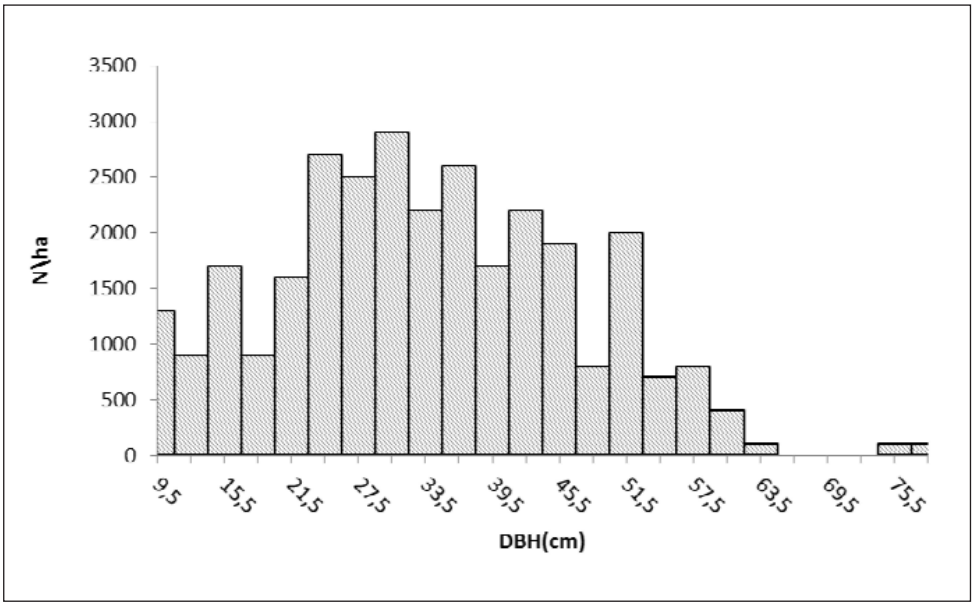

Fig. 6. Diameter distributions of the fir stand on Mt. Roudi.

Pinus nigra trees were found on poor, calcareous, sandy, pure limestone soils and steep slopes were the main topographic characteristic of its habitat. Moreover, the forest road (white outline in Fig. 5) near pine trees, was constructed recently, i.e. in 2009. All the above facts support our hypothesis that the black pine is native in Ainos National Park

The structure of the *Abies cephalonica* forest on the Mt. Roudi component of the National Park was examined too. The results of the study revealed a multi-aged structure that can be attributed to continuous anthropogenic influences (e.g. fire, grazing etc.). The forest had many attributes that were consistent with a fire-resistant evolutionary strategy. Forest structure was relatively open with large trees and high crown bases, reducing vulnerability to crown fire behavior. Shallow forest floors and low woody debris burden,

Table 3. Typical descriptive features of the forest formations on Mt. Roudi of the National Park, resulting from the survey of all sampling areas of forest stand (30 plots). SDI: Stand Density Index; N/ha (number of stems per ha); Basal area of the stand (m^2/ha); V: Stand volume (m^3/ha).

Indices	Min	Max	Mean	Standard deviation
SDI	592.25	3,033.67	1,906.47	685.10
N/ha	400.00	1,900.00	1,020.00	366.15
G	32.02	217.64	105.93	41.73
V	126.06	1,294.33	672.98	270.06

probably due to repeated fires, were also conducive to reduced fire severity. The Mt. Roudi forest stand had a wide range of large fir trees. The multi-aged stand structure indicated that regeneration had been dominated by fire events for at least 350 years, with mature over story trees surviving many surface fires.

More research and further scientific analyses are needed to study the dynamics of the forests of Ainos National Park and this is the purpose of the scientific team of its Management Body Mt. Ainos National Park, which monitors biodiversity and implements appropriate management practices.

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