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Research papers

Site quality assessment for *Pinus sylvestris* L. in mixed forests of the central part of "Rhodope Mountains" in northeastern Greece

Elias Milios[1], Kyriaki Kitikidou[1*], Elias Pipinis[2], Athanasios Stampoulidis[1], Sofia Akritidou[3], Pavlos Smiris[2]

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Abstract - In this work, site index curves are developed for *Pinus sylvestris* in Greece, because of the ecological, social and economic importance of the species. Data from the forest of the Central Rhodope Mountains of north-eastern Greece are used. Thirty one dominant trees, which had the mean height of the 100 tallest trees per hectare were randomly selected and cut, in the 1990s. For each sampled tree a stem analysis was conducted. The selected height-age model for *Pinus sylvestris* was $\hat{h} = 0.53089t - 0.00275t^2$. The mean annual increment from stem analyses was equal to 0.212 m, corresponding to a base age of 68 years. The height estimation, calculated by the selected model, for a 68 year-old tree, is 23 m (SI23). Using the quadratic model as the guide curve for the development of anamorphic site index curves, we produced two more curves, SI20 and SI27. The main findings of this research are that *Pinus sylvestris* seems to grow faster in height in the productive site of the present study compared with that of Sweden, its growth is similar to that of the two most productive sites in forests in northwestern Spain, and it seems comparable to the fairly productive sites of northwestern Turkey.

Keywords - Scotch pine; productivity; site index curves.

Introduction

Pinus sylvestris L., commonly known as Scots pine, is a species of pine that naturally occurs in the forests of Asia and Europe (Farjon, 2005). In Greece, it appears in the North part of the country, at elevations between 800 and 1950 m (Christensen, 1997). The mountains of North Greece are the southernmost limit of *Pinus sylvestris* expansion in the Balkans (Korakis, 2015). *Pinus sylvestris* covers the 0.32 % of Greek forests (Ministry of Agriculture, 1992). Because of its vast geographic distribution, *Pinus sylvestris* is known to have immense ecological, social and even economic importance (Palahí et al., 2004). As such, much of the recent efforts in the field of forest management planning are made to understand the maximum growth rate of *Pinus sylvestris* in a variety of locations, which may have varied soil properties, different climate, temperature and other environmental indices, and hence, having distinctive patterns of *Pinus sylvestris* growth. An in-depth analysis of *Pinus sylvestris* growth in all areas and ecological conditions in Greece will contribute to a better understanding of the species ecology and management of the species forests in its total expansion area, since the present ecological conditions in Greek mountains will probably appear in northern areas, if climate becomes warmer as a result of climate change (see Perry, Oren, & Hart, 2008).

Indeed, a thorough evaluation of the patterns of height growth is critical in gaining a deeper understanding of forest dynamics. As such, site quality assessment has become mainstream in forest management planning, especially as it allows experts to assess the productivity of a particular forest site or determine this site's ability to produce forest biomass or timber (Sharma, Brunner, & Eid, 2012). In the past, foresters have used height growth in ascertaining the quality of a specific forest site. As has been cited by Pinto et al. (2008), height growth is the one variable, which allows experts to gain insight on the vertical structure of a particular forest community as well as the ability of trees to intercept light, which is essential for vertical growth. As such, vertical growth determines the individual success of many forest communities (Pinto et al., 2008). It is for this reason that the main means of site quality assessment was through determining the height growth of the tree community (Clutter et al., 1983).

Commonly, site quality is evaluated using site index curves, which predict the stand development of a particular tree community. Creating site index curves is traditionally determined via three methods, which include the following: the parameter prediction method, the guide curve method and the difference equation method (Clutter et al., 1983). A similar study for *Pinus sylvestris* was conducted in Spain; based on the results, a mean curve was cre-

[1] Democritus University (Greece)
[2] Aristotle University of Thessaloniki
[3] Region of Eastern Macedonia & Thrace, Regional Unit of Xanthi (Greece)
* corresponding author: kkitikid@fmenr.duth.gr

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ated and from it, a set of anamorphic curves were forged (Palahí et al., 2004). The subsequent curves were then used in assessing the productivity of a particular site. Other studies regarding site index curves of the species are found in Elfving & Kiviste (1997), Bravo & Montero (2001), Diéguez-Aranda et al. (2005), Diéguez-Aranda et al. (2006), Condés, et al. (2013), Ercanli, Kahriman, & Yavuz (2014), while a study regarding species' volume tables was conducted in Greece (Kitikidou, Milios, & Lipiridis, 2014).

The relative growth of a particular tree community in a given site can be used in determining or assessing site productivity. As such, the site index tool has become important in determining or assessing site productivity. The oldest method for measuring site index is through equations that generate average site curves. Height-age observations of dominant-codominant trees are plotted on a graph and are used in assessing site productivity (Laubhann et al., 2009; Hernández-Ramos et al. 2014); height-age observations of trees with height close to the mean height of the tallest 100 trees per hectare can also be used (Beekhuis, 1966; Kitikidou et al., 2015). It has also been further mentioned by Pinto et al, (2008) that site index curves may be drawn from three unique sources of information about age-to-height data, which include the following: stem analysis (SA), temporary sample plots (TSP) and permanent sample plots (PSP).

The guide curve method, as cited by Palahí et al. (2004), "assumes the proportionality among curves of different site indices." An average curve is then created, and another set of anamorphic site indices can later be created based on this curve (Barrero–Medel et al. 2011). Another method, which can be used for determining site index curves, classifies the sampled trees and fits separate curves to each cluster (site) (Wenger, 1984).

In the light of the aforementioned studies, this research aims to perform site quality assessment through index curves for P. Sylvestris using the guide curve method, in order to assess the productivity of this ecologically important tree in Greece. The purpose of this study is to develop anamorphic site index curves for in the central part of the Rhodope Mountains in northeastern Greece. The study area is the eastern limit of the species expansion in Greece.

Materials and Methods

The study was conducted in the central Rhodope Mountains of northeastern Greece, in a part of the Chaintou area (coordinates are shown in figure 1). The climate of the area is humid with harsh winters, while the soils of the forest are acid brown forest soils (Dystric Cambisols). The first silvicultural treatments in the area took place in the 1960s. Formerly, only people from the nearby villages and shepherds cut trees illegally in the studied area (see Milios 2000a, 2000b). Data were collected at elevation between 1,200 to 1,500 m approximately.

The forest in the study area is mainly composed by natural stands of *F. sylvatica* L. s.l., *P. sylvestris-F. sylvatica*, *P. sylvestris - F. sylvatica - Abies borisii - regis* and *F. sylvatica - A. borisii-regis stands* (Milios, 2000a, 2000b, 2004, Tsiripidis, 2001; Tsiripidis et al., 2005; Milios et al., 2008). For the development of site index curves, thirty one dominant *P. sylvestris* trees having the mean height of the 100 tallest trees per hectare were cut, in the second half of 1990s. Sampled trees were cut from thirty one sample plots of 500 m^2 (25 x 20 m) that have been established randomly in the *P. sylvestris-F. sylvatica* stands of the study area. In most plots *F. sylvatica* appears in the understory and in the middlestory. The plots from where the trees were cut, were established in many developmental stages of *P. sylvestris-F. sylvatica* stands. The structure analysis of those developmental stages is analytical presented in Milios (2000a, 2000b).

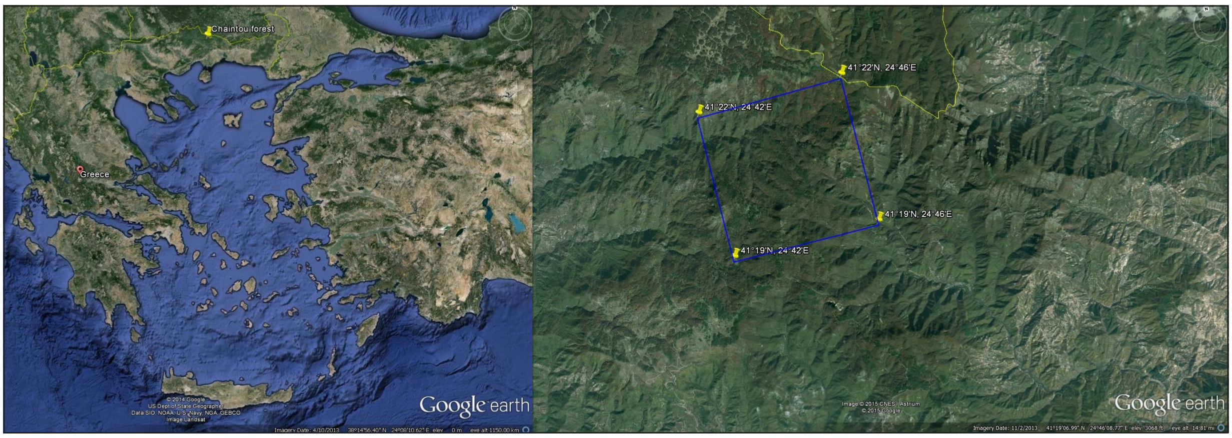

Figure 1 - Study area.

In each plot, a *P. sylvestris* tree that was randomly selected among the trees that had a height close to the mean height of the 5 tallest trees of the plot was cut. As a result, all the trees that were cut had the approximate mean height of the 100 tallest trees per hectare. From each sampled tree, cross sectional discs were cut and taken from the stump height (0.3 m), breast height (1.3 m), 3.3 m level and every 3 m, up to the bole. The last disc was cut from the 5 cm bole diameter. The number of annual growth rings was counted in each cross sectional disc using

Table 1. - Summary statistics of the sampled trees.

	Mean	Standard deviation	Min	Max ax
Age (years)	88.42	22.00	49.00	123.00
Height (m)	26.10	3.76	19.20	32.00

a stereoscope. For each sampled tree a stem analysis was conducted, calculating the tree height at each age using the improved version of Carmean's formula (Carmean, 1972; Newberry, 1991).

Summary statistics for the dataset are given in table 1. Age-height scatterplot followed a curve trend, as later shown in figure 2. This is the reason for testing the following ten regression models ([1] to [10]) for fitting (Arlinghaus, 1994):

Linear	$\hat{h} = b_1 t$	[1]
Logarithmic	$\hat{h} = b_1 \ln t$	[2]
Inverse	$\hat{h} = \frac{b_1}{t}$	[3]
Quadratic	$\hat{h} = b_1 t + b_2 t^2$	[4]
Cubic	$\hat{h} = b_1 t + b_2 t^2 + b_3 t^3$	[5]
Compound	$\hat{h} = b_1^{\,t}$	[6]
Power	$\hat{h} = t^{b_1}$	[7]
S-curve	$\hat{h} = e^{\frac{b_1}{t}}$	[8]
Growth	$\hat{h} = e^{b_1 t}$	[9]
Logistic	$\hat{h} = \frac{1}{\frac{1}{u} + b_1^{\,t}}$	[10]

where u = upper boundary value = max h rounded up = 33.00
$\hat{h}$ = estimated height (m)
t = age from stem analyses (years)
bi (i = 1, 2) =regression coefficients.

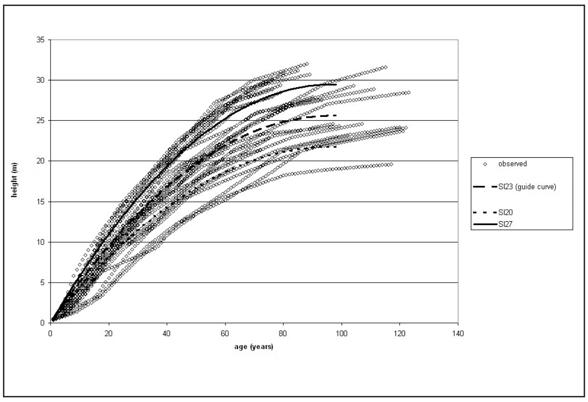

Figure 2 - Site index curves developed for *Pinus sylvestris* in northeastern Greece (SI23: estimated tree height is 23 m at 68 years of age; SI20: estimated tree height is 20 m at 68 years of age; SI27: estimated tree height is 27 m at 68 years of age;).

Table 2. - Comparison criteria for tested regression models.

N°	Criterion	Formula	Optimum value
1	Absolute mean error	$\frac{\sum_{i=1}^{n} \left\| h_i - \hat{h}_i \right\|}{n}$	0
2	Standard error of the estimate	$\sqrt{\frac{\sum_{i=1}^{n} \left(h_i - \hat{h}_i\right)^2}{n-p}}$	min
3	Coefficient of determination R²	$1 - \left(\sum_{i=1}^{n} \left(h_i - \hat{h}_i\right)^2 \Big/ \sum_{i=1}^{n} \left(h_i - \overline{h}_i\right)^2 \right)$	1
4	Root of the mean squared error	$\sqrt{\frac{\sum_{i=1}^{n} \left(h_i - \hat{h}_i\right)^2}{n}}$	min
5	Sum of squared errors	$\sum_{i=1}^{n} \left(h_i - \hat{h}_i\right)^2$	0
6	Sum of relative squared errors	$\sum_{i=1}^{n} \left(\frac{h_i - \hat{h}_i}{h_i}\right)^2$	0
7	Relative mean squared error %	$\frac{\sum_{i=1}^{n} \left(\frac{h_i - \hat{h}_i}{h_i}\right)^2}{n} 100$	0
8	Average deviation	$\left(\sum_{i=1}^{n} \left\| h_i - \hat{h}_i \right\| \Big/ \sum_{i=1}^{n} \hat{h}_i \right) 100$	0
9	Variance ratio	$\sum_{i=1}^{n} \left(\hat{h}_i - \overline{\hat{h}}_i\right)^2 \Big/ \sum_{i=1}^{n} \left(h_i - \overline{h}_i\right)^2$	1

Where:

h: measured height from stem analyses (m)

$\hat{h}$: estimated height (m)

$\overline{h}$: average height from stem analyses

$\overline{\hat{h}}$: average estimated height

p: number of regression coefficients

n: number of observations from stem analyses (2741 age-height pairs).

Nine criteria were used for model comparison (Kitikidou, 2005) (table 2). Firstly, we checked the significance of regression coefficients; then we calculated the comparison criteria and made a decision.

Results - Discussion

Regression coefficients of all models were significant ($P < 0.05$, Table 3). Comparison criteria values for all models are given in table 4 (best values for each criterion are highlighted).

The quadratic model had clearly better values for all criteria. The selected height-age model for *P. sylvestris* was $\hat{h} = 0.53089t - 0.00275t^2$. The mean annual increment from stem analyses was equal to 0.212 m, corresponding to a base age of 68 years. At 68 years the selected model estimated a height of 23 m (SI23). Using the quadratic model as the guide curve for the development of anamorphic site index curves, we drew two more curves, SI20 (at the age of 68 years the estimated tree height is 20 m) and SI27 (at the age of 68 years the estimated tree height is 27 m) (figure 2).

Gatzojiannis & Arabatzis (1996) developed site index curves for *P. sylvestris* in Elatia forest, in the western part of Rhodope mountains (Greece). One hundred sixty eight dominant and codominant trees were used for the development of these curves. In this study, *P. sylvestris* seems to grow slightly faster than the present study. For example, they estimated that for the base age (at the breast height) of 40 years, the height of trees ranges from 25 to 29 m. The oldest tree that was used was about 65 years old. However, Gatzojiannis & Arabatzis do not describe the methodology of their tree height analysis, as well as the instruments they used for the age determination, in order to construct the site index curves. They only mention that they obtained 1133 observations. In the present study, 2741 age-height pairs were used.

Apart from the abovementioned facts that differentiate the present study results from the rest site index

Table 3. - Significance test (t-test) for regression coefficients of tested regression models.

Model	Coefficient	Value	Standard error	t	p-value
Linear	b1	0.319	0.002	192.547	0.000
Logarithmic	b1	4.847	0.025	190.680	0.000
Inverse	b1	20.522	2.565	8.000	0.000
Quadratic	b1	0.531	0.003	154.661	0.000
	b2	-0.003	0.000	-64.823	0.000
Cubic	b1	0.500	0.008	62.064	0.000
	b2	-0.002	0.000	-8.066	0.000
	b3	-6.252E-006	0.000	-4.172	0.000
Compound	b1	1.046	0.000	3060.672	0.000
Power	b1	0.729	0.002	437.581	0.000
S-curve	b1	3.124	0.374	8.345	0.000
Growth	b1	0.045	0.000	138.120	0.000
Logistic	b1	0.939	0.000	2638.252	0.000

Table 4. - Values for comparison criteria for tested regression models.

Criterion	1	2	3	4	5	6	7	8	9
Optimum	0	min	1	min	0	0	0	0	1
Model									
Linear	3.775	4.844	0.768	4.843	64,285.247	221.530	8.082	25.000	1.608
Logarithmic	3.147	3.720	0.638	3.674	539.788	49.039	122.598	23.537	0.469
Inverse	10.741	12.503	<0	12.346	6,096.711	2041.727	5,104.317	489.293	0.329
Quadratic	1.632	2.090	0.889	2.038	166.058	0.972	2.430	17.433	0.629
Cubic	1.835	2.309	0.868	2.220	197.205	1.073	2.683	20.069	0.622
Compound	8.109	9.581	<0	9.338	3,488.183	21.313	53.283	281.691	0.057
Power	2.490	3.242	0.732	3.160	399.464	5.185	12.962	28.635	0.410
S-curve	10.447	12.240	<0	12.086	5,842.524	2329.503	5,823.757	546.466	0.309
Growth	8.109	9.457	<0	9.338	3,488.183	21.313	53.283	281.691	0.057
Logistic	7.102	8.272	<0	8.062	2,599.977	17.351	43.379	182.771	0.148

curves developed for the species in Greece, an important differentiation among these studies is the existence of *F. sylvatic* in *P. sylvestris* stands in the central part of the Rhodope mountains. In these mixed stands, the competition regime among trees is different than in pure stands, leading probably to different growth rates for the constituent species. In some growth environments created in mixed *F. sylvatica* in *P. sylvestris* stands in central Rhodpe mountains, *F. sylvatica* has a competitive advantage, while *P. sylvestris* exhibits slower growth rates than usual (Milios, 2000b, 2004).

The growth of *P. sylvestris* in the stands of the present study cannot be considered inferior compared to other world regions, even though in most cases trees with different characteristics than those of the present study were used in the construction of site index curves. In particular, *P. sylvestris* seems to grow faster in height in the productive site of the present study compared with that of Sweden according to the site index curves created by Elfving & Kiviste (1997). Moreover, the curve of the less productive site of central Rhodope mountains resembles that of medium productivity site of Sweden. However, Elfving & Kiviste (1997) used top tree height from permanent plots, where top height is related to top diameter which is the average of the diameter of the 100 thickest trees.

The site index curves of the present study are very close to those of the two most productive sites in the plantations of the species in Galicia in northwestern Spain (Diéguez-Aranda et al., 2005). In the case of northeastern Spain (Palahí, et al., 2004), *P. sylvestris* stands seem to exhibit poorer site quality compared with the stands of the present study. In both aforementioned studies in Spain, dominant trees from permanent plots were used for the development of site index curves. The mean height of the 100 largest (regarding diameter) trees per hectare was considered as dominant height.

In the study of Bravo & Montero (2001) in northern Spain, where the same dominant height as in Spanish studies was used, site index curves correspond to lower productivity sites than those of the present study. It is obvious that the mean height of the 100 thickest trees per hectare is lower up to equal to the mean height of the 100 tallest trees per hectare which was used in the present study. But we do not think that there is great difference between the two heights.

Regarding the site index curves created by Ercanli et al. (2014) for *P. sylvestris* in mixed *P.sylvestris - F. orientalis* stands in northwestern Turkey, the *P. sylvestris* stands of the central Rhodope mountains seem comparable to the fairly productive sites of Turkey. However, *P. sylvestris* grows faster in the most productive sites of Turkey, compared with the productive site of the present study. A common characteristic of the two studies is that trees having the height of the 100 tallest trees per hectare were used for the development of site index curves. We should note that in the case of Turkey the trees were cut in plots where both Oriental beech and Scots pine were in the overstory.

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Conclusions

In this study, even though *P. sylvestris* grows with *F. sylvatica* (which possibly reduces pine growth), this species exhibits a height growth that cannot be considered inferior compared to other, northern regions. This conclusion is significant, considering that site index curves for this species are developed in one of the southernmost regions of the species' expansion in Europe. More research is needed regarding *P. sylvestris* growth performance under various ecological conditions in the southern part of Europe, in order to increase the ability to develop successful management practices in *P. sylvestris* in analogous environments.

References

Arlinghaus S. 1994 - *Practical handbook of curve fitting* (1st ed.). Boca Raton: CRC Press.

Barrero-Medel H., Mothe F., Nepveu G., Álvarez-Lazo C., García-Corona I., Guera M. 2011 - *Curvas anamórficas de* índice *de sitio para plantaciones de Pinus caribaea Morelet var. caribaea Barret y Golfari de la empresa forestal integral macurije (EFI) en la provincia de pinar del* Río, Cuba. Revista Chapingo Serie Ciencias Forestales y del Ambiente, XVII(2) :245-252. http://dx.doi.org/10.5154/r.rchscfa.2010.06.035

Beekhuis J. 1966 - *Prediction of yield and increment in Pinus radiata stands in New Zealand* (1st ed.). Wellington.

Bravo F., Montero G. 2001 - *Site index estimation in Scots pine (*Pinus sylvestris *L.) stands in the High Ebro Basin (northern Spain) using soil attributes*. Forestry, 74(4): 395-406. http://dx.doi.org/10.1093/forestry/74.4.395

Carmean W. 1972 - *Site index curves for upland oaks in the central states*. Forest Science, 18(2): 109-120.

Clutter L., Fortson J., Pienaar L., Brister G., Bailey R. 1983 - *Timber management: a quantitative approach* (1st ed.). New York (etc.): J.Wiley.

Condés S., Del Rio M., Sterba H. 2013 - *Mixing effect on volume growth of Fagus sylvatica and Pinus sylvestris is modulated by stand density*. Forest Ecology And Management, 292: 86-95. http://dx.doi.org/10.1016/j.foreco.2012.12.013

Christensen K. 1997. In A. Strib & K. Tan, *Flora Hellenica* (1st ed., pp. 1-9). Konigstein, Federal Republic of Germany: Koeltz Scientific Books.

Diéguez-Aranda U., Álvarez González J., Barrio Anta M., Rojo

Alboreca A. 2005 - *Site quality equations for* Pinus sylvestris *L. plantations in Galicia (northwestern Spain)*. Annals Of Forest Science, 62(2): 143-152. http://dx.doi.org/10.1051/forest:2005006

Diéguez-Aranda U., Castedo Dorado F., Álvarez González J., Rojo Alboreca A. 2006 -*Dynamic growth model for Scots pine (*Pinus sylvestris *L.) plantations in Galicia (north-western Spain)*. Ecological Modelling, 191(2): 225-242. http://dx.doi.org/10.1016/j.ecolmodel.2005.04.026

Elfving B., Kiviste, A. 1997 - *Construction of site index equations for* Pinus sylvestris *L. using permanent plot data in Sweden*. Forest Ecology And Management, 98(2): 125-134. http://dx.doi.org/10.1016/s0378-1127(97)00077-7

Ercanli İ., Kahríman, A. Yavuz H. 2014 - *Dynamic base-age invariant site index models based on generalized algebraic difference approach for mixed Scots pine (*Pinus sylvestris *L.) and Oriental beech (*Fagus orientalis *Lipsky) stands*. Turkish Journal of Agriculture and Forestry, 38: 134-147. http://dx.doi.org/10.3906/tar-1212-67

Farjon, A. (2005). *Pines* (1st ed.). Leiden: Brill.

Gatzogiannis S., Arabatzis A. 1996 - *Site index system for Scots pine stands in Elatia forest.* Geotechnical Scientific Issues, 7(4): 71-82.

Hernández-Ramos J., García-Magaña J., Olvera-Delgadillo E., Velarde-Ramírez J., García-Cuevas X., Muñoz-Flores H. 2014 - *Site index for* Pinus greggii *Engelm. Plantations in Metztitlán, Hidalgo, Mexico*. Revista Chapingo Serie Ciencias Forestales Y Del Ambiente, XX(2): 167-176. http://dx.doi.org/10.5154/r.rchscfa.2013.04.016

Kitikidou K. 2005 - *Applied statistics with use of the SPSS statistical package* (1st ed.). Thessaloniki: Tziolas Publications.

Kitikidou K., Milios E., Lipiridis I. 2014 - *Tree volume model estimates and nearest neighbour analysis in the stands of Scots pine (*Pinus sylvestris*) in the central part of Rodope mountain. Šumarski* List, 138(11-12): 573-582.

Kitikidou K., Milios E., Tsirekis E., Pipinis E., Stampoulidis A. 2015 - *Site quality assessment of degraded* Quercus frainetto *stands in central Greece*. Iforest - Biogeosciences And Forestry, 8(1): 53-58. http://dx.doi.org/10.3832/ifor1069-007

Korakis G. 2015 - *Forest Botany* (1st ed., pp. <http://hdl.handle.net/11419/742>). Athens, Greece: Hellenic Academic Libraries Link.

Laubhann D., Sterba H., Reinds G., De Vries W. 2009 - *The impact of atmospheric deposition and climate on forest growth in European monitoring plots: An individual tree growth model.* Forest Ecology And Management, 258(8): 1751-1761. http://dx.doi.org/10.1016/j.foreco.2008.09.050

Milios E. 2000a - *Dynamics and evaluation of the Rhodope mixed stands in the region of Xanthi (Doctoral thesis)*. Aristotle University of Thessaloniki, Greece.

Milios E. 2000b - *Dynamics and development patterns of* Pinus sylvestris *L.* - Fagus sylvatica *L. stands in Central Rhodope.* Silva Gandavensis, 65. http://dx.doi.org/10.21825/sg.v65i0.814

Milios E. 2004 - *The influence of stand development process on the height and volume growth of dominant* Fagus sylvatica *L. s.l. trees in the central Rhodope Mountains of north-eastern Greece.* Forestry, 77(1): 17-26. http://dx.doi.≤/10.1093/forestry/77.1.17

Milios E., Pipinis E., Smiris P., Aslanidou M. 2008 - *The influence of overhead shade on the shade mortality of* Abies borisii-regis *Mattf. seedlings and saplings in the central Rhodope mountains of north-eastern Greece.* Plant Biosystems - An International Journal Dealing With All Aspects Of Plant Biology, 142(2): 219-227. http://dx.doi.org/10.1080/11263500802150332

Ministry of Agriculture 1992 - *Results of the first national forest inventory. The final data process was made by Tsaprounis I.* (1st ed.). Athens, Greece.

Newberry J. 1991 - *Note: A note on Carmean's estimate on height from stem analysis data.* Forest Science, 37(1) : 368-369.

Palahí M., Tomé M., Pukkala T., Trasobares A., Montero G. 2004 - *Site index model for* Pinus sylvestris *in north-east Spain.* Forest Ecology And Management, 187(1): 35-47. http://dx.doi.org/10.1016/s0378-1127(03)00312-8

Perry D., Oren R., Hart S. 2008 - Forest ecosystems (1st ed.). Baltimore: Johns Hopkins University Press.

Pinto P., Gégout J., Hervé J., Dhôte J. 2008 - *Respective importance of ecological conditions and stand composition on* Abies alba *Mill. dominant height growth.* Forest Ecology And Management, 255(3-4): 619-629. http://dx.doi.org/10.1016/j.foreco.2007.09.031

Sharma R., Brunner A., Eid T. 2012 - *Site index prediction from site and climate variables for Norway spruce and Scots pine in Norway*. Scandinavian Journal Of Forest Research, 27(7): 619-636. http://dx.doi.org/10.1080/02827581.2012.685749

Tsiripidis I. 2001 - *Plant communities of beech forests in Rodopi mountain range and their environmental assessment for reforestation* (Doctoral thesis). Aristotle University of Thessaloniki, Greece.

Tsiripidis I., Karagiannakidou V., Athanasiadis N. 2005 - *Ecological and phytogeographical differentiation of beech forests in Greek Rodopi* (Northeast Greece). Biologia, 60(1): 57-67.

Wenger K. 1984 - *Forestry Handbook* (1st ed.). New York: