

QUANTITATIVE AND QUALITATIVE WOOD PRODUCTION OF FIR (*ABIES BORISII-REGIS* MATTF.) IN DIFFERENT SITE QUALITIES

Dimitrios Koutsianitis, Elias Voulgaridis

**Aristotle University, Thessaloniki, GR: e-mails: koutsian@for.auth.gr,
evoulga@for.auth.gr**

ABSTRACT

Of the numerous environmental factors affecting tree growth, the relationship between site quality and tree growth seems to be the most important. In this work, the production of fir wood (*Abies borisii-regis* Mattf.) on quantitative and qualitative basis was investigated in relation to three different site qualities (II, III, IV) at the University forest of Pertouli-Trikala, Greece. For the grading of round timber produced from 268 fir trees, the EN 1927-1:2008 CEN standard was employed. The results showed that the site quality has an influence on both quantitative and qualitative production of fir wood. Higher production and better quality of fir wood were found to be produced in the site quality II, while in the site quality IV, the quantity and quality of wood produced were less and inferior, respectively. In the site quality III, the production and quality of fir wood were at intermediate level.

Key words: fir, wood production, quality of wood, site quality

INTRODUCTION

Tree as a living biological unit of a forest, appears in a variety of forms and characteristics in stem morphology as well as in wood properties, due to a combination of genetic and environmental factors, as long as it grows up. Hence, the qualitative features and characteristics created by this procedure determine the potential value of the tree stem and its wood products, according to market and productive process requirements. Wood shows a large variation in properties, between species and trees, under different growth conditions, as well as

within each tree. The variability is a weakness of wood as a material and improved procedures are needed to predict properties of trees and logs, in order to allocate the wood in an optimal way to different products of better quality. Qualitative defects not only can primarily derive from tree's growth rate and growth conditions but also, secondarily, from harvesting conditions in the forest and mechanical processing conditions in forest industries (Voulgaridis 2002, Tombaziotis and Voulgaridis 2006).

* This work is part of the PhD Thesis of the first author entitled "Quantitative and qualitative wood production of fir and beech forests" carried out at the School of Forestry and Natural Environment, Laboratory of Forest Utilisation, Thessaloniki, GR. This research has been co-financed by the European Union (European Social Fund – ESF) and Greek national funds through the Operational Program "Education and Lifelong Learning" of the National Strategic Reference Framework (NSRF) - Research Funding Program: Thales. Investing in knowledge society through the European Social Fund.

Site quality refers to the combination of physical and biological factors characterizing a particular geographic location or site. The properties that determine site quality are inherent to the site or may be influenced by management. In that sense, forest site productivity is defined as the potential of a particular forest stand to produce aboveground wood volume, and is related to the site quality (Skovsgaard and Vanclay 2008). When growth conditions deteriorate in natural forest ecosystems (e.g. through a decrease in soil fertility) a forest community adapts to the new environmental conditions with slower growth and species' substitution. This change does not imply an inevitable decrease in productivity, because nutritionally more efficient species can increase in dominance. In contrast, forest plantations are usually monospecific and their productivity changes directly in response to environmental conditions (De Moraes Gonçalves et al. 2004).

The relationship between the growth conditions of forest trees and the structural characteristics of their wood produced has been investigated by several investigators. Tsoumis and Panagiotidis (1980), investigated the effect of geographical location, social position of trees in a forest stand and site quality and found that wood produced at good or intermediate site qualities exhibited better quality characteristics.

The relationships between the wood quality and the silvicultural regime and environmental conditions (i.e. site quality, climate, etc.) are established through biological (i.e. height growth, stem radial growth, crown development and branch growth and decay), environmental (i.e. competition for resources, including growing space) and biomechanical processes and constraints which can be

described at various levels of organisation and on various time scales (Kellomaki et al. 1999). In this context, Houllier et al. (1995) reported a project about modelling the influence of site quality and of silvicultural regime on individual tree growth, on stand yield and on wood quality of Norway spruce. They claim that the proposed consistent framework can be used either to establish statistical relationships between growth and wood quality or to model some of the processes that determine wood quality. Farrelly et al. (2009) analyzed the site characteristics on which Sitka spruce has been planted and conducted a test on what effect site has on the productivity of the species. The results indicated that the highest productivities of Sitka spruce occurred on sites with deep, moist, well-aerated soils, of moderate to rich nutrient status. In contrast, the lowest growth potential of Sitka spruce was on poor sites, due to poor drainage and low nutrient level.

Quality grading of forest products and particularly of round timber is of great significance to the timber market, since it specifies the usage, constitutes the base for trading and finally influences significantly market prices. Standards are applied for the quality classification of round timber. European countries apply their national standards or European standards where they exist. Quality classification of round timber in state forests in Greece is based on visual appearance of logs and their dimensions (length and diameter). As sorting criteria for the visual appearance of round wood the following characteristics are evaluated: number and size of knots, checks and splits, spiral grain, eccentricity, reaction wood, discoloration, fungal and insect attack, shakes, taper and sweep of logs, double pith, false heartwood, etc. Softwood species are assorted into three main quality classes: A

(superior quality timber, top quality sawn timber), B and C classes (medium and poorest quality timber, respectively) (Tsoumis 1991, Voulgaridis 2002).

Previous investigations on hybrid fir trees are limited. In the present investigation, a qualitative and quantitative evaluation of wood production of hybrid fir trees (*Abies borisii regis* Matff.) has been carried out in the University Forest at Pertouli (Trikala, Greece) in relation to the growth conditions in three different site qualities (II, III, IV). The aim of this work was to investigate the influence of site

quality to wood production and quality at the timber produced.

EXPERIMENTAL METHODS

As experimental area, the stands numbered 804, 805 and 806 of the forest site „Lioupeika“ at the University Forest at Pertouli were selected according to the forest management plan 2009-2018 (Fig. 1). The forest area is characterized by variable landscapes and environmental conditions. General information of the stands selected and the number of the investigated trees per site quality are shown in Table 1.

Table 1. General information of forest stands and number of trees per site quality investigated.

Stand	Area [Ha]	Elevation [m]	Orientation	Slope [%]	Site quality/ Experimental area [ha]			Number of Trees		
					II	III	IV	II	III	IV
804	9,75	1160-1300	NW	40-60	2,08	-	-	41	-	-
805	11,75	1160-1260	NW	10-50	-	8,47	2,04	-	108	83
806	13,8	1160-1240	NW	30-50	0,74	-	-	36	-	-
Total trees investigated per site quality								77	108	83



Figure 1: View of the investigated stands at the University Forest of Pertouli.

Totally 268 marked hybrid fir trees were investigated which were scheduled to be cut and logged in summer 2011. Before tree felling, additional data for each individual standing tree were taken, such as diameter at breast height, stem deviations, vertical position, irregular perimeter,

branchless height, health condition, etc. Based on the stem diameter at breast height, trees were classified in 10 diameter classes. Tree diameter ranged from 21 cm to 60 cm and a 4 cm scale was used for the classification of the above mentioned classes (Table 2).

Table 2. Classification of investigated trees into 10 diameter classes and distribution of trees per diameter class and site quality.

Class	1	2	3	4	5	6	7	8	9	10	
Diameter [cm]	21-24	25-28	29-32	33-36	37-40	41-44	45-48	49-52	53-56	57-60	
Number of trees	II	12	8	8	6	7	8	6	6	9	7
	III	6	11	10	19	13	15	13	8	7	6
	IV	1	4	4	9	10	17	9	13	10	6
	Total	19	23	22	34	30	40	28	27	26	19

When trees were cut, tree height, crown height, and unbarked diameter at the middle of the tree stem were measured. Each log of the tree obtained was given a serial number. Based on the tree height and the diameter of the stem, tree volume was calculated. Additionally, the age of each tree was measured, at the tree base that is the surface

of stump cross section. Based on the diameter at the base of the tree and the number of annual rings, mean ring width was calculated. Trees were classified in 10 diameter classes based on their stem diameter at breast height.



Figure 2: Produced round wood of quality class A and B (a), C (b), D (c) and industrial wood (d).

Trees were cut and converted to (produced) 559 logs. The logs were inspected on all their sides, and all features were checked, recognized, classified and measured manually. The diameter, volume and defects of each log were recorded in detail on special forms. Sorting criteria for appearance evaluation, were based on determination of size and quantity of individual logs characteristics (Fig. 2) such as type and size of knots, rate of growth, resin pocket, spiral grain, eccentric pith, shakes, taper and sweep of logs, compression wood, double pith, false heartwood, fungal and insect attacks, rot, discoloration (stain), ovality, fluting, checks and splits (Tsoumis 1961). Pith eccentricity in a butt end was calculated according to pith's deviation from the centre of the cross section. Compression wood was visually recognized in logs through the contrast with normal wood from the darker color and different growth's rings formation (presence of eccentric growth rings, different widths). The amount of compression wood in each cross section was expressed as a percent of the total cross sectional area and classified into grades. The appearance, magnitude and direction of spiral grain were measured in debarked logs. Furthermore, images from 559 freshly cut logs and their butt ends, were taken with a digital camera (Sony DSC-W115) and were processed in PC by digital camera analysis software (Adobe Photoshop). These images were used to check the accuracy of the visually estimated defects in the field.

The grading standard EN 1927-1 2008 was applied to set the threshold values for four quality grades: A (highest grade), B, C and D (lowest grade). The grading rules

were modified somewhat, by combining quality classes A and B and using one grade, namely A and B class. The grading was based on the following description of quality classes (BS EN 1927-1 2008):

Quality class A: First quality timber, corresponding to a butt log with clear timber. There may be very minor defects and with few restrictions to timbers' use.

Quality class B: Timber of average to first quality, with no specific requirements for clear wood. Knots are permitted to such an extent as is considered to be average for each species.

Quality class C: Timber of average to low quality, allowing all quality characteristics which do not significantly reduce the physical and mechanical properties of the wood.

Quality class D: Low quality timber, which can be sawn into usable wood in certain applications. Because of its characteristics, falls into none of the quality classes A, B or C.

RESULTS AND DISCUSSION

QUANTITATIVE PRODUCTION

From the total number of trees, 77 came from the stands 804 and 806, with the site quality II, and the remaining 191 trees came from the stand 805, separated in 108 and 83 trees from site qualities III and IV, respectively. Dimensions of the produced round wood were mostly 4m, and in some cases 6m in length. The results of the mean ring width calculated from the 268 stump cross sections in relation to diameter class of the studied trees and site quality, are shown in Fig. 3.

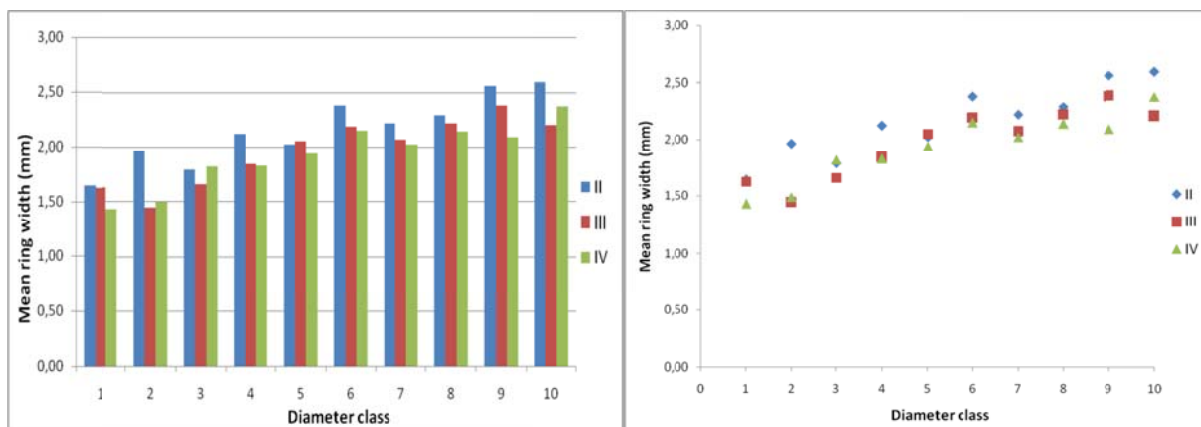


Figure 3: Mean ring width of investigated trees in relation to diameter class and site quality.

The tree ring width allows for direct and meaningful comparisons across species, site types and growth regions than an index based on stand height at a certain age. The mean annual volume increment is often considered a more useful measure of site productivity than an index based on stand height or height growth (Skovsgaard and Vanclay 2008). The results in column graph show that in the site quality II, mean ring width was found higher for each one of the 10 diameter classes than the site qualities III and IV, except from the 5th class, where the ring width was higher in the site quality III. The same trend is observed in XY scatter graph. After a regression analysis in the graph and the creation of a linear equation, the coefficient of determination (R^2) for the II, III, and IV site qualities was 0,869, 0,832 and 0,857, respectively. This revealed a strong relationship between the mean annual ring and the diameter class of trees, for the three site qualities. In this way, the better

site quality was directly connected with the higher mean annual volume production and therefore to the site productivity, than in the poor site qualities. Thus, certain differences in growth potential were evident among fir trees of the same diameter class growing under different site conditions. It turned out that fir tree species growing under rich site quality (II), have attained the highest mean ring increment.

The use of height or height growth as a site productivity indicator relates to the fact that, in many situations, stand height or current height growth seems to correlate well with stand volume growth. In addition, height is a simple variable, easy and inexpensive to measure and generally not much affected by management practices (Skovsgaard and Vanclay 2008). In the present work, the results of the mean tree height measurements in relation to diameter class of the studied trees and site quality, are shown in Fig. 4.

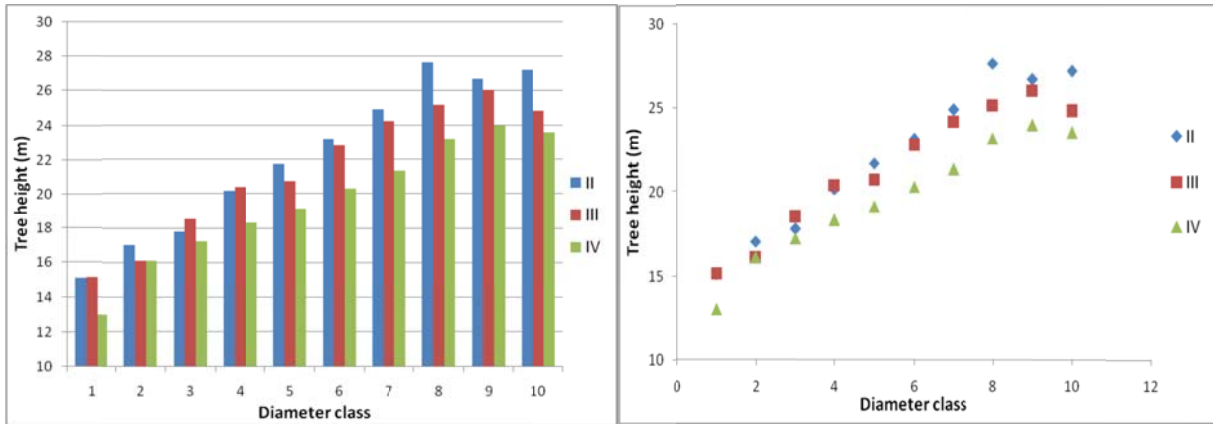


Figure 4: Mean tree height of investigated trees in relation to diameter class and site quality.

The results in column graph show that in the site quality II, mean tree height was found higher for almost each one of the diameter classes (except in 1st, 3rd and 4th class, where lower values were found), than the mean tree height of site qualities III and IV. The plotted XY scatter graph, revealed a

similar trend where the coefficients of determination (R^2) for the II, III, and IV site qualities were 0,960, 0,934 and 0,957, respectively. This indicated a strong relationship between the mean tree height and the diameter class of the studied trees, for the three site qualities.

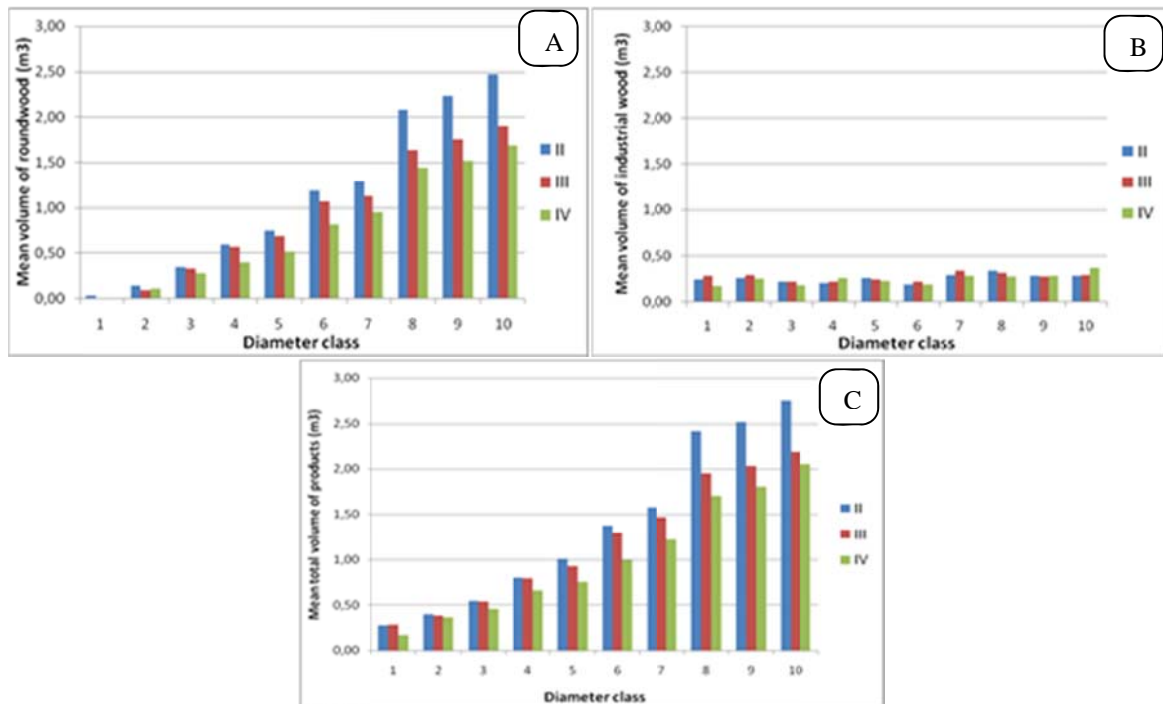


Figure 5: Mean volume of roundwood (A), industrial wood (B), and mean total volume of products (C), in relation to diameter class and site quality.

The volume of each log was calculated, all volumes of the same diameter class were added and the mean volume was calculated.

The mean volume of roundwood, industrial wood and mean total volume of products, in relation to diameter class and site quality,

are shown in Fig. 5. The highest volume of timber produced as well as that of round wood, for each diameter class, appeared to be in the site quality II than in the other site qualities (III, IV).

were knots, spiral grain and compression wood. The results of grading the round wood obtained from the 268 hybrid fir trees are shown in Fig. 6, separately for each site quality (II, III, IV) and diameter class (1 to 10).

QUALITATIVE PRODUCTION

This work revealed that the main defects that cause most downgrading in round wood

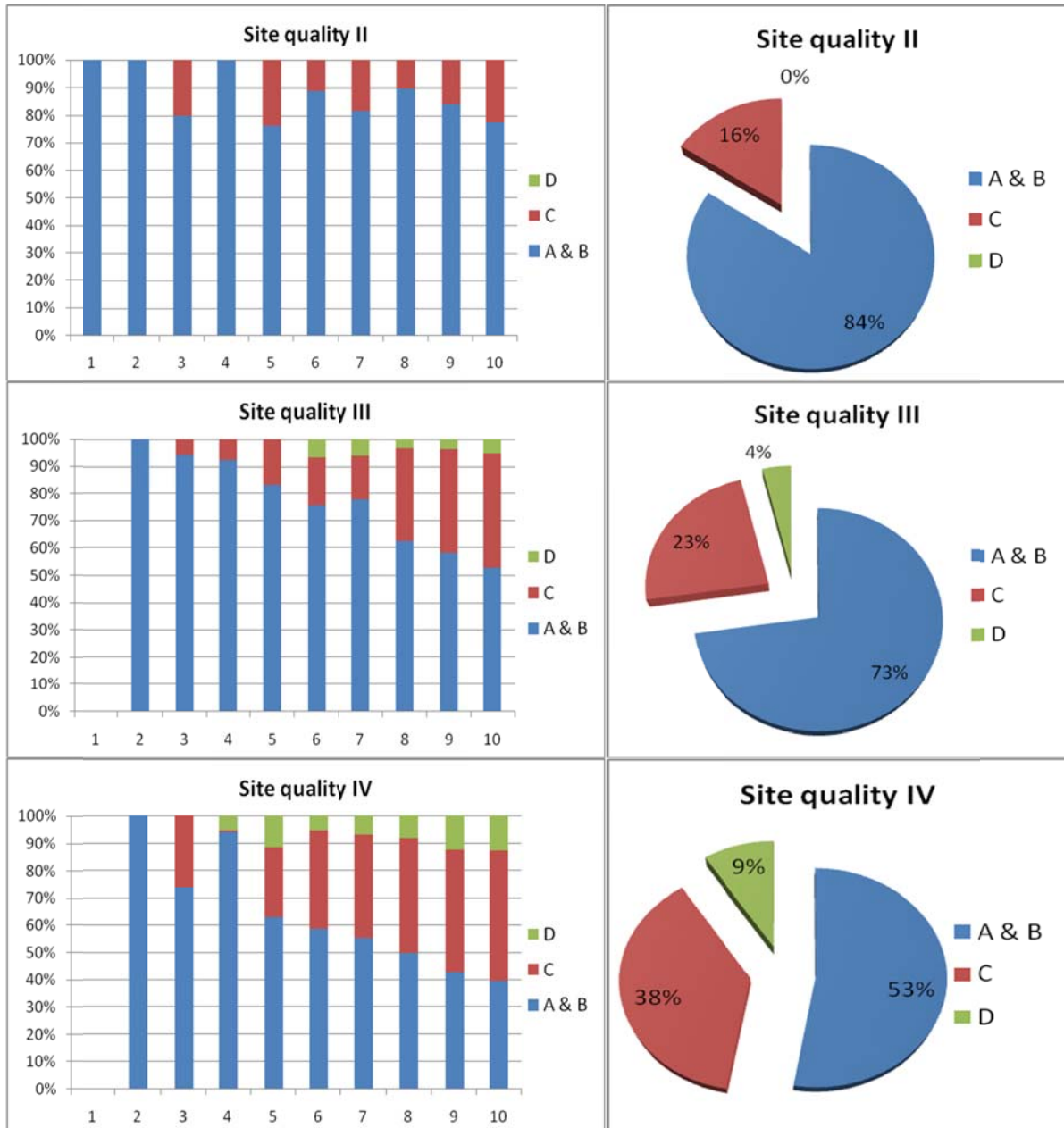


Figure 6: Qualitative production of round timber in relation to diameter class and site quality.

The percentages of quality grades of each class diameter are shown on the

columns. On pie charts, all volumes of the same grade were added and the total volume

of each grade was expressed as a percentage of the total round wood production. In the site quality II, the total percentage of quality class A and B produced wood (84%) was significantly greater in every diameter class, than in the site quality III (73%) and IV (53%), while 16% was of the grade C. Furthermore, logs of low quality timber were absent. The 1st diameter class trees, for the site qualities III and IV, had no timber production and therefore no quality measurements were made.

Fig. 6 shows that with increasing tree diameter in the site quality III, the percentage of the produced round wood classified to qualities A and B, declined. The opposite trend was found for timber of average to low quality, where the percentage of logs for quality class C increased for larger tree diameters. Timber of quality class D was found in the middle and large diameter class trees.

In general, 73 % of the total volume produced in the site quality III was attributed to timber of average to first quality, 23% to timber of average to low quality and the rest 4 % to low quality timber. As for the poorer site quality (IV), the volume of logs of quality class C was found greater in the middle and large diameters and smaller in small tree diameters, with a percentage 38% of total production. It was found that the volume of low quality timber increased with tree diameter increase, whereas the volume of wood of average to first quality was found smaller in large diameter trees, with percentage 9 % and 53 % of total production, respectively.

This proves the capability of Greek fir forests to produce good quality round timber. However there are big differences in the quantity and quality of the produced products, varying from one site quality to

another, with indications that the second (II) site quality could produce higher quality and quantity of timber.

CONCLUSIONS

The conclusions of the present investigation on qualitative and quantitative wood production of hybrid fir can be summarized as follows:

Certain differences in growth potential were found to exist among fir trees of the same diameter class grown under different site qualities. It was recorded that trees grown under the site quality (II), have attained the highest mean ring increment and produce the highest quantities of wood. In the site quality II, the frequency of appearance of timber of average and first quality class (A and B class) was the highest. From the total logs examined, a great percentage of 84% of the total round wood production was classified in the quality class A and B. The remaining produced volume (16%) was accounted for the timber of average to low quality (class C), whereas wood production of the lowest quality (class D) was absent.

In the site quality III, fir trees produced 73 % of round wood of class A and B, 23 % of class C and 4 % of class D, whereas in the site quality IV these percentages were only 53 %, 38 % and 9 %, respectively. The present results showed that fir trees grown in better site qualities produce more timber volume and of better quality than in inferior site qualities.

The application of proper silvicultural measures, the training of forest workers and the application of round quality grading standards is expected to increase the percentages of round wood production of better quality in all site qualities.

REFERENCES

1. De Moraes Gonçalves J.L., Stape J.L., Laclau J.P., Smethurst P., Gava J.L. (2004). Silvicultural effects on the productivity and wood quality of eucalypt plantations. *Forest ecology and management*, 193, 1–2: 45–61.
2. BS EN 1927-1. (2008). Qualitative classification of softwood round timber – Part 1: Spruces and firs. European Committee for Standardization.
3. Farrelly, N., Ni Dhubhain, A., Nieuwenhuis, M., Grant, J. (2009). The distribution and productivity of Sitka spruce (*Picea sitchensis*) in Ireland in relation to site, soil and climatic factors. *Irish Forestry*, 66, 1–2: 51–73.
4. Houllier, F., Leban, J., Colin, F. (1995). Linking growth modelling to timber quality assessment for Norway spruce. *Forest Ecology and Management*, 74, 1–3: 91–102.
5. Kellomaki, S., Ikonen, V.-P., Peltola, H., Kolstrom, T. (1999). Modelling the structural growth of Scots pine with implications for wood quality. *Ecological Modelling* 122, 1–2: 117–134.
6. Skovsgaard, J.P., Vanclay, J.K. (2008). Forest site productivity: A review of the evolution of dendrometric concepts for even-aged stands. *Forestry* 81(1):13–31.
7. Tarasiuk, S., Jednoralski, G., Krajewski, K. (2007). Quality assessment of old-growth Scots pine stands in Poland. COST E53 Conference “Quality Control for Improving Competitiveness of Wood Industries”, 15–17 October 2007, Warsaw.
8. Tombaziotis, M., Voulgaridis, E.V. (2006). The appearance of compression wood in hybrid fir trees (*Abies borisii regis* Matff.) and its impact on the quality of sawn timber. *Proceedings in 5th IUFRO Symposium „Wood Structure and Properties 06“*, 3–6/09/2006, Sliac-Sielnica, Slovakia.
9. Tsoumis, G. (1961). Grading fir logs and lumber in the University Sawmill at Pertouli. *Annals of the School of Agriculture and Forestry, Aristotelian University, Thessaloniki, Greece*, 103–135 (In Greek with summary in English).
10. Tsoumis, G. (1991). *Science and Technology of Wood: Structure, Properties, Utilization*. Van Nostrand Reinhold, New York, 494 pp.
11. Tsoumis, G., Panagiotidis, N. (1980). Effect of growth conditions on wood quality characteristics of black pine (*Pinus nigra* Arn.). *Wood Science and Technology*, 14, 4, 301–310.
12. Voulgaridis, E. (2002). *Wood Quality (University Lectures)*, University Press, 128 pp. (In Greek).