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Wood production potential of beech (*Fagus sylvatica* L.) from natural forests in West Central Greece

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Abstract

Beech is an important tree species in natural and managed forests in Europe. Beech natural forests in Greece have a great ecological and economic importance and represent a very valuable species with respect to its potential of wood production and utilization. The aim of this work was to analyze the wood production potential of beech (*Fagus sylvatica* L.) natural forests on a quantitative and qualitative basis with respect to the forest site quality conditions. For this analysis, the wood production potential of 228 beech trees growing under different site qualities at the Aspropotamos forest district, Trikala, western-central Greece, was evaluated. For the quality grading of 787 produced beech logs, the EN 1316-1:1997 CEN standard was employed. The results showed that there is a very good potential of both quantitative and qualitative wood production in the natural beech forest as well as that the site quality has an influence on quantity and quality of wood production. It was recorded that beech trees grown under the better site quality, have attained the highest mean ring increment and produced the highest quantities of wood. Particularly, higher production and better quality of beech wood was produced in the better site quality, while in the inferior site quality the quantity of round wood produced was less and the quality was inferior.

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

1. Introduction

Tree as a living biological unit of a forest, appears in a variety of forms and characteristics regarding stem morphology as well as wood properties, due to a combination of genetic and environmental factors, as long as it grows. 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 of wood as raw material is necessary to be taken into account and, hence, 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 cannot only primarily derive from tree's growth rate and growth conditions but also, secondarily, from harvesting conditions and management systems in the forest and mechanical processing conditions in forest industries (Voulgaridis, 2002; Tombaziotis and Voulgaridis, 2006; Ayan et. al., 2012).

The site where trees grow refers to a geographic location that is considered homogeneous in terms of its physical and biological environment. Forest site is defined by the location's potential to maintain tree growth, often with a view to site-specific silviculture. It may be classified into site types according to their similarity regarding soil, topography, climate and vegetation. Site classification can provide a range of management aims, including ecological stratification for optimizing the evaluation of forest site productivity. In that sense, 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 reduction in soil fertility) a forest community adapts to the new environmental conditions with slower growth and species' substitution. However, this change does not imply an inevitable decrease in productivity because nutritionally more efficient species can increase in dominance (Goncalves *et al*., 2004). A study by Kirdyanov *et al*. (2013) revealed the dependence of tree

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growth on local site conditions, as soil factors dramatically influenced tree ring formation and therefore wood productivity changed. Dafis (1969) reported that in the better site qualities beech species show the maximum productive capacity, in the intermediate site qualities beech presents less but sufficient productivity, while in the inferior site qualities beech stands indicate small productivity and low timber quality.

The relationships between wood quality, silvicultural system and environmental conditions (i.e., site quality) are established through biological (i.e., height growth, stem radial growth), environmental (i.e., competition for resources) and biomechanical processes and limitations (Kellomäki *et al*., 1999). In this context, the relation between the growth conditions of forest trees and the structural characteristics of their wood produced has been examined 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 in high or intermediate site qualities exhibited greater quality characteristics. Gutierrez-Oliva *et. al*. (2006) also concluded that site quality had considerable influence on the wood density values, where the highest values were found in the best site qualities. Farrelly *et al*. (2009) investigated the effect of forest site conditions on the productivity of Sitka spruce. Their study revealed that the highest productivities occurred on forest sites with deep, moist, well-aerated soils, of moderate to rich nutrient status, whereas the lowest growth potential was on poor sites, due to poor drainage and low nutrient level. Houllier *et al*. (1995) reported on a project modelling the influence of site quality on individual tree growth, on stand yield and on wood quality of Norway spruce. They claim that this 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. Liu *et al*. (2005) studied the variation of color in trees under different growing conditions and management practices. Their study revealed a significant effect of site conditions on color variation and red heartwood development, which devaluate beech timber.

Quality grading of forest products and particularly of round wood is of great importance to the timber market, since it specifies the usage, constitutes the base for trading and finally greatly influences market prices. Standards are applied to the quality classification of round wood. European countries apply their national standards or European standards where they exist. Quality classification of round wood in state forests in Greece is based on visual appearance of logs and their dimensions (length and diameter). Both softwood and hardwood species are assorted into three main quality classes: A (superior quality timber, top quality sawn timber), B (normal or less valuable quality timber) and C (inferior quality timber) (Tsoumis, 1991; Voulgaridis, 2002).

The quality and quantity of wood production from different sites of beech natural forests have been the subject of limited research so far, and, in Greece, such research is lacking. The aim of this work was to analyze the wood production potential of beech (*Fagus sylvatica* L.) natural forests on a quantitative and qualitative basis with respect to the forest site quality conditions. Such investigations are expected to better evaluate the influences of growth conditions on the quantity and quality of the timber produced, and to improve existing timber quality assessment procedures with respect to final product requirements.

2. Materials and methods

2.1 General information of the stands and tree selection

As experimental area, the stands numbered 11b and 28d of the forest sites "Elatos" and "Kastania", respectively, at the Aspropotamos forest district of Kalampaka, western-central Greece, were selected according to their corresponding forest management plans. These two forest stands are 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.

In total 228 marked beech trees, which were scheduled to be cut and logged in summer 2012, were investigated. According to the forest management plan of the investigated forest district, the study focused on site qualities II and III. The distinction of the different site qualities in the selected forest stands was conducted using the site quality maps of the management plan. Additionally, tree height and breast height diameters were measured in the two experimental forest stands, in order to confirm the existing map data for site qualities (Dafis, 1969). In addition, quality data of standing trees like stem crook, forked stem, sweep, vertical position, irregular perimeter, branchless height, health condition, etc., were taken.

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

Species	Stand	Area (ha)	Elevation (m)	Orientation	Slope (%)	Site quality/Exp. area (ha)		Number of trees	
						II	III	II	III
Beech	11b	31,69	1190-1510	N-NE	40-70	12,00	12,00	93	65
	28d	33,4	1200-1400	N-NE	50-70	17,00	14,00	38	32
Total beech trees investigated per site quality								131	97

Trees were classified into 8 diameter classes based on their stem diameter at breast height. Tree diameter ranged from 29 to 60 cm and a 4 cm scale was used for the classification of the above mentioned classes (Table 2). 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.

Table 2. Classification of investigated trees into 8 diameter classes and distribution of trees per diameter class and site quality

Class	1	2	3	4	5	6	7	8
Diameter [cm]	29-32	33-36	37-40	41-44	45-48	49-52	53-56	57-60
Beech								
II	10	11	16	26	25	17	15	11
III	8	8	11	18	21	12	10	9
Total	18	19	27	44	46	29	25	20

2.2. Roundwood quality assessment

Trees were cut and converted to (produced) 787 beech logs. All sides of the logs were inspected, 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 such as type and size of knots, rate of growth, spiral grain, eccentric pith, shakes, taper and sweep of logs, tension wood, red heart, fungal and insect attacks, rot, discoloration (stain), double pith, ovality, fluting, checks, splits (Tsoumis 1961; 1991) and formation and level of the heart rot (Ayan et. al., 2012). Furthermore, images from 787 beech freshly cut logs and their butt ends, were taken with a digital camera (Sony DSC-W115) and were processed on a PC using digital camera analysis software (Adobe Photoshop). These images were used to check the accuracy of the visually estimated defects in the field. For grading of beech produced logs, EN 1316-1 (1997) was employed to set the threshold values for four quality grades: A – an exceptional quality class, B – a normal quality class, C – a less valuable quality class and D – a quality class which includes long pole, log or portion of long pole not permitted in the other quality classes (for all the characteristics in class D more than 40% of the volume of the wood shall be usable). Quality classes are not applied to small sized timber (wood 1 m long, used for particleboards, fiberboards and pulpwood) and fuelwood of short length (used as a fuel). The assessment followed the log grading standards in full terms.

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3. Results

1.1. Quantitative production

From the total number of 228 beech trees, 131 were present in site quality II and 97 in site quality III. The produced beech round wood varied between 3, 4 and 5 m long. Based on Skovsgaard and Vanclay (2008) the maximum mean annual volume increment is considered a more suitable measure of site productivity than an index based on stand height or height growth. An index that represents volume production allows for direct and meaningful comparisons across species, site types and growth regions compared to an index based on stand height at a certain age. Tree ring width is an indicator of volume production. The results of the mean ring width calculated from the 228 beech stump cross sections in relation to diameter class of the studied trees and site quality, are shown in Figure 1.

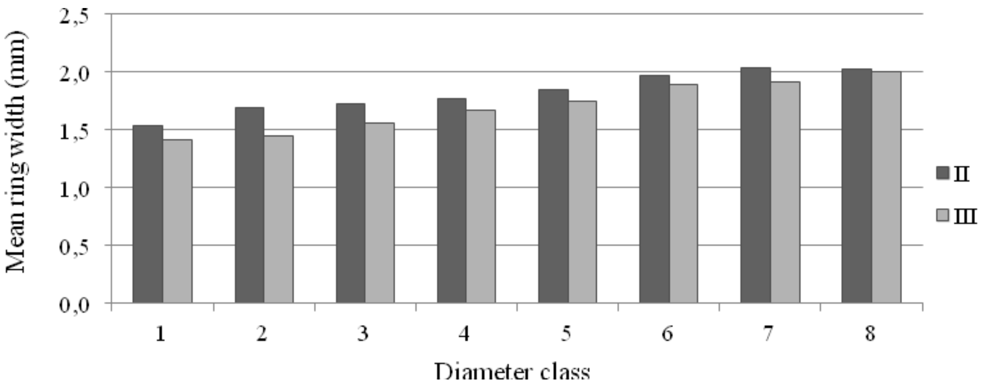

Figure 1. Mean ring width of investigated trees in relation to diameter class and site quality

The mean ring width of beech trees of site quality II is approximately 7 % higher than the mean ring width of the inferior site quality III (Table 3). This difference was confirmed as significant from the ANOVA-test. Hence, the better site quality was directly connected with the higher mean annual volume production than in poorer site quality and therefore with the site productivity. Thus, certain differences in growth potential were evident among beech trees of the same diameter class growing under different site conditions. It turned out that beech tree species growing in the rich site quality II attained the highest mean ring increment. According to Spanos (2011), the wood production of beech stands in Greece is lower than that of fir (*Abies* spp.) and Norway spruce (*Picea abies*) and only under proper silviculture conditions, beech can produce higher amount of round wood, in comparison to other broadleaves and conifers.

Table 3. Calculated mean values and variances of the tree ring width and height for statistical evaluation (ANOVA)

		Ring width		Tree Height	
		Mean value	Std. Deviation	Mean value	Std. Deviation
Beech	II	⎡1,84	0,22	⎡27,46	3,42
	III	⎣1,72	0,26	⎣24,43	3,07

[: Statistically significant differences at 5% level of significance

The results of the mean tree height measurements in relation to diameter class of the studied trees and site quality are shown in Figure 2. The highest mean tree height of beech was found in site quality II. The mean tree height for beech in site quality II is approximately 12.5 % higher than the mean tree height in site quality III. This difference was confirmed as significant from the ANOVA-test (Table 3). Skovsgaard and Vanclay (2008) suggest that 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, they claim that height is a simple variable, easy and inexpensive to measure and generally not much affected by management practices. The mean volumes of round wood and small sized timber plus fuelwood production in relation to diameter class and site quality are shown in Figure 3. The volume of each log was calculated, all volumes of the same diameter class were added and the mean volume was calculated. The round wood production appears to be higher in better site quality, while the differences of small sized timber plus fuelwood production between the site qualities were found to be small.

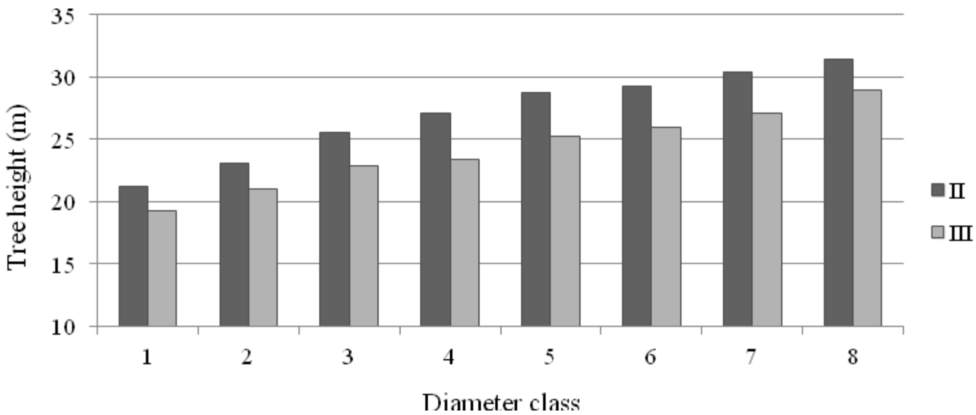

Figure 2. Mean tree height of investigated trees in relation to diameter class and site quality

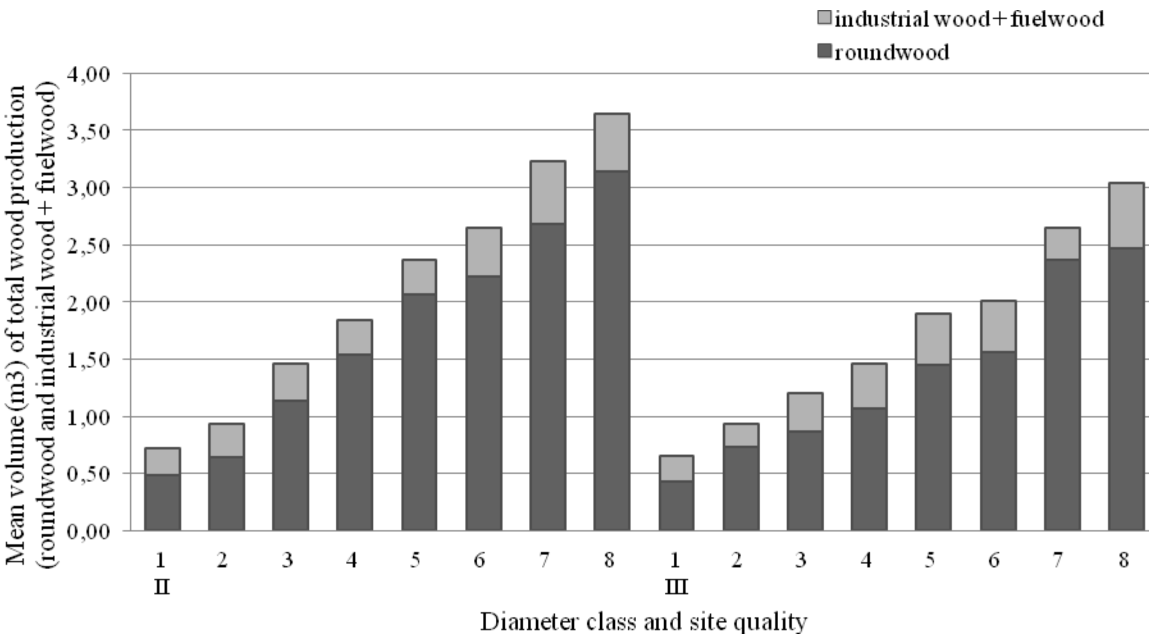

Figure 3. Mean stem volume production (roundwood and small sized timber plus fuelwood) for beech, in relation to diameter class and site quality

1.2. Qualitative production

The quality assessment according to EN 1316-1 (1997) grading standard classified the round wood by a range of different characteristics and properties which had to meet particular limits. In this way, the parameter which presented the lowest quality of the log determined the overall classification of the log. However, there were some exceptions where an extremely benign performance in one characteristic compensated a small deviation from the required limit in another characteristic. This work revealed that the main defects that cause most downgrading of beech round wood were knots, red heart and to a small extent tension wood. All volumes of the same quality class were added and the total volume of each quality class was expressed as a percentage of the total round wood production.

Figure 4 shows the qualitative classification of the round wood obtained from 228 beech trees, separately for the investigated site qualities II and III. In site quality II, the percentages of beech round wood produced as A and B quality classes were significantly higher (24 % for A and 53 % for B) than those in site quality III (9 % for A and 45 % for B). On the contrary, the percentages of round wood produced as C and D quality classes increased from II to III site quality, from 22 to 39 % (class C) and from 1 to 7 % (class D). Wood production analysis per tree diameter class showed that by increasing the tree diameter, the percentages of the produced beech round wood corresponding to four quality classes A, B, C and D did not follow any consistent trend from II to III site quality.

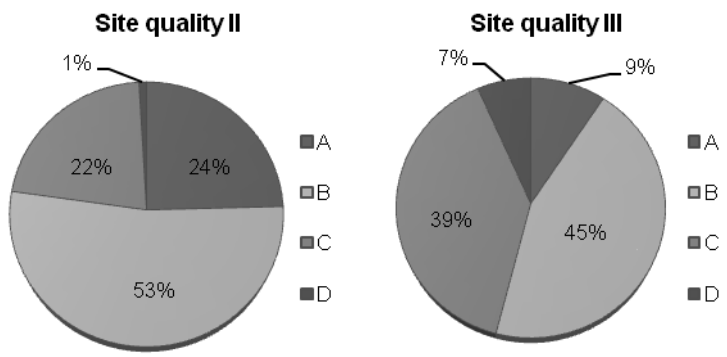

Figure 4. Qualitative production of beech round wood in relation to site quality

4. Conclusions and discussion

The conclusions of the present investigation on qualitative and quantitative wood production of beech natural forests can be summarized as follows:

Certain differences in growth potential were found to exist among beech trees of the same diameter class grown in different site qualities. It was recorded that beech trees grown in site quality II, have attained the highest mean ring increment and produce the highest quantities of wood when compared with the inferior site quality III.

The natural beech forests exhibit a potential to produce more timber of higher wood qualities (A and B class) in the better site quality II (77 % of the total wood volume produced) than in the inferior site quality III (54% of the total wood volume produced). The round wood production of inferior quality (C and D classes) was increased from the better site quality (II) to inferior site quality (III).

The results of this work indicate that, under the specific experimental conditions, natural beech forests produce higher quantities of better quality round wood when they are grown in better site qualities than in inferior ones. The application of proper silvicultural measures, training of forest workers and application of roundwood quality grading standards is expected to increase the percentages of beech round wood production of better quality in all site qualities..

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