Stand Structure Analyses of *Quercus ithaburensis* subsp. *macrolepis* silvopastoral Systems in Greece

Goudelis G.[1], Papadopoulos A.[1], Pantera A.[1], Fotiadis G.[2], Aidinidis E.[1] And Mosquera-Losada Mr[3]

[1] Department of Forestry and Natural Environment Management, Technological Education Institute (TEI) of Sterea Ellada, 36100 Karpenissi, Greece

[2] Forest Research Institute, ELGO-Dimitra, Thessaloniki, Greece

[3]Crop Production and Project Engineering Departament. Escuela Politécnica Superior. Universidad de Santiago de Compostela. 27002-Lugo

*corresponding author:

e-mail: ggoudelis@teiste.gr

Abstract The species *Quercus ithaburensis* subsp. *macrolepis* forms open forests in Greece that belong in the sub-Mediterranean vegetation zone (*Quercetalia pubescentis*), forming typical silvopastoral systems. These forests are degraded with a major part of them having being converted to agricultural fields, pastures or urban areas. The structural analysis of these forests is analyzed in this study from a wide network of sample plots, representative of the species growing area. The parameters measured from each sample plot were: ground cover at each layer, number of tree per hectare, diameter at breast height (Dbh), total height, height at the crown base (HCB), crown length, basal area, slenderness index (H/D), crown ratio (CR), dominant height and crown competition factor (CCF). The low values of the CCF, H/D, stand density and basal area as well as the high values of CR confirm that the stands formed by the species not only are widely scattered but also, in most areas, cannot be characterized as forest but as individual trees, that is almost open growing trees.

Keywords: valonia oak, Mediterranean region, silviculture, stand structure

1. Introduction

Valonia oak (Quercus ithaburensis ssp. macrolepis) is an Eastern Mediterranean species mostly found in Turkey, Greece, Albania, and South-East Italy, (Tutin *et al*. 1993; Dufour-Dror and Ertas 2004; Pantera *et al*. 2008). In Greece, valonia oak appears inside small thickets, within forest formations, inside lowland and semi-mountainous agricultural fields or as individual isolated trees as remnants of previous forests (Pantera 2001; Pantera and Papanastasis 2003). Its presence, in most Mediterranean areas, is the result of its natural distribution. However, its import in certain areas cannot be excluded taking into account that in the past it was widely cultivated for the production of acorn cups for the extraction of tanning substances used for leather and tanning industry.

In the past few decades valonia oak forests have been abandoned due to the depreciation of the acorn cups rending them exposed, due to their position in the lowland zone, to intense human pressure and influences (overgrazing, illegal lumbering, land reclamation, forest fires). It can be considered as a suitable species for use in reforesting degraded xerothermic areas of the lowland and semi-mountainous zone, capable to contribute to the ecological balance of non suitable environments for other broad-leaved species (Pantera 2001; Pantera *et al*. 2008). Nowadays, as their sole use is for grazing, they are considered as silvopastoral systems (Papanastasis *et al*. 2009), maintaining, however, their ecological and productive values (Pantera *et al*. 2015).

These systems have not been adequately studied from a silviculture point of view, as they are not managed almost throughout the country. It is the purpose of this work to analyze the stand structure of the remaining valonia oak forests as a useful tool to investigate their evolution and previous management but also for their future management. The study of valonia oak silvopastoral systems structure in Greece represents an important element to support the efforts undetaken within the framework of the EU project AGFORWARD for their exploitation by agroforestry practices.

2 Materials and Methods

The study areas were all over the Greece: Rethymno (Crete) Lesvos island, Alexandroupolis, Sparta, Patra (Strofilia), Almyros, Kea island, Galaxidi, Mesologi (Pentalofos), Xeromero (Prodromos), Amfilochia (Sardinia), Preveza and Egoumenitsa (Fig. 1). In these areas were established sample plots, size 0.2 ha (40X50 m) representatives of the valonia oak forests. From each sample plot, stand characteristics (ground cover at each layer number and the past and present management) was estimated, and the following tree variables were measured and calculated: diameter at breast height (Dbh), total tree height (H), height at crown base (HCB), crown length (CL), basal area (g), slenderness index (H/D), crown ratio (=CL/H, CR), dominant height (H_{dom}), crown competition factor (CCF), stand density (N/Ha), tree classification according to IUFRO classification system (height classes,

vitality, development trend, stem quality), diameter and height distribution and height – diameter relationship.

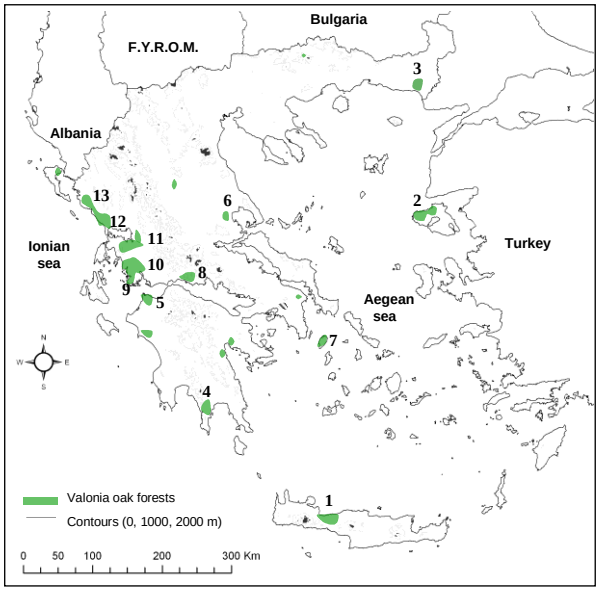


Figure 1. Distribution of valonia oak forests in Greece (adapted by Pantera *et al*. 2008). Numbers indicate the locations of the thirteen selected forests (1. Rethymno (Crete), 2. Lesvos island, 3. Alexandroupolis, 4. Sparta, 5. Patra (Strofilia), 6. Almyros, 7. Kea island, 8. Galaxidi, 9. Mesologi (Pentalofos), 10. Xeromero (Prodromos), 11. Amfilochia (Sardinia), 12. Preveza and 13. Egoumenitsa.

In order to determine the relationship between crown width (diameter) and Dbh, open-grown trees were measured (additional measures were concern four crown radii). The resulted equation was used to estimate the Crown Competition Factor (CCF), which is another measure of stand density on a predetermined relationship and is appropriate for both even-aged and all-aged stands (Clutter at al. 1983).

3. Results and Discussion

Valonia oak forests exhibit a three-level structure consisting of a tree layer (overstorey) with ground cover ranging from 30 to 80%, the shrub layer with groundcover 5-75% and the grasses layer with soil cover of 30-80% (Table 1). In the tree layer, the number of trees ranges from 20 to 500 per ha for all the studied forests, while for mature stands (mean diameter at breast height greater than 28 cm) the number of trees ranged from 20 to 180. This stand structure is the result of past land uses in each region focused mostly for acorn production, which required open structure stands (open forests), and for grazing. Undoubtedly, during the last five decades, acorn collection has almost been abandoned and, along with it, the management of these forests. The only management practiced in the valonia oak woodlands is grazing by livestock, mainly sheep and goats (Pantera *et al*. 2008). Grazing in some areas, and mainly in W. Greece, is intense, while illegal logging is a commonn phenomenon in many other areas. Flora of the *Q. ithaburensis* subsp. *macrolepis* forest understorey (synanthropic and phryganic species) confirms the past uses of the forests, mainly overgrazing but also the abandonment and encroachment. Generally the understorey differentiates according to the vegetation zone and consists mainly of: 1. Grasslands and shrubby vegetation in the supramediterranean layer (Alexandroupolis, Lesvos, Almyros, Patra, Mesologi, Xeromero, Amfilochia, Preceza, Egoumenitsa); 2. Phryganic and shrubby vegetation in the mesomediterranean and thermomediterranean layer (Rethymno, Sparta, Kea island, Galaxidi) (Pantera *et al*. 2008).

Table 1. Stand characteristics and past and present management of the studied valonia oak forests

Nb	Area	Trees/ ha	Ground cover %			Past uses	Present uses
			Tr	Sh	He		
1	Rethymno	235	46	9	79	Acorn harvesting, cultivation in terraces	Abandoned fields, grazing
2	Lesvos	180	61	11	67	Acorn harvesting, cultivation in terraces	Abandoned fields, grazing
3	Alex/polis	340	49	61	57	Acorn collection, overgrazing	Grazing
4	Sparta	500	62	12	24	Acorn harvesting, firewood collection, grazing	Grazing
5	Patra	180	75	20	60	Overgrazing	Protection, grazing
6	Almyros	120	67	10	80	Grazing	Protection, forest recreation
7	Kea island	160	65	5	74	Acorn harvesting, cultivation in terraces	Abandoned fields, grazing
8	Galaxidi	25	30	75	65	Overgrazing	Grazing
9	Mesologi	35	77	9	67	Acorn harvesting, firewood collection, overgrazing	Overgrazing
10	Xeromero	40	80	8	69	Acorn harvesting, firewood, collection, overgrazing	Overgrazing
11	Amfilochia	20	51	16	58	Acorn harvesting, firewood, collection, overgrazing	Overgrazing
12	Preveza	20	70	30	10	Acorn harvesting, grazing, firewood collection	Grazing
13	Egoumenitsa	30	55	30	58	Acorn harvesting, grazing, firewood collection	Grazing

The relationship between crown width (CW) and diameter (Dbh) is assumed to be the form:

$$CW = a + b*Dbh \quad (1)$$

Observations from 300 open-grown trees were used to determine (a) and (b).

The relationship between crown width (CW) and diameter (Dbh) is assumed to be the form:

$$CW = a + b*Dbh \quad (1)$$

Observations from 300 open-grown trees were used to determine (a) and (b). So, the equation (1) takes the form:

$$CW = 1{,}2887 + 0{,}1679 * Dbh \quad (2) \text{ (Fig. 2)}$$

The crown area (CA) is given by

$$CA = \frac{\pi}{4} * (CW)^2 \quad (3),$$

or $CA = \frac{\pi}{4} * (a + b * Dbh)^2$ (4)

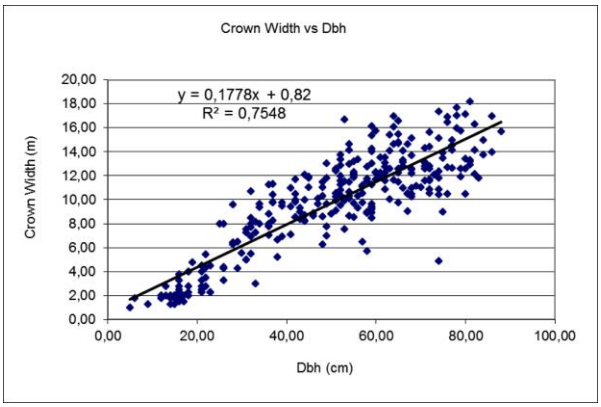


Figure 2. Regression line crown width vs tree diameter from 300 open – grown valonia oak trees.

The maximum crown area (MCA), that is, the crown area for an open-grown tree of diameter Dbh, expressed as a percentage of a hectare, is given by:

$$MCA = \frac{CA}{10000} * 100 \quad (5)$$

or

$$MCA = 0{,}00785 * (a + b * Dbh)^2 \quad (6)$$

An MCA value is then calculated for each tree in a stand, and the sum of all these values, on a hectare basis, is the CCF. The CCF values of the study areas range from 8.3 (Galaxidi) to 79.2 (Alexandoupolis).

The height – diameter curve is:

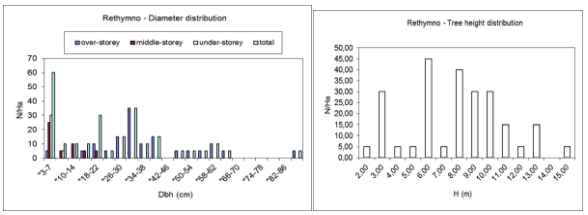
$$H = 2{,}0189 + 0{,}2067 * Dbh - 0{,}0008 * Dbh^2 \quad (7)$$

The plots of Galaxidi, Mesologi, Xeromero, Amfilochia, Egoumenitsa, and Preveza had inadequate data for analysis. The values of stand characteristics (variables) are given in the Table 2 and the diameter distributions are shown in figures 1, 2, 3, 4, 5, and 6.

Table 2. Stand characteristics of the studied plots (H= dominant tree height Dbh= mean diameter at breast height, H= mean tree height, G= basal area, H/D= slenderness index, CR= crown ratio, CCF= crown competition factor.

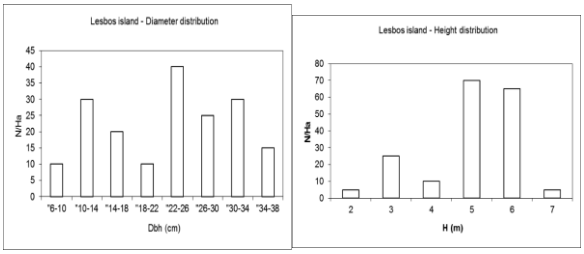
Nb	Area	H_{dom}	Dbh (cm)	H (m)	G (m^2/Ha)	H/D	CR (%)	CCF (%)
1	Rethymno	10,43	25,98	7,66	19,2001	46,1	86	77,9
2	Lesvos	5,70	23,22	4,96	8,5841	23,2	72	40,7
3	Alexandroupolis	6,64	20,20	4,03	18,2671	24,3	62	79,2
4	Sparta	8,25	17,87	6,05	14,4458	36,9	65	77,6
5	Patra	9,60	29,15	8,11	13,6849	33,6	80	58,7
6	Almyros	10,00	39,00	8,67	20,3294	28,4	79	74,5
7	Kea island	6,90	28,69	5,89	11,9385	21,8	64	51,3
8	Galaxidi		30,80	6,70	1,9085	22,0	71	8,3
9	Mesologi		62,57	10,36	11,7429	17,0	76	41,0
10	Xeromero		61,75	12,69	12,7985	21,0	79	45,0
11	Amfilochia		57,50	10,88	5,3398	19,1	78	19,2
12	Egoumenitsa		70,75	9,63	8,0497	13,9	81	27,8
13	Preveza		38,17	9,67	3,5079	25,8	75	14,2

Rethymno (Crete): The stand is three-storied irregular uneven-aged and relatively open (CCF 78), and tree density is 235/Ha (Figures 3 & 4). Tree diameter ranges from 3 to 89 cm and tree height between 2 and 15m. The under-storey individuals (Dbh < 10cm) represent the natural regeneration of the stand. The values of slenderness index and crown ratio suggest that the canopy closure is relatively open.



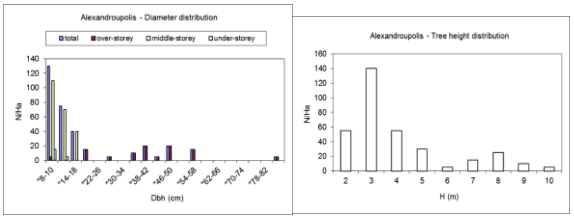
Figures 3 and 4. Diameter and tree height distributionin Rethymno (Crete).

Lesvos island: The stand is one-storied irregular uneven-aged and widely open (CCF 40.7). This is also confirmed by the low value of H/D (23.2) together with the high value of CR (72) (Figures 5 & 6). In addition, the low value of H/D and the high value of CR suggest that trees are in a wide growing space, like "open-grown" ones. Tree diameter ranges from 6 to 38 cm and tree height between 2 and 7m.



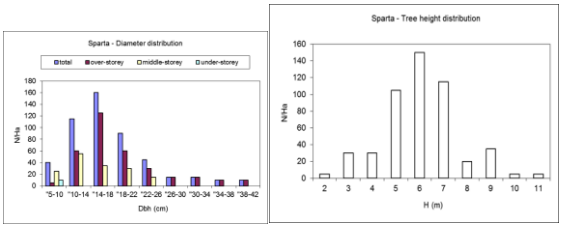
Figures 5 and 6. Diameter and tree height distribution in Lesbos island.

Alexandroupolis: The stand is three-storied uneven-aged. Tree diameter ranges from 8 to 85 cm and tree height between 2 and 10m (Figures 7 & 8). The majority of tree diameter (72%) and tree height (73.5%) ranges between 8 and 18cm and 2 and 4m correspondingly and this indicates a young stand. The values of slenderness index and crown ratio suggest that the canopy closure is relatively open.



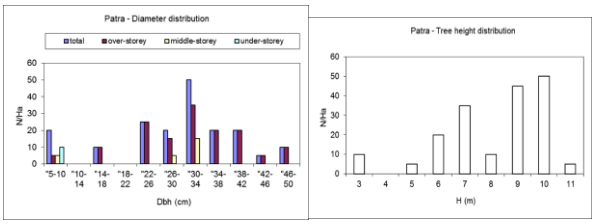
Figures 7 and 8. Diameter and tree height distribution in Alexandroupolis.

Sparta: It is a young three–storied even-aged stand. Mean diameter is 17.87cm (range 5 – 42cm) and mean height is 6.05m (Figures 9 & 10). The stand density, expressed as 500 stems / Ha, is the highest from all study areas.



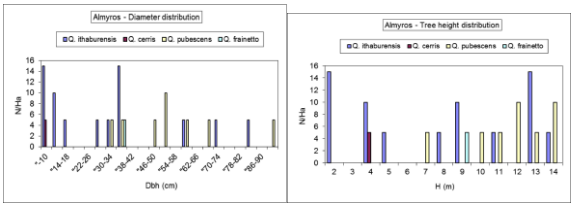
Figures 9 and 10. Diameter and tree height distribution in Sparta.

Patra: The stand is three-storied irregular even-aged. It's a wide open stand (CCF 58.7), with 180 trees / Ha (Figures 11 & 12). The mean diameter and mean tree height are 29.15cm and 8.67m correspondingly. The diameter ranges 5 to 50cm and height from 3 to 11m. Trees have adequate growing space like "open-grown" ones (H/D 33.6, CR 0.80).



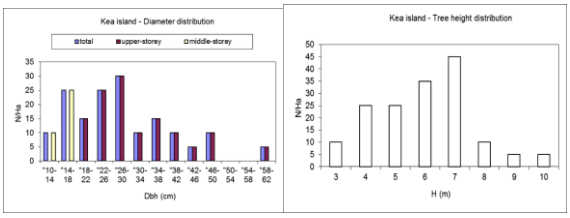
Figures 11 and 12. Diameter and tree height distribution in Patra.

Almyros: It's a mixed stand *Q. ithaburensis – Q. pubescens* with few trees of *Q. frainetto* and *Q. cerris*. The stand structure is irregular uneven-aged. Tree diameter ranges from 3 to 92cm and height from 2 to 14m (Figures 13 & 14). The stand density is low (120 trees / Ha) as well as the slenderness index (28.4).



Figures 13 and 14. Diameter and tree height distribution in Almyros.

Kea island: The stand is two-storied irregular even-aged with low density (160 trees / Ha) (Figures 15 & 16). The values of diameter ranges between 10 and 62cm and the values of height are from 3 to 10m. The slenderness index is quite low and means that trees grow free of competition from neighboring trees.



Figures 15 and 16. Diameter and tree height distribution in Kea island.

The stand structure of valonia oak forest in Greece resembles with the structure of montado in Portugal and dehesa in Spain witch are open agroforestry systems with or less 80 oak tree per ha (mainly cork oak in montado and holm oak in dehesas) and with 5-65% tree cover (Moreno and Pulido 2009; Moreno *et al.* 2016).

Conclusions

The low values of CCF, H/D, stems/Ha, and basal area, as well as the high values of CR indicate that the stands are widely open and the individuals are closed to "open-grown trees". The stand structure in most areas ranges from irregular even-aged to irregular uneven-aged except the area of Alexandroupolis where the structure tends to uneven-aged and the areas of Patra and Sparta tends to even-aged. This is an indication or a confirmation that these degraded and residual forests are suffered from heavy anthropogenic impact that is irregular and extreme cuttings, heavy grazing or/and catastrophic wildfires.

Acknowledgments

This research is part of the AGFORWARD project (Grant Agreement N° 613520) is co-funded by the European Commission, Directorate General for Research & Innovation, within the 7th Framework Programme of RTD, Theme 2 - Biotechnologies, Agriculture & Food. The views and opinions expressed in this report are purely those of the writers and may not in any circumstances be regarded as stating an official position of the European Commission.

References

Clutter J, Forston J, Pienaar L, Brister G, Baily R (1983) Timber Management: A Quantitative Approach. John Wiley & Sons, Inc. ISBN 0-471-02961-0.

Dufour-Dror JM, Ertas A (2004) Bioclimatic perspectives in the distribution of *Quercus ithaburensis* Decne. subspecies in Turkey and in the Levant Journal of Biogeography Volume 31, Issue 3: 461–474

Moreno G, Pulido F (2009) The functioning, management and persistence of dehesas. In: Rigueiro-Rodríguez A, McAdam J, Mosquera-Losada MR (eds) Agroforestry in Europe: current status and future prospects. Springer, Dordrecht, pp 127–160

Moreno G, Aviron S, Berg S, Burgess PJ, Cáceres Y, Crous-Duran J, Faias SP, Firmino PN, Fotiadis G, Franca A, Garcia de Jalon S, Hartel T, Lind T, López Bernal A, Mantzanas K,

Mirck J, Palma J, Pantera A, Paulo JA, Papadopoulos A, Papanastasis V, Papaspyropoulos K, Popa R, Porqueddu C, Rákosy L, Re GA, Sanna F, Thenail C, Tsonkova P, Valinger E, Varga A, Viaud V, Vityi A (2016) Agroforestry of High Nature and Cultural Value: Synthesis of System Descriptions. Deliverable 2.4 (2.1) for EU FP7 Research Project: AGFORWARD 613520, pp 23, http://www.agforward.eu/index.php/en/describing-high-natural-and-cultural-value-agroforestry-systems-a-summary.html

Pantera A (2001) Establishment of *Quercus ithaburensis* Decaisne ssp. *macrolepis* (Kotschy) Hedge & Yaltirik) in competence with understory vegetation in sylvopastoral systems. Ph.D. Dissertation. Thessaloniki: Aristotle University of Thessaloniki. 143 p. (In Greek, with English summary).

Pantera A, Papanastasis VP (2003) Inventory of valonia oak (*Quercus ithaburensis* Decaisne subsp. *Macrolepis* (Kotschy) Hedge & Yalt.) in Greece. Geotechnical Scientific Subjects, 14(1):34-44 (In Greek, with English summary)

Pantera A., Papadopoulos AM, Fotiadis G, Papanastasis VP (2008) Distribution and ptytogeographical analysis of Quercus ithaburensis ssp. macrolepis in Greece. Ecologia Mediterranea Vol. 34:73-81

Pantera A, Papadopoulos A, Mantzanas K, Papanastasis V, Fotiadis G, Vrachnakis M, Alifragis D, Ispikoudis I, Parissi ZM, Pantera M, Kandrelis S, Vergos S, Mosquera-Losada MR, Zianis D, Papaspyropoulos KG (2015). The contribution of valonia oak silcopastoral systems in Western Greece to local development and the environment. In: Lekkas TD (eds), Proceedings of the 14th International Conference on Environmental Sciences and Technology, Rhodes, Greece, 3-5 September 2015, electronic edition, CEST-2015_00100

Papanastasis VP, Mantzanas K, Dini-Papanastasi O, Ispikoudis I (2009) Traditional agroforestry systems and their evolution in Greece. In: Rigueiro-Rodríguez, A., McAdam, J., Mosquera-Losado, M. (eds.), Agroforestry in Europe, Springer Netherlands, pp. 89-109

Tutin TG, Burges NA, Chater AO, Edmondson JR, Heywood VH, Moore DM, Valentine DH, Walters SM, Webb DA (1993) Flora Europaea, 2nd ed Vol 1, Cambridge University Press, Cambridge, p 581