Agroforest Syst (2018) 92:921–931
https://doi.org/10.1007/s10457-018-0220-z

Valonia oak agroforestry systems in Greece: an overview

Anastasia Pantera · Andreas Papadopoulos · Vasilios P. Papanastasis

Received: 30 March 2017 / Accepted: 13 March 2018 / Published online: 16 March 2018

Abstract Valonia oak agroforestry systems of Greece are Mediterranean systems of high natural and cultural value with distinct economic, environmental, social and historical characteristics. These systems can be silvopastoral or agrosilvopastoral, and have been used since ancient times for grazing, and acorn and wood harvesting. Acorn cup collection for use in tanning, which has been undertaken since at least the fifteenth century, was an important economic activity from the nineteenth to the mid-twentieth century contributing to the local economy and development. This overview describes the historical importance of valonia oak in Greece, and the present extent, structure, ecology, products and services of valonia oak agroforestry. The sustainability of such systems is being promoted through the sale of traditional and new products, eco- and agri-tourism, and engagement with local stakeholders.

Keywords Agroforestry · Ecosystem services · Products · *Quercus ithaburensis* subsp. *macrolepis* · Structure

A. Pantera (✉) · A. Papadopoulos
Department of Forestry and Natural Environment Management, Technological Education Institute (T.E.I.) of Stereas Elladas, 36100 Karpenissi, Greece
e-mail: pantera@teiste.gr

V. P. Papanastasis
Department of Forestry and Natural Environment, Aristotle University of Thessaloniki, Thessaloniki, Greece

Introduction

Valonia oak (*Quercus ithaburensis* subsp. *macrolepis* (Kotschy) Hedge and Yaltirik) is an eastern Mediterranean endemic deciduous tree species, grown naturally in western and southern Anatolia (Turkey), Greece, southern Albania, and very locally in southeast Italy (Tutin et al. 1993; Strid and Tan 1997; Dufour-Dror and Ertas 2004; Pantera et al. 2008). Within its distribution range, this species is present in the form of open forests or individual trees that remain from older Mediterranean forests (Quezel and Barbero 1985). In certain Mediterranean regions, the presence of the species may not be spontaneous but artificially introduced for agricultural purposes (Turland et al. 1993; Dufour-Dror and Ertas 2002). The valonia oak woodlands are considered to be a natural habitat type of community interest and they have been included in Annex I of the European Union Habitats Directive (92/43/CEE), NATURA 2000 network.

The systems formed by this species in Greece are considered as agroforestry systems with high natural and cultural value (den Herder et al. 2017; Moreno et al. 2017). They are traditional agroforestry systems (Papanastasis et al. 2009) similar to the well known multipurpose open Spanish dehesas, and Portuguese montado systems, which are characterized by combinations of agricultural, pastoral, and forestry uses (Moreno et al. 2017; Simões et al. 2015). Valonia oak systems differ from other oak wood pastures in Greece

(Tsitsoni 2003; Dimopoulos and Bergmeier 2004) because of the specific tree species, the prevailing sparse structure, and the intense anthropogenic influence, especially regarding the past use and management of the trees for acorn production. Residents living near valonia oak woodlands had previously developed a long-standing economic, social, and cultural relationship with this tree. However, the abandonment of traditional activities after the 1970s, particularly oak harvesting for tanning since acorn cups extracts were replaced by much cheaper chemical substitutes, has led to the economic depreciation of oak trees and to the reduced appreciation of the value of these systems by the local inhabitants (Pantera et al. 2013, 2014). Given the ecological, environmental and obvious economic value of these systems, an effort has been undertaken in the past few years, by some local organizations and individuals, to re-use and re-evaluate these systems within the context of organic agriculture and animal husbandry, and also for historical and environmental protection reasons.

The purpose of this paper is to review the available data for valonia oak systems in Greece and describe the experiences and practices of the past in order to inform the conservation and management of these systems and for the restoration of traditional uses for economic and ecological purposes. The paper includes a description of the history and past uses of valonia oak in Greece, the distribution and dynamics of today's systems as they were shaped by human influences and environmental changes, the ecology and structure of the systems, and their products and ecosystem services. Finally, the challenges and opportunities for valonia oak agroforestry in Greece are highlighted.

History of valonia oak in Greece

Oaks are frequently reported in ancient Greek history and mythology. Valonia oak, specifically, is mentioned by Theophrastus in his work "Enquiry into plants'' as "imeris" meaning cultivated and it was, like all the other oaks, a holy tree dedicated to Zeus. Historical testimonies indicate that valonia oak woodlands were used in antiquity and subsequent times for animal grazing, for collecting acorns to feed domestic animals (even humans in difficult times) as well as for tanning and dyeing, and for providing shelter to people while they were housing divine creatures and exerting a religious influence to local inhabitants (Diapoulis 1939; Grispos 1973; Pantera 2001; Giannakopoulou 2002). In Odyssey, reference is made to the acorns that were fed to the numerous flocks of Odysseus, the king of Ithaca, grazing in the valonia oak forests of western Greece. On the other hand, Theophrastus refers to the gallows of valonia oak as the only ones among all oaks to be used in tanning. He also mentions the sweet taste of its acorns and ranks them second after *Quercus pubescens*, while Herodotus refers to the acorns of valonia oak as part of the Arcadians' diet.

Giannakopoulou (2002) has reported the organised production and marketing of acorn cups for tanning in Greece from the fifteenth and sixteenth centuries and the industry continued into the following centuries. The interest in the production and exploitation of acorn cups increased in the nineteenth and early twentieth centuries with the development of the traditional tanning and tannin extraction industry (Grispos 1936, Christodoulopoulos 1937, Giannakopoulou 2002). Furthermore, in the nineteenth century, there was a demand for export of acorns, besides the cups, as fodder for pigs mainly to Italy and Malta (Giannakopoulou 2002). Acorn collection was greatly appreciated by farmers as this practice generated additional revenue besides their agricultural and livestock production income. Acorn cup production was impressive; based on 1930s data, the average annual yield of acorn cups reached 14,000 t (Diapoulis 1939). This harvest was directed to the Greek oak extraction industry or exported as raw material to European markets (Grispos 1936). Exports were also made as processed material in the form of powder, liquid or extract. In some years, national production was not sufficient to cover the local industry needs, so acorn cups were imported from Turkey where the annual production reached 45,000 t in productive years, with a peak of 70,000 t (Diapoulis 1939). Acorn cups harvesting represented an important asset for the local economy, in general, so local stakeholders placed a high value to the trees as an economic source (Christodoulopoulos 1937; Diapoulis 1939). Quite often, the locations with valonia oak trees were recorded in cadastres not only by their area but also by the number of trees included, indicating the importance of the individual trees. As a consequence, local people protected and managed the trees for their own economic benefit.

Valonia oak wood was widely used for production of charcoal and of timber for the production of staves for barrels and other technical uses (Giannakopoulou 2002). In the fifteenth to the eighteenth centuries, particularly, oak wood had exceptional value and demand for shipbuilding. A special forest management plan was prepared for the valonia oak forests of western Greece during the eighteenth century, which was implemented by the French in order to produce shipping wood. It focused on old oak trees since the needs were for curved timber to be used for the construction of large warships in the shipyards of Toulon. Its timber, besides its convexity, was considered of high strength and suitable for the construction of ship keel and hulls (Grispos 1973; Giannakopoulou 2002). Another important product from the valonia oak forests, highly demanded by the market in the past, was oak galls. They were produced when pest insects of the family *Cynipidae* laid their eggs on the trunk and the leaves of the tree causing wounds full of pigments at the infection spots. These galls, along with the eggs produced colors, as they were rich in tannins, which were used in the pharmaceutical, dyeing and leather industry (Grispos 1973; Giannakopoulou 2002).

The high value of valonia oak woodlands has been recognized since the founding of the Greek state. Indeed, the first forest management plan in Greece was drafted in 1901–1902 for the stately-owned valonia oak forest of Xeromero, western Greece (Grispos 1973). Afterwards, in the 1930 s, pioneer conservation decrees for valonia oak were issued, with which the state requested strict conservation measures for the conservation of valonia oak trees by prohibiting, with few exceptions, the logging, felling and pruning of the trees, as well as the regulation of grazing only on locations where this was necessary (Diapoulis 1939). At the beginning of the twentieth century, the presence of significant valonia oak forests was associated with the prosperity of these areas. An example is the establishment of a valonia acorn cups distillery plant in Mytilini, Lesvos, with a processing capacity of 7000 t of oak-cups per year that boosted local industry and, subsequently, employment (Diapoulis 1939). In the same period, the port of Astakos in Aitoloakarnania, western Greece, was developed into one of the most important export sites, thanks to the high acorn cup production in the neighbouring area of Xeromero, destined for Italy and other European countries.

Present extent of valonia oak systems

In Greece, valonia oak systems are found in most parts of the country (Fig. 1) and cover an area of 29,632 ha (Pantera et al. 2008) excluding small plots with individual trees. The greatest areas of valonia oak systems can be found in the prefectures of Aitolakarnania, Rethymno (Crete), Lesvos Island, Lakonia and Cyclades island-Aegean sea (Pantera et al. 2008). As far as land use is concerned, 81% of the occupied area is classified as forest land that includes forests, partly forested land and oak rangelands; and 19% as farmland or abandoned arable fields containing oak trees and forested parts (fences and wooded islets) inside agricultural plots (Pantera 2001; Pantera and Papanastasis 2003). Valonia oak woodlands on public land are considered as silvopastoral systems (Fig. 2) rather than productive forests because of their open structure and the combined use for wood and livestock production (Papanastasis 2015). Similarly, those on agricultural land can be described as agrosilvopastoral systems (Fig. 3), since they combine agricultural and wood production with grazing by domestic animals. These latter systems have emerged from over thinning of natural forests and/or, especially in the Aegean islands, from plantations to produce acorns for tanning. In terms of ownership, 75% of the occupied area is public and/or communal and 25% private or claimed as private by individuals (Pantera and Papanastasis 2003).

The present extent of valonia oak agroforestry reflects the consecutive influences exerted by humans according to the location and the historical evolution of the site (Pantera et al. 2008). On mountainous and semi-mountainous areas, forested allotments of the species have been preserved despite the human pressure, and function as silvopastoral systems. On lowlands, in contrast, under the demand for arable land, valonia oak forests have often been reduced to individual trees within farms, and function as agrosilvopastoral systems. A characteristic case showing the dynamics of the valonia oak systems in recent decades is the region of Xeromero (Aitolakarnania prefecture, western Greece). The comparison of the land-cover between 1945 and 2008 shows that the area of valonia oak forests and pastures declined by 6.5 and 2.6% respectively, while the area of agricultural land and shrubland increased by 5.8 and 3.2% respectively (Kaloudis et al. 2017). According to the forest

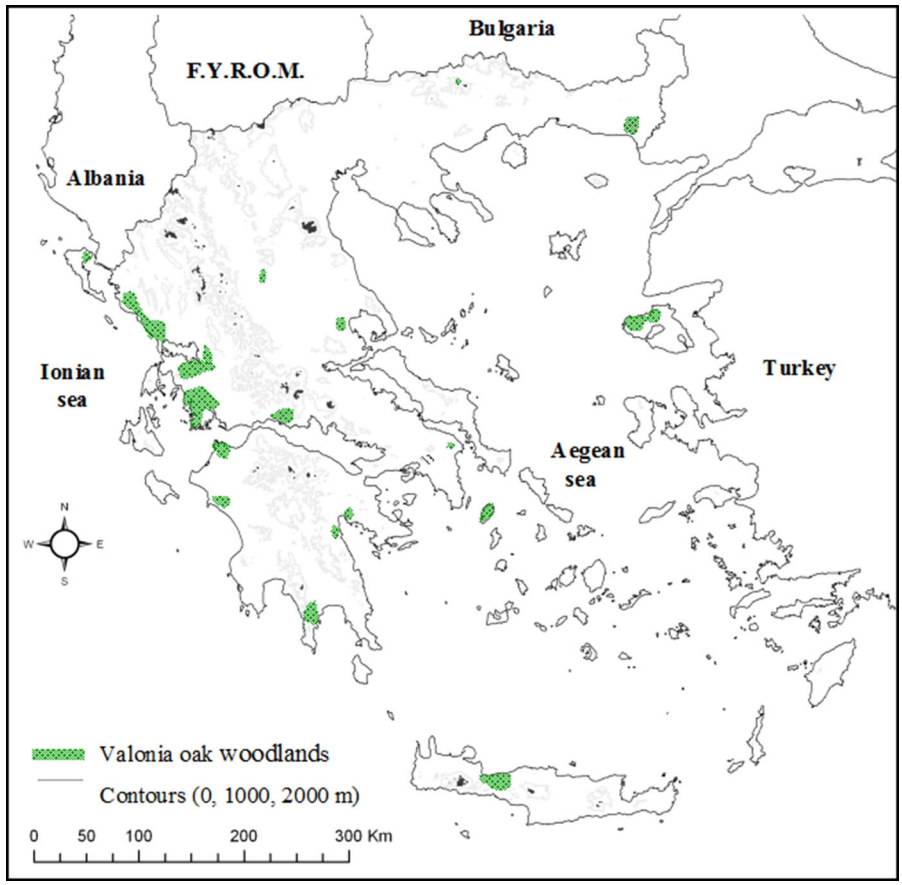

Fig. 1 Location of valonia oak systems in Greece. adapted from Pantera et al. 2008

Fig. 2 Valonia oak silvopastoral system in western Greece

management plan of this region (Hellenic Agricultural Ministry 2005), in the mountainous and hilly areas, there has been a conversion of fully-forested to partially-forested land due to uncontrolled logging and overgrazing, while tree cover increased on abandoned agricultural fields. At the same time, the

Fig. 3 Valonia oak agrosilvopastoral system in Kea island—Aegean sea

area of agricultural land expanded in the plains and around the settlements at the expense of valonia oak forests and other cleared wooded land. These changes are attributed to the human intervention related to land cultivation and livestock grazing (Kaloudis et al. 2017).

Ecology and structure of valonia oak systems

Most valonia oak systems in Greece can be found in plain, hilly and semi-mountainous sites up to an altitude of 600 to 700 m, on different types of bedrocks and soils with different depth, exposure and inclination, but most often are found in shallow to moderately deep limestone soils (Pantera et al. 2008). The systems develop in the thermo-mediterranean and meso-mediterranean climatic zones and occasionally in restricted areas of the supramediterranean layer, as well as in semi-arid, subhumid and humid bioclimates. However, the optimal distribution and growth of the species is in meso-mediterranean regions with a subhumid bioclimate.

The structure of valonia oak systems is similar to that of open forests and reflects their historical management (Goudelis et al. 2017). They are typically characterised by three distinct vegetation layers: trees, shrubs and herbs. The overstorey consists mainly of valonia oak trees with a density ranging from 20 to 180 mature trees ha^{-1}, with a ground cover ranging from 30 to 80%, an average diameter at breast height ranging from 29 to 71 cm and an average tree height from 5.9 to 12.7 m (Goudelis et al. 2017). The middle layer, with 5 to 75% ground cover, typically has a high abundance of Jerusalem sage (*Phlomis fruticosa* L.) and shrubs such as kermes oak (*Quercus coccifera*), mock privet (*Phillyrea latifolia* L.), and heath (*Erica* sp.) (Pantera et al. 2008). Finally, the understorey, with a ground cover ranging from 10 to 80%, is typically species rich including grasses, annual legumes and broad-leaved herbs such as pink asphodel (*Asphodelus fistulosus*) and sea onion (*Drimia maritime*) (Pantera and Papanastasis 2001; Pantera et al. 2008). Valonia oak woodlands are distinguished by the presence of therophytes and characterized by the dominance of Mediterranean elements, with sub-mediterranean elements increasing substantially at the northern limits of its distribution (Pantera et al. 2008). According to Vrahnakis et al. (2014), the floristic diversity of Greek valonia oak silvopastoral systems is determined mostly by human-imposed land use which, in some cases, is further supported by the specific abiotic environment where they grow.

Pantera and Papanastasis (2003) reported that about 88% of the valonia oak silvopastoral systems can be characterized as high forests (seedling-derived), with an open to widely open canopy. The age structure of most stands is irregular suggesting that they are

remnants of older forests which experienced intense logging, overgrazing and/or wildfires (Goudelis et al. 2017), although some stands appear to comprise only of ancient trees (Papadopopulos and Pantera 2013). The average age of trees exceeds 200 years in many stands while older individuals (e.g. over 400 years) can be found in several parts of the country (Papadopopulos and Pantera 2015). A small proportion of the valonia oak woodlands (11.8%) is composed of mixed seeded and coppices stands (Pantera and Papanastasis 2003). These mixed stands have an overstorey of seeded individuals and an understory of oak and other evergreen broadleaved coppices or mixed stands with other deciduous oak species (e.g., *Quercus pubescens*, *Q. frainetto*, *Q. cerris*, *Q. trojana*, and *Q. petraea*). The latter typically benefits from wildfire with other sprouting species such as *Quercus coccifera* and *Erica* sp., *Pistacia* sp. *Arbutus* sp. that are favoured by the canopy cover reduction of an oak forest. The natural regeneration of valonia oak has been categorised as abundant within 19.2% of its distribution area, limited in 53.7%, and non-existent in 27.1% of the area (Pantera and Papanastasis 2003).

In the case of managed valonia oak agrosilvopastoral systems, the vegetation structure is typically composed of two layers: the tree and the annual crop layer (wheat, barley, oats, vetch and other species) or spontaneous vegetation in fallow areas. Quite often, however, due to the presence of terraces or hedgerows, there is an intermediate layer of shrubs. In field terraces, which are a popular practice in the Aegean islands, valonia oak trees and shrubs are planted at the edges of the terraces to retain the soil. A three-layer structure can also appear in abandoned fields containing valonia oak trees.

Products and ecosystem services

The rich herbaceous vegetation of valonia oak understorey constitutes an important feed for livestock, mainly to sheep and secondarily to goats, as well as to cattle and to freely grazing pigs, depending on the location. Extensive grazing by sheep and goats is the main current activity carried out in most valonia oak systems for the production of meat and dairy products (Platis 2006; Pantera et al. 2015). This is typically practiced throughout the year unlike the past when, for example in western Greece, these systems were used only as winter pastures (from October to May). According to Papanastasis (2002), the combination of an overstorey of trees, shrub species, and understorey of herbaceous plants can be highly productive. For example, in the valonia oak silvopastoral systems of western Greece, the aboveground shrub biomass is typically about 2360 kg ha^{-1} (Papanastasis and Gogos 1983) while the herbaceous biomass can range, depending on the local conditions, from 500 to 3500 kg ha^{-1} (Papanastasis and Gogos 1983; Pantera 2001; Platis 2006; Pantera et al. 2017). A specific economic benefit of the valonia oak systems is the prolongation of the grazing season into summer because of the shade provided by the tree canopy to the herbaceous plants of the understorey. In addition the high plant diversity of the valonia oak systems (Pantera et al. 2008; Vrahnakis et al. 2014) can result in animal products (e.g., meat, milk, and cheese) considered to be of high quality (Papanastasis 2002).

Currently, the old use of valonia oak trees of acorn harvesting is no longer practiced. The only exception is in the island of Kea (Cyclades, Aegean Sea) where a local initiative launched the collection of acorns in 2011 for using their cups in leather tanning and the cosmetic industry, while their nuts were used to produce flour for human consumption. In 2016, collection of acorns was also initiated in the Xeromero forest (Aitolakarnania, western Greece). In the period between 2011 and 2017, 85.4 t of acorn cups and 15.9 t of acorn nuts were collected (Marcie Mayer, personal communication). Of these amounts, the majority of cups were exported and a smaller proportion used by the local traditional tanning industry, while the oak nuts were used locally in Kea island to make flour for the production of cookies and other confectionery. A valonia oak tree can start to produce acorns about 15 years after planting, and medium- and large-size trees can produce 50–100 kg or 128 of acorn cups respectively in a productive year. Acorn cups contain 20–30% hydrolysable tannins while the level in the scales (trillos) of the cups can be 30–40%; hence from 100 t of valonia oak cups, 30 t of extract is normally produced, which contains 64–66% of tannins (www.artukimya.com).

Wood production of valonia oak systems is not an important economic activity today, apart from firewood production. However, harvesting is not often practised under an authorized management plan, resulting in illegal logging and pruning of the valonia

oak trees. In general, systematic logging in valonia oak woodlands is forbidden in order to preserve trees for acorn production and to protect and conserve biodiversity due to the old age of the trees in most areas. The only legal logging is for local firewood consumption from pruned or dead material on the ground. Finally, in addition to wood and livestock outputs, valonia oak agrosilvopastoral systems can result in some annual crop production. Annual crops mainly include barley, wheat, clover, oats and vetches and are grown within rotations including fallow. Based on personal observations, the production varies, depending on the year, from 1 to 2 t ha^{-1}.

Like many traditional agroforestry systems, valonia oak systems in Greece provide numerous provisioning, regulating, supporting, and cultural ecosystem services (Jose 2009; Moreno et al. 2017). Small-scale activities, mainly in western Greece and the island of Kea, to produce high quality food and ornamental products (e.g. honey, mushrooms, local farm products and folk art) and initiatives for the production of aromatic and medicinal plants (Fotiadis et al. 2012; Pantera et al. 2015) are examples of provisioning services. The valonia oak systems, mainly in western Greece, also provide recreational activities such as ecotourism, education and leisure (Pantera et al. 2015). Concerning the regulating services, old large valonia oak trees significantly contribute to carbon storage. For example, in a valonia oak forest in western Greece, the aboveground woody biomass of valonia oak trees based on the Bayes theorem (Papadopoulos et al. 2015; Zianis et al. 2017), ranged from 16 to 164 t ha^{-1}, compared to 73 t ha^{-1} in a representative forest plot. Even when the trees are located on the edges of farm terraces in the Cyclades islands, or on the limits of or within fields, they can help to control soil erosion and reduce runoff. Regarding the supporting services and biodiversity, the valonia oak systems provide shelter to wildlife, contributing to the conservation of the ecosystem biodiversity. Valonia oak, as a drought resistant species, is suitable for afforestation in dry habitats of the Mediterranean basin countries, particularly in the context of climate change. Finally, concerning the cultural services, the semi-circular crowns, thick branches and old age of the trees are of particular aesthetic and religious value since they are part of the myths and the beliefs of the local people.

Challenges and opportunities for valonia oak agroforestry

Currently in Greece, many public valonia oak silvopastoral systems receive no management and the areas have been degraded due to overgrazing, illegal logging, forest fires and tree clearance. By contrast many of the private agrosilvopastoral systems on agricultural land have been abandoned. In some cases such as the systems of Attica prefecture, the island of Kea and other Cyclades islands, because of the high value of land, the areas have been converted to residential use. In view of the high nature and cultural value of valonia oak systems, it is argued that forest/agricultural services and land managers need to map, conserve and pro-actively manage areas of valonia oak agroforestry.

A particular problem with the resilience of the systems is the limited or total lack of natural regeneration of valonia oak. Valonia oak regeneration is negatively affected by intense grazing and is reduced by increasing temperatures and drought conditions (Plieninger et al. 2011; Papadopoulos et al. 2017). Given that livestock grazing is an essential traditional activity carried out by local farmers, it cannot and should not be banned but properly regulated. In cases where natural regeneration problems are caused by overgrazing, ways should be examined to regulate stocking rates and the grazing season, in addition to planting new seedlings but in such a density so that their open tree structure is maintained (40–100 medium-sized trees ha^{-1}).

Given that grazing is a key element in valonia oak silvopastoral systems and that pasture demand is often high, there can be benefits from improving pasture quantity and quality by establishing shade tolerant legumes. The use of commercial seed mixtures with a high number of self-reseeding legumes, such as *Trifolium subterraneum*, can enhance production (Pantera et al. 2017). This practice can be applied both to silvopastoral systems and previously-cultivated fields with oak trees that are being grazed. Such an approach would provide a means of combining tree cover with intensive animal production in the context of a decline in traditional ecological knowledge (Kizos et al. 2013).

Acorn harvesting also provides an opportunity for the protection and utilization of oak agroforestry systems. At present, acorn use in the Greek leather

industry, despite the low ecological footprint, is limited to traditional tanning and mainly concerns the production of leather covers for books and decorative and touristic items. There are economic and ecological reasons to extend the use of acorns (Pantera et al. 2015) and research is supporting the development of tanning and dyeing substances from acorn cups (Ioannidis 2002), the use of natural dyes for the furniture industry (Peker et al. 2012), and the preparation of phenolic resins as adhesives for wood particleboard (Abdalla et al. 2015).

Natural, organic tanning substances from valonia oak acorn cups are increasingly sought by the international market for eco-friendly leather production, yarn dyeing, cosmetics and pharmacology. This demand is expected to increase prices, and hence farmers' interest in acorn harvesting. The acorn cup processing factory in Salihli/Manisa, Turkey produces about 8000 tonnes per year of a distillate extracted from valonia oak acorns cups, known as "valex" (www.artukimya.com), and the international market demand for this product is reported to be higher than the supply (Faik Tuna Yagci, personal communication). Hence one of the activities within the EU-sponsored AGFORWARD research project between 2014 and 2017 was to help farmers and forestry service representatives invigorate acorn harvesting in Greece. There is also potential to explore the demand for oak galls, which could be integrated with acorn harvesting.

In addition to the cups, acorns nuts are also used in organic pig farming systems that produce high value livestock products. Furthermore in recent years, there has been an interest for the use of acorn nuts for human consumption. Acorn extracts are used in the pharmaceutical and fragrance sectors as well as in cooking due to their nutritional value. Acorn flour is gluten-free, with high levels of protein, potassium, magnesium, calcium, vitamin B6 and antioxidants, and some companies (e.g. www.oakmeal.com) are creating new innovative food products for the Greek and European markets. Agrosilvopastoral systems can also play a role in the production of organic arable crops and livestock products (e.g. cheese, meat, honey, wine, fruit, and vegetables) which can secure high prices.

Special attention should also be given to the ecological and aesthetic value of valonia oak agroforestry systems in terms of developing ecotourism alongside the historical and cultural attractions of specific Greek regions. For example, in the Xeromero silvopastoral system in Aitolakarnania, farms combining organic livestock and ecotourism could be developed. Similarly, abandoned valonia oak agrosilvopastoral systems in Kea Island should be restored to supply high value products and agrotourism-ecotourism services, taking advantage of the beaches and ancient pathways of the island.

The sustainable restoration of valonia oak agroforestry systems in Greece depends on the decisions of local stakeholders. According to Pantera (2014), local stakeholders perceive the positive attributes of valonia oak agroforestry systems for animal health and welfare, animal production, and increasing the diversity of products. Similar responses from a wider group of stakeholders have been observed for similar agroforestry systems across Europe (García de Jalón et al. 2017). However consumers and the general public can be reluctant to pay for these benefits. In a survey of some stakeholders in western Greece, Pantera et al. (2014) reported that 65% were unwilling to pay for any change in the use of an adjacent valonia oak woodland, although 10% were willing to pay a maximum of €50. Another negative issue is the aversion of young people to the traditional valonia oak uses or agricultural activities in general (Pantera et al. 2013) as they prefer to work in the secondary production or service sectors. At a European level, the wider societal benefits of agroforestry are being recognised through some of the agri-environmental measures of the Common Agricultural Policy. The challenge at national, regional and local levels is to increase the appreciation of valonia oak systems, by demonstrating their wider social, environmental, and economic benefits, and to enable the transfer of ecological knowledge about such systems from one generation of farmers to the next.

Conclusions

Valonia oak agroforestry systems of Greece are traditional wood pastures of high natural and cultural value. These systems are spread throughout Greece and they depend on management that avoids the total loss of trees and the total encroachment of forest cover. Ideally, the restoration of valonia oak agroforestry should be based on the development of profitable enterprises. Possible practices include the

harvesting of acorns, as well as the development of organic farming, particularly by using acorns to feed pigs. Agro-livestock organic products (local cheese, meat, honey, wine, fruit, and vegetables) produced in these systems can have a high added value. The cultural value of these systems is also important and there are opportunities to support management through agri-tourism and local engagement. Well-managed valonia oak systems can provide benefits for local communities, the rural economy and the environment.

Acknowledgements This research is part of the AGFORWARD project (Grant Agreement No. 613520), 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. This research has been co-funded by the Hellenic Ministry of Education, Research and Religion, General Secretariat for Research and Technology (Grant No. 71815/28-4-2016).

References

Abdalla S, Pizzi A, Bahabri F, Ganash A (2015) Analysis of valonia oak (*Quercus aegylops*) acorn tannin and wood adhesives application. BioResources 10(4):7165–7177

Christodoulopoulos A (1937) Production and use of the oak acorns. Forest Life 51–52:87–89 **(in Greek)**

den Herder M, Moreno G, Mosquera-Losada MR, Palma JHN, Sidiropoulou A, Santiago Freijanes JJ, Crous-Duran J, Paulo JA, Tomé M, Pantera A, Papanastasis VP, Mantzanas K, Pachana P, Papadopoulos A, Plieninger T, Burgess PJ (2017) Current extent and stratification of agroforestry in the European Union. Agr Ecosyst Environ 241:121–132. https://doi.org/10.1016/j.agee.2017.03.005

Diapoulis Ch (1939) *Quercus aegilops* L. (Valonia Oak). Agricult Bull E(2a):11–44 (in Greek)

Dimopoulos P, Bergmeier E (2004) Wood pastures in an ancient submediterranean oak forest (Peloponnese, Greece). Ecologia mediterranea, tome 30, fascicule 2:137–146

Dufour-Dror JM, Ertas A (2002) Cupule and acorn basic morphological differences between *Quercus ithaburensis* Decne. subsp. *ithaburensis* and *Quercus ithaburensis* subsp. *macrolepis* (Kotschy) Hedge and Yalt. Acta Bot Malacitana 27:237–242

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

Fotiadis G, Pantera A, Papadopoulos A (2012) Medicinal plants of *Quercus ithaburensis* woodland pastures in West Greece. In: Vrahnakis M, et al. (eds) Dry grassland of Europe: Grazing and Ecosystem services, proceedings of 9th European dry grassland meeting (EDGM), 19–23 May 2012, Prespa, Greece, 89–90

Giannakopoulou E (2002) Valonia oak forests (17th–19th century): economic factor and competition challenge. In: TEI of Lamia (eds) *Q. ithaburensis* ssp. *macrolepis* forests: past, present and future. Conference proceedings, Messologi, 17 May 2002, pp 67–96 (in Greek)

Goudelis G, Papadopoulos A, Pantera A, Fotiadis G, Aidinidis S, Mosquera-Losada MR (2017) Stand structure analysis of *Quercus ithaburensis* subsp. *macrolepis* silvopastoral systems in Greece. In: Lekkas DF (eds) Proceedings of the 15th international conference on environmental sciences and technology, Rhodes, Greece, 31 August–2 September 2017, CEST-2017_0829

Grispos P (1936) The acorns' extracts forest industry. Forest Life 44–45:157–160 (in Greek)

Grispos P (1973) Greek forest history. Publication 25 of the Forest Applications Service, Ministry of Nation. Econ., Agricultural Sector, Forest Division, Athens, p 385 (in Greek)

Hellenic Agricultural Ministry (2005) Protection and management study of the public forest ecosystem of Manina-Xeromero. Forestry service of Amfilochia, Prefecture of Aitoloakarnania, Conducted by the Geopliroforiki Company (in Greek)

Ioannidis A (2002) *Q. ithaburensis* ssp. *macrolepis* cups and tannery: present status and perspectives. In: TEI of Lamia (eds) *Q. ithaburensis* ssp. *macrolepis* forests: past, present and future. Conference proceedings, Messologi, 17 May 2002, pp 129–135 (in Greek)

Jose S (2009) Agroforestry for ecosystem services and environmental benefits: an overview. Agrofor Syst 76:1–10

Kaloudis S, Papadopoulos A, Pantera A, Papavasiliou Ch, Galanopoulou S (2017) Land cover in a valonia oak silvopastoral system in W. Greece—ecological and sociological implications. In: Lekkas DF (eds) Proceedings of the 15th international conference on environmental sciences and technology, Rhodes, Greece, 31 August–2 September 2017, CEST-2017_00686

Kizos Th, Plieninger T, Schaich H (2013) "Instead of 40 sheep there are 400": traditional grazing practices and landscape change in Western Lesvos. Landscape Research, Greece. https://doi.org/10.1080/01426397.2013.783905

Moreno G, Aviron S, Berg S, Crous-Duran J, Franca A, García de Jalón S, Hartel T, Mirck J, Pantera A, Palma JHN, Paulo JA, Re GA, Sanna F, Thenail C, Varga A, Viaud V, Burgess PJ (2017). Agroforestry systems of high nature and cultural value in Europe: provision of commercial goods and other ecosystem services. Agrofor Syst (2017). https://doi.org/10.1007/s10457-017-0126-1

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

Pantera A (2014) Valonia oak silvopastoral systems in Greece. Initial stakeholder meeting report for EU FP7 research project: AGFORWARD 613520, p 9. http://www.agforward.eu/index.php/en/valonia-oak-silvopastoral-systems-in-greece.html

Pantera A, Papanastasis VP (2001) Grazing effects on forage production and botanical composition in a valonia oak silvopastoral system. In: Radoglou K (eds) Proceedings of the international conference: forest research: a challenge for an integrated European approach, vol II, pp 681–687

Pantera A, Papanastasis VP (2003) Inventory of valonia oak (*Quercus ithaburensis* Decaisne subsp. *Macrolepis* (Kotschy) Hedge & Yalt.) in Greece. Geotech Sci Subj 14(1):34–44 (in Greek with English summary)

Pantera A, Papadopoulos A, Fotiadis G, Papanastasis VP (2008) Distribution and phytogeographical analysis of *Quercus ithaburensis* ssp. *macrolepis* in Greece. Ecol Mediterranea 34:73–82

Pantera A, Papadopoulos A, Pantera M, Papaspyropoulos KG (2013) Socioeconomic dimension of oak forests: Understanding local people perceptions with emphasis on children. In: Lekkas TD (eds) Proceedings of the 13th international conference on environmental science and technology Athens, Greece, 5–7 September 2013 (electronic edition), CEST-2013_638

Pantera A, Papaspyropoulos KG, Papadopoulos A, Kaloudis S, Kandrelis S (2014) Willingness to pay for ecosystem services in a valonia oak forest, In: Proceedings of the 12th international conference on protection and restoration of the environment, Skiathos island, Greece, June 29 to July 3, 2014 (electronic edition)

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 silvopastoral 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)

Pantera A, Papadopoulos A, Fotiadis G, Papaspyropoulos K (2017) The traditional agrosilvopastoral valonia oak systems in Kea island – Greece: productivity and ecosystem services. In: Lekkas DF (eds) Proceedings of the 15th international conference on environmental sciences and technology, Rhodes, Greece, 31 August–2 September 2017, CEST-2017_00927

Papadopopulos A, Pantera A (2013) Dating and tree rings analysis of valonia oak aged trees from the Xeromero forest of Aetoloakarnania Prefecture In: Hellenic Forestry Association (eds) Protection and management of Greek forests in a period of financial crisis and the challenge of natural silviculture, Proceedings of 16th Panhellenic forest conference, Thessaloniki, Greece, 6–9 October 2013, pp 311–318 (in Greek, with English summary)

Papadopopulos A, Pantera A (2015) Age estimation of *Quercus ithaburensis* ssp *macrolepis* trees in W. Greece. In: Hellenic Forestry Association (eds) The contribution of modern forestry and the protected areas to sustainable development, proceedings of 17^{ου} Panhellenic forest conference. Agrostoli-Cephalonia, Greece 4–7 October 2015, pp 480–486 (in Greek, with English summary)

Papadopoulos A, Zianis D, Pantera A, Vergos S (2015) Bayesian and classical models to estimate aboveground stand biomass in an oak silvopastoral system. 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_01255)

Papadopoulos A, Pantera A, Fotiadis G, Papaspyropoulos K, Mantzanas K, Papanastasis VP (2017) Effects of grazing and understorey clearing on regeneration of a valonia oak silvopastoral system in Western Greece. In: Lekkas DF (eds) Proceedings of the 15th international conference on environmental sciences and technology, Rhodes, Greece, 31 August–2 September 2017, CEST-2017_00924

Papanastasis VP (2002) Rangeland value of valonia oak forests. In: TEI of Lamia (eds) *Q. ithaburensis* ssp. *macrolepis* forests: past, present and future, Conference proceedings. Messologi, 17 May 2002, pp 49–54 (in Greek)

Papanastasis VP (2015) Agroforestry. Ziti (eds), Thessaloniki, p 191

Papanastasis VP, Gogos AM (1983) Contribution to the distinction and evaluation of rangelands in the low west Epirus zone. Forest research IV:93–129 (in Greek with English summary)

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 Losada MR (eds) Agroforestry in Europe. Springer, Netherlands, pp 89–109

Peker H, Atilgan A, Ulusou H, Goktas O (2012) Usage opportunities of the natural dye extracted from acorn (*Quercus ithaburensis* Decaisne) in the furniture industry upper surface treatment. Int J Phys Sci 7(40):5552–5558. https://doi.org/10.5897/IJPS12.479

Platis P (2006) Valonia oak ecotope and livestock grazing in the Acarnanika mountains. In: Proceedings of 5th Panhellenic rangeland conference, Heraklion 1–3 November 2006, Hellenic Rangelands Society, pp 233–238 (in Greek, with English summary)

Plieninger T, Schaich H, Kizos Th (2011) Land-use legacies in the forest structure of silvopastoral oak woodlands in the Eastern Mediterranean. Reg Environ Chang 11:603–615. https://doi.org/10.1007/x10113-010-0192-7

Quezel P, Barbero M (1985) Carte de la végétation potentielle de la région méditerranéenne. Feuille No 1: Méditerranée Orientale, C.N.R.S. Paris, p 69

Simões MP, Belo AF, Fernandes M, Madeira M (2015) Regeneration patterns of *Quercus suber* according to montado management systems. Agrofor Syst 90:107–115. https://doi.org/10.1007/s10457-015-9818-6

Strid A, Tan K (1997, 2002) Flora Hellenica, vol 1–2. Koeltz Scientific Books, Königstein

Theophrastus, enquiry into plants, vol I: books 1–5, Translated by Hort AF, Loeb Classical Library, London, Heinemann W Ltd, Cambridge, Massachusetts, Harvard University Press, 1916 (in ancient Greek with English translation)

Tsitsoni Th (2003) Silvicultural research of oak forests in N. Greece. In: Proceedings 11th Panhellenic forestry conference: forestry policy, coppice, natural environment, Hellenic Forestry Society, pp 116–125 (in Greek, with English summary)

Turland NJ, Chilton L, Press JR (1993) The flora of the Cretan area: annotated checklist & atlas. The Natural History Museum and HMSO, London, p 439

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

Vrahnakis SM, Fotiadis G, Pantera A, Papadopoulos A, Papanastasis PV (2014) Analysis of floristic diversity of the remaining valonia oak silvopastoral dry grasslands of Greece. Agrofor Syst 88:877–893. https://doi.org/10.1007/s10457-014-9733-2

Zianis D, Pantera A, Papadopoulos A, Mosquera Losada MR (2017) Bayesian and classical biomass allometries for open grown valonia oaks (*Q. ithaburensis* subs. *macrolepis* L.) in a silvopastoral system. Agrofor Syst. https://doi.org/10.1007/s10457-016-0060-7