Agroforestry Systems, August 2018, Volume 92, Issue 4, Pages 877-891.
DOI:10.1007/s10457-017-0126-1

Agroforestry systems of high nature and cultural value in Europe: provision of commercial goods and other ecosystem services

G. Moreno[1], S. Aviron[2], S. Berg[3], J. Crous-Duran[4], A. Franca[5], S. García de Jalón[6], T. Hartel[7], J. Mirck[8], A. Pantera[9], J.H.N. Palma[4], J.A. Paulo[4], G.A. Re[5], F. Sanna[5], C. Thenail[2], A. Varga[10], V. Viaud[2], P.J. Burgess[6]

[1] Forest Research Group, University of Extremadura, Plasencia 10600, Spain. gmoreno@unex.es
[2] INRA, 65 Rue de Saint Brieuc, CS 84215, 35042 Rennes, France
[3] The European Forest institute, Joensuu, Finland
[4] Forest Research Centre, School of Agriculture, University of Lisbon, Tapada de Ajuda s/n, 1349-017, Lisbon, Portugal
[5] CNR-ISPAAM, Trav. La Crucca 3, Reg. Baldinca, Sassari 07100, Italy
[6] School of Water, Energy and Environment, Cranfield University, Cranfield, Bedfordshire, UK
[7] Sapientia Hungarian University of Transylvania, Department of Environmental Studies, Cluj Napoca, Romania
[8] Department of Soil Protection and Recultivation, Brandenburg University of Technology Cottbus – Senftenberg, Germany
[9] TEI Stereas Elladas, Dpt. of Forestry & Natural Environment, 36100, Karpenissi, Greece
[10] MTA Centre for Ecological Research, Alkotmány u. 2-4, 2163, Vácrátót, Hungary

Abstract

Land use systems that integrate woody vegetation with livestock and/or crops and are recognised for their biodiversity and cultural importance can be termed high nature and cultural value (HNCV) agroforestry. In this review, based on the literature and stakeholder knowledge, we describe the structure, components and management practices of ten contrasting HNCV agroforestry systems distributed across five European bioclimatic regions. We also compile and categorize the ecosystem services provided by these agroforestry systems, following the Common International Classification of Ecosystem Services. HNCV agroforestry in Europe generally enhances biodiversity and regulating ecosystem services relative to conventional agriculture and forestry. These systems can reduce fire risk, compared to conventional forestry, and can increase carbon sequestration, moderate the microclimate, and reduce soil erosion and nutrient leaching compared to conventional agriculture. However, some of the evidence is location specific and a better geographical coverage is needed to generalize patterns at broader scales. Although some traditional practices and products have been abandoned, many of the studied systems continue to provide multiple woody and non-

woody plant products and high-quality food from livestock and game. Some of the cultural value of these systems can also be captured through tourism and local events. However there remains a continual challenge for farmers, landowners and society to fully translate the positive social and environmental impacts of HNCV agroforestry into market prices for the products and services.

Keywords: wood pastures, bocage, dehesa/montado, parklands, biodiversity, provisioning services, regulating services, cultural services

1. Introduction

Most traditional European agroforestry systems comprise livestock farming amongst varied tree species that provide products like timber, firewood, fodder and fruit, and services like shelter (Mosquera-Losada et al. 2012; Plieninger et al. 2015). Many of the systems are located in marginal areas where orography, low soil fertility and and climate are not conducive to intensive agriculture (Plieninger et al. 2015). Hence, these agroforestry systems typically receive a low quantity of external inputs and often maintain a high share of semi-natural habitats and trees and therefore high biodiversity, i.e. they are agroforestry systems of high nature value (Andersen et al. 2003). Examples of such farming systems and practices include grazed woodlands, anthropogenic savannas, wood pastures and fodder-tree systems (Paracchini et al. 2008), together with farmland rich in hedges with trees and shrubs (Oppermann et al. 2012).

Local management practices have resulted in distinctive “cultural landscapes” adapted to specific climate and geographic areas. The processes leading from “natural” environments to “cultural landscapes” make a major contribution to the world heritage of biodiversity (Hartel and Plieninger 2014). We will refer to them as High Nature and Cultural Value (HNCV) agroforestry defined here as systems that integrate woody vegetation with livestock and/or crops and which are valued for their biodiversity and their cultural heritage.

Agricultural mechanisation, increased labour costs, and regulations arising from the Common Agricultural Policy have often led to land use intensification and the tree layer has been lost from many traditional European agroforestry systems and landscapes (Eichhorn et al. 2006; Bergmeier et al. 2010; Mosquera-Losada et al. 2016). By contrast under harsher edaphoclimatic conditions, the low profitability of farming activities accompanied by the rural depopulation, has resulted in the progressive abandonment of some HNCV agroforestry systems in Europe (Plieninger and Bieling 2013; Plieninger et al. 2015).

Although systematic assessments of the profitability of HNCV agroforestry are not available (except for Iberian dehesas and montados; e.g. Borges et al. 1997, and Campos et al. 2013), it seems that sustainability of such systems depends on a greater appreciation of the societal benefits of their high nature and cultural value. Surprisingly, few HNCV agroforestry products are marketed as such despite their high quality and a willingness of consumers to pay more for high quality products with more positive ecological footprints. Indeed, better branding for these products was stressed as one important innovation to increase the resilience of these systems (Moreno et al. 2016a). Governments and society could also support the sustainability of HNCV agroforestry by placing a monetary value for public ecosystem services, either directly through extra-payment of commercial products or indirectly through policy measures and grants. These kinds of payments for ecosystem services have gained a wide interest in the last years (see Gómez-Baggethun et al. 2010 for a review). Explicit long-term strategies should be designed and specific policies implemented to promote management practices that ensure the conservation of HNCV agroforestry and reinforce their social, economic and ecological roles. A first step is the need for landowners, administrators and policy-makers to understand the functioning and the ecosystem services provided by HNCV agroforestry (MEA 2005; Torralba et al. 2016).

In this review, we compiled and summarized the knowledge regarding the components, management practices, commercial goods and ecosystem services of HNCV agroforestry systems in Europe, distributed across ten countries and five European bioclimatic regions (Mediterranean, Continental, Atlantic, Pannonian and Boreal). They include wood pastures, grazed woodlands, and meadows and farming mosaics rich in hedgerows (Table 1; Figure 1). We define three objectives: (i) to describe how HNCV agroforestry varies across Europe; (ii) to identify the potential of these systems to provide high quality products; and (iii) to quantify how HNCV agroforestry provides biodiversity and regulating services. With this, we aim to share the knowledge of these traditional systems (and detect the gap of knowledge) to increase the interest of society and policy makers in these valuable systems, and to facilitate future economic assessments of their wide societal benefits.

2. Components and vegetation structure

HNCV agroforestry systems in Europe vary in structure, components, farming activities and management practices (Table 1). The most frequent structure is a two-layered wood pasture, devoted to livestock production, combining scattered large trees with an understorey of native grasses. Trees are usually at a low density typically ranging from 4-7 trees ha^{-1} in open wood pastures, where sheep and cattle are dominant, up to about 100 trees ha^{-1} where tree-based products are more important (e.g. cork oak montados and Iberian pig fattening). In some systems, the presence of ancient trees is important. For example, 25 wood pastures of Romania contained large ancient oaks at a density of 0.0085 – 1.25 trees ha^{-1}, which is a higher density than large old trees in thick forests (Moga et al. 2016). Wood pastures are also often located within agrosilvopastoral mosaics that include arable land, open pastures, sparse ancient trees, hedgerows and forests. Crop production and trees may be integrated either at plot level (e.g. Iberian dehesa; Moreno and Pulido 2009) or at farm level with separate crop and wood plots (Hungary and Sardinia; Varga et al. 2016; Franca et al. 2012).

Grazed woodlands are also common in Europe. Good examples include the *pascoli arborati* in Sardinia, the Valonia oaks woodlands in Greece, and the dense woodlands (1000-2000 trees ha^{-1}) managed for reindeer husbandry in boreal countries. Hedges surrounding fields are a common feature in North-western Europe; example include hedgerows spaced at intervals of about 50 m in the Spreewald floodplain in Germany and at, for example, 100 m in the bocage systems of North and West France where hedgerow density ranges from 16 to 94 m ha^{-1}.

Bio-regions | **Wood pastures** | **Hedge-rich systems**

Atlantic

Wood pastures in UK

Bocage in Britany, France

Conti-nental

Ancient wood pastures in Transylvania (Romania)

Hedged meadows in Spreewald floodplain of Germany

Grazed woodlands

Medite-rranean

Iberian Dehesas and Montados (Portugal and Spain, respectively)

Grazed woodlands in Sardinia (Italy) and Greece

Boreal and Panonian

Ancient wood pastures in Hungary (Panonian)

Woodlands grazed by reindeers in Sweden (Boreal)

Figure 1. Images of the ten agroforestry systems of high nature and cultural value representative of the different European biogeographical regions. They are mostly devoted to livestock farming.

Table 1. The structure, components, farming activities, management practices, and main marketable products associated with ten types of high nature and cultural agroforestry.

Bioregion	**System and estimated area**	**Structure and components**	**Farming activities and management practices**	**Main marketable products**	**Current state and trends**
MEDITE-RRANEAN	Montado, Portugal 737,000 ha	Oak (mainly *Quercus suber* in montado and *Q. ilex* in dehesas) at < 80 trees ha^{-1} + grass understory + livestock (0.2–0.5 Livestock units (LU) ha^{-1})	Planting trees and/or natural regeneration, shrub control, periodical pruning and cropping (currently less important), and regular grazing. Debarking of cork oaks. Transhumance (now marginal)	Meat, cheese, cereal cork, firewood, charcoal hunting, fishing	Progressive farm specialization in few products. Extension stabilized, but with very low tree density in more cultivated areas, deficient tree regeneration in areas devoted to continuous grazing, and excessive tree and shrub encroachment in areas devoted to cork production and hunting
	Dehesa, Spain 2,300,000 ha				
	Agrosilvopastoral mosaics, Sardinia, Italy 806,000 ha	Oak species (7-250 trees ha^{-1}) + grass understory + occasional cereal crops + shrub understory + dairy sheep in more open stands and cattle in more dense stands (0.2-0.5 LU ha^{-1})	Forest policy in Sardinia restricts and seasonally limits grazing in the woods. Vertical short-distance transhumance	Meat and dairy product (sheep, cattle, pig and goat)	Dividing line between forests and wood pastures is unclear and estimations of the wood pasture area are still imprecise. Increase separation of farming activities with respect to the woodland management and use for grazing
	Valonian oak silvopasture, Greece 29,600 ha	*Q. ithaburensis* and other oaks (40-50% tree cover) + grasses and bushes understory + sheep, goats, pigs, cows (< 1 LU ha^{-1})	Grass can be grazed directly by livestock or cut in more productive areas to provide animal feed (silage or hay)	Meat and dairy products (sheep, goats, pigs, cows) Acorns, acorn cups, fuelwood, artefacts, Tourism, and herbs	Poor or no natural tree regeneration in Valonia oak silvopastoral systems Almost exclusive use for grazing Progressive switching of Valonia oak silvopastoral systems to olive groves or arable crops
ATLANTIC	Bocage Bretagne, France 183,000 km over 2.7 million ha	Hedges of high- and medium-stem trees (multispecific; hardwoods) surrounding fields. Hedgerow density varies between 16 and 94 m ha^{-1}	Planting hedges, with or without bank, pruning/pollarding, thinning and harvesting. Cultivation of maize, winter cereals and temporary or permanent grass	Milk, beef, pork, eggs Crops (cereal and silage maize) Firewood, mulch, timber	Farm intensification has tended to reduce the length and quality of hedgerows and hedge planting schemes during the 1990s have not compensated for the loss of hedgerows over the same period
	Lowland wood-pastures and parklands, UK 10,000-20,000 ha in working condition	Traditional land use in the UK comprising open-grown trees in grassland, often associated with large country estates.	Trees (often pollarded), grazing livestock, and an understorey of grassland or heathland	Meat and fuelwood Ad-hoc harvesting of blackberries and mushrooms	Mostly lost as farming system. Wood pastures are generally found on a small scale, often confined to designated conservation areas, and managed according to targeted management plans

Bio-Region	**System**	**Structure and components**	**Farming activities and management practices**	**Main marketable products**	**Current state and trends**
CONTI-NENTAL	Hedgerows surrounding meadows, Spreewald, Germany	Trees (including alders) and shrubs hedgerows surrounding meadows and field crops. Inter-row spacing ~50 m. Deadwood up to 50% of stand trees.	Cattle grazing (3 per ha from May to October) and mowing of grass. Traditional harvest of hedgerow biomass every 5-15 years now needing special permission and most are almost abandoned.	Meat Milk Fuelwood	Hedgerow management practices and uses almost abandoned Rejuvenation is hindered by trampling and grazing by cattle, and tree diseases. Currently deadwood forms up to 50% of stand biomass of the trees In the Spreewald Reserve
	Transylvanian wood-pastures, Romania ~7,000 ha	Oaks (*Q. robur*, *Q. petraea*), pear trees (*Pyrus communis, P. pyraster*) + natural grass. The number of large old trees is typically high in some of the wood-pastures.	Grazing with cattle, sheep and occasionally buffalo and horse ≥ 0.3 LU ha^{-1}. Grazing management is complemented with shrub removal. Scattered trees are currently valued for their shade.	Lamb and sheep (meat, milk and their products)	Overall, the abandonment of the traditional tree products from Transylvanian wood-pastures and the lack of any clear initiative to revive the value of trees for the local community suggest a narrowing and more specialized valuation and use of these systems. The economic valuation of the current wood-pasture systems is now largely based on the herbaceous layer while the trees are in sharp decline.
PANNONIAN	Wood-pastures, Hungary ~8,000 ha	Mosaic of open grassland, wood-pastures with ancient trees and forest. Sheep, cattle, buffalo, goat, horse. Mostly traditional breeds for the Carpathian-basin.	Grazing is officially prohibited in forests, but livestock use woody species as fodder.	Meat, cheese Fuelwood and wild fruits, Edible plants and mushrooms	Traditionally most of the wood pastures were owned and managed by communities. Now community management is rare, and some families and small agriculture companies are restarting abandoned wood pasture Grazing in forests is prohibited in areas officially qualified as forests, and the infilling of abandoned wood pastures difficult their future use for graze farming
BOREAL	Woodlands devoted to reindeer husbandry, Sweden 24 million ha	Conifers + birch forest: 1,500-2,000 trees ha^{-1}. Understory rich in herbs, berries and terrestrial and arboreal lichens. Grazed by migrating reindeer herds. Stocking rate < 0.01 ha^{-1}	Soil scarification, planting/ seeding, and natural regeneration , with further cleaning, thinning and clear-cut (cycles of 100-130 years)	Wood, Meat Milk	Increased specialization of forests for timber production, promoting an excessive tree density incompatible with the grazing use. Only 450,000 ha out of the 24 million ha can now be defined as wood pasture

Mediterranean HNCV agroforestry systems are dominated by oak species (the evergreen *Quercus ilex* subsp. *rotundifolia* and *Q. suber* in Iberian dehesas and montados, the deciduous *Q. ithaburensis* in Greece, and a mix of oak species *Q. ilex* subsp. *ilex*, *Q. suber* and *Q. pubescens* in Sardinian agrosilvopastoral farms). Penduncculate oak (*Q. robur*) is common in Continental, Pannonian and Atlantic systems but usually mixed with other hardwood tree species such as beech, chestnut, hornbeam, pear, ash, maple, lime, and whitebeam. These tree species together with willows, poplars and alders are also found in hedgerow systems, and the boreal silvopastures are dominated by conifer species and birches.

In dry Mediterranean regions, self-seeding annual grass species dominate the pasture, with herbaceous plants present from mid-October to mid-June. Pastures in more humid regions can be dominated by perennial species such as sedge, meadow soft grass, creeping buttercup, rabbitfoot clover, bitter dog and reed sweet-grass. Plant assemblages vary from below-tree canopy areas to open areas (Garbarino and Bergmeier 2014). If the grazing pressure in wood pasture is very low, then a shrub understory can develop. In fact partial shrub encroachment can be beneficial for tree regeneration as reported for Swiss Jura wood pastures (Smit et al. 2006), and Iberian dehesas (Rolo et al. 2013). Berries and terrestrial and arboreal lichens are important to feed livestock in boreal regions. In the bocage hedgerow system, a mix of high- and medium-stem trees and bush species, sometimes combined with the presence of banks and ditches, form multilayer hedges of different height, width and structure (Baudry and Jouin 2003). In the Spreewald in Germany, hedge trees are mixed with glossy buckthorn, common buckthorn, wild rose, blackberry, European cranberrybush and hops.

3. Farm management practices

Farm management practices include livestock grazing, fodder crops, tree planting, thinning and pruning, understory shrub removal, and harvest of cork, timber, firewood, charcoal, fruits, medicinal and aromatic plants, mushrooms, and berries (Table 1). However, the primary focus of most commercial HNCV agroforestry systems is free-range livestock production. In productive areas and years, the understory can be mown and harvested to provide winter or dry season feed i.e. silage or hay. In some Mediterranean wood pastures, fodder crops are also grown (Eichhorn et al. 2006). Livestock can also benefit from browsing the trees and shrubs directly (Mayer at al. 2003; López-Díaz et al. 2015) or pruned branches (Papanastasis et al. 2008). Pannaging (releasing domestic pigs in wooded areas) is still practised for fattening Iberian pigs in dehesas and montados, and marginal Hungarian wood pastures.

Continuous grazing, browsing and trampling can hamper tree and shrub regeneration. For instance, natural tree regeneration was poor or non-existent in more than 80% of the total area covered by Valonia oak forest in Greece (Pantera and Papanastasis 2003). For Iberian oak-based dehesas, of the *Q. ilex*, *Q. suber*, and *Q. pyrenaica* plots studied, 49%, 62%, and 20% were lacking any small seedlings, and 82%, 96%, and 56% did not have any large saplings, respectively (Plieninger et al. 2010). Similar problems are described for wood pastures in Portugal (Simões et al. 2016) and Romania (Hartel et al. 2013). Where mowing occurs and periodical fodder crops are grown, the natural regeneration of the tree layer is even more difficult (Plieninger et al. 2016).

Cattle and sheep are present in most of the systems, but goats in the Mediterranean and buffalo in Romanian wood pastures are also common. HNCV wood pastures support many traditional breeds. The stocking rates are typically low, about 0.2–0.5 livestock units (LU) ha^{-1} in Valonian Greek silvopastures, Transylvanian wood pastures and Iberian dehesas and montados. Boreal forests are grazed by migrating reindeer herds at a stocking rate of less than 0.01 LU per hectare. Short-(vertical) and medium-distance transhumance is also practised in Mediterranean French regions, in Italian Sardinia, Alpine and Apennine regions, and in Spain (Pastomed, 2007). The progressive introduction of more productive breeds and the increase of cattle, less dependent of daily herding, is also a threat for some wood pastures (Moreno et al. 2013; Hartel et al. 2013).

Most wood pasture systems were created by gradually opening native forests, removing the shrub layer and the least useful tree species. For instance, *Quercus ilex* that produces more acorns with a less bitter taste are retained in Iberian dehesas. In Hungary and Romania, wood pastures oaks and pear trees are favoured as they provide both livestock fodder and edible fruits (Hartel et al. 2013, Oellerer 2014, Varga and Molnár 2014). The selection of more useful tree species resulted in some cases in a reduction of the tree diversity of wood pastures compared to the original forests, but in other cases, wood pastures were a kind of refuge for tree species where native forests were eliminated. Mechanised shrub clearance is required in some locations to maintain the wood pasture (Molnár et al. 2016) and more recently to keep the electric fences operational in hedgerow margins. Overgrazing, periodic cropping and shrub removal by harrowing has also led to progressive soil degradation and erosion in many Mediterranean wood pastures (Schnabel and Ferreira 2004).

Tree management in the form of pruning, pollarding or shredding trees is widely practiced (Table 1) to i) feed livestock, ii) provide firewood and charcoal, iii) favour fruit production, and/or iv) minimize light competition for intercrops (Le Dû *et al*, 2008). Although these practices are often abandoned, markets for mulch, bioenergy and organic dyes are bringing new opportunities. Lateral pruning of branches (notably with the use of a tractor-mounted hedge trimmer) is being used to produce wood chips in the French bocage. In the specific case of the cork oaks in Iberian dehesas and montados and the wood pastures of Italy and Southern France, an additional practice is periodical debarking (every 9-10 years) to produce cork. Rules that restrict grazing and tree management are common in many HNCV agroforestry systems. Tree cutting and pruning is rigorously regulated in the Spreewald floodplain and Iberian dehesas, and forbidden in Greece. Also forest grazing is forbidden in Hungary and Romania (although livestock use woody species as fodder wood pastures) and seasonally limited in Sardinia.

4. Biodiversity

By definition, HNCV agroforestry systems are biodiverse. The ancient trees of British, Hungarian and Romanian wood pastures are especially rich in fungi, epiphytes, macroinvertebrates, bats and birds. In an ancient 133 ha oak wood-pasture in Romania, there were 476 species of vascular plants, 121 species of macromycetes, 281 species of Lepidoptera, 40 species of xylophagous beetles, 27 species of nesting birds and 38 species of mammals (Hartel et al. 2013). Wood-pastures in Romania contain more bird species and functional groups than comparable high forests and open pastures (Hartel et al. 2014). More recent surveys carried out by these authors in a moderately intensively grazed wood-pasture (with 1.1 Livestock Unit per ha) revealed an exceptional diversity of spider communities in such systems, with 140 species and four new species of spiders for Romania.

In Portugal, a comprehensive biodiversity survey on a 220 ha montado farm has identified 264 fungi, 75 bryophytes, 304 vascular plants and 121 vertebrate species (Santos-Reis and Correia 1999). In Spain, 135 plant species in 0.1 ha in holm oak dehesas and 60–100 species per 0.1 ha in cork oak stands have been described (Marañon 1986). The diversity of butterflies in bocage was found to be higher in hedgerow banks than other herbaceous habitats, in relationships with a high diversity of plant species (Ouin and Burel 2002). Le Feon (2010) found that the diversity of pollinators such as solitary bees increased with hedgerow density in farming landscapes, due to the high quality of nectar and nesting resources in these elements. Regarding the communities of natural enemies of crop pests, the diversity of predatory carabid beetles, ladybugs and aphid parasitoids in cereals fields was found to be positively related to the density of hedgerows and/or their proximity to crops in the surrounding landscape (Puech et al. 2015). Hedgerows are not only important because of their role of habitat, but also because they can be used as corridor for the dispersal of some species between remnant habitat fragments (e.g. for forest carabid beetles, Petit and Burel 1998).

Trees in agroforestry systems provide additional resources for many species, but also a refuge for nesting and they introduce spatial heterogeneity on the distribution of resources (tree-based gradients *sensu* Moreno et al. 2013). Although high biodiversity values found in Iberian dehesas can be partly explained by the scattered trees in pastures, the intimate mix of tree and treeless pastures and marginal habitats has also a significant role given the high β diversity or low species redundancy among habitats (Moreno et al. 2016b). In Hungary grazing and habitat mosaics are important for endemic and rare plant species such as *Paeonia officinalis* subsp. *banatica*, and *Pulsatilla pratensis* subsp. *nigricans*. In the Spreewald in Germany, rare plant species include *Caltha palustris*, *Ranunculus auricomus*, *Stellaria palustris*, *Carex vesicaria*, and *Lychnis flos-cuculi* (LUGV 2011).

Lowland wood pasture in the UK provides a habitat for priority beetles such as *Limoniscus violaceus* and *Lucanus cervus* (UK Biodiversity Group 1988), and ancient trees and grazing in Hungary provides a habitat for birds such as *Upupa epops, Coracias garrulous, Ciconia nigra,* and *Curruca nisoria* (Varga et al. unpublished). Iberian dehesas and montados are also important for the conservation of red list species such as Iberian lynx, Iberian imperial eagle, black vulture and the black stork (Diaz et al. 1997).

Because of this biodiversity, many of the European HNCV agroforestry systems are listed under the categories of natural and semi-natural grasslands formations and forests in the European Habitats Directive. Some examples are the i) oak woods with *Q. robur* and *Q. pyrenaica* frequently grazed in the Atlantic and Mediterranean region; ii) Iberian dehesas; iii) Valonia oak forests grazed in Greece, and iv) Fennoscandian wooded pastures and meadows in boreal regions. Nearly half of the Spanish dehesas, 59% of all Hungarian wood pastures, and all of the German Spreewald floodplain are protected by the European Natura 2000 network, and wood pastures are also identified as a priority habitat in the UK.

5. Ecosystem services

HNCV agroforestry and the associated species and habitat biodiversity provides a wide range of ecosystem services that can be categorized as provisioning, regulation and maintenance, and cultural services (Table 2).

Table 2. Relation of ecosystem services reported for 10 European agroforestry systems of HNCV of five different bioregions (see Table 1 for full names of countries and bioregions). Ecosystem services are grouped according to the Common International Classification of Ecosystem Services (CICES; Haines-Young and Potschin 2013). We use + to denote the cases reported by experts and stakeholders knowledge, and ++ to denote the cases scientifically documented.

Section	Division	Group	Example documented	MED				ATL		CONT		PAN	BOR
				PO	SP	IT	GR	UK	FR	GE	RO	HU	SE
Provisioning	Nutrition	Biomass	Meat, dairy products, game and fish	++	++	+	+	+	+	+	+	+	++
			Crops, fruits, berries, mushrooms, honey	+	+	+	+	+	++	+	+	+	+
		Water	Surface and ground water for drinking	+					++				
	Materials	Biomass, Fibre	Timber, cork, wood chip mulch, dyes and tannings, aromatic and medicinal plants, manure	++	++		++		+	++		+	+
		Water	Surface and ground water for other uses										
	Energy	Biomass-based energy sources	Charcoal, firewood, pellets	+	++		+	+	++	++		+	
		Mechanical energy	Physical labour provided by animals										
Regulation & Maintenance	Mediation of waste, toxics and other nuisances	Mediation by biota	Bio-remediation										
		Mediation by ecosystems	Retention of heavy metals and organic compounds										
	Mediation of flows by natural abiotic structures	Mass flows	Control of soil erosion	++	++		+		++		+		
		Liquid flows	Fostering groundwater recharge						+				
			Flood protection				+	+		+			
		Gaseous / air flows	Reduced noise and atmospheric pollution					+					
	Maintenance of physical, chemical, abiotic conditions	Lifecycle maintenance, habitat and gene pool protection	Pollination′ seed dispersal										
			Habitat for plant and animal reproduction	++	++	+	+	++	++	++	++	+	
			Reduction of wildfire risk	+	++	++	+						
		Pest and disease control	Pest and disease control										
		Soil formation and composition	Soil fertility	++	++	++	+		++				
		Water conditions	Control of nutrient leaching	+					++	+			
		Atmospheric composition and climate regulation	Carbon sequestration	+	++	+	+	+	+	++		+	+
			Improved microclimate	++	++		+	++	++		+	+	
Cultural	Physical and intellectual interactions with ecosystems and landscapes	Physical and experiential interactions	In-situ recreational activities (e.g. bird watching) and sports, included leisure hunting and fishing	+	++	+	+	++		++			+
		Intellectual and representational interactions	Scientific, educational, cultural heritage, ex situ entertainment, aesthetic	+	++			++	+	+	++	++	+
	Spiritual, symbolic and other interactions with ecosystems and landscapes	Spiritual and/or emblematic	Emblematic or symbolic places, species	+	++		+	+			++	++	
		Other cultural outputs	Willingness to preserve species, habitats, landscapes	+	++			++	+	+	++		

These three categories are explicitly indicated as final services by CICES (Haines-Young and Potschin 2013). The so-called supporting services (e.g. nutrient cycling) are excluded because they can be considered as intermediate processes that lead to the final services. If ecosystem and economic accounts are to be linked, then an essential step is to identify and describe the 'final outputs' from ecosystems that people use and value, so as to avoid the problem of 'double counting' (La Notte et al. 2017).

5.1. Provisioning services

The primary products from many HNCV agroforestry systems are livestock that graze the understorey (Table 2). There is still uncertainty about the conditions where the net effect of trees on pasture change from negative to positive (Rivest et al. 2013; Blaser et al. 2013), and changes in the seasonal distribution of the growing period of pasture understorys can be more important than the net effect on yield (Moreno et al. 2013). Although trees can reduce the pasture biomass production, the total metabolisable energy produced can increase in the presence of the trees. For example López-Díaz et al. (2015) showed that in the Iberian dehesas the metabolisable energy (pasture understorey + acorn + tree leaf browse) increased as the tree cover increased to 60-70%. Moreover, the sheltering effect of the trees could reduce the energy needed by livestock, giving an additional economic advantage. There remains a need to develop systematic and scientific comparisons of the foraging potential of wood pastures against open pastures under different edapho-climatic conditions and vegetation structures (see also Oliveira et al., this volume).

There is a range of traditional marketed products from European HNCV agroforestry. Some such as tree hay, firewood, charcoal, and fruits are no longer produced in many areas due to the high labour costs. Other traditional products are still traded, sometimes with specific labels that identify them as produced in HNCV agroforestry systems (e.g. Iberian ham, Sardinian cheeses: cheeses such as Pecorino Romano PDO, Pecorino Sardo PDO and Fiore Sardo PDO, and the cheese graviera Amphilochias in Greece). While high quality livestock-based foods (meat, cheese, milk, eggs) are common to most of the systems studied, other goods are regionally specific. For instance, cork is the main marketable product of Portuguese montado (also important in Spanish dehesas and Sardinian silvopastures), and Valonian acorn cups are used for tanning in Greece, and oak biomass as organic dyes (Pantera et al. 2008). Vinegar from wild pear or wild apple, wild fruit and berry jam (rosehips and mulberry), and fruit-based spirits are gaining popularity in Hungary. Other novel products from HNCV agroforestry, which are receiving increasing consumer interest, include mulch, honey, mushrooms, wild-edible fruit, and medicinal and aromatic plants.

Self-consumption of products by farming households is still an important part of the micro-economy associated with some HNCV agroforestry. For instance, in Iberian dehesas and French (Brittany) bocage, farm households use firewood from tree branches as a main source of heating energy, i.e. more than 10 m^3 y^{-1} (for Brittany). In the Valonia oak system in Greece, more than 40 medicinal or aromatic plants are used locally (Fotiadis et al. 2012

5.2. Regulating services

HNCV agroforestry provides a range of regulating ecosystem services including carbon sequestration, moderation of the microclimate, and control of nutrient leaching, soil erosion and wildfires (Table 2). The trees in each system enable the storage of greater amounts of above-ground carbon than the comparable agricultural system (monocultures and open grasslands). For example, the annual average growth rate in Spreewald hedgerows for the period 2000 to 2010 was 6.3-6.7 m^3 ha^{-1}. Compared with the average wood extraction of 2.9 and 3.3 m^3 ha^{-1} yr^{-1} in these regions, the trees are storing a significant amount of carbon in their biomass (MLUL 2012). Below-ground the effect of trees in pasture on carbon sequestration is mixed. Upson et al. (2016) reported that trees on grazing land may reduce carbon in the first 0-10 cm of soil, whereas topsoil organic carbon contents under old hedgerows can be up to 2.5 times higher than those in the adjacent crop field (Walter et al. 2003). The importance of HNCV agroforestry to store soil carbon has also been noted for the hedgerows of Spreewald floodplain and for different Mediterranean wood pastures (e.g. Howlett et al. 2011; Seddaiu et al. 2013; Francaviglia et al. 2014; Zianis et al. 2017).

The capacity of trees to increase water infiltration and reduce soil erosion is well documented for Iberian dehesas (Shakesby et al. 2002). Hedgerows can also increase water infiltration (Carroll et al. 2004) and can reduce soil erosion, although there is high spatial variability at the landscape scale (Lacoste et al. 2015).

Reduction of nitrate leaching from agricultural land can be important. For example the societal costs of 0-20 and 30-70 kg N ha^{-1} yr^{-1} from extensive and intensive grassland respectively have been reported to be 100 and 400 € ha^{-1} yr^{-1} (Osterburg et al. 2007; Matzdorf et al. 2010). One way to reduce nitrate leaching that has been demonstrated in French bocage is to increase the hedgerow tree density (Benhamou et al. 2013). In a similar way, Moreno et al. (2007) in Spain has shown that trees can significantly build up the soil fertility.

Another important regulating service provided by the integration of grazing with trees is the control of wild fires. This has been demonstrated in Mediterranean cases, where grazed woodlands accumulate much less fuelwood than non-grazed ones (Franca et al. 2012; Ruiz-Mirazo and Robles 2012). For Iberian dehesas, it has been showed that the risk of wildfire decreases and the production of trees and pastures increase in open wood pastures (tree cover < 50 %) respect to the original dense forests (Moreno and Cubera 2008; López-Díaz et al. 2015). By contrast, the carbon sequestration (Ruiz-Peinado et al. 2013) and the control of soil erosion (Schnabel and Ferreira 2004) are less effective in dehesas than in forests.

5.3. Cultural services

In some HNCV agroforestry systems, the primary objective is the maintenance of an aesthetic landscape of high cultural value and the associated traditional knowledge and potential for tourism and local recreation. Fagerholm et al. (2016) showed that 58% of places visited by the population of a rural area rich in dehesas in Western Spain were related to cultural services, while only 24% and 15% were related to provisioning and regulating/supporting services, respectively. In Romania, ancient wood-pastures were historically important areas for cultural gatherings (e.g. Sighisoara, Medias, Rupea and Sibiu towns) and new initiatives are reviving these gatherings (e.g. the 'Breite days'; Sighisoara, Mihai Eminescu Trust). Varga et al. (2015) and Varga and Molnár (2014) also report similar community gatherings in ancient wood pastures in Hungary (e.g. May fest and the Birds and Trees Day for school pupils).

The promotion of the HNCV agroforesty could maintain and preserve unique heritages of European culture (Molnár et al. 2016) and provide a focus for tourism and recreation. In Sardinia, 'agriturismi' events are often based in wood pasture systems combining multifunctional agriculture with hospitality for tourists. Some recreational activities such as hunting and fishing, education and leisure activities can provide a direct income. In Spain, hunting is frequently more profitable than livestock breeding for some dehesa farms (Macaulay et al. 2013), and birdwatching is an important commercial activity in the dehesa territory. In Germany the high aesthetic and cultural value of the Spreewald floodplain is important for tourism. It is estimated that around 2 million people visit the area between May and September every year. In Germany the willingness to pay to preserve biodiversity of HNCV grasslands has been estimated to be about 10€ per month and person (Matzdorf et al. 2010).

6. Final remarks

Our knowledge of HNCV agroforestry in Europe is still patchy with the Iberian dehesas and montados receiving the most comprehensive study. Many of the other studies are purely descriptive and the assessment of the provision of ecosystem services has largely been determined from experience-based knowledge from local stakeholders. More studies are needed to explore the fine-scale relationship between the structural elements of HNCV agroforestry systems, their biodiversity the provision of ecosystem services, and how these relate to management.

Despite the limited scientific information, this review shows that whilst European HNCV agroforestry systems differ in terms of structure, management, products and current socio-economic interest, they are of biodiversity and cultural importance and they generally enhance the environment through multiple positive effects on regulating services compared to conventional agriculture. Each system can provide farmers with an opportunity to produce marketable products and services. However whilst there is a rising demand for high-quality food produced in ways that enhance the environment and animal welfare, in many cases it is difficult for landowners and farmers to financially justify the high labour costs needed to maintain the systems. In this sense, while the market for meat and dairy-based products still work for most of the cases, the use and marketing of traditional tree-based products has been largely abandoned. An increased interest in wood-fuel, in some areas, provides an increased marketing opportunity. However in many cases, the greatest financial opportunities are likely to derive from a focus on the market for cultural services.

There is clear evidence that HNVC agroforestry can improve regulating services such as reducing fire risk compared to forest systems, and can increase carbon storage, moderate the microclimate, and improve groundwater quality compared to conventional agriculture. However it is difficult for farm enterprises to capture these benefits in financial terms. One approach to integrate these benefits is “green accounting” that integrates both commercial and non-commercial goods and services in a consistent manner. Such analyses can help guide policy-makers and wider society to identify where public interventions such as subsidies, the tax system, and regulation can help ensure the high nature and cultural value of these agroforestry systems.

Acknowledgement

This paper was developed as part of the AGFORWARD project (Grant Agreement N° 613520) which is co-funded by the European Commission, Directorate General for Research & Innovation, within the 7th Framework Programme of RTD, Theme 2 - Biotechnologies, Agriculture & Food.

References

Andersen E, Baldock D, Bennet H, Beaufoy G, Bignal E, Brower F, Elbersen B, Eiden G, Godeschalk F, Jones G, McCracken DI, Nieuwenhuizen W, van Eupen M, Hennekes, S, Zervas G (2003) Developing a high nature value indicator. Report for the European Environment Agency, Copenhagen

Baudry J, Jouin A (eds) (2003) De la haie aux bocages—organisation, dynamique et gestion, INRA edn. INRA, Paris

Benhamou C, Salmon-Monviola J, Durand P, Grimaldi C, Merot P (2013). Modeling the interaction between fields and a surrounding hedgerow network and its impact on water and nitrogen flows of a small watershed. Agricultural Water Management 121 : 62-72.

Bergmeier, E., Petermann, J., Schroder, E., 2010. Geobotanical survey of woodpasture habitats in Europe: diversity, threats and conservation. Biodivers. Conserv. 19, 2995-3014.

Blaser, W. J., Sitters, J., Hart, S. P., Edwards, P. J., & Olde Venterink, H. (2013). Facilitative or competitive effects of woody plants on understorey vegetation depend on N-fixation, canopy shape and rainfall. Journal of Ecology, 101(6), 1598-1603.

Borges JG, Oliveira AC, Costa MA, 1997. A quantitative approach to cork oak forest management. Forest Ecology and Management 97: 223–229.

Campos P, Huntsinger L, Oviedo JL, Starrs PF, Diaz M, Standiford RB, Montero G (Eds.) (2013). Mediterranean Oak Woodland Working Landscapes. Dehesas of Spain and Ranchlands of California. Series: Landscape Series, Vol. 16, Springer.

Carroll, Z.L., Bird, S.B., Emmett, B.A., Reynolds, B., Sinclair, F.L. (2004). Can tree shelterbelts on agricultural land reduce flood risk? Soil Use and Management 20, 357-359.

Diaz, M., Campos, P., & Pulido, F. J. (1997). The Spanish dehesas: a diversity in land-use and wildlife. Farming and birds in Europe, 178, 209.

Eichhorn MP, Paris P, Herzog F, Incoll LD, Liagre F, Mantzanas K, Mayus M, Moreno G, Papanastasis VP, Pilbeam DJ, Pisanelli A, Dupraz C (2006). Silvoarable systems in Europe - past, present and future prospects. Agroforestry Systems 67: 29-50.

Fagerholm, N., Oteros-Rozas, E., Raymond, C. M., Torralba, M., Moreno, G., & Plieninger, T. (2016). Assessing linkages between ecosystem services, land-use and well-being in an agroforestry landscape using public participation GIS. Applied Geography, 74, 30-46.

Fotiadis G., A. Pantera, A. Papadopoulos. 2012. Medicinal plants of Quercus ithaburensis woodland pastures in west Greece, 9th European Dry Grassland Meeting (EDGM) Prespa, Greece, 19-23 May 2012

Franca A, Sanna F, Nieddu S, Re GA, Pintus GV, Ventura A, Duce P, Salis M, Arca B (2012). Effects of grazing on the traits of a potential fire in a Sardinian wooded pasture, Options méditerranéennes. Série A: séminaires méditerranéens, CIHEAM, Centre international de hautes études agronomiques méditerranéennes, 102, 307—311, ISSN : 1016-121X.

Francaviglia R, Benedetti A, Doro L, Madrau S, Ledda L (2014). Influence of land use on soil quality and stratification ratios under agro-silvo-pastoral Mediterranean management systems. Agriculture, Ecosystems & Environment 183: 86-92

Garbarino, M., & Bergmeier, E. (2014). Plant and vegetation diversity in European wood-pastures. European wood-pastures in transition: a social-ecological approach. Earthscan from Routledge, Abingdon, New York, 113-131.

Gómez-Baggethun, E., De Groot, R., Lomas, P. L., & Montes, C. (2010). The history of ecosystem services in economic theory and practice: from early notions to markets and payment schemes. *Ecological economics*, *69*(6), 1209-1218.

Haines-Young, R. and M. Potschin (2013): Common International Classification of Ecosystem Services (CICES), Version 4.3. Report to the European Environment Agency (download: www.cices.eu)

Hartel T, Dorresteijn I, Klein C, Máthé O, Moga CI, Öllerer K, Roellig M, von Wehrden H, Fischer

J (2013). Wood-pastures in a traditional rural region of Eastern Europe: characteristics, management and status. Biological Conservation 166: 267–275.

Hartel T, Hanspach J, Abson D, Mathe O, Moga C, Fischer J (2014). Bird communities in traditional wood-pastures with changing management in Eastern Europe. Basic and Applied Ecology 15: 385-395.

Hartel, T., & Plieninger, T. (2014). European wood-pastures in transition: A social-ecological approach. Routledge.

Howlett DS, Moreno G, Mosquera Losada MR, Nair PKR, Nair VD (2011). Soil carbon storage as influenced by tree cover in the Dehesa cork oak silvopasture of central-western Spain. J Environ Monit. 13 : 1897-1904.

Lacoste M, Viaud V, Michot D, Walter C (2015). Landscape-scale modelling of erosion processes and soil carbon dynamics under land-use and climate change in agroecosystems. European Journal of Soil Science 66: 780-791.

La Notte A, D'Amato D, Mäkinen H, Paracchini M L, Liquete C, Egoh B, Geneletti D, Crossman N D. (2017). Ecosystem services classification: A systems ecology perspective of the cascade framework. *Ecological Indicators*, *74*, 392-402.

Le Du, L., Le Coeur, D., Thenail, C., Burel, F., Baudry, J., 2008. New hedgerows in replanting programmes: assessment of their ecological quality and their maintenance on farms. In: Berlan-Darqué, M., Terrasson, D., Luginbühl, Y. (Eds.), Landscape: From knowledge to action. Editions Quae, Versailles, pp. 177-191.

Le Feon V (2010). Insectes pollinisateurs dans les paysages agricoles : approche pluri-échelle du rôle des habitats semi-naturels, des pratiques agricoles et des cultures entomophiles. Thèse Université de Rennes 1, Rennes, France.

López-Díaz ML, Rolo V, Benítez R, Moreno G. 2015. Shrub encroachment of Iberian dehesas: implications on total forage productivity. Agroforestry Systems 89: 587-598.

LUGV (2011). Lebensräume im Wandel – Ergebnisse der ökosystemaren Umweltbeobachtung (ÖUB) im Biosphärenreservat Spreewald, Landesamt für Umwelt, Gesundheit und Verbraucherschutz, Potsdam p. 158

Macaulay, L. T., Starrs, P. F., & Carranza, J. (2013). Hunting in managed oak woodlands: contrasts among similarities. In Mediterranean Oak Woodland Working Landscapes (pp. 311-350). Springer Netherlands.

Matzdorf B, Reutter M, Hübner C. (2010). Gutachten-Vorstudie Bewertung der Ökosystemdienstleistungen von HNV-Grünland (High Nature Value Grassland). Leibniz-Zentrum für Agrarlandschaftsforschung (ZALF) e.V. Müncheberg, p. 71.

Mayer, A. C., Stöckli, V., Huovinen, C., Konold, W., Estermann, B. L., & Kreuzer, M. (2003). Herbage selection by cattle on sub-alpine wood pastures. Forest Ecology and Management, 181(1), 39-50.

MEA. 2005. Millennium ecosystem assessment. Ecosystems and Human Well-Being: Biodiversity Synthesis, Published by World Resources Institute, Washington, DC.

MLUL (2012). Ministerium für Ländliche Entwicklung, Umwelt und Landwirtschaft des Landes Brandenburg. Bericht zur Überprüfung des UNESCO BR Spreewald. Last accessed 26.04.2016 at: http://www.mlul.brandenburg.de/media_fast/4055/br_evaluierung.pdf.

Moga CI, Samoila C, Öllerer K, Bancila R, Reti KO, Craioveanu C, Poszet Sz, Rakosy L, Hartel T (2016). Environmental determinants of the old oaks in wood-pastures from a changing social-ecological system. Ambio 45: 480-489.

Molnár, Zs., Kis, J., Vadász, Cs., Papp, L., Sándor, I., Béres S., Sinka G., Varga, A. (2016). Common and conflicting objectives and practices of herders and nature conservation managers: the need for the 'conservation herder'. Ecosystem Health and Sustainability 2(4):

Moreno G, Cubera E. 2008. Impact of stand density on water status and leaf gas Exchange in Quercus ilex. Forest Ecology and Management, 254: 74-84.

Moreno G, Obrador JJ, García A (2007). Impact of evergreen oaks on the fertility and oat

production in intercropped dehesas. Agriculture, Ecosystems & Environment 119: 270-280.
Moreno G, Pulido F (2009). The functioning, management and persistence of Dehesas. In: Rigueiro-Rodriguez, A. McAdam, J. Mosquera-Losada, M.R. (eds.) Agroforestry in Europe, Current Status and Future Prospects, Advances in Agroforestry. pp. 127-160. Springer, Heidelberg.
Moreno, G., Bartolome, J. W., Gea-Izquierdo, G., & Cañellas, I. (2013). Overstory–Understorey Relationships. In Mediterranean Oak Woodland Working Landscapes (pp. 145-179). Springer Netherlands.
Moreno G, Berg S, Burgess PJ, Camilli F, Crous-Duran J, Franca A, Hao H, Hartel T, Lind T, Mirck J, Palma J, Pantera A, Paula JA, Pisanelli A, Rolo V, Seddaiu G, Thenail C, Tsonkova P, Upson M, Valinger E, Varga A, Viaud V, Vityi A. 2016a. Challenges and potential innovations to improve the resilience European wood-pastures. World Congress Silvo-Pastoral Systems. Silvopastoral systems in a changing world: functions, management and people. Septmeber 2016, Evora, Portugal.
Moreno G, Gonzalez-Bornay G, Pulido F, Lopez-Diaz ML, Bertomeu M, Juárez E, Diaz M (2016b). Exploring the causes of high biodiversity of Iberian dehesas: the importance of wood pastures and marginal habitats. Agroforestry Systems 90: 87-105.
Mosquera-Losada, M. R., Moreno, G., Pardini, A., McAdam, J. H., Papanastasis, V., Burgess, P. J., Lamersdorf, M. Castro, F. Liagre, and Rigueiro-Rodríguez, A. (2012). Past, present and future of agroforestry systems in Europe. In Agroforestry-The Future of Global Land Use (pp. 285-312). Springer Netherlands.
Mosquera-Losada, M.R., Santiago Freijanes, J.J., Pisanelli, A., Rois, M., Smith, J., den Herder, M., Moreno, G., Malignier, N., Mirazo, J.R., Lamersdorf, N., Ferreiro Domínguez, N., Balaguer, F., Pantera, A., Rigueiro-Rodríguez, A., Gonzalez-Hernández, P., Fernández-Lorenzo J.L., Romero-Franco, R., Chalmin, A., Garcia de Jalon, S., Garnett, K., Graves, A., Burgess, P.J. (2016). Extent and success of current policy measures to promote agroforestry across Europe.Deliverable 8.23 for EU FP7 Research Project: AGFORWARD 613520. (8 December 2016). 95 pp.
Oellerer, K. (2014). The ground vegetation management of wood-pastures in Romania–insights in the past for conservation management in the future. Applied Ecology and Environmental Research, 12(2), 549-562.
Oppermann R, Beaufoy G, Jones G (Eds.) (2012). High Nature Value Farming in Europe. 35 European countries – experiences and perspectives. Verlag Regionalkultur, Ubstadt-Weiher, Germany.
Osterburg B, Rühling I, Runge T, Schmidt TG, Seidel K, Antony F, Gödecke B, Witt-Altfelder P (2007). Kosteneffiziente Maßnahmenkombinationen nach Wasserrahmenrichtlinie zur Nitratreduktion in der Landwirtschaft. In: Osterburg B, Runge T (Hrsg.): Maßnahmen zur Reduzierung von Stickstoffeinträgen in die Gewässer – eine wasserschutzorientierte Landwirtschaft zur Umsetzung der Wasserrahmenrichtlinie. Landbauforschung Völkenrode. Sonderheft 307. p. 312.
Ouin A, Burel F (2002). Influence of herbaceous elements on butterfly diversity in hedgerow agricultural landscapes. Agriculture, Ecosystems and Environment 93 (2002) 45–53
Pantera A, Papanastasis VP (2003). Inventory of *Q. ithaburensis* ssp. *macrolepis* (*Quercus ithaburensis* Decaisne ssp. *macrolepis* (Kotschy) Hedge & Yalt. in Greece. Geotechnical Scientific Issues 1/2003: 34-43. [In Greek].
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
Papanastasis, V. P., Yiakoulaki, M. D., Decandia, M., & Dini-Papanastasi, O. (2008). Integrating woody species into livestock feeding in the Mediterranean areas of Europe. Animal Feed Science and Technology, 140(1), 1-17.

Paracchini ML, Petersen JE, Hoogeveen Y, Bamps C, Burfield I, van Swaay C (2008). High Nature Value Farmland in Europe - An estimate of the distribution patterns on the basis of land cover and biodiversity data, Report EUR 23480 EN. 87 p.

PASTOMED 2007. Le Pastoralisme Méditerranéen, situation actuelle et perspectives, Final Report of the projet INTERREG IIIC Zone Sud PASTOMED «Traditions et modernité du pastoralisme méditerranéen : connaissance et reconnaissance de rôles du pastoralisme dans le développement durable des territoires ruraux méditerranéens », Maison Régionale de l'Elevage, MANOSQUE (France), www.pastomed.org, p. 100.

Petit S, Burel F. 1998. Connectivity in fragmented populations: Abax parallelepipedus in a hedgerow network landscape. Life Sciences 321: 55-61.

Plieninger T, Rolo V, Moreno G. (2010). Large-scale patterns of *Quercus ilex, Quercus suber,* and *Quercus pyrenaica* regeneration in Central-Western Spain. Ecosystems, 13(5), 644-660.

Plieninger, T., Bieling, C., 2013. Resilience-based perspectives to guiding high nature value farmland through socio-economic change. Ecol. Soc. 18 (4), 20.

Plieninger, T, Hartel, T, Martín-López, B, Beaufoy, G, Bergmeier, E, Kirby, K, Montero, MJ, Moreno, G, Oteros-Rozas, E, Van Uytvanck, J (2015) Wood-pastures of Europe: Geographic coverage, social–ecological values, conservation management, and policy implications. Biological Conservation 190: 70-79.

Porqueddu C., Franca A. (2013). Sardinian agro-silvo-pastoral systems: management and constraints, In: Proceedings of MONTADOS and DEHESAS as High Nature Value Farming Systems: implications for Classification and Policy Support, ICAAM International Conference, 6 - 8 February 2013, p. 77.

Puech C, Poggi S, Baudry J, Aviron S (2015) Do farming practices affect natural enemies at the landscape scale? Landscape Ecology 30:125–140

Rivest D, Paquette A, Moreno G, Messier C (2013). A meta-analysis reveals mostly neutral influence of scattered trees on pasture yield along with some contrasted effects depending on functional groups and rainfall conditions. Agriculture, Ecosystems & Environment 165: 74-79.

Rolo V, Plieninger T, Moreno G (2013). Facilitation of holm oak recruitment through two contrasted shrubs species in Mediterranean grazed woodlands: Patterns and processes. Journal Vegetation Science 24: 344-355.

Ruiz-Mirazo, J., & Robles, A. B. (2012). Impact of targeted sheep grazing on herbage and holm oak saplings in a silvopastoral wildfire prevention system in south-eastern Spain. Agroforestry systems, 86(3), 477-491.

Ruiz-Peinado R, Moreno M, Juárez E, Montero G, Roig S. (2013). The contribution of two common shrub species to aboveground and belowground carbon pool in Iberian Dehesas. Journal of Arid Environments 91: 22-30.

Santos-Reis M, Correia AI (1999) Caracterização da flora y fauna do montado da Herdade da Ribeira Abaixo (Grândola – Baixo Alentejo). Centro de Biologia Ambiental, Lisboa.

Seddaiu G, Porcu G, Ledda L, Roggero PP, Agnelli A, Corti G (2013). Soil organic matter content and composition as influenced by soil management in a semi-arid Mediterranean agro-silvo-pastoral system. Agriculture, Ecosystems & Environment 167: 1-11.

Shakesby, R. A., Coelho, C. O. A., Schnabel, S., Keizer, J. J., Clarke, M. A., Lavado Contador, J. F., Doerr, S. H. (2002). A ranking methodology for assessing relative erosion risk and its application to dehesas and montados in Spain and Portugal. Land Degradation & Development, 13(2), 129-140.

Schnabel S, Ferreira A. (eds.) (2004). Sustainability of Agrosilvopastoral Systems-Dehesas, Montados. Advances in GeoEcology. Catena Verlag: Reiskirchen.

Simões MP, Belo AF, Fernandes M, Madeira M. (2016). Regeneration patterns of *Quercus suber* according to montado management systems. *Agroforestry systems*, *90*(1), 107-115.

Torralba M, Fagerholm N, Burgess P, Moreno G, Plieninger T (2016) Do European agroforestry systems enhance biodiversity and ecosystem services? A meta-analysis. Agriculture, Ecosystems and Environment 230: 150-161.

UK Biodiversity Group (1988). Tranche 2 Action Plans Terrestrial and Freshwater Habitats. Accessed 21 August 2017. http://jncc.defra.gov.uk/PDF/UKBAP_Tranche2-ActionPlans-Vol2-1998.pdf

Upson MA, Burgess PJ, Morison JIL (2016). Soil carbon changes after establishing woodland and agroforestry trees in a grazed pasture. Geoderma, 283, 10-20.

Varga A, Molnár Zs. 2014.The Role of Traditional Ecological Knowledge in Managing Wood-pastures.In: Hartel, T., Plininger, T.: European Wood-pastures in Transition. Routledge. pp.187-202.

Varga, A., Ódor, P., Molnár, Z., & Boloni, J. (2015). The history and natural regeneration of a secondary oak-beech woodland on a former wood-pasture in Hungary. Acta Societatis Botanicorum Poloniae, 84(2).

Varga, A., Molnár, Z., Biró, M., Demeter, L., Gellény, K., Miókovics, E., Molnár, Á., Molnár, K., Ujházy, N., Ulicsni, V. & Babai, D. (2016). Changing year-round habitat use of extensively grazing cattle, sheep and pigs in East-Central Europe between 1940 and 2014: Consequences for conservation and policy. Agriculture, Ecosystems & Environment, 234, 142-153.

Walter C, Merot P, Layer B, Dutin G (2003). The effect of hedgerows in soil organic carbon storage on hillslopes. Soil Use and Management 3: 201-207.

Zianis D. Pantera A. Papadopoulos A. Mosquera Losada MR (2017). Bayesian and classical biomass allometries for open grown valonian oaks (Q. ithaburensis subs. macrolepis L.) in a silvopastoral system. Agroforest Syst DOI 10.1007/s10457-016-0060-7.