Preliminary stratification and quantification of agroforestry in Europe

Project name	AGFORWARD (613520)
Milestone	**Milestone 1**
Milestone name	**Preliminary stratification and quantification of agroforestry according to systems studied in WP2-WP5**
Original version	**9 December 2014**
Current version	24 April 2015
Authors	Michael den Herder, Paul Burgess, María Rosa Mosquera-Losada, Felix Herzog, Tibor Hartel, Matthew Upson, Iida Viholainen and Adolfo Rosati
Contributors	Nathalie Corroyer, John Erik Hermansen, Jaconette Mirck, João Palma, Anastasia Pantera, Vasilios Papanastasis, Tobias Plieninger, Andrea Vityi, Ansgar Quickenstein and Jeroen Watté
Reviewer	Approved by Nora Fagerholm (9 December 2014) Updated by Paul Burgess (24 April 2015)

AGFORWARD (Grant Agreement N° 613520) is co-funded by the European Commission, Directorate General for Research & Innovation, within the 7th Framework Programme of RTD. 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

Content

den Herder, M., Burgess, P.J,., Mosquera-Losada, M.R., Herzog, F., Hartel, T., Upson, M., Viholainen, I. and Rosati, A. (2015). Preliminary stratification and quantification of agroforestry in Europe. Milestone Report 1.1 for EU FP7 AGFORWARD Research Project (613520).

1 Context

The AGFORWARD research project (January 2014-December 2017), funded by the European Commission, is promoting agroforestry practices in Europe that will advance sustainable rural development. The project has four objectives:

1) to understand the context and extent of agroforestry in Europe,
2) to identify, develop and field-test innovations (through participatory research) to improve the benefits and viability of agroforestry systems in Europe,
3) to evaluate innovative agroforestry designs and practices at a field-, farm- and landscape scale, and
4) to promote the wider adoption of appropriate agroforestry systems in Europe through policy development and dissemination.

This report describes a milestone to address objective 1.

In the AGFORWARD project, researchers are working with about 40 stakeholder groups focused on agroforestry in different regions and sectors. It is proposed that many farmers across Europe distinguish themselves in terms of the key products that they produce. Hence farmers may identify themselves as arable farmers, livestock farmers, farmers who manage orchards or olive groves, or even farmers who manage systems that have high cultural and natural value. Hence within the AGFORWARD project, we have identified four target groups who could benefit from improved agroforestry practices. Each of these groups is the focus of a separate work-package (WP). They include farmers who manage agroforestry systems of high nature and cultural value (WP2), and farmers who manage high value trees such as olives, fruit trees, and walnut and chestnut grown for high value timber (WP3). WP4 focuses on agroforestry for arable systems and WP5 focuses on agroforestry for livestock systems.

One of the objectives of the AGFORWARD project is to advance the mapping and quantification of agroforestry in Europe. This milestone is a first attempt at stratifying and quantifying, within Europe, the extent of agroforestry of high nature and cultural value, agroforestry involving high value trees such as olive and fruit trees, and agroforestry involving arable and livestock production. It is based on examination of published scientific literature and statistical databases. In turn this task will inform the participatory research and development networks and the some of the scaling up work in the project.

2 Introduction

2.1 Definitions

AGFORWARD has defined agroforestry as "the practice of deliberately integrating woody vegetation (trees or shrubs) with crop and/or livestock production systems to benefit from the resulting ecological and economic interactions" (Figure 1). This is similar to definitions adopted by the World Agroforestry Centre (ICRAF), the European Agroforestry Federation (EURAF), and the Association for Temperate Agroforestry (AFTA). This builds on previous definitions of agroforestry as a land use practice combining trees, crops and/or livestock on the same area of land in all spatial or temporal arrangements (Nair 1993, Mosquera-Losada et al. 2009). The need for ecological and economic interactions was present in the definition from Lundgren and Raintree (1982) that agroforestry is "a collective name for a land-use systems and technologies where woody perennials are deliberately used on the same land-management unit as agricultural crops and/or animals, in some form of spatial and temporal arrangement". In agroforestry systems there are both ecological and economic interactions between the different components".

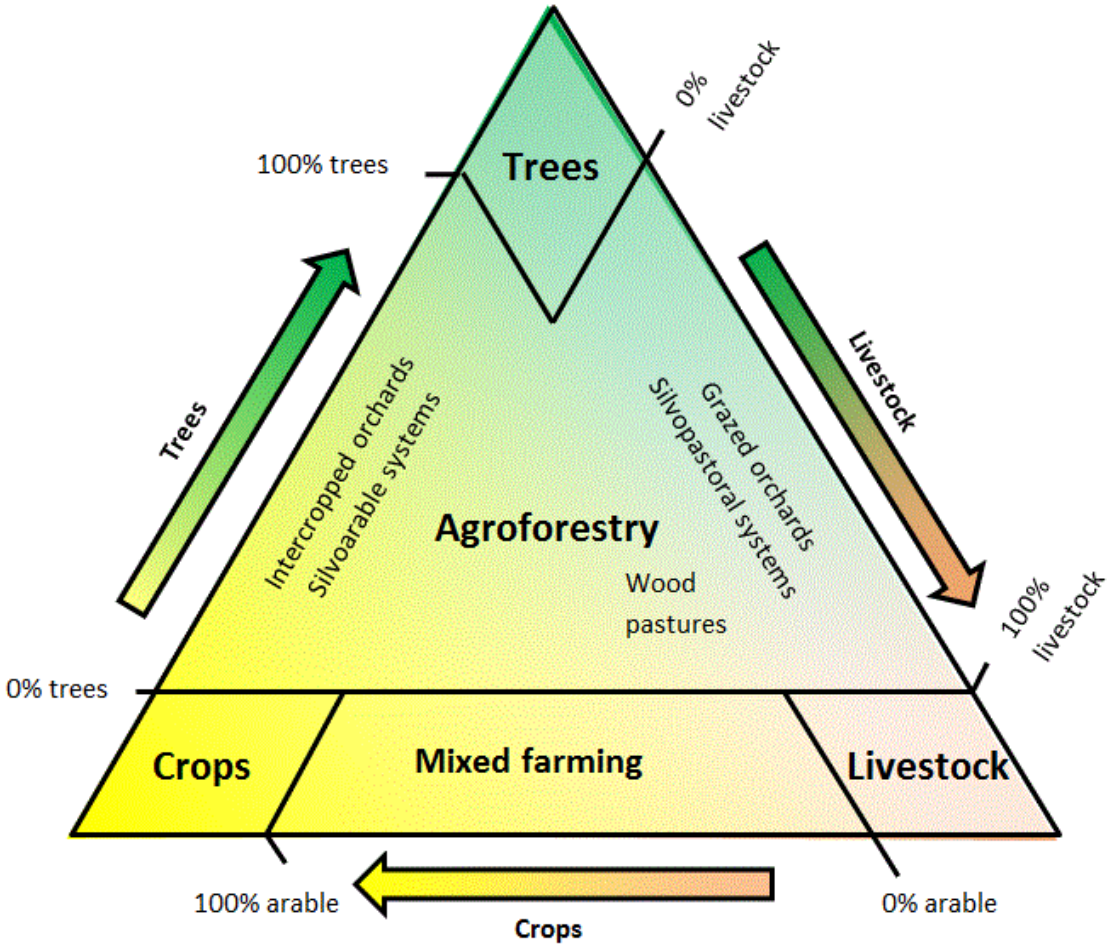

Figure 1. The AGFORWARD project is promoting agroforestry practices i.e. the integration of trees with farming. Agroforestry comprises the integration of trees (and shrubs) with crop and/or livestock systems.

The definition of agroforestry used by ICRAF (Leakey, 1996) is: “a dynamic, ecologically based, natural resources management system that, through the integration of trees on farms and in the agricultural landscape, diversifies and sustains production for increased social, economic and environmental benefits”. All agroforestry systems integrate people as a part of the system and are artificial systems to a higher or lower degree (Mosquera-Losada et al. 2009). Sommariba (1992) defines agroforestry as a form of multiple cropping which satisfies at least three basic conditions:

1. There are at least two species that interact biologically
2. At least one of the species is a woody perennial
3. At least one of the plant species is managed for forage, annual or perennial crop production.

An agroforestry system is always more complex, for example in structure, function and economy, than a monoculture system (Nair 1993).

Nair (1993) argues that agroforestry is a relatively new name for a very old practice which dates back millennia (Bergmeier et al. 2010, Papanastasis et al. 2009). In fact various authors (Herzog 1998, Eichhorn et al. 2006, Bergmeier et al. 2010, Mosquera-Losada et al. 2012) have reported the historic importance of agroforestry across Europe. Traditional agroforestry systems are still widespread in the Mediterranean region, such as the *montados* and *dehesas* in Portugal and Spain, where cattle and livestock are grazing between widely spaced oak trees, providing wood, cork and fodder for the animals. *Streuobst* is a traditional system in central Europe where crops are grown or livestock grazed under high fruit trees. Woodland grazing can also be found in central, southern, western and northern Europe. In the boreal forest and sub-arctic tundra zone, reindeer husbandry has been practiced since the middle ages providing meat, reindeer hides and wood products for local consumption and export (Jernsletten and Klokov 2002). There are also other less well known traditional and novel agroforestry systems.

Although many traditional agroforestry systems have disappeared with the intensification of agriculture and forestry since the 1960s, there is a revived interest in integrating trees with agriculture. This interest comes from farmers who can see benefits in terms of increased and more diversified production. There is also interest from policy makers who understand that agroforestry can provide a wide range of social and environmental benefits. Hence in Europe, agroforestry is a recognized practice in the “ecological focus areas” of the Common Agricultural Policy (European Commission, 2013a) and as a measure in rural development programmes (European Commission, 2013b). Agroforestry is also mentioned in the EU Forestry Strategy (European Commission 2013c) and as a sustainable land management practice by the Intergovernmental Panel on Climate Change (IPCC, 2014).

2.2 Classifying and mapping agroforestry

In Europe there is a lack of cartographic information on the location of different types of agroforestry practices. Moreover, the information that is available is scattered and fragmented. European land cover and land use classifications have traditionally separated "farmland" from "forests" and this in turn feeds through discrete policies and incentives which can cause problems both to farmers and policy makers. In order to support multifunctional and sustainable land use, policy makers and planners need access to a more nuanced land cover classification system that explicitly considers agroforestry as a continuum between crop, livestock and tree-based systems (Figure 1).

Nair (1993) reports that classifications should provide practical frameworks for synthesising and analysing information about existing practices and for developing new ones. In the early 1980s, ICRAF completed an inventory of agroforestry systems in the tropics and subtropics (Nair 1985). This classified agroforestry systems in terms of the spatial and temporal arrangement of the components, the importance and role of the components, the production aims and outputs from the system, and the social and economic features (Nair, 1993).

Sinclair (1999) used the same inventory (from Nair 1985) to update the classification, but argues that agroforestry is rarely practised as a whole farm or forest system, but primarily as practices in various productive niches around the farm. Sinclair (1999) also argues that agroforestry researchers should be able to "advise on the spectrum of land use options in a particular context, from agricultural activity without trees, through agroforestry combinations to pure forest and woodland scenarios, rather than being over-zealous about one particular form of land use".

Dixon et al (2001) distinguish between a "farm system" (the system operating within an individual farm) and "farming systems" which is a grouping of farm systems which can be usefully considered together (Table 1). The phrase "farm practice" is often used to refer to a discrete way of carrying out a specific task such as cultivation or harvesting (Ikerd, 1993). In some cases, agroforestry can be considered as a farming system, but in others it may also be considered as a farm practice, or a grouping of farm practices (Poisot et al. 2004).

Table 1. Agroforestry can be considered as a "farm practice", a group of farm practices, or in some rare cases as a "farming system".

Level of organisation	Description
Farming system	A population of individual farm systems that have broadly similar resource bases, enterprise patterns, household livelihoods and constraints, and for which similar development strategies and interventions would be appropriate (Dixon et al., 2001)
Farm system	A system focused at the individual farm level including the household, its resources, the resource flows and interactions (Dixon et al., 2001)
Farm practice	A discrete way of carrying out a farming task, i.e. soil cultivation, harvesting (Ikerd, 1993). Practices can often be grouped and given an over-arching terms such as "conservation agriculture", or "integrated pest management" (Poisot et al 2004), or in this case "agroforestry".

The scale of the analysis can also be important when mapping agroforestry practices (Minang et al. 2015). For instance, a fruit orchard or alley cropping system in central Europe may cover several hectares and be part of a larger farm practising conventional agriculture as well, so it would operate at the field scale (Figure 2). A typical *montado*, *dehesa* or reindeer farm, on the other hand, may have agroforestry as their main practice and often these farms cover several square kilometres or more; this type of practice would be referred to as farm-scale agroforestry. When several agroforestry farms and/or practices can be found in the same area, agroforestry would operate at the landscape scale.

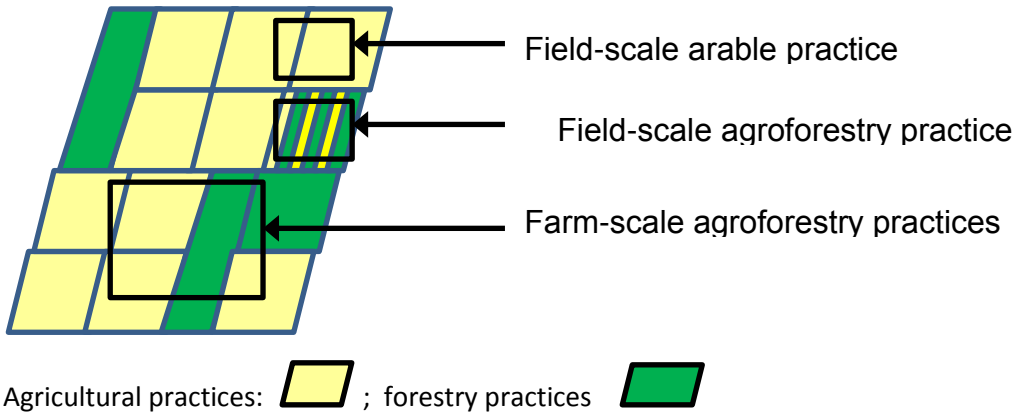

Figure 2. Agroforestry can be considered at a range of scales: field-scale, farm-scale and landscape-scale.

Mosquera-Losada et al. (2009) identified six basic types of agroforestry existing in Europe today: silvoarable, silvopasture, forest farming, riparian buffers, improved fallow, and multipurpose trees (Table 2).

Table 2. Six agroforestry practices in Europe identified by Mosquera-Losada et al. (2009)

Agroforestry practice	Brief description
Silvoarable agroforestry	Widely spaced trees inter-cropped with annual or perennial crops. It comprises alley cropping, scattered trees and line belts
Forest farming	Forested areas used for production or harvest of natural standing specialty crops for medicinal, ornamental or culinary uses
Riparian buffer strips	Strips of perennial vegetation (tree/shrub/grass) natural or planted between croplands/pastures and water sources such as streams, lakes, wetlands, and ponds to protect water quality
Improved fallow	Fast growing, preferably leguminous woody species planted during the fallow phase of shifting cultivation; the woody species improve soil fertility and may yield economic products
Multipurpose trees	Fruit and other trees randomly or systematically planted in cropland or pasture for the purpose of providing fruit, fuel wood, fodder and timber, among other services, on farms and rangelands
Silvopasture	Combining trees with forage and animal production. It comprises forest or woodland grazing and open forest trees

McAdam et al. (2009) reviewed the existing classification methods, adapted it to a European context and complemented it with a classification based on the functions of agroforestry systems (Table 3).

Table 3. Agroforestry systems are classified by their components, spatial and temporal arrangements, function, agro-ecological zone and socio-economic aspects (modified from Nair 1993; McAdam et al. 2009)

Classification method	Example categories
i) Components	**Agrisilviculture:** crops and trees including shrub/trees and trees **Silvopastoral:** pasture/animals and trees **Agrosilvopastoral:** crops, pasture/animals and trees **Other**: multipurpose tree lots, apiculture with trees, aquaculture with trees
ii) Predominant land use	**Primarily agriculture** **Primarily forestry**
iii) Spatial (in space) arrangements	**Mixed dense** (e.g. home garden), **Mixed sparse** (e.g. most systems of trees in pasture) **Strip** (width of strip to be more than one tree) **Boundary** (trees on edges of plots/fields)
iv) Temporal (in time) arrangements	Overlapping, separate, (coincident, interpolated)
v) Agroecological (environmental adaptability)	Humid, arid, mountainous or high land/low land
vi) Socio-economic and Management level	Based on level of technology input: Low, medium and high input Based on cost/benefit relations: commercial, intermediate, subsistence
vii) Function (*)	**Productive function (provisioning)**: food, fodder, fuel wood, other products **Habitat function (supporting):** Biodiversity **Regulating:** Climate, flood and drought prevention, water purification, shelterbelt, soil and water conservation, shade **Cultural functions**: recreation and landscape

(* vii) Function: It is possible to classify agroforestry systems according to the function of the system.

Productive functions of the tree components of European agroforestry systems include fruit, oil and nuts, timber, firewood, cork, fodder, grain seeds, vegetables, soft fruits and grapes, biomass feedstock.

Habitat functions – Agroforestry creates heterogeneity in time and within system there is an increase in invertebrate species and numbers of arthropods, birds and mammals. (Rigueiro-Rodríguez et al. 2009). Biodiversity increases the connection between forest and agricultural habitats, functioning as wildlife corridors (Rigueiro-Rodríguez et al. 2009).

Regulating functions - Agroforestry systems can provide a wide range of regulating services such as soil, water and nutrient conservation, fire prevention and carbon sequestration.

Cultural functions- Traditional agroforestry systems are an important part of the culture and heritage of several areas in Europe.

2.3 Our approach

It is obvious that there have been many classifications of agroforestry practices. The AGFORWARD project does not propose a new classification system but it builds on previous classifications in the context of the structure of the project. The objective of this report is to make a preliminary stratification of agroforestry in Europe and categorise them into systems or practices focussed on high nature and cultural value (WP2), high value trees (e.g. olive and fruit trees) (WP3), arable systems (WP4) and livestock systems (WP5) (Figure 3).

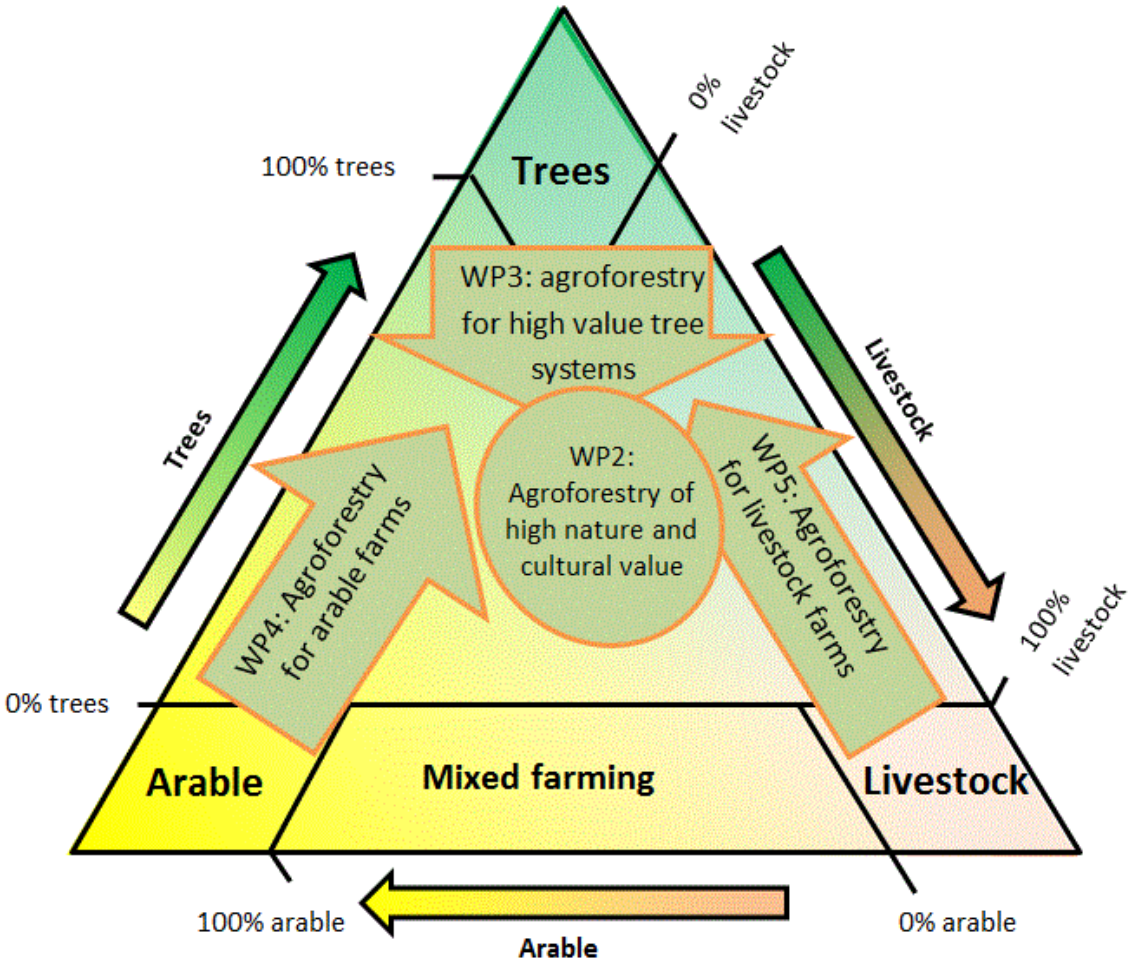

Figure 3. The participation networks within the AGFORWARD project considers agroforestry in four key areas: existing agroforestry practices of high nature and cultural value (HNCV) (WP2), integrating livestock and crops into high value tree systems (WP3), agroforestry for arable farms (WP4) and agroforestry for livestock farms (WP5).

When attempting to classify European agroforestry into different practices or systems, we also face the challenge that systems can be temporarily or spatially overlapping (Figure 4). For example agroforestry systems such as *montados* and *dehesas* can be described of high nature and cultural value, but also as the integration of trees with a livestock system. Likewise it is unclear when the intercropping of apple trees becomes an arable system with alleys formed from apple trees. In this report, we will consider agroforestry of high nature and cultural value first, followed by agroforestry with high value trees, and then any remaining practices.

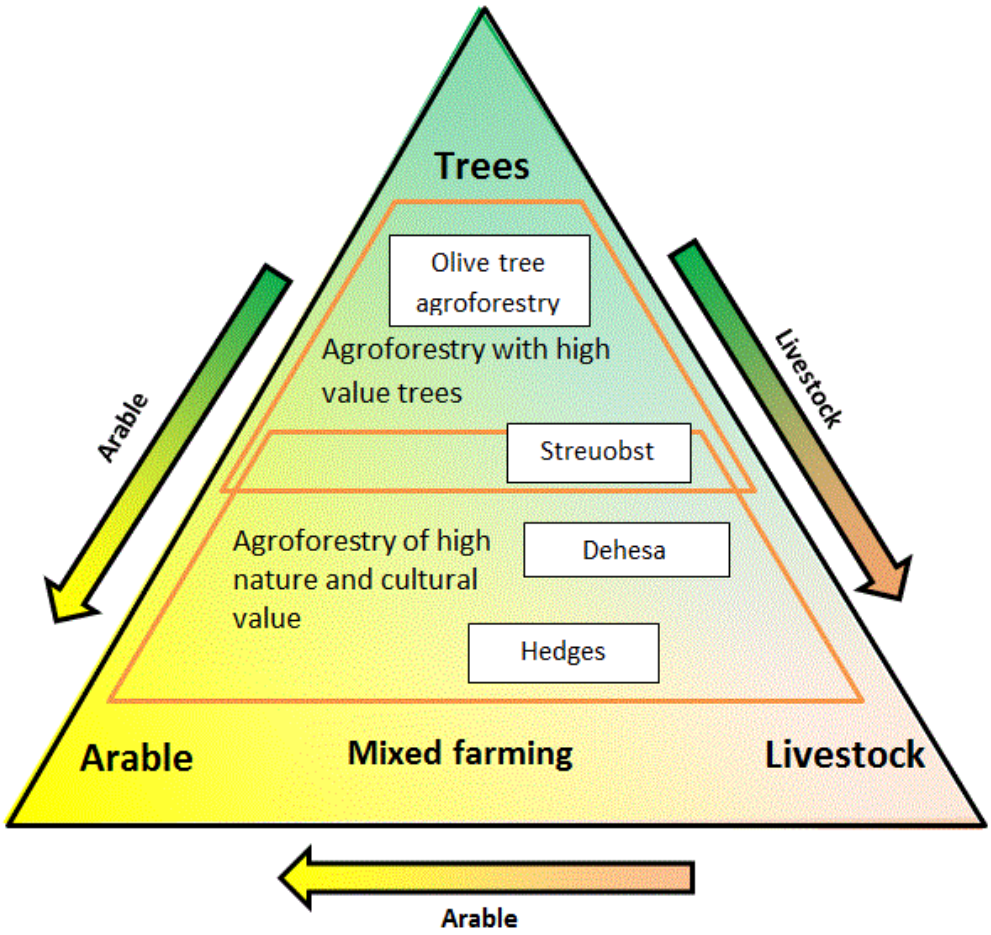

Figure 4. Agroforestry practices can be divided into those of "high nature and cultural value" and those focused on high value trees, but there is overlap. Practices can also be divided into whether they include arable crops and livestock.

Data on the extent of agroforestry systems were collected from scientific research and review articles, published technical reports, statistical databases and internet sites. A list of published articles was composed from a SCOPUS "article title, abstract, keywords" search using a combination of the following words as a search string: "agroforestry" or "silvopasture" or "silvoarable" or "alley cropping" and "Europe" or "Mediterranean" or "temperate" or "Atlantic" or "boreal" or "pannonian" or the name of the country. A similar search was carried out in Google. Hereafter references were checked to ensure if the described agroforestry practices fell within the European continent and to see if they contain information on the areal extent of agroforestry practices. Consistent difficulties were encountered during attempts to document the type and extent of agroforestry practices in Europe. These included a lack of official statistical data and difficulties in differentiating between practices. Sources of information also varied between countries and systems. Therefore, figures from different countries cannot be compared directly because of the different years, different definitions of the systems and methodological differences in data collection. It does, however, provide a first general overview of the location and extent of the different agroforestry practices and systems in Europe.

3 Agroforestry of high nature and cultural value

The high nature value (HNV) concept was proposed by the European Environment Agency (Parachini et al. 2006). The concept recognizes that specific farming practices and systems support high biodiversity levels (Pointereau et al. 2007). For instance, the *dehesas* and *montados* agroforestry systems in Spain and Portugal are among the highly diverse HNV systems in Europe.

The HNV concept was introduced at the beginning of the 1990s, and the intention was to integrate biodiversity and environmental aspects concerning agriculture in Europe. The methodological guidelines defined by the European Commission consider three different approaches to identify HNV: the land cover, the farming system, and a species and habitat approach (Almeida et al. 2013). Paracchini et al. (2006) identifies three types of HNV farmland: 1) farmland with a high proportion of semi-natural vegetation, 2) farmland with a mosaic of low intensity agriculture and natural and structural elements, such as field margins, stone walls, patches of woodland or scrub, and small rivers, and 3) farmland supporting rare species or a high proportion of European or world populations.

Traditional Agricultural Landscapes (TAL) is another recent classification that has parallels with the HNV farmland concept. However, rather than focusing on nature value, the TAL concept takes a broader view of farmed landscapes that retain certain 'traditional' aspects (Cooper et al. 2007). These may be elements of the farming system itself, for example, diversity of production, the fact that it is small scale, or historical features that remain in the landscape but that are no longer part of the production system. TALs are characterised by the existence of high aesthetic and cultural values and a traditional or locally adapted management approach. Natural and cultural values depend on continuity of the traditional farming practices and this on the social and economic sustainability of the respective farming systems (Caballero and Gíl 2009). The AGFORWARD project does not have a particular focus on the traditional aspects; however, we do consider cultural aspects a key issue in managing viable and sustainable agroforestry systems. Therefore we have adopted the term "high natural and cultural value" agroforestry.

In addition to the *dehesas* and *montados* in Spain and Portugal, there are other examples of agroforestry systems that have high nature and cultural values. Hence this section considers high nature and cultural value agroforestry in terms of oak-dominated agroforestry in the Mediterranean, other wood pastures, hedgerow systems, and reindeer husbandry.

Wood pastures can be defined as tree-land systems where animals or wildlife are grazing systematically (Bergmeier et al. 2010). They are traditional systems with multiple uses, where animals provide fertilisation and control tree encroachment. Due to their widespread distribution, there exist many regional or local terms to describe wood-pasture types. The importance of wood pastures can be illustrated by the variety of names of this kind of practice (Bergmeier et al. 2010) (Table 4).

Table 4. Some local, regional and temporal meanings for wood pasture systems (adapted from Bergmeier et al. 2010 and Oppermann et al. 2012).

Name of the system	Description
Montado and *dehesa*	Pastoral woodland of the Iberian Peninsula dominated by oak trees.
Forest	In its original sense in Britain means woodland or non-wooded unfenced areas where owners are keeping deer
Park (game park, wild park)	An enclosed woodland or grassland used to keep deer and other animals in quantities that require additional feeding
Garrigue, Macchia and *matorral*	Mediterranean low scrub systems of evergreen trees and shrubs, sub-shrubs and herbs grazed long-term with dense sclerophyllous vegetation
Bocage and *haie*	Pastureland systems in France
Hudewald	Pastoral systems dominated by tall and old oaks, beech, hornbeam and other deciduous trees, which are often pollarded
Kratt	A Norwegian/Fennoscandian deciduous coppiced wood pasture with oaks (*Quercus petraea, Q. robur).* Animals: cattle, sheep.
Lövängar	Swedish/Fennoscandian deciduous or semi-deciduous low intensity pastures and meadows with open scrub and groves (*Betula, Populus tremula)*
Hakamaa	Mixed deciduous or coniferous forests with herbaceous vegetation grazed by cattle, sheep and horses. Pollarding was a common practice until the 1960s. It still exists in some parts in the archipelago of Finland.
Shibliak	Thermophilous deciduous or semi-deciduous scrubland of the Balkans and the Black Sea area.
Streuobst	Low density orchard system with fruit trees (apple, pear, plum and cherry tree) and crops close to villages in temperate Europe. Understory vegetation is usually mowed or grazed.
Wacholderheide	Nutrient poor grassland and heathlands with scrubs, dominated by Juniper. Occurs in Central Europe, especially in Germany.
Weidfeld	Low density pasture with scrubs
Knick	Hedgerow landscapes from northern Germany
Freiberge and *Pâturages boisés*	Wood pastures of the Jura mountains in France and Switzerland

3.1 Oak dominated agroforestry in the Mediterranean

Oak tree systems include a variety of habitats ranging from open wood pastures and meadows to closed-canopy forest, and the largest extent of such systems in found in the Mediterranean region (Figure 5). This system of land use may have been practised for up to 4500 years (Stevenson and Harrison 1992). The cover of oak tree systems in Spain and Portugal is in excess of 15% of the Utilised Agricultural Area (Figure 5).

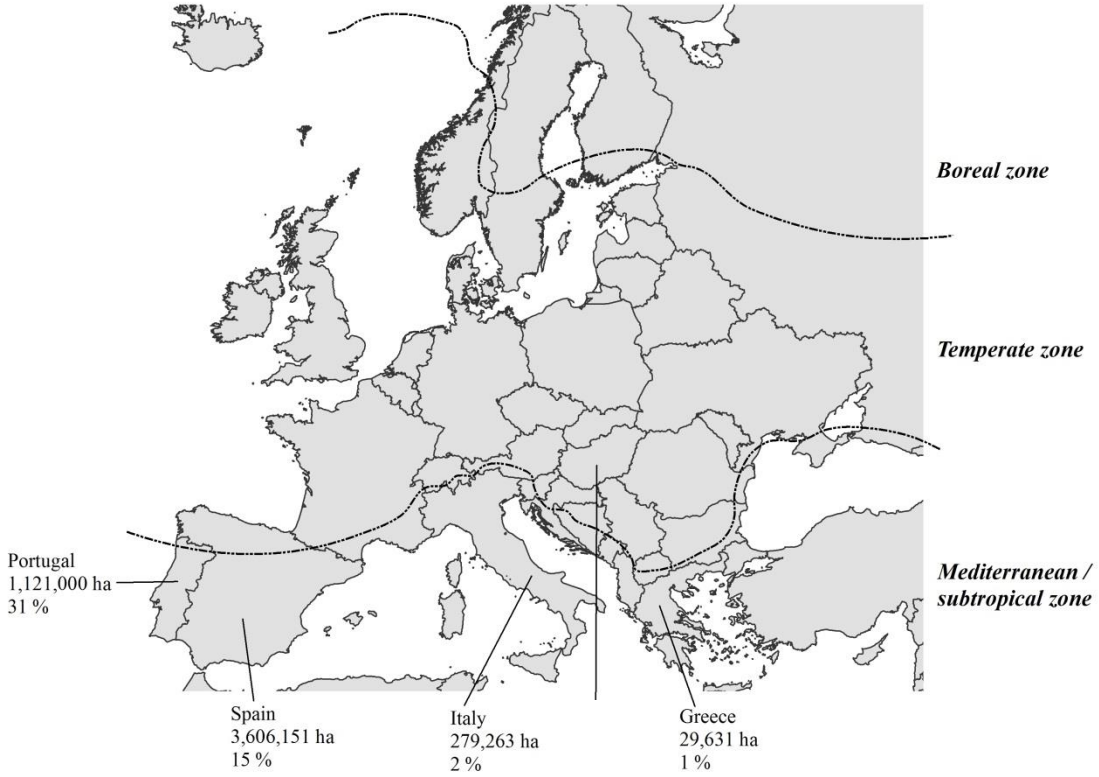

Figure 5. The distribution of Mediterranean oak tree systems in Europe. Estimated area in hectares and as per cent of the Utilized Agricultural Area (year 2012) of each country (see also Table 5).

Dehesas and *montados* were mostly created by clearing natural forest and can be considered as multipurpose open woodlands (Moreno and Pulido 2009) (Figure 6). They provide browse, forage and shade during early summer drought periods, reducing fire risk at the same time. Many *dehesas* combine silvopastoral and silvoarable practices as well as multipurpose trees. Examples of practices include livestock keeping, cereal cultivation, cork and firewood harvesting, and hunting. *Dehesa* is considered to be the most biodiverse man-made landscape in Europe (Moreno and Pulido 2009). Because of their high biological diversity, including several globally endangered animal species, these systems have qualified as habitats to be preserved within the EU Habitat Directive (Castro 2009, Moreno & Pulido 2009). At present, *dehesas* occupy 3.6 million hectares in Spain and 1.1 million hectares in Portugal where they are called "*montados*" (Ministerio de Agricultura, Alimentación y Medio Ambiente 2008, Inventário Florestal Nacional 2013a) (Table 5).

Figure 6. Montado and goat grazing in Portugal, photo by João HN Palma.

Moreno and Pulido (2009) report that *dehesa* and *montado* typically involve traditional livestock breeds at low densities. The environmental settings make arable farming unprofitable and therefore these systems have arisen to be the only feasible way of productively using the land in these areas (Montero et al. 1998). *Dehesas* and *montados* have tree, livestock and crop components.

Tree component: the tree layer is dominated by holm oak (*Quercus ilex*) and cork oak (*Q. suber*). Other deciduous tree species in these systems include *Q. pyrenaica* Willd., *Q. faginea* L. and *Fraxinus angustifolia* Vahl.. The trees have a density ranging from 5 to 80 trees per hectare (usually 15–45 trees per hectare) and 21–40% canopy cover, this variation depending on its main use: lower densities occur in intercropped areas and higher densities in areas devoted to big game hunting (Montero et al. 1998, San Miguel 1994, Moreno and Pulido 2009).

Livestock component: grazing of pastures by livestock is important for maintaining stable understory vegetation. Different types of livestock (cattle, sheep, goats, pigs, horses) are common depending on the vegetation type and socio-economic characteristics. Sheep are found in most systems, cattle tend to be found in more humid areas, and goats are often used to make better use of tree fodder. In some systems, pigs are introduced during October-January to eat acorns. Cork and holm oak trees have a direct value as a fodder crop, providing acorns in autumn and fresh leaves in summer (Rigueiro-Rodríguez et al. 2009, San Miguel 1994). In recent decades, a noticeable increase of stocking rates in *dehesas* has taken place, mainly due to an increase in the number of cattle and sheep (Moreno and Pulido 2009).

Crop component: in the traditional *montados* and *dehesas*, the herbaceous layer has been maintained by cereal cultivation over long rotations. Regular ploughing is necessary as an efficient method to avoid shrub colonization. More recently, this practice has been associated with the spread of cork oak diseases (Castro 2008).

Pyrenean oak (*Quercus pyrenaica* Willd) is one of the most abundant and characteristic oak species in the Iberian Peninsula with animal husbandry (Castro 2009) and is mainly found as coppice or in young forests. Pyrenean oak occurs where there is a transition from typical Mediterranean sclerophyllous vegetation to temperate deciduous forests. This type of oak forest is restricted to SW Europe (west-northwest Spain, southwest France, northeast Portugal and some isolated sites in Morocco) and covers about 60,000 ha in Spain and 62,000 ha in Portugal (Castro 2009). They provide a diverse mosaic-like landscape. Generally, the herds feeding on the coppices are not managed under private control but are held and managed by the communities. Similar systems are also found in Greece, mainland Italy and Sardinia (called *seminativo* or *pascolo arborato*).

In Greece, Papanastasis et al (2009) considered that agroforestry included all open forests (i.e. less than 100 m^3 ha^{-1} of timber stock), where the trees had a measurable diameter at breast height of more than 5 cm. They reported that this area was 1,022,252 ha. They assumed that such forests have a crown canopy cover less than 40% and supported an understory with herbaceous or woody vegetation that provides forage to livestock. Some of the forests would include oak species, but many would include *Pinus* species. In Greece, Papanastasis et al (2009) also reported that there are 843,700 hectares of agroforestry systems on agricultural land comprising oaks, wild pears, and other forest trees. However a specific area (29,631 ha) has only be quantified for Valonia oak (*Quercus ithaburensis* subsp. *macrolepis* (Kotschy) Hedge and Yaltirik) as reported by Pantera and Papanastasis (2003) (Table 5).

Transhumance and transtermitance

An important aspect of the dehesas and other wood pasture systems is the movement of animals according to the availability of food within each year. This movement of animals can be carried out in short distances and even in a daily basis is called transtermitance. However, if long distances happen then we describe transhumance systems. A good description of transtermitance systems is described by Castro (2009), while transhumance is described by Bunce et al. (2009).

Table 5. Extent (ha) of agroforestry systems and practices of "High natural and cultural value", based on examination of published literature

System	Practice	Country	Extent (ha)	Arable/ Livestock	Source
Oak dominated agroforestry in Mediterranean	*Dehesa*	Spain	3,606,151	Both/ livestock	Ministerio de Agricultura, Alimentación y Medio Ambiente 2008
	Cork oak *montado*	Portugal	730,000	Both	Inventário Florestal Nacional 2013a
	Holm oak *montado*	Portugal	329,000	Both	Inventário Florestal Nacional 2013a
	Pyrenean oak	Spain	60,000	Livestock	In 2000, Castro 2009
	Pyrenean oak	Portugal	62,000	Livestock	In 1995, Castro 2009
	Grazed woodland (some oak but also *Pinus* on forest land)	Greece	1,022,252	Livestock	Papanastasis et al. 2009
	Oak and other agroforestry on agricultural land	Greece	843,700	Both	Papanastasis et al 2009
	Valonia oak	Greece	29,631	Both	Pantera and Papanastasis 2003
	Grazed oak woodlands	Italy	279,263	Livestock	In 1995, Pardini 2009
	Sub-total (oak tree systems)		**6,961,997**		
Other wood pastures	Wood pasture and parklands	UK	15,000	Livestock	Maddock 2008 (10,000-20,000)
		Germany	75,000	Livestock	Luick 2009
	Hudewald	Germany	5,500	Livestock	Glaser and Hauke 2004
		Austria	40,000	Livestock	Greif 1992
	Wood pasture	Switzerland	52,000	Livestock	Herzog 1998
	European larch (*Larix decidua*)	Italy	102,319	Livestock	Pardini 2009
	Wood pasture	Romania		Livestock	
	Wood pasture and meadows	Hungary	5,500	Livestock	Bölöni et al. 2008
	Lövängar, hagmarker (regular meadows also included)	Sweden	100,000	Livestock	Statistics Sweden 2013
	Haka and *metsälaidun* (1920 and 5400 ha)	Finland	7,320	Livestock	Vainio et al. 2001
	Sub-total(wood pastures and meadows)		**402,639**		
Hedges and scattered trees	Hedgerows & scattered trees	France	342,500	Both	Bélouard and Coulon 2002
	Hedgerows	England, Scotland and Wales	117,174	Both	Forest Commission 2001a, 2001b, 2001c
	Hedgerows	Wallonia, Belgium	12,400	Both	Etat de l'Environnement en Wallonie, 2010
	Sub-total		**470,074**		
Reindeer husbandry		Finland	11,400,000	Livestock	Jernsletten and Klokov 2002
		Sweden	16,000,000	Livestock	Jernsletten and Klokov 2002
		Norway	14,000,000	Livestock	Jernsletten and Klokov 2002
	Sub-total		**41,400,000**		

3.2 Other wood pasture systems

Wood pasture systems also exist in other parts of Europe beyond the oak trees systems in Portugal, Spain, Italy, and Greece. In central, eastern and western Europe, trees can provide shelter to cattle and sheep during the winter months.

In Ireland there exists wood pasture, but there are no real figures about the extent of wood pastures or meadows. The extent of wood pastures in Eastern Finland is also unclear. No estimates of wood pasture were found for France.

In the United Kingdom wood pastures and parklands consist of lowland beech (*Fagus sylvatica*) and yew (*Taxus baccata*) woodland, lowland mixed deciduous woodland, upland mixed ash (*Fraxinus excelsior*) woods, upland oak (*Quercus* spp.) wood, wet woodland, wood pasture, and parkland. Usually they have an open structure where grazing occurs (Figure 7). Oak, beech, hornbeam (*Carpinus betula*) and ash tend to be the most common tree species. There is no precise figure for the extent of wood pasture and parkland in England because it compromises a mixture of land-cover types from dense to open stands. The UK Biodiversity Steering Group report estimates that there are between 10,000 ha and 20,000 ha of parkland in the UK. The New Forest in southern England is one of the largest remaining areas of wood-pasture in temperate Europe, with over 3,000 ha of woodland grazed by ponies, deer, cattle and pigs (Smith 2010), whilst Epping Forest, an historic common, is home to at least 50,000 pollarded trees (at about 30-70 per hectare), many of either veteran or ancient status (Dagley 2006).

Figure 7. Wood pastures in Glenamara, Cumbria, Lake District, UK by Matthew Upson.

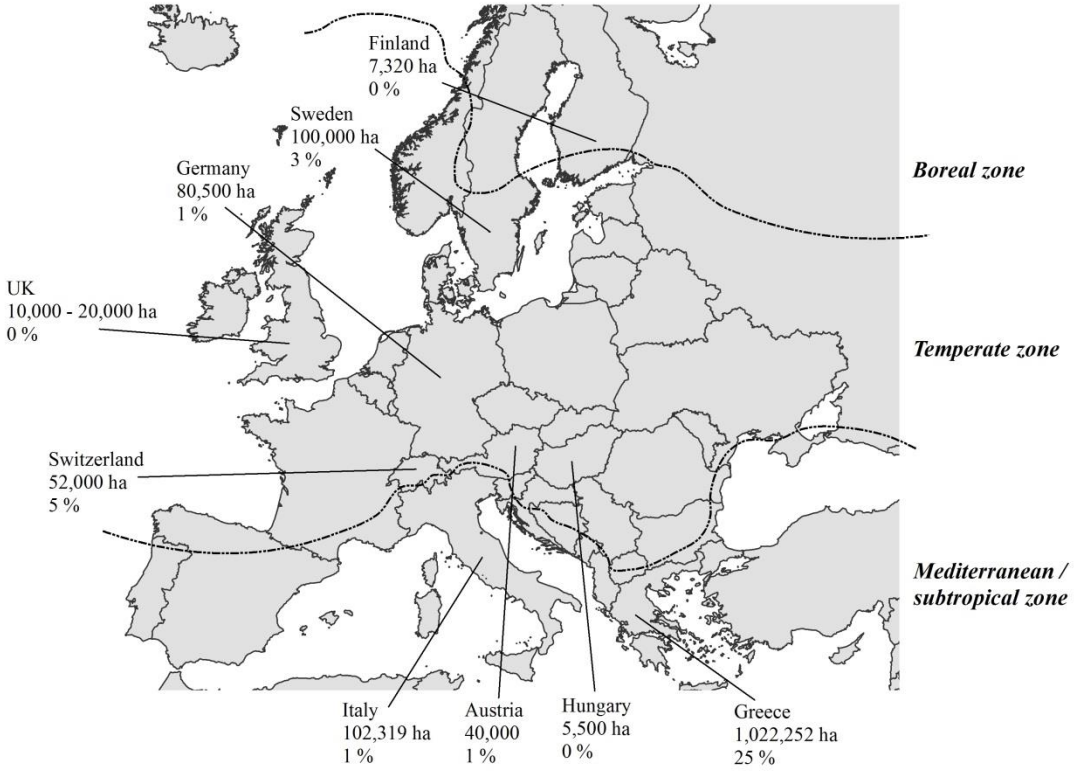

Figure 8. The distribution of wood pastures and meadows in Europe. Estimated area in hectares and as per cent of Utilized Agricultural Area (year 2012) of each country (see Table 5).

In northern Italy, forests of European larch (*Larix decidua*) cover approximately 102,319 ha (Pardini 2009). Some of these forests have pastures under low-density tree stands. Pastures are normally native, comprise 30-60 herbage species, and are important for biodiversity. These pastures are grazed in summer.

Wood pastures, often dominated by oak, can also be found in Eastern Europe although there is little information on their extent (Hartel et al. 2013). Historical information suggests that many wood-pastures from Southern Transylvania in Romania originated from forest grazing and selective tree removal from forests. They are now grazed by a mixture of livestock, mainly cattle, buffalo, horse and sheep. Cattle and buffalo grazing have been traditionally practiced in these landscapes for centuries. Sheep grazing increased in the communist period and afterwards. There was a significant decrease of cattle and buffalo and horse after the collapse of the communism while the number of sheep increased. Most of wood-pastures which were previously grazed by cattle and buffalo are currently grazed by sheep (Tibor Hartel, personal communications). The wood-pasture presented in Figure 9 is still traditionally managed and contains a large number of ancient trees.

Hartel et al. (2013) demonstrated that wood pastures are very important in the conservation of ancient trees, as in their study area in Transylvania, ancient trees were found in the wood pastures but not in surrounding forests. Ancient wood pastures are common in this rural area in Romania and there might in fact be more common in Eastern Europe than previously thought.

Figure 9. Ancient oak-dominated wood-pasture from southern Transylvania, photo by Tibor Hartel.

In Slovenia there exist different types of silvopastoral systems. For instance, grazed forests have been used in the mountain regions of the north part of Slovenia, where dominating tree species are Norway spruce (*Picea abies*) and sometimes fir (*Abies alba* Miller) and beech (*Fagus sylvatica*) are found.

In Fennoscandia, wood pastures cover various habitat types ranging from sparse forest to coppice of trees and scrub, in a mosaic with patches of open grassland. The tree layer consists mostly of deciduous trees, including oak, ash, lime, birch and grey alder, although conifers may also occur. The impact of grazing is a key element and the ground vegetation is characterised by species typical for grassland and meadow habitats. Using outlying forest land for grazing was a traditional way of keeping livestock in most parts of the Nordic countries, often combined with slash-and-burn practice, from the establishment of permanent settlements in Northern Europe around 5000-6000 years ago until recently. This practice started disappearing with the shift towards more intensive livestock husbandry on cultivated land and the use of artificial fertilisers during the 20th century. The changes over the last 100-150 years have resulted in a drastic decline of various kinds of wooded pastures (Eriksson 2008).

3.3 Hedgerow systems and scattered trees

If agroforestry is considered at a farm- or a landscape level, then the hedgerow systems found in France and the UK are examples of the integration of trees with farming systems. They are also considered to have important nature and cultural value. In France, Bélouard and Coulon reported in 2002, that trees outside of forests in France covered 1.7 million ha, and that hedgerows and scattered trees were found on 342,500 ha in 1998.

Estimates of the area of wide hedges (greater than 16 m width) are reported for England, Scotland, and Wales (Forest Commission 2001a, 2001b, 2001c). The area of wide hedges in 2001 was 20,395 ha. The length of hedges narrower than 16 m was 91,181 km in England, 15,291 km in Scotland and 14,502 km in Wales. Assuming a mean width of 8 m, this equate to a hedge area of 96,779 ha, giving a total hedge area (wide and narrow) of 117,174 ha.

In Belgium in the Wallonia region it was estimated that there was about 15,500 km of hedgerows and windbreaks. This would equal to about 16 m of hedgerow per hectare of the Utilized Agricultural Area (Etat de l'Environnement en Wallonie, 2010). Assuming a mean width of 8 m, this would be equivalent to 12,400 ha.

3.4 Reindeer husbandry

Reindeer husbandry is practiced on boreal and subarctic wood-pastures (Figure 10; Figure 11). Reindeer husbandry represents a traditional way of life and has a great economic and cultural importance for many indigenous peoples. The predominant trees are *Betula pubescences* and *Pinus sylvestris* (Bergmeier et al. 2010). The reindeer husbandry area in Finland is the smallest in extent, but has the largest number of reindeer (Figure 11, Table 5). The number of reindeer in Norway, Sweden and Finland has shown a similar development. There was an increase in animals from the 1970's and a peak between 1989 and 1991. After this the trend has been a decline of the herds (Jernsletten and Klokov 2002).

Figure 10. Reindeer round-up before movement to winter grazing area in an area close to Åkroken, county of Jämtland, Sweden by Daana Fjällberg.

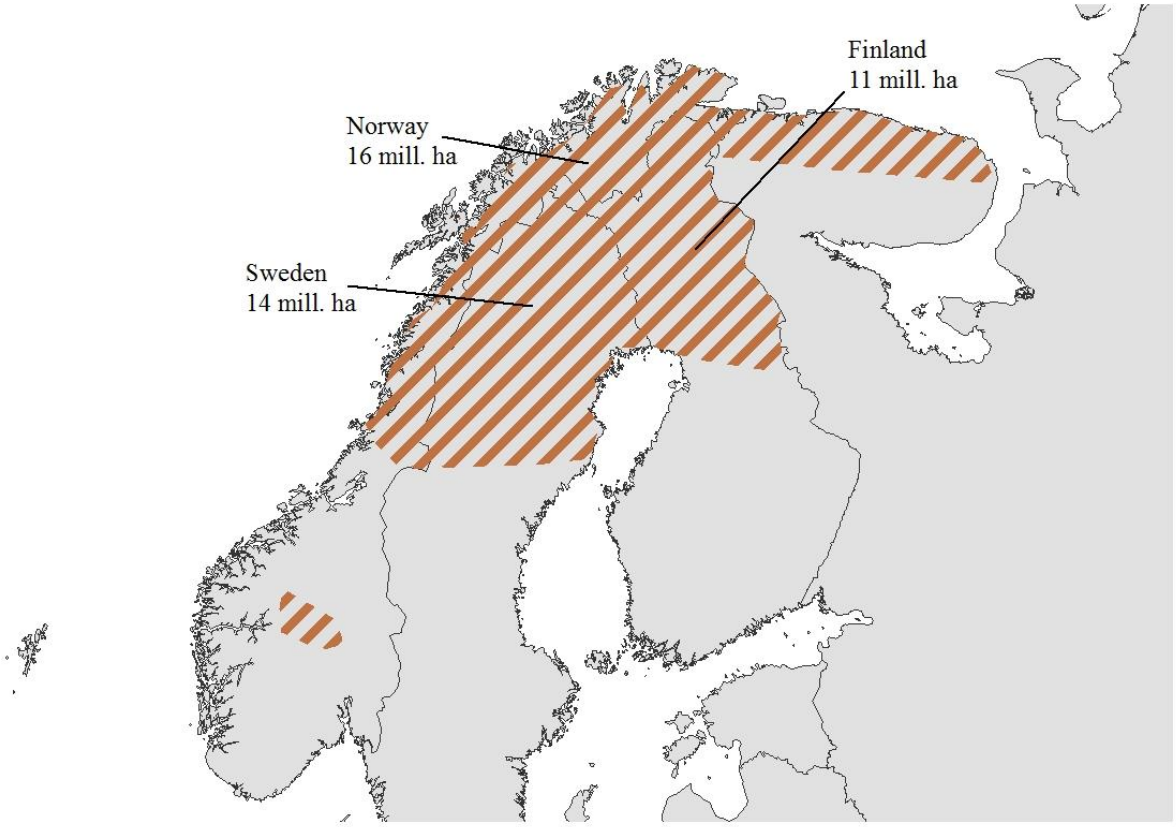

Figure 11. The distribution (ha) of reindeer husbandry in Norway, Sweden and Finland (adapted from Jernsletten and Klokov 2002).

4 Agroforestry with high value trees

The second focus of agroforestry systems is based on the use of high value trees such as fruit trees (e.g. apple, pear, olive, carob, pine-nut, walnut, almond, chestnut,) and trees grown for high value timber (e.g. walnut and wild cherry) (Table 6). Fruit trees cover the largest area in Europe regarding high value tree systems, followed by olive tree systems.

Table 6. High value trees and their functions

High value trees	Functions
Apple *(Malus)*, peach *(Prunus)* and pear *(Pyrus)*, apricot *(Prunus)*, plum *(Prunus)*, quince *(Cydonia)* and fig *(Ficus)*	Fruits
Olive tree (*Olea europaea* L.)	Olives, olive oil, timber, firewood
Wild cherry (*Prunus avium)*	Fruit, timber, the gum from bark
Walnut (*Juglans*)	Nuts, timber, firewood
Italian stone pine (*Pinus pinea)*	Pine nuts, timber, firewood, resin, woodchip
Chestnut (*Castanea*)	Nuts for human food and fodder for animals, timber, tannin, firewood
Holm oak (*Quercus ilex)*	Cork, timber, acorns for feed, leaves for fodder, tannin
Carob (*Ceratonia siliqua)*	Dried pods for human consumption and animal fodder the seeds source of a food thickening agent (E410 as in E-number)

High value trees can be fruit and/or other trees randomly or systematically planted in cropland or pasture. High value tree products can have a significant market value. Examples of wood-based products include timber, poles, paper fibre, firewood, and charcoal. Non-timber products primarily focus on fruits but can include the leaves (as flavouring or for tannins) and the bark, for example cork. Cork is an important product from cork oak, which can be used in construction, bottle cork and several industries. Tannin is used for leather tanning and for extraction of several products. Traditionally tannery products come from chestnut and oaks. Nowadays, the natural tannery products have been largely replaced by synthetic ones.

4.1 Agroforestry with fruit trees

Up until the last century, most fruit production systems incorporated the grazing of animals or the intercropping of crops. For example, silvoarable systems for fruit and nut production covered large areas of central Europe (Smith 2010). Long-established systems remain in certain countries, such as 18,000 ha of almond trees with cereals or fodder in Sicily, and 10,200 ha of fig trees with cereals in Crete and the Aegean islands (Eichhorn et al. 2006) (Table 7). Many of the fruit tree systems are in the Mediterranean and central Europe (Figure 12, Table 7). Some fruit tree systems probably exist in Scandinavia but their extent is small and the system has almost completely disappeared (Herzog 1998).

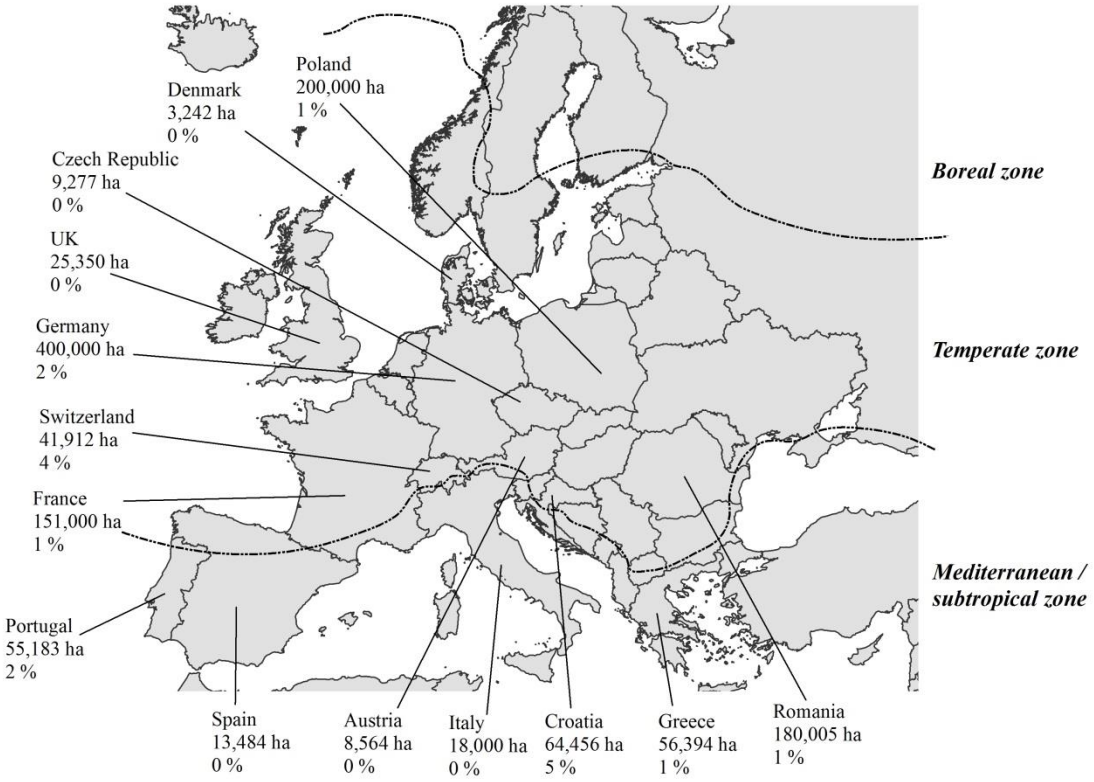

Figure 12. The distribution of fruit tree systems in Europe. Estimated area in hectares and as per cent of the Utilized Agricultural Area (year 2012) of each country (see also Table 7).

Streuobst is a traditional agroforestry system found in continental and central Europe. It is defined as tall trees of different types, varieties and ages of fruit, scattered in croplands, meadows and pastures. The tree density varies from 20 to 100 trees per hectare or more (Herzog 1998). There exist silvoarable (s*treuobstäcker*) and silvopastoral (s*treuobstwiesen*) s*treuobst* practices (Smith 2010). Fruit tree alleys along streets are also considered a form of *streuobst*. Fruit trees in gardens, on the other hand, are not treated as *streuobst* (Herzog 1998).

Table 7. Extent (ha) of agroforestry systems and practices with high value fruit trees

Practice	Country	Extent (ha)	Arable/ Livestock	Source
Streuobst	Germany	400,000	Arable/Both	Eichhorn et al. 2006
	Switzerland	41,912	Arable/Both	Herzog 1998
	Austria	8,564	Arable	in 1993 Herzog 1998
	Croatia	64,456	Arable	In 1996, Herzog 1998
	Romania	180,005	Arable	In 1996, Herzog 1998
	Poland	200,000	Arable	In 1996, Herzog 1998
	Czech Rep.	9,277	Arable	Herzog 1998
Pré-vergers	France	151,000	Arable/Both	In Ducros et al. 2005 in Eichhorn et al 2100 ha; 163000 ha in Bélouard, and Coulon 2002
Traditional orchards	UK	25,350	Arable	Robertson et al. 2010 suggest 24,600 ha in England, but Burrough et al (2010) report 16,992 ha for England in a more comprehensive study.
Orchards	Denmark	3,242		Statistics Denmark 2013 apples 1563 ha, pears 299 ha, cherry 1380 ha)
Prunus dulcis	Italy	18,000	Arable	Cullotta et al. (1999) in Eichhorn et al. 2006
Pomaradas	Spain	13,484	Arable	INE (2002) in Eichhorn et al. 2006. (but 464000 in 1997 (Eichhorn et al)
Citrus trees (orange, lemon, mandarin, etc)	Greece	6,498	Arable	Papanastasis et al. 2009
Fruit trees (apple, pear, peach, apricot, cherry, etc)	Greece	17,700	Arable	Papanastasis et al. 2009
Nuts and dried fruits (almond, walnut, fig)	Greece	20,952	Arable	Papanastasis et al. 2009 reports 41,352 ha for nuts and dried fruits, but this figure also includes chestnut and carob which are reported separately in this table (see further down).
Other trees: incl. Plum, mastic, poplars, cypress	Greece	11,244	Arable	Papanastasis et al. 2009
Almond orchards	Portugal	38,049	Arable/Both	Anuario Vegetal (2006)
Hazel nut (mostly as scattered trees or in hedgerows)	Portugal	585	Both	Anuario Vegetal (2006)
Cherry orchards	Portugal	6,255	Arable/Both	In 2005, Anuario Vegetal (2006)
Fig orchards	Portugal	7127	Arable/Both	In 2005, Anuario Vegetal (2006)
Walnut orchards	Portugal	3167	Arable/Both	In 2005, Anuario Vegetal (2006)
Total		**1,226,867**		

Figure 13. Sweet cherry in combination with vegetables on an organic farm in north-western Switzerland by Felix Herzog

Today s*treuobst* systems occupy approximately one million hectares in 11 European countries (Herzog, 1998). It has an essential impact on the fruit production and markets in Europe. *Streuobst* systems are less profitable for farmers than intensive orchard systems, mainly due to their higher requirements for labour input. However *streuobs*t systems have many ecological and socio-cultural advantages and it has particular value in terms of landscape aesthetics, biodiversity, recreation and regional identity (Herzog 1998). Eichhorn et al. (2006) observed that *streuobst* declined by 50 percent during the last century, mainly due to intensification, increased mechanisation and abandonment of subsidy programmes. Nowadays, *streuobst* systems are again supported by non-governmental organizations, state conservation policies and agri-environmental schemes in many countries (Herzog, 1998).

Pré-verger systems in France are associated with fruit trees (apple, peach and walnut are the most common) mixed with meadows and sometimes grazing animals. Such *pré-vergers* systems in France cover about 150,000-168,000 ha, especially in Normandy, Bretagne and Pay de Loire (Eichhorn et al 2006, Bélouard and Coulon, 2002). The tree density is about 50 to 100 trees per ha, where animals graze and trees provide shade. As a silvoarable system, they may be intercropped for the first five to 15 years of a 30-year cycle (Eichhorn et al. 2006). Fruit trees are usually combined with crops such as maize, sorghum, soybean, oil-seed rape, sunflower, tobacco, alfalfa, lavender and bush fruits.

In the UK, traditional orchards share some of the characteristics of the *Pré-verger* systems and are considered a priority habitat under the UK Biodiversity Action Plan (BRIG 2007). These systems,

combine fruit trees (predominantly apple, pear, and plum) with grazing at planting densities similar to *Pré-vergers*, traditionally up to around 170 trees per ha (Hoare 1928). Around 16,992 ha of traditional orchards remain in England (Burrough et al. 2010) concentrated in Herefordshire, Worcestershire, Gloucestershire, Somerset and Devon (Table 7). Of those that are still actively managed, many continue to be grazed by a combination of sheep, cattle, horses, pigs, and fowl.

Bouguards in the Netherlands are high-growing fruit tree systems with an understory of grass which is mowed or grazed by cattle and sheep (Oosterbaan & Kuiters 2009). Since the 1970s most of the high-stem fruit tree orchards have been replaced by more intensive low stem trees of new cultivars, with trees planted at high densities. In these more intensive orchards the combination with livestock farming did not work out particularly well. Only in combination with poultry it is sometimes combined successfully.

Pomaradas in Spain are usually apple trees planted either in lines or scattered trees in meadows and arable croplands containing maize or vegetables. The system has declined dramatically over the last 35 years (Smith 2010). They exist especially in the Atlantic biogeographic region of Spain in Galicia, Asturias, Cantabria and in the Basque country. Throughout the Mediterranean region, small orchards of walnut, almond, peach, apricot and olive are intercropped with vegetables and cereals. In Greece, mulberry (*Morus nigra*), fig (*Ficus carica*) and common pear (*Pyrus communis*) are intercropped with maize, other cereals, tobacco, fodder legumes, vegetable and grape vines.

4.2 Olive agroforestry

According to Papanastasis (2008), the olive tree (*Olea europea* L.) is the most important planted evergreen species forming agrosilvopastoral systems in the Mediterranean region (Figure 14). In Europe, olive tree systems are confined to the Mediterranean region (Figure 15; Table 8). Olives provide a great economic and socio-cultural significance for the Mediterranean region, where 98 % of the world's olive production is located (Kiritsakis 1998, Papanastasis et al. 2009). Olive tree systems are multipurpose, offering both olives for human consumption (including table olives and olives for olive oil) and foliage for animal feed. The area of olive agroforestry expands the analysis of Eichhorn et al. (2006) by including a value for Portugal. The olive agroforestry area in Greece of 650,000 ha reported by Schultz et al (1987), and quoted by Eichhorn et al., has been replaced by the value of 124,311 ha from Papanastasis et al. (2009).

Figure 14. Olive trees intercropped in Lesvos, Greece, by Vasileios Papanastasis

Figure 15. The distribution of olive tree systems in Europe. Estimated area in hectares and as per cent of the Utilized Agricultural Area (year 2012) of each country (see also Table 8).

Table 8. Extent (ha) of agroforestry systems and practices with high value trees such as olive trees, vines, chestnut trees and pine trees

System	Practice	Country	Extent (ha)	Arable/ Livestock	Source
Olive tree systems		Spain	15,030	Arable/both	INE (2002) in Eichhorn et al. 2006
	Olive groves for olive oil	Portugal	365,308	Arable	In 2005, Anuario Vegetal (2006)
	Olive groves for table olives	Portugal	11,216	Arable	In 2005, Anuario Vegetal (2006)
	Both for table olives and oil	Greece	124,311	Arable	Papanastasis et al. 2009
		France	3,000	Arable	F. Liagre (Eichhorn et al. 2006)
		Italy	20,000	Arable/both	ISTAT 1990 (Eichhorn et a. 2006)
	Sub-total		**538,865**		
Vine tree systems	*Piantata*	Italy, Sicily	153,030	Arable	In 2002, Eichhorn et al. 2006
		Spain	48,605	Arable	in 2002, Eichhorn et al. 2006
	Vinhos verdes (not necessarily all in agroforestry)	Portugal	74,000	Arable	Altieri & Nicolls 2002
	Sub-total (vines)		**275,635**		
Chestnut systems	*Souto*	Portugal	30,097	Arable/both	in 2005, Anuario Vegetal (2006)
		France	7,330	Arable/both	In 2004, Anuario Vegetal (2006)
		Greece	7,800	Arable/both	In 2004, Anuario Vegetal (2006)
		Italy	23,500	Arable/both	In 2004, Anuario Vegetal (2006)
	Chestnut orchards	Hungary	900	Arable/both	Conedera et al. 2004
	Chestnut orchards	Romania	100	Arable/both	Conedera et al. 2004
	Chestnut orchards	Slovakia	92	Arable/both	Conedera et al. 2004
	Chestnut orchards	Slovenia	185	Arable/both	Conedera et al. 2004
	Chestnut orchards	Spain	37,679	Arable/both	Conedera et al. 2004
	Chestnut orchards	Switzerland	3,400	Arable/both	Conedera et al. 2004
	Sub-total (chestnut)		**111,083**		
Carob tree systems		Italy	8,800	Both	Anuario Vegetal (2006)
		Portugal	11,800	Both	Anuario Vegetal (2006)
		Spain	59,000	Both	Anuario Vegetal (2006)
		Greece	12,600	Both	Anuario Vegetal (2006)
	Sub-total (carob)		**92,200**		
Pine tree systems		Italy	362,126	Livestock	Pardini 2009
	Pinheiro manso	Portugal	173,716	Livestock	In 2010, Inventário Florestal Nacional (2013b)
	Sub-total (pine)		**535,842**		
Total			**1,553,625**		

Olive tree agroforestry typically comprises olive trees intercropped with cereals, vegetables and fodder crops. Olive trees associated with grape vines are also quite common thus the two systems often overlap. The Common Agricultural Policy provided substantial support across the EU for the establishment and maintenance of olive systems, typically on poor soils, sloping sites and dry environments (Schultz et al. 1987). However, the removal of production related subsidies threatens the financial sustainability of many olive systems and policies are needed to prevent the further abandonment of such systems. The systems are also vulnerable to climate change and its impacts on drought, fire and wind damage (Hemery et al. 2010).

4.3 Vine agroforestry

Vine agroforestry systems mainly combine the vines with other crops. For example, in northern Portugal, *Quercus lusitanica, Ulmus* spp. and *Prunus* are used in vineyards as living trellis to support vines (*Vitis vivifera).* In the intermediate spaces between the grape rows, maize and vegetables are grown (Altieri & Nicholls 2002).

Virtually all the Portuguese *vinho verde* is produced in the Minho region in northwest Portugal. Approximately 26% (74,000 ha) of the agricultural area in the *vinho verde* region is devoted to grape production (Altieri & Nicholls 2002). *Vinho verde* grapes are traditionally grown on trees bordering crop fields in Portugal. The combination of high vine and maize is characteristic of the area. The systems preferred host trees are Portuguese oak (*Quercus lusitanica*), elm (*Ulmus* sp.), poplar (*Populus* sp.) and wild cherry (*Prunus* spp.).

Joualle and *houtain* systems in France are associations with vegetables, fruits and cereals with grapes, "pêches de vigne". *Joualle* is composed of rows of grapevine with peach, walnut and olive trees. In *houtains* the trees are used to support the vines (a distance of 5 m between the trees). To maximise returns, the gaps between the rows are planted with cereals. *Joualle* is associated with lavender and with truffle. There exists no clear data about the extent of vine tree systems in France.

In Italy vines were typically grown on live trellis such as different maple (*Acer* spp.), ash (*Fraxinus* spp.), elm (*Ulmus* spp.) species and less frequently on other species. In the south of the country, very high curtains of vine were obtained using live poplars (*Populus* spp.) as poles to hold the wires. Nowadays, these systems have all disappeared (Adolfo Rosati 2015, personal communication).

4.4 Pine tree agroforestry

In Portugal, stone pines *Pinus pinea* occupy an area of approximately 173,716 hectares (Inventário Florestal Nacional 2013b), of which 68% are located in the Alentejo region and the remaining 32% in Ribatejo region (Anuario Vegetal 2006). More than 50% of the annual pine cone production comes from the Grândola and Alcácer do Sal municipalities. The latter is even called the "*Solar do Pinheiro Manso*" ("Stone Pine Manor"). Pine cone production does not have any particular demands in terms of costs but has strong social and economic impacts as traditional harvest involves a lot of labour and is relatively well paid (Anuario Vegetal 2006).

In Italy, *Pinus pinea* and *Pinus pinaster* forests are mainly distributed in the central part of the country and cover about 362,126 ha. The understory normally consists of unpalatable shrubs, and

livestock are only occasionally grazed on them. These systems support horse riding and trekking from nearby farms, forming an important source of additional income for local farms. Public administration benefits from tourism in the municipalities in which these systems are present, whilst pine nut harvesting is also a valuable source of income (Pardini 2008).

4.5 Chestnut agroforestry

Chestnut (*Castanea sativa* Mill.) is a multipurpose species that is cultivated for timber, nut and tannin production. No official data on the distribution of the European chestnut exist, but Conedera et al. (2004) recorded a total of 2.25 million hectares of forest dominated by chestnut with 1.78 million hectares (79%) cultivated for wood and 0.43 million hectares (19%) for fruit production. In countries with a strong chestnut tradition (Italy, France, southern Switzerland, Spain, Portugal and Greece), sweet chestnut has been cultivated for centuries in coppices or orchards (Conedera et al. 2004). In northern Portugal and Galicia it has been cultivated since the Roman times. Chestnut ecosystems are an important silvopastoral system in mountain regions and in Galicia and Portugal chestnut forests cover around 40,000 and 35,000 ha respectively. Chestnut orchards for nut production are called "*soutos*" in Portuguese and Galician languages. In the Bragança region in Portugal, chestnut orchards are frequently intercropped with cereals for direct consumption by sheep. Chestnut orchards are mainly grazed by sheep as the owners exclude goats since they can damage the bark of the trees (Castro 2009). Pigs are also fed with the non-commercial chestnut fruits or within the chestnut forest. Chestnut trees could also be used as a silvopastoral system when coppiced, similar to Pyrenean oak. This form of management was practiced for millennia to manage crops for timber production in short rotations. Most stands are currently over-mature or have been abandoned (Castro 2009).

4.6 Carob tree agroforestry

Carob (*Ceratonia siliqua* L.) trees are used as fodder and can be intercropped with cereals and fodder legumes. The pods are used as raw material for the food processing industry, e.g. as a substitute for cacao. Carobs are cultivated mainly in Mediterranean countries, particularly Spain, Portugal, Italy, Greece, Malta, Cyprus, Morocco and Turkey, which together account for approximately 92% of the global production (Anuario Vegetal 2006, Eichhorn et al. 2006). In Portugal, carobs were the only crop of the traditional non-irrigated orchard of which the area under cultivation and production increased as recently as the year 2006 (Anuario Vegetal 2006). However, more recent data have not been found.

5 Agroforestry in arable systems

The fourth work-package of the AGFORWARD project focuses on the integration of trees in arable systems. Cropland is the dominant agricultural land cover in much of Europe (Table 9). In Hungary (47%) and Denmark (48%) the proportion of the land that is cropped is almost 50%. The lowest proportional areas of cropland in the European Union are 4-6% in Finland and Sweden (Table 9) (where crop production is limited by low temperatures) and 5% in Ireland, where high rainfall means that the principal land cover is grass.

Many of the negative environmental impacts associated with agriculture are associated with the intensive production of arable and horticultural crops often in short rotations. These negative effects include reduced soil and water quality, loss of biodiversity including pollinators, and greenhouse gas emissions. Reisner et al. (2007) reported that it was possible to profitably integrate trees and crops and reduce soil erosion and nitrate leaching on 40% of the European arable land. Palma et al. (2007) demonstrated that landscape biodiversity could also be increased by the introduction of agroforestry systems.

There exist a range of potential ways of integrating trees into arable systems. These include alley cropping, buffer strips, windbreaks, hedgerows, and shelterbelts. These practices can be found all over Europe. Nevertheless, precise and reliable information about the current extent of such agroforestry practices is lacking.

5.1 Linear features with trees

Linear features with trees include buffer strips, windbreaks and hedgerows (Schoeneberger et al. 2012). They can improve landscape aesthetics, increase biodiversity, and provide a range of provisioning and regulating environmental services.

Buffer strips are strips of perennial vegetation (tree/shrub/grass), which are planted between croplands/pastures and water sources (streams, lakes, wetlands) to protect water quality. The tree root systems have a potential to absorb nutrients leaching from the soil below the grass or crops. Riparian buffer strips are of particular value as they protect water bodies against sedimentation, soil erosion and nitrate contamination (Mosquera-Losada et al. 2009). The Food and Agriculture Organization of the United Nations considers trees forming riparian strips and line forests (hedgerows, shelterbelts, windbreaks/belts) to belong under the definition of “trees outside forests” (de Foresta et al. 2013).

Windbreaks are practices where trees are planted in rows to control wind damages to crop. The windbreaks are formed by various parallel tree lines at least 10 meters apart. Windbreaks can also be used in livestock systems to improve animals’ health, reduce heat stress and enhance fodder production.

Table 9. Rural land cover in the EU (primarily as determined by the LUCAS 2009 dataset) (Hart et al 2013)

Member State	Total Total Land Area (ha)	Artificial land Area (ha)	(%)	Cropland Area (ha)	(%)	Woodland Area (ha)	(%)	Shrubland Area (ha)	(%)	Grassland Area (ha)	(%)	Bareland Area (ha)	(%)	Water Area (ha)	(%)	Wetland Area (ha)	(%)
Austria	8,392,100	430,600	5%	1,457,700	17%	3,944,700	47%	143,200	2%	1,948,800	23%	250,900	3%	176,700	2%	39,500	0%
Belgium	3,066,600	300,800	10%	824,800	27%	812,300	26%	22,900	1%	1,025,600	33%	33,600	1%	43,800	1%	2,800	0%
Bulgaria	11,096,100	557,994	5%	2,771,160	25%	3,927,000	35%	737,510	7%	2,980,600	27%	15,022	0%	95,793	1%	11,068	0%
Cyprus	924,600	78,393	8%	144,150	16%	387,047	42%	195,092	21%	108,700	12%	7,125	1%	1,589	0%	2,483	0%
Czech Rep	7,887,000	331,200	4%	2,799,000	35%	2,948,900	37%	40,200	1%	1,583,800	20%	54,400	1%	105,400	1%	24,100	0%
Denmark	4,285,300	276,000	6%	2,075,700	48%	787,300	18%	49,600	1%	942,500	22%	42,200	1%	70,900	2%	41,100	1%
Estonia	4,345,200	81,000	2%	502,500	12%	2,384,200	55%	43,700	1%	828,900	19%	38,500	1%	221,900	5%	244,500	6%
Finland	33,576,500	520,700	2%	2,019,400	6%	22,857,800	68%	1,390,700	4%	981,900	3%	433,000	1%	3,415,400	10%	1,957,600	6%
France	54,876,300	2,848,000	5%	16,691,900	30%	17,386,800	32%	1,817,200	3%	14,658,700	27%	531,700	1%	800,300	1%	141,700	0%
Germany	35,711,400	2,435,800	7%	11,811,500	33%	12,093,400	34%	208,200	1%	8,134,800	23%	237,500	1%	624,300	2%	165,900	0%
Greece	12,016,700	384,000	3%	2,833,600	24%	4,008,100	33%	2,580,600	21%	1,600,700	13%	312,900	3%	216,800	2%	80,000	1%
Hungary	9,301,200	341,100	4%	4,417,400	47%	2,156,200	23%	149,900	2%	1,893,000	20%	48,300	1%	181,100	2%	114,200	1%
Ireland	6,988,300	277,700	4%	350,000	5%	819,100	12%	418,000	6%	4,476,600	64%	56,600	1%	188,600	3%	401,700	6%
Italy	30,139,200	2,186,800	7%	10,033,300	33%	9,995,000	33%	1,566,400	5%	4,904,000	16%	644,400	2%	745,500	2%	63,800	0%
Latvia	6,459,900	106,600	2%	784,000	12%	3,390,600	52%	155,900	2%	1,620,800	25%	55,500	1%	191,300	3%	155,200	2%
Lithuania	6,481,800	167,500	3%	1,576,600	24%	2,380,000	37%	53,400	1%	2,021,500	31%	43,400	1%	204,000	3%	35,400	1%
Luxembourg	259,600	19,200	7%	56,400	22%	92,800	36%	400	0%	86,300	33%	2,100	1%	2,400	1%	-	0%
Malta	31,600	9,270	29%	10,330	33%	347	1%	3,927	12%	7,700	24%	-	0%	-	0%	25	0%
Netherlands	3,735,700	491,800	13%	882,200	24%	443,900	12%	54,300	1%	1,397,500	37%	34,700	1%	410,300	11%	21,000	1%
Poland	31,192,500	1,133,500	4%	10,956,800	35%	10,763,500	35%	204,400	1%	7,139,500	23%	245,100	1%	624,900	2%	124,800	0%
Portugal	8,884,000	467,700	5%	1,647,400	19%	4,083,800	46%	939,900	11%	1,222,400	14%	354,100	4%	129,200	1%	39,500	0%
Romania	23,845,600	1,500,908	6%	9,212,900	39%	6,733,000	28%	576,018	2%	4,164,600	17%	22,008	0%	445,922	2%	342,615	1%
Slovakia	4,901,300	119,400	2%	1,388,100	28%	2,261,000	46%	128,800	3%	925,500	19%	18,900	0%	54,100	1%	5,500	0%
Slovenia	2,028,000	68,700	3%	215,300	11%	1,283,800	63%	47,300	2%	364,900	18%	28,700	1%	13,000	1%	6,300	0%
Spain	49,349,800	1,760,700	4%	15,001,300	30%	15,745,600	32%	6,898,500	14%	6,869,100	14%	2,568,400	5%	425,500	1%	80,700	0%
Sweden	44,915,900	679,400	2%	2,000,300	4%	29,647,800	66%	2,658,700	6%	1,874,000	4%	1,032,200	2%	4,086,200	9%	2,937,300	7%
UK	24,443,600	1,630,100	7%	4,853,800	20%	3,614,700	15%	2,502,400	10%	10,366,300	42%	408,100	2%	578,200	2%	490,000	2%
EU-12	108,494,800	4,495,565	4%	34,778,240	32%	38,615,594	36%	2,336,147	2%	23,639,500	22%	576,955	1%	2,139,004	2%	1,066,191	1%
EU-15	320,641,000	14,709,300	5%	72,539,300	23%	126,333,100	39%	21,251,000	7%	60,489,200	19%	6,942,400	2%	11,914,100	4%	6,462,600	2%
EU-27	429,135,800	19,204,865	4%	107,317,540	25%	164,948,694	38%	23,587,147	5%	84,128,700	20%	7,519,355	2%	14,053,104	3%	7,528,791	2%

Based primarily on LUCAS 2009 data with supplementary data provided from information set out in Table 1 in Hart et al. (2013) for Romania, Bulgaria, Malta and Cyprus.

In Hungary, landscape elements containing shelterbelt-systems were estimated at around 16,415 ha in 2001 (Takáczs & Frank 2008). Shelterbelt systems mean all areas bordering cultivated areas, where the area of the shelterbelt is less than 10% of the agricultural area. They are important for conserving the soil and adding spatial heterogeneity.

Hedgerows are usually made of trees or thorny bushes to separate land parcels of different owners (Herzog 2000). This kind of agroforestry practice reached its peak in the 18th century after which it started to decline. It is estimated that since 1969 between 40-80% of the hedgerows have disappeared in Europe due to the reallocation of agricultural holdings in order to create larger field plots (Herzog 2000). Hedgerows in France and parts of the UK and Belgium have been described in Section 3.3.

In WP4 of the AGFORWARD project, several demonstration case studies are focussing on linear features with trees (AGFORWARD 2014). The demonstration case in the Veneto region in north-eastern Italy, covers about 65 ha with about 15 ha occupied by an agroforestry system established in 2013. The agroforestry system comprises oaks and poplar intercropped with cereals. Tree species are planted along the border of the fields with a distance of about 35 m between the rows. Along these rows, poplars are planted at approximately 10 m intervals, alternated with oak (*Quercus robur*) (Figure 16). In the demonstration case in Voio in northern Greece, arable fields containing field beans, cereals and grassland are bordered by walnut trees and fast growing poplars (Figure 17).

Figure 16. Oaks (not visible) and poplars planted in linear formations in a cereal field in north-eastern Italy, photo by Piero Paris.

Figure 17. Trees with arable crops and grassland in Macedonia, Greece by Anastasia Pantera.

5.2 Within-field agroforestry

Trees can also be planted, either in single or grouped rows, within agricultural or horticultural fields whilst allowing machinery to operate in alleys between the trees (Mosquera-Losada et al. 2009). Depending on the spacing between the rows, in the later stages of tree development, canopy closure may prevent crop growth. As a rule of thumb, once tree height exceeds the width of the alley, the system is often no longer suitable for cropping.

Poplar intercropped with cereals (e.g. maize) became fashionable in France in the 18th century, and still covers about 6,000 ha in well irrigated alluvial regions (Eichhorn et al. 2006) (Table 10).

In WP4 of the AGFORWARD project, several case studies are focussing on alley cropping systems (http://www.agforward.eu/index.php/en/FarmerNetworks.html). One demonstration case is in the Languedoc-Roussillon region in the south of France. The focus of this group is on field crops such as durum wheat, chickpea, and canola in such systems. Another demonstration case of alley cropping is situated in Fajsz, Bács-Kiskun county in the Hungarian Great Plains. In Hungary, the extent of alley cropping is not known, but it seems that it has not been widely adopted, except in small gardens and orchards. Modern alley cropping systems seem limited to small farms or newly established pilot systems. In the AGFORWARD demonstration case, the agroforestry system consists of *Paulownia tomentosa* var. *Continental E*. in rows and alfalfa as intercrop. The total area of the experimental and demonstration site is two hectares, one hectare of which is alley cropping, and one hectare of alfalfa managed as a monoculture. In the demonstration site in Germany, alley cropping systems combine rows of fast growing trees, for example, poplar, black locust or willow, with agricultural crops. However, this system is not yet common practice in Germany and exists currently at the experimental field level only (Figure 18).

Figure 18. Alley cropping system of poplar (*Populus* spp.), black locust (*Robinia pseudoacacia*) and winter wheat, northeastern Germany. Photo by Dirk Freese.

Table 10. Extent (ha) of other agroforestry practices focused on the integration of trees in arable systems or livestock systems

Practice	Country	Extent (ha)	Arable/ livestock	Source
Shelterbelts	Hungary	16,415	Both	Takács and Frank 2008
Alley cropping with poplar	France	6,300	Arable	Segouin and Valadon (1997) quoted by Eichhorn et al 2006; Liagre 2002.
Trees in rows with livestock	Netherlands	3,000	Livestock	Oosterbaan & Kuiters 2008

6 Agroforestry practices for livestock systems

The fifth work-package focuses on the application of agroforestry in livestock production. This can include forest and woodland grazing, open forests or tree plantations either with wild or domestic animals.

Ruminant livestock enterprises are associated with grasslands, which occupies about 20% of the land area of the EU-27 (Table 9). The highest proportions of grassland are in the Netherlands (37%), UK (42%) and Ireland (48%). The lowest proportional areas of grassland in the European Union are 3-4% in Finland and Sweden (both are countries with a high forest cover ranging from 66-68%). However even for ruminant production systems, the off-farm costs of feed can be high ranging from 1,460€/farm in Romania to 52,718€/farm in Sweden (Table 11). A significant number of livestock production enterprises in Europe, and particular pig and poultry production, occur separate from grassland areas within purpose-built sheds with food purchased from other farms (Table 11). The highest expenditures on feed for pigs and poultry are in the Netherlands (61,752€/farm) and Denmark (101,975€/farm) and the lowest in Romania (514€/farm).

Table 11. Off-farm inputs (€/farm) in 2012, feed for grazing livestock, pigs and poultry in the EU (Data from Farm Accountancy Data Network).

Country	Feed for grazing livestock[1] (€/farm)	Feed for pigs and poultry (€/farm)
Austria	5,090	7,038
Belgium	26,023	47,791
Bulgaria	2,657	3,193
Cyprus	10,573	4,471
Czech Republic	41,392	24,067
Denmark	47,518	101,975
Estonia	20,683	6,299
Finland	21,298	7,103
France	14,910	13,336
Germany	23,964	27,875
Greece	3,011	593
Hungary	5,415	9,307
Ireland	18,298	155
Italy	4,775	2,055
Latvia	8,152	3,774
Lithuania	5,244	2,156
Luxembourg	24,982	14,180
Malta	7,558	8,723
Netherlands	32,755	61,752
Poland	2,292	4,714
Portugal	4,070	3,095
Romania	1,460	514
Slovakia	89,700	19,259
Slovenia	6,959	1,422
Spain	6,370	4,089
Sweden	52,718	10,336
United Kingdom	50,084	15,198
Average (€/farm, whole EU)	**7,575**	**6,248**

[1]Concentrated feeding stuffs (including mineral licks and preservatives), coarse fodder, expenditure on the use of common grazing land, cost of renting forage land not included in the UAA for equines, cattle, sheep and goats.

Intensive livestock production can lead to negative environmental impacts such as methane production by ruminants, ammonia and nitrous oxide (Burgess and Morris 2012). It is estimated that meat and dairy consumption in Europe is responsible for 14% of the total CO_2 emission in the EU (Weidema et al. 2008) and livestock production is considered a major driver in global land use changes with impacts on climate change and biodiversity. Hence many farmers are seeking ways to make livestock production more sustainable.

Combining trees with livestock is seen as one method to mitigate ammonia emissions and to store more carbon as an offset for methane and nitrous oxide emissions due to the reduction of air speed and temperature which avoid volatilisation. Measures to estimate emissions have been specifically drawn for agroforestry (Eve et al 2014). Animal welfare is another important aspect in livestock production. Agroforestry livestock systems have been demonstrated to have welfare benefits for the animals, for example woodland hens in the UK (Burgess et al. 2014).

Agroforestry combining animals and trees are often called "silvopastoral" systems. Such systems include the wood pasture and reindeer systems considered under high nature and cultural value agroforestry in Section 3. They also included the grazed orchard systems described in Section 4. Hence the rest of this section considers other livestock agroforestry practices that have not been described.

Woodland egg, poultry and pig production

There are several demonstration cases in WP5 of the AGFORWARD project focussing on agroforestry for livestock systems (AGFORWARD 2014). The participating farm situated in Terschuur in the Netherlands rears about 20,000 slow-growing broilers in a stable with a free-range area in which 550 cherry trees are planted. The other Dutch demonstration case near Winterswijk combines organic poultry farming with the growing of walnut trees. In the UK, some of the eggs produced by hens with access to areas of trees are marketed as woodland eggs (Figure 19). At a minimum, all woodland eggs follow the standards for free-range egg production. To qualify as woodland eggs, the UK Woodland Trust specifies 20% cover in the free range area with some trees within a 20 m distance from the shed. In the demonstration cases in Denmark, pigs and poultry are combined with fruit and vegetable production. In addition, some Danish organic pig producers have established combinations of free-ranging pigs and energy crop production (Figure 20).

One of the WP5 demonstration cases is focussing on *Celta pigs* or "*porco celta*", an autochthonous pig breed of Galicia in North West Spain. The breed is believed to derive from northern-central European pig breeds. They are usually farmed in semi-extensive or extensive conditions in forest areas where chestnut (*Castanea sativa* Miller) and oak (*Quercus robur* L.) trees are dominant. Silvopastoralism with this pig breed could increase social and economic benefits and reduce fire risk, as Galicia is one of the most fire-prone areas of Europe.

Fodder crops

In another demonstration case, the farmers are part of a group of farmers called 'Overlegplatform Duinboeren' ("Dune farmers") in the southern part of the Netherlands. During a former project, four test sites with fodder trees were planted on four farms (http://www.voederbomen.nl). Within the original project dairy goats were allowed to browse on fodder trees such as willow (*Salix* spp).

Figure 19. Woodland chicken system in the county of Devon, UK, by Jo Smith

Figure 20. Pigs and rows of willow for energy crop production in Denmark by Anne Grete Kongsted.

7 Other agroforestry practices

There are also other agroforestry systems which have not been covered in sections 3, 4, 5 and 6, which are briefly discussed in this section for completeness. They include forest grazing, grazed heathlands, agroforestry practices associated with fish (aquaculture) and bees (apiculture), and home gardens and forest farming,

Forest grazing

The focus of the AGFORWARD project is primarily the use of trees on agricultural land. Although it does consider wood pasture systems across Europe and the reindeer husbandry in Northern Europe, it does not specifically focus on the grazing of commercial forest plantations. Armstrong et al (2003) reviewed grazing in 104 woodlands, covering about 30,774 ha, across England, Scotland and Wales in the UK. Although most of the forests and woodlands were described as semi-natural, 6000 ha were plantation woodlands with species such as Sitka spruce. Timber production, rather than nature conservation, was also the primary aim of the managers on about 20,044 ha of the sites.

Grazed heathlands

Dwarf shrub heathland covers about 1,487,000 ha in Great Britain (Howard et al. 2003). They are categorised as areas where 25% of the cover of species from the ericaceae (or heather) family of plants. Common heather (*Calluna vulgaris*) which is the plant most characteristic of North-West European upland heath (Thompson et al. 1995), is a perennial shrub. In many areas the shrub is managed by sheep grazing, and hence the practice of sheep grazing of heathlands could be recognised as a form of agroforestry. In a similar way to dehesas, arable farming would be unprofitable and this system is one of the few ways of productively using the land.

Aquaculture with trees

Aquaculture is defined by the Food and Agriculture Organization of the United Nations as “the farming of aquatic organisms including fish, molluscs, crustaceans and aquatic plants” with “some sort of intervention in the rearing process to enhance production, such as regular stocking, feeding and protection from predators” (FAO, 2015). Aquaculture can also be integrated with trees, for example in the leaves of selected trees and shrubs that line fish ponds are used as “forage” for fish (Nair 1993). In 2010, about 10% of the EU seafood market came from EU aquaculture, with 25% from EU fisheries and 65% from imports (which would have included aquaculture systems) (European Commission, 2013d). Aquaculture has also been identified as one of the pillars of the EU's blue growth strategy.

Apiculture and trees

Trees and beekeeping have a long combined history. Combining beekeeping with trees can provide annual honey bee products (e.g. honey, bee wax) to supplement the landowner's income next to income from long-term forest management (Hill & Webster 1995). Some agroforestry practices, for instance *Streuobst* are often mixed with apiculture, with benefits for both fruit and honey production (Herzog 1998). Due to the mixture of tree species and varieties in a *streuobst* system, flowering is spread over a longer period of time increasing the availability of nectar and pollen. Furthermore, the bees are not affected by pesticides as is often the case in more intensively managed orchards (Herzog 1998).

In the Galician Region, the majority of the honey produced is the multi-flower type, although mono-floral honey from eucalyptus, chestnuts, heather or blackberry is also produced. Presently there are 100,000 man-made beehives in Galicia that annually produce between 1,500 to 2,000 tons of honey (Rigueiro-Rodriguez 2001), as reported by the bee keepers, which provides between 6 to 12 million of Euros per year. To improve the trading of honey, the "certificate of origin" was created and is labelled "Honey from Galicia" or "Mel de Galicia" which indicates that it is Galician honey and produced in the traditional way. The Regulatory Council of this denomination specifically listed more than 30,952 man-made beehives belonging to 410 bee keepers, with 38 packaging plants which in 2014, certified more than 620 tons of honey (Consejo Regulador de Miel de Galicia 2014).

Home gardens and forest farming

Home gardens include a multitude of species of trees and agricultural crops. They can be multi-storey systems with mixed species of trees, shrubs and crops usually grow around the house or farm. Home gardens can provide an important source of food and income, helping to improve food security and livelihoods on a regional and global scale. Some new fashionable projects that can be considered as home gardens are currently funded in the Netherlands and this practice is so-called "Food Forestry" (Food Forestry Netherlands, 2015). It is generally practiced in large gardens, but also parks, agricultural areas and more natural forested area are suitable. Therefore, "Food Forestry" also shows some resemblance with forest farming.

Forest farming includes forested areas used for the production or harvest of crops which grow naturally or are cultivated and includes the harvesting of medicinal plants, mushrooms and berries.

Medicinal plants: the recent increased demand for medicinal and aromatic plants is anticipated to continue as demand increases for natural medicines and plant therapy (Rodríguez-Barreira et al. 2011; Romero-Franco 2011). Many of these plants are derived from woodlands and the harvesting of medicinal plants is still important in Albania, Bulgaria, Hungary and Spain (Mosquera-Losada et al. 2009). Although medicinal and aromatic plants can be found in European regions, such as Galicia in Spain, they are often unharvested due to lower cost competition from outside Europe, and the ageing rural population. The species that are traditionally gathered in Galicia include *Gentiana lutea* L., *Arnica montana* L., *Frangula alnus* Miller, *Ruscus aculeatus* L., *Laurus nobilis* L., *Achillea millefolium* L., *Valeriana officinalis* L., and *Hypericum perforatum* L.. It should be noted that the utilization of these species, especially those from which roots or branch cuttings are used, notably reduces their natural populations. This fact should be considered if we want to make sustainable use of the natural populations of these plants and to give incentives to their cultivation.

Mushrooms: wild mushroom gathering can provide a higher income than other non-timber forest products. For example in Galicia in North-West Pain, the annual mushroom trade (prices paid to collectors) is estimated to be 24-30 million Euros (Rigueiro-Rodríguez 2001). There are several dozen species of edible and economically valuable wild mushrooms (e.g. *Amanita caesarea, Boletus edulis* and *Cantharellus cibarius*) that are harvested in Europe. They represent about 27 % of the share of the total non-wood forest products. However continued mushroom production requires reforestation with appropriate tree species and the use of mycorrhizae. Examples of economically important wild mushrooms are described by Rodríguez-Barreira et al. (2011).

Berries: gathering of small wild fruits such as blackberries and raspberries for fresh consumption is traditionally practised in areas such as Galicia in Spain. The local species harvested are *Rubus idaeus* L. (raspberry), *Rubus* spp. (blackberry), *Ribes petraeum* Wulfen in Jacq. (red bush), *Ribes rubrum* L. (red and white currant) and *Vaccinium myrtillus* L. (bilberry). It must be considered that the gathering of these small fruits in the wild may bring about the problem of conservation and the loss of a wild food resource in the forest. One possible solution is the cultivation of local varieties which could contribute to the conservation of local sources. In Galicia, some experiments involving the cultivation of American species such as *Vaccinium corymbosum* L. have proven successful.

8 Discussion

This report focussed on delivering a preliminary stratification and quantification of agroforestry in the EU based on examination of the available literature. As a result of the literature study, we were able to produce a preliminary stratification of agroforestry systems in Europe (Table 12). This initial analysis suggests that the area of agroforestry, including reindeer herding, across Europe is at least 52 million hectares. Excluding the reindeer herding system, the estimate is at least 10.6 million hectares (Table 12).

Table 12. Preliminary stratification and quantification of key agroforestry practices in Europe

System	Country	Extent (ha)	Arable/ Livestock	Source
Mediterranean oak tree Agroforestry	Dehesa in Spain	3,606,151	Both	Table 5
	Montado in Portugal	1,059,000	Both	Table 5
	Grazed woodlands and oak and other agroforestry on agricultural land in Greece	1,895,583	Both	Table 5
	Pyrenean oak in Spain and Portugal	122,000	Livestock	Table 5
	Grazed oak woodlands in Italy	279,263	Livestock	Table 5
	Sub-total	**6,961,997**		
Other wood pastures and Meadows	Larix decidua in Italy	102,319	Livestock	Table 5
	Lövängar, hagmarker in Sweden	100,000	Livestock	Table 5
	Other parklands, woodland, wood-pasture, *Hudewald, Haka* and *metsälaidun* in UK, Germany, Austria, Switzerland, Hungary, Finland	200,320	Livestock	Table 5
	Sub-total	**402,639**		
Reindeer husbandry	Finland, Sweden, Norway	**41,400,000**	Livestock	Table 5
Hedges and scattered trees	France and parts of UK and Belgium	**472,074**	Both	Table 5
Agroforestry with fruit trees	Germany, Switzerland, Austria, Romania, Croatia, Czech Rep, France, UK, Denmark, Italy, Greece, Poland, Portugal	1,226,867	Both	Table 7
with olives	Portugal, Greece, France, Italy, Spain	538,865	Arable	Table 8
with pine-trees	Italy, Portugal	535,842	Livestock	Table 8
with vines	Italy, Spain, Portugal	275,635	Arable	Table 8
with chestnuts	Portugal, France, Italy, Greece, Hungary, Romania, Slovakia, Slovenia, Spain and Switzerland	111,083	Both	Table 8
with carob trees	Italy, Portugal, Spain, Greece	92,200	Both	Table 8
	Sub-total	**2,780,492**		
Shelterbelts	Hungary	**16,415**	Both	Table 10
Alley cropping	France	**6,300**	Arable	Table 10
Trees with livestock	Netherlands	**3,000**	Livestock	Table 10
Total		**52,042,917**		
Total (excluding reindeer)		**10,642,917**		

It should be noted that our estimate of the total extent of agroforestry in Europe is incomplete. For example the role of hedges and scattered trees is only included for France and the UK. There are also no wood pasture estimates for countries like Romania, Poland and Bulgaria. In addition no records are provided of walnut-based agroforestry outside of Portugal and Greece.

The published literature sources cover different time frames and also the data in the publications retrieved have been collected in different ways, which makes it difficult to give a uniform and up-to-date snapshot of the current total extent of agroforestry in Europe.

An alternative approach to determining the extent of agroforestry is to use existing European databases such as the CORINE Land Cover (CLC) database. However, an accurate estimate on the extent of agroforestry systems is difficult under the current CORINE land cover classification as agroforestry may fall under several classes (Rois-Díaz et al. 2006). These include olive groves, pastures, annual crops associated with permanent crops, agricultural mosaic with natural vegetation, agroforestry areas and natural grasslands (Table 13).

Table 13. Nomenclature definitions of CORINE Land Cover Classes that may include agroforestry areas (after EIONET, 2000)

Level 1	Level 2	Level 3
2. Agricultural areas		2.23. Olive groves: Areas planted with olive trees, including mixed occurrence of olive trees and vines on the same parcel
	2.3 Pastures	2.3.1. Pastures: Dense, predominantly graminoid grass cover, of floral composition, not under a rotation system. Mainly used for grazing, but the fodder may be harvested mechanically. Includes areas with hedges (bocage).
	2.4. Heterogeneous agricultural areas	2.4.1. Annual crops associated with permanent crops Non-permanent crops (arable lands or pasture) associated with permanent crops on the same parcel.
		2.4.3. Agricultural mosaic with significant areas of natural vegetation: Areas principally occupied by agriculture, interspersed with significant natural areas.
		2.4.4. Agro-forestry areas: Annual crops or grazing land under the wooded cover of forestry species.
3. Forests and semi-natural areas	3.2. Shrub and/or herbaceous vegetation associations	3.2.1. Natural grassland: low productivity grassland. Often situated in areas of rough uneven ground. Frequently includes rocky areas, briars, and heathland.

Within CORINE, “agroforestry” land cover class 2.4.4. is described as “Annual crops or grazing land under the wooded cover of forestry species, where the annual crops or grazing land and fallow land cover less than 50 % of the surface. It includes combinations of forest trees with fruit and olive trees and agricultural land shaded by carob and palm trees” (EIONET, 2000). According to the CORINE database, this “agroforestry” land cover is greatest in Spain, Portugal and Italy and reaches a total of 3.3 million hectares (Table 14).

The area (2.5 million ha) reported as “agroforestry” by CORINE for Spain, although 30% smaller, is of a similar magnitude to that reported in the literature for dehesa in Spain (3.6 million ha) (Table 12). The area reported as “agroforestry” by CORINE in Portugal (622,243 ha), is 40% lower than the 1,059,000 ha of montados reported in the literature (Table 12).

Table 14. Area of CORINE Land Cover classes that may include agroforestry systems across European countries and Turkey.

Country	Olive groves	Pastures	Annual crops associated with permanent crops	Agriculture mosaics with significant natural vegetation	Agro-forestry areas	Natural grasslands
Albania	39,467	42,846		303,413		294,628
Austria		747,833		166,704	60	598,830
Belgium		355,548		189,068		886
Bosnia/Herzegovina		403,979		578,016		244,139
Bulgaria		409,617		1,011,480		391,599
Croatia	20,192	299,646	76	527,230		254,637
Cyprus	6,548	1,171	32,246	41,848		28,164
Czech Rep		700,445		706,313		26,996
Denmark		56,230		355,470		26,540
Estonia		247,057		374,451		39,779
Finland		4,809		1,238,614		3,572
France	10,584	8,695,099		1,491,289	375	1,249,377
Germany		4,394,204		905,269		169,025
Greece[1]	613,144	70,396	2,346	1,428,375		1,199,451
Hungary		655,024		149,545		227,022
Iceland		245,113				288,483
Ireland		3,577,843		441,069		89,613
Italy	1,209,285	425,884	378,823	2,048,216	175,072	1,464,116
Kosovo		17,932		131,583		72,592
Latvia		851,391		436,227		5,352
Liechtenstein		574		319		2,189
Lithuania		420,685		515,301		1,089
Luxembourg		37,615	87	22,357		
Macedonia FYR		203,562		185,958		191,931
Malta				14,962		
Montenegro	481	20,822		184,085		130,760
Netherlands		1,027,260		115,111		42,114
Norway		25,263		969,837		927
Poland		2,714,765		1,446,734		37,897
Portugal	262,855	42,722	404,382	693,804	622,243	179,336
Romania		2,572,829		1,095,683		318,017
Serbia		157,461		1,005,308		204,534
Slovakia		270,613		323,961		28,609
Slovenia		116,324		181,194		20,492
Spain	1,865,943	648,208	140,679	2,498,219	2,495,438	2,642,457
Sweden		268,258		565,253		191,577
Switzerland		376,316		20,353		447,046
Turkey	371,014	1,476,472		7,595,671		8,963,155
UK		7,039,929		184,771		1,935,999
Total (ha)	**4,399,513**	**39,621,745**	**958,639**	**30,143,061**	**3,293,188**	**22,012,930**

Source: CORINE Land Cover 2006 by nuts units, Land accounts data viewer 1990-2006, http://www.eea.europa.eu/data-and-maps/data/data-viewers/land-accounts

[1]Data for Greece are from CLC 2000.

CORINE also has a category entitled “annual crops associated with permanent crops” which totals 958,629 ha. Again the largest areas occur in Spain, Portugal and Italy. Adding this total to the “agroforestry” total results in 4,251,827 ha. In Spain, the combination of the two classes results in an agroforestry area of 2,636,117 ha, which is 27% lower than the area of dehesa reported in the literature. In Portugal, the two classes result in an agroforestry area of 1,026,625 ha which is similar to the area of 1,059,000 ha reported for *montados* in the literature.

Other CORINE classes which could include agroforestry include “agricultural mosaic with significant natural vegetation”, olive groves, pastures and natural grasslands. For example, there is no agroforestry in Greece according to CORINE (Table 14), whilst the literature review highlighted large areas of wood pastures and meadows (1.0 million hectares, Table 5), Valonia oak agroforestry systems (29,631 ha, Table 5) and 124,311 ha of olive tree agroforestry systems (Table 8). It could be that the Greek wood pastures and meadows are reported in CORINE under the 1.4 million hectares described as “agricultural mosaic with significant natural vegetation” (Table 14). Spain, Italy, France, Poland and Finland also have a high cover of “agricultural mosaic with significant natural vegetation” (Table 14).

From the above analyses it is clear that there is not a simple relationship between the estimates of the area of agroforestry in the literature and land cover classes defined by CORINE. The total area defined as “agricultural mosaic with significant vegetation” excluding Turkey, Sweden, and Finland is 20,743,523 ha. If we further exclude Poland, Romania, Serbia, and Bulgaria (i.e. areas for which we were able to gain few values from the literature), then the remaining area of “agricultural mosaic with significant vegetation” is 16,184,318 ha. If we assumed that half of this area is “agroforestry”, then adding this to the 4,251,827 ha (from “agroforestry” and “annual crops associated with permanent crops”) would result in 12.3 million ha, which is of a similar magnitude to the 10.6 million hectares derived from the literature review.

According to the literature study, approximately 10.6 million hectares are covered by some kind of agroforestry practice for those countries for which we were able to retrieve data from published literature (Table 12; Table 15). This equates to about 6.5% of the total utilised agricultural area of the investigated countries. The “utilised agricultural area” is the total area taken up by arable land, permanent pasture and meadow, and the land used for permanent crops.

Table 15. Estimated area covered by agroforestry based on the summarised results from the literature study as shown in Table 5, Table 7, Table 8, and Table 10 and as a percentage of the utilised agricultural area.

Country[4]	Estimated area covered by agroforestry (ha)	Utilised agricultural area[3] (ha)	Estimated agroforestry area as a proportion of UAA (%)
Austria	48,564	2,863,583	1.7%
Belgium	12,400	1,358,020	0.9%
Croatia	64,456	1,300,000	5.0%
Czech Republic	9,277	3,525,889	0.3%
Denmark	3,242	2,664,000	0.1%
Finland[1]	7,320	2,285,200	0.3%
France	510,130	29,000,829	1.8%
Germany	480,500	16,667,300	2.9%
Greece	2,096,688[2]	4,150,990	50.5%
Hungary	22,815	5,338,015	0.4%
Italy	967,038	13,133,855	7.4%
Netherlands	3,000	1,841,600	0.2%
Poland	200,000	14,529,400	1.4%
Portugal	1,842,320	3,597,979	51.2%
Romania	180,105	13,733,143	1.3%
Slovakia	92	1,927,000	0.0%
Slovenia	185	480,000	0.0%
Spain	3,839,949	23,463,115	16.4%
Sweden[1]	100,000	3,031,500	3.3%
Switzerland	97,312	1,051,630	9.3%
UK	157,524	17,172,000	0.9%
Total	**10,642,917**	**164,473,028**	**6.5%**

[1] This area does not include the reindeer husbandry area; Reindeer herding is mostly practiced in boreal forest and (sub-) arctic and alpine tundra and only to a very small extent on agricultural land.

[2] Includes 1,022,252 ha designated as forestry by Greek Ministry of Agriculture (Papanastasis et al., 2009)

[3] Utilised Agricultural Area in 2012. The figures from Italy and United Kingdom refer to 2011, and Belgium for 2010. Source: Eurostat.

[4] Bulgaria, Cyprus, Estonia, Ireland, Latvia, Lithuania, Luxembourg and Malta are not included.

A more uniform approach, for example an approach based on remote sensing data may help in providing a more accurate estimate. For example, high resolution remote sensing data can be used to assess tree cover density in the agricultural landscape (e.g. Copernicus Land Cover Monitoring Services). Another recent development has been the Land Use and Land Cover Aerial Frame Survey (LUCAS, Eurostat 2012). This survey has been gathering simultaneous on-site measurements of land cover and land use, which are also harmonised with agricultural census information and forestry inventories. Our current understanding of EU27 land cover and use can be progressed through an examination of how the LUCAS data can be used to describe the current extent of agroforestry at a field- or a landscape-scale.

The current agroforestry definitions and classifications make it difficult to estimate the current areal extent of agroforestry in Europe. New classifications provided to EUROSTAT by the Multisward project, could help to quantify it (Peeters et al. 2014). New and further understanding on agroforestry practices quantification will also come from the report of the EIP focus group of Permanent Grassland (EC 2015).

9 Conclusions

The literature study revealed a large diversity of agroforestry practices in Europe, which was reviewed through the lens of the four participative research networks used in the AGFORWARD project. These include agroforestry of high nature and cultural value (which included wood pasture, reindeer herding, and some hedgerow systems), agroforestry focused on fruit trees, olives, chestnut and other high value trees, and to a more limited extent novel practices focused on integrating trees in arable and livestock systems. Agroforestry systems are more diverse in the south, but some systems for instance Scandinavian wood pastures and reindeer husbandry are practiced far in the north, even extending into the sub-arctic tundra zone.

In Europe there is a lack of cartographic information on the different types of agroforestry systems and practices. Exact information on the distribution and extent of agroforestry systems in Europe is currently not readily available. Moreover, the information is scattered, fragmented and difficult to compare. There would be a need for a more uniform approach for the whole of Europe, for instance one based on a combination of Pan-European data (e.g. LUCAS) and remote sensing. In addition, it would be good to properly include agroforestry in existing Land Use and Land Cover classification nomenclatures, for instance in the Land Use and Land Cover Aerial Frame Survey (LUCAS).

Nevertheless this report gives a first impression of the stratification and quantification of the most important agroforestry systems and practices in Europe. Of the European agroforestry systems, wood pastures cover the largest area and are distributed around Europe in all climatic zones ranging from the Mediterranean to boreal zones. The oak tree systems in the Mediterranean and reindeer husbandry in northernmost Fennoscandia in particular cover large areas. Most of the fruit tree systems are located in the central and Mediterranean regions of Europe, with large areas of olive agroforestry in the Mediterranean region. Due to the overlap of the different systems, it was not possible to subdivide silvoarable and silvopastoral practices. Nevertheless, considering the large area of cropland and grassland in Europe there would be a huge potential for integrating trees in both arable and livestock systems. The extent of recent projects and programmes to promote within-field planting of trees in arable and livestock still needs to be determined, but the areas are small relative to the extent of traditional systems.

Based on the literature study, agroforestry (excluding reindeer husbandry) in Europe is practiced on an area of at least 10.6 million hectares, equivalent to about 6.5% of the utilised agricultural area in Europe. This is substantially larger than the 3.3 million hectares classified as “agroforestry” by the CORINE database. If the agroforestry practice of reindeer husbandry is included, then the area of agroforestry in Europe was estimated to be at least 52 million hectares. However we anticipate that the total area covered by agroforestry is larger as the analysis contains only limited amounts of data from large countries such as Poland, Romania and Bulgaria. A more accurate estimate would require more studies, involving a combined approach using European databases and remote sensing. Despite the shortcomings of the literature study, this report provides a first estimate of the current distribution and quantification of agroforestry in Europe.

10 Acknowledgements

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

References

AGFORWARD (2014). Farmer Research Groups. Information on the participatory research and development network and stakeholder reports of the case studies. Available online: http://www.agforward.eu/index.php/en/FarmerNetworks.html

Almeida, M., Carlos, G. and Pinto-Correia, T. (2013). Unfolding relations between land cover and farm management: high nature value assessment in complex silvo-pastoral systems. Danish Journal of Geography 113: 97–108.

Altieri, M.A. and Nicholls, C.A. (2002). The simplification of traditional vineyard based agroforests in northwestern Portugal: some ecological implications. Agroforestry Systems 56: 185-191.

Armstrong, H.M., Poulsom, E., Connolly, T. and Pearce, A. (2003) A survey of cattle-grazed woodlands in Britain. Roslin: Forest Research. http://www.forestry.gov.uk/pdf/cattle_report.pdf/$FILE/cattle_report.pdf

Anuário Vegetal (2006). Crop Production Yearbook. Ministério da Agricultura, do desenvolvimento Rural e das Pescas. Available online: http://www.gpp.pt/publicacoes.html

Bélouard, T. and Coulon F. (2002). Trees outside forests: France. In: Trees outside forests. Towards a Better Awareness. 149-155. FAO Conservation Guide 35. ftp://ftp.fao.org/docrep/fao/005/y2328e/Y2328E03.pdf

Bergmeier, E., Petermann, J. and Schröder, E. (2010). Geobotanical survey of wood-pasture habitats in Europe: diversity, threats and conservation. Biodiversity Conservation 19: 2995-3014.

Bunce, R.G.H., Pérez-Soba, M. and Smith, M. (2009). Silvopastoral systems in Portugal: Current status and future prospects. In: Rigueiro-Rodríguez, A., McAdam, J. and Mosquera-Losado, M. (eds.) *Agroforestry in Europe* (pp. 321-330). Springer Netherlands

Bölöni, J., Molnár, Z., Biró, M. and Horváth, F. (2008). Distribution of the (semi-) natural habitats in Hungary II. Woodlands and shrublands. Acta Botanica Hungarica 50: 107-148.

Burgess, P.J. and Morris, J. (2009). Agricultural technology and land use futures: the UK case. Land Use Policy 26S: S222-S229.

Burgess, P.J., Belot, V., Buachie, E., Cuartero de Frias, F., Nedved, K. and Rodríguez Arquero, E. (2014). The economics of woodland eggs in the UK. 2nd European Agroforestry Conference 04-06 June 2014 Cottbus – Germany, Book of Abstracts 67-70. (Eds. J.H.N. Palma, A. Chalmin, P. Burgess, J. Smith, M. Strachan, J. Ruiz Mirazo, A. Rosati), ISBN: 978-972-97874-4-7.

Burrough, A.E., Oines, C.M., Oram, S.P., and Robertson, H.J. (2010). Traditional Orchard Project in England - The creation of an inventory to support the UK Habitat Action Plan. Natural England. Commissioned Reports, Number 077. Available online: http://publications.naturalengland.org.uk/publication/47015 (accessed: 13.01.2015)

BRIG (2007). Report on the Species and Habitat Review. Report by the Biodiversity Reporting and Information Group (BRIG) to the UK Standing Committee. DEFRA, London. Available online: http://jncc.defra.gov.uk/PDF/UKBAP_Species-HabitatsReview-2007.pdf (accessed 13.01.2015)

Caballero, R. and Gil, Á. (2009). Binding constraints in Castile-La Mancha, Spain's cereal-sheep system. Journal of Sustainable Agriculture 33(1): 3-27.

Castro, M. (2009). Silvopastoral systems in Portugal: Current status and future prospects. In: Rigueiro-Rodríguez, A., McAdam, J. and Mosquera-Losada, M. (eds.) *Agroforestry in Europe* (pp. 111-126). Springer Netherlands.

Conedera, M., Manetti, M.C., Giudici, F. and Amorini, E. (2004). Distribution and economic potential of the Sweet chestnut (*Castanea sativa* Mill.) in Europe. Ecologia Mediterranea 30(2): 179-193.

Consejo Regulador de Miel de Galicia (2014). Available online: http://www.mieldegalicia.org/miel2/datostecnicos_es.php

Cooper, T., Arblaster, K., Baldock, D., Farmer, M., Beaufoy, G., Jones, G., Poux, X., McCracken, D., Bignal, D., Elbersen, B., Wascher, D., Angelstam, P., Roberge, J.-M., Pointereau, P., Seffer, J. and Galvanek, D. (2007). Final report for the study on HNV indicators for evaluation. Report prepared by the Institute for European Environmental Policy for DG Agriculture. 187pp.

Copernicus (2014). Copernicus Land Monitoring Services. Satellite-borne earth observation data, available online: http://land.copernicus.eu/

Cullotta S., La Mantia T. and Barbera G. (1999). Descrizione e ruolo dei sistemi agroforestali in Sicilia. In: Secondo Congresso Nazionale di Selvicoltura, Venezia, Italy, 24–27 June 1999, Consulta Nazionale per le Foreste ed il Legno. Ministero delle Politiche Agricole e Forestali, Accademia Italianadi Scienze Forestali, EdAs, Italy, pp. 429–438

Dagley, J. (2006). Pollarding in Epping Forest. 1er Colloque Européen sur les Trognes, pp. 1–7. Available online: http://www.maisonbotanique.com/dyn/15acte_6_dagley.pdf

De Foresta, H., Somarriba, E., Temu, A., Boulanger, D., Feuilly, H. and Gauthier, M. (2013). Towards the assessment of trees outside forests. Resources Assessment Working Paper 183. Rome: Food and Agriculture Organization of the United Nations. Available online: http://www.fao.org/docrep/017/aq071e/aq071e00.pdf.

Dixon J., Gulliver, A. and Gibbon, D. (2001). Farming Systems and Poverty: Improving Farmers' Livelihoods in a Changing World. Rome and Washington DC: FAO and World Bank. ftp://ftp.fao.org/docrep/fao/003/y1860e/y1860e.pdf

Ducros D., Képhaliacos C. and Ridier A. (2005) Systèmes de production diversifiés. Les prés-vergers : une alternative à l'arboriculture intensive face à l'évolution de la PAC. Toulouse: ENFA Toulouse, Laboratoire Dynamiques rurales (UMR UTM-ENFA- INP ENSAT).

Eichhorn, M.P., Paris, P., Herzog, F., Incoll, L.D., Liagre, F., Mantzanas, K., Mayus, M., Moreno, G., Papanastasis, V.P., Pilbeam, D.J., Pisanelli, A. and Dupraz, C. (2006). Silvoarable systems in Europe - Past, present and future prospects. Agroforestry Systems 67(1): 29-50.

Eriksson, M.O.G. (2008). Management of Natura 2000 habitats. 9070 Fennoscandian wooded pastures. European Commission, DG ENV B2, Technical Report 2008 21/24, 23 pp.

Etat de l'Environnement en Wallonie (2010). Rapport sur l'Etat de l'Environnement en Wallonie. Direction générale opérationnelle de l'Agriculture, des Ressources naturelles et de l'Environnement (DGARNE). Available online: http://etat.environnement.wallonie.be

European Topic Centre on Spatial Information and Analysis (EIONET) (2000). Corine Land Cover Classes. http://sia.eionet.europa.eu/CLC2000/classes

European Commission (2013a). Regulation (EU) No 1307/2013 of the European Parliament and of the Council of 17 December 2013 establishing rules for direct payments to farmers under support schemes within the framework of the common agricultural policy and repealing Council Regulation (EC) No 637/2008 and Council Regulation (EC) No 73/2009. http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2013:347:0608:0670:EN:PDF

European Commission (2013b). Regulation (EU) no 1305/2013 of the European Parliament and of the Council of 17 December 2013 on support for rural development by the European Agricultural Fund for Rural Development (EAFRD) and repealing Council Regulation (EC) No 1698/2005 http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2013:347:0487:0548:en:PDF

European Commission (2013c). Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: A new EU Forest Strategy: for forests and the forest-based sector. http://ec.europa.eu/agriculture/forest/strategy/communication_en.pdf

European Commission (2013d). Communication from the Commission to the European parliament, the Council, the European Economic and Social Committee and the Committee of the Regions: Strategic Guidelines for the sustainable development of EU aquaculture. http://ec.europa.eu/fisheries/cfp/aquaculture/official_documents/com_2013_229_en.pdf

European Commission (EC) (2015). Permanent Grassland Focus Group. http://ec.europa.eu/eip/agriculture/en/content/eip-agri-focus-group-profitability-permanent-grassland-starting-paper

Eve M, Pape D, Flugge M, Steele R, Man D, Riley-Gilbert M, Biggar (2014). Quantifying Greenhouse Gas Fluxes in Agriculture andForestry: Methods for Entity-Scale Inventory. USDA technical bulletin 1939.

FAO (2015). Global Aquaculture Production. Accessed 22 April 2015. http://www.fao.org/fishery/statistics/global-aquaculture-production/en

Farm Accountancy Data Network (FADN). (2014). FADN Public Database. Available online: http://ec.europa.eu/agriculture/rica/database/database_en.cfm (accessed 26.11.2014).

Finck, P., Riecken, U. and Glaser, F. (2005). Situation and perspectives of silvopastoral systems in Germany. In: Mosquera-Losada, M. R., Rigueiro-Rodríguez, A., & McAdam, J. (eds). Declaration for silvopastoralism. In: Silvopastoralism and sustainable land management. Proceedings of an international congress on silvopastoralism and sustainable management held in Lugo, Spain, April 2004. CABI Publishing.

Food Forestry Netherlands (2015). Food Forestry Netherlands. Accessed 22 April 2015. http://www.foodforestry.nl/

Forestry Commission (2001a). National Inventory of Woodland and Trees - England. Edinburgh: Forestry Commission. http://www.forestry.gov.uk/pdf/niengland.pdf/$FILE/niengland.pdf

Forestry Commission (2001b). National Inventory of Woodland and Trees - Scotland. Edinburgh: Forestry Commission. http://www.forestry.gov.uk/pdf/niscotland.pdf/$FILE/niscotland.pdf

Forestry Commission (2001c). National Inventory of Woodland and Trees - Wales. Edinburgh: Forestry Commission. http://www.forestry.gov.uk/pdf/niwales.pdf/$FILE/niwales.pdf

Glaser, F.F. and Hauke, U. (2004). Historisch alte Waldstandorte und Hudewälder in Deutschland. Schriftenreihe Angewandte Landschaftsökkologie H. 61 (eds.: Bundesamt für Naturschutz), Landwirtschaftsverlag, Münster, Germany.

Greif, F. (1992). Waldweide in Österreich aus agrar-, forst- und volkswirtschaftlicher Sicht. Monatsber. Österr. Landwirtsch. 7: 515–526.

Hart, K., Allen, B., Lindner, M., Keenleyside, C., Burgess, P., Eggers, J. and Buckwell, A. (2013). *Land as an Environmental Resource.* Annex Prepared for DG Environment, Contract No ENV.B.1/ETU/2011/0029, Institute for European Environmental Policy, London.

Hartel, T., Dorresteijn, I., Klein, C., Máthé, O., Moga, C.I., Öllerer, K., Roellig, M., von Wehrden, H. and Fisscher, J. (2013). Wood-pastures in a traditional rural region in Europe: Characteristics, management and status. Biological Conservation 166: 267-275.

Hemery, G.E., Clark, J.R., Aldinger, E., Claessens, H., Malvolti, M.E., O'Connor, E., Raftoyannis, Y., Savill, P.S. and Brus, R. (2010). Growing scattered broadleaved tree species in Europe in a changing climate: a review of risks and opportunities. Forestry 83: 65-81.

Herzog, F. (1998). Streuobst: a traditional agroforestry system as a model for agroforestry development in temperate Europe. Agroforestry Systems 42: 61-80.

Herzog, F. (2000). The importance of perennial trees for the balance of northern European agricultural landscapes. Unasylva 200(51): 42-48.

Hill, D. B., and Webster, T. C. (1995). Apiculture and forestry (bees and trees). Agroforestry Systems, 29(3), 313-320.

Hoare, A.H. (1928). *The English Grass Orchard*. Ernest Benn Limited, London. pp 27

Howard, D.C., Watkins. J.W., Clarke, R.T., Barnett, C.L. and Stark, G.J. (2003). Estimating the extent and change in Broad Habitats in Great Britain. Journal of Environmental Management 67: 219–227.

Ikerd, J.E (1993). The need for a systems approach to sustainable agriculture. Agriculture, Ecosystems and Environment 46: 147-160.

INE (2002). Censo Agrario de Espanã 1999. Instituto Nacional de Estadıstica, Madrid, 444 pp.

Intergovernmental Panel on Climate Change (IPCC) (2014). Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Core Writing Team, R.K. Pachauri and L.A. Meyer (eds.)]. IPCC, Geneva, Switzerland, 151 pp. http://www.ipcc.ch/report/ar5/syr/

Inventário Florestal Nacional (2013a). Inventário Florestal Nacional -National Forest Inventory. Instituto da Conservação da Natureza e das Florestas. Lisboa. Available online: www.icnf.pt/portal/florestas/ifn

Inventário Florestal Nacional (2013b). IFN6 – Áreas dos usos do solo e das espécies florestais de Portugal continental. Resultados preliminares [Land use and forest species cover in continental Portugal] . 34 pp, Instituto da Conservação da Natureza e das Florestas. Lisboa. Available online: http://www.icnf.pt/portal/florestas/ifn/resource/ficheiros/ifn/ifn6-res-prelimv1-1

Jernsletten, J.L. and Klokov, K. (2002). Sustainable reindeer husbandry. Arctic Council 2000-2002.

Kiritsakis, A.K. (1998). Olive Oil from the Tree to the Table, 2nd edition. Food and Nutrition Press, Trubull, CT.

Leakey, R. (1996). Definition of agroforestry revisited. Agroforestry Today 8(1): 5-7.

Liagre, F. (2002). 2. Country Reports: France. In: Extant Silvoarable Practices in Europe Report (Ed. P. Paris). Accessed 22 April 2015 http://www1.montpellier.inra.fr/safe/english/results/annual_report/Extant-SA-parctices-in-Europe.pdf

Luick, R. (2009). Wood pastures in Germany. In: Rigueiro-Rodríguez, A., McAdam, J., Mosquera-Losado, M. (eds) *Agroforestry in Europe: current status and future prospects.* Springer Science + Business Media B.V., Dordrecht, p. 359-376.

Lundgren, B.O. and Raintree, J.B. (1982). Sustained agroforestry. In: Nestel, B. (ed.). *Agricultural Research for Development: Potentials and Challenges in Asia*, pp. 37-49. ISNAR, The Hague, The Netherlands.

Land Use and Land Cover Aerial Frame Survey (LUCAS) (2012). Land cover / Land use statistics from Eurostat 2012. Available online at: http://epp.eurostat.ec.europa.eu/portal/page/portal/lucas/introduction

Maddock, A. (Ed) (2008). Wood-Pasture and Parkland. In *UK Biodiversity Action Plan; Priority Habitat Descriptions*.

MAPYA (2004). Anuario de Estadística Agroalimentaria. Ministerio de Agricultura, Pesca y Alimentación. Series initiated in 1929.

McAdam, J. H. and McEvoy, P. M. (2008). The potential for silvopastoralism to enhance biodiversity on grassland farms in Ireland. In: *Agroforestry in Europe* (pp. 343-356). Springer Netherlands.

McAdam, J., Burgess, P., Graves, A., Riguero-Rodríquez A. and Mosquera-Losada, M. (2009). Classifications and functions of agroforestry systems in Europe. In: Rigueiro-Rodríguez, A., McAdam, .J, Mosquera-Losada, M. (eds) *Agroforestry in Europe: Current Status and Future Prospects.* Springer Science + Business Media B.V., Dordrecht, p. 21–42.

Minang, P. A., Duguma, L. A., Alemagi, D., and van Noordwijk, M. 2015. Scale considerations in landscape approaches (2015). *In*: Minang, P. A., van Noordwijk, M., Freeman, O. E., Mbow, C., de Leeuw, J. and Catacutan, D. (eds.) *Climate-Smart Landscapes: Multifunctionality in Practice*, 121-133. Nairobi, Kenya: World Agroforestry Centre (ICRAF).

Ministerio de Agricultura, Alimentación y Medio Ambiente (2008). Diagnóstico de las Dehesas Ibéricas Mediterráneas. Tomo I.

Montero, G., San Miguel, A. and Cañellas, I. (1998). System of Mediterranean silviculture "La Dehesa". In: Jiménez Diaz, R.M. and Lamo de Espinosos, J. (eds.) *Agricultura Sostenible*. Mundi Prensa, Madrid.

Moreno, G. and Pulido, F. J. (2009). The functioning, management and persistence of dehesas. In: Rigueiro-Rodríguez, A., McAdam, J., Mosquera-Losado, M. (eds) *Agroforestry in Europe* (pp. 127-160). Springer Netherlands.

Mosquera-Losada, M.R., McAdam J., Romero-Franco, R., Santiago-Freijanes, J.J and Riguero-Rodríquez A. (2009). Definitions and components of agroforestry practices in Europe. In: Rigueiro-Rodríguez, A., McAdam, J., Mosquera-Losado, M. (eds) *Agroforestry in Europe: current status and future prospects*. Springer Science + Business Media B.V., Dordrecht, p. 3-19.

Mosquera-Losada, M., Moreno, G., Pardini, A., McAdam, J.H., Papanastasis, V., Burgess, P.J., Lamersdorf, N., Castro, M., Liagre, F. and Rigueiro-Rodríguez, A. (2012). Past, Present and Future of Agroforestry Systems in Europe. *Agroforestry- The Future of Global Land Use*, Advances in Agroforestry 9 . Springer Science + Business Media B.V., Dordrecht

Mosquera-Losada, M.R., Freese, D. and Rigueiro-Rodríguez, A. (2011). Carbon Sequestration in European Agroforestry Systems. B.M. Kumar and P.K.R. Nair (eds*.), Carbon Sequestration Potential of Agroforestry Systems: Opportunities and Challenges*, Advances in Agroforestry 8, Springer Science + Business Media B.V., Dordrecht

Nair, P.K.R. (1985). Classification of agroforestry systems. Agroforestry Systems 3: 97-128.

Nair, P.K.R. (1993). *An Introduction to Agroforestry*. Kluwer, The Netherlands, 499 pp.

Natural England (2015). SSSI Condition Summary for the whole of England. https://designatedsites.naturalengland.org.uk/ReportConditionSummary.aspx?SiteType=ALL

Oosterbaan, A. and Kuiters, A.T. (2009). Agroforestry in the Netherlands. In: Rigueiro-Rodríguez, A., McAdam, J., Mosquera-Losado, M. (eds) In: *Agroforestry in Europe: Current Status and Future Prospects*. Springer Science + Business Media B.V., Dordrecht, p. 331-341.

Oppermann R., Beaufoy G. and Jones G. (eds.) (2012) High Nature Value Farming in Europe. Ubstadt-Weiher, Verlag Regionalkultur.

Palma, J.H.N., Graves, A.R., Burgess, P.J. and Herzog, F. (2007). Integrating environmental and economic performance to assess modern silvoarable agroforestry in Europe. Ecological Economics 63: 759-767.

Pantera A. and Papanastasis V.P. (2003). Valonia oak (*Quercus ithaburensis Decaisne* subsp. *Macrolepis* (Kotschy) Hedge & Yalt.) in Greece. Geotechnical Scientific Subjects, 14(1), 33-44

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

Paracchini, M.L., Terres, J.M., Petersen, J.E. and Hoogeveen, Y. (2006). Background document on the methodology for mapping high nature value farmland in EU27. European Environment Agency, Copenhagen, 32 pp.

Pardini, A. (2009). Agroforestry systems in Italy: Traditions towards modern Management. In: Rigueiro-Rodríguez, A., McAdam, J., Mosquera-Losado, M. (eds.) *Agroforestry in Europe:* Springer Science + Business Media B.V., Dordrecht, p. 255-267.

Pointereau, P., Paracchini, M.L., Terres, J.M., Jiguet, F., Bas, Y. and Biala, K. (2007). Identification of High Nature Value farmland in France through statistical information and farm practice surveys. JRC Scientific and Technical Reports. European Commission Joint Research Centre, Institute for Environment and Sustainability. Luxembourg: Office for Official Publications of the European Communities, 76 pp.

Poisot, A-S., Speeddy, A. and Kueneman, E. (2004) Good Agricultural Practices – a working concept Background paper for the FAO Internal Workshop on Good Agricultural Practices. FAO GAP Working Paper Series 5. Rome, Italy 27-29 October 2004. http://www.fao.org/prods/gap/docs/pdf/5-gapworkingconceptpaperexternal.pdf

Reisner, Y., de Filippi, R., Herzog, F. and Palma, J. (2007). Target regions for silvoarable agroforestry in Europe. Ecological Engineering 29, p. 401-418.

Rigueiro-Rodríguez, A. (2001). Producciones complementarias del bosque gallego. Actas del II Congreso Técnico Científico Forestal del Arco Atlántico. Silleda-Pontevedra, Spain.

Rigueiro-Rodríguez, A., Fernández-Núñez, E., González-Hernández, P., McAdam, J. H., & Mosquera-Losada, M. R. (2009). Agroforestry systems in Europe: productive, ecological and social perspectives In: Rigueiro-Rodríguez, A., McAdam, J., Mosquera-Losada, M. (eds.) *Agroforestry in Europe: current status and future prospects* (pp. 43-65). Springer Netherlands.

Robertson, H. J., Wedge, C. and Cordrey, L. (2010). Traditional orchards working UK habitat action plan URL: http://www.orchardnetwork.org.uk/content/traditional-orchard-hap [Accessed January 2015].

Rodríguez-Barreira, S., Romero-Franco, M.R., Mosquera-Losada, M.R., Rigueiro-Rodríguez, A. (2011). Non-Timber forest products of agroforestry systems in Galicia In: Agroforestry Systems as a Technique for Sustainable Territorial Management. Mosquera-Losada MR, Fernández-Lorenzo JL, Rigueiro-Rodríguez A. pp. 345-353.

Rois-Díaz, M., Mosquera-Losada, R. and Rigueiro-Rodriguez, A. (2006). Biodiversity indicators on silvopastoralism accross Europe. EFI Technical Report 21, 66 pp.

Romero-Franco, R. (2011). Medicinal plants: Cultivation possibilities 3 In: Agroforestry Systems as a Technique for Sustainable Territorial Management. Mosquera-Losada MR, Fernández-Lorenzo JL, Rigueiro-Rodríguez A. pp. 53-363.

San Miguel, A. (1994). La Dehesa Española. Origen, Tipología, Características y Gestión. Fundación Conde del Valle de Salazar, Madrid.

Schoeneberger, M., Bentrup, G., Gooijer, H., Soolanayakanahally, R., Sauer, T., Brandle, J., Zhou, X. and Current, D. (2012). Branching out: Agroforestry as a climate change mitigation and adaptation tool for agriculture. Journal of Soil and Water Conservation 67(5): 128A-136A.

Schultz, A.M., Papanastasis, V., Katelman, T., Tsiouvaras, C., Kandrelis, S. and Nastis, A. (1987). Agroforestry in Greece. Working document. Laboratory of Range Science, Department of Range and Wildlife Science, Aristotle University of Thessaloniki. Thessaloniki, 101 pp.

Segouin, O. and Valadon, A. (1997). Enquête sue les boisements récents de peupliers en Lot-et-Garonne. Analyse de pratiques agroforestières; les cultures intercalaires. CEMAGREF, Nogent-sur-Vernisson, France, 45 pp.

Sinclair, F.L. (1999). A general classification of agroforestry practice. Agroforestry Systems 46(2): 161-180.

Smith, J. (2010). The history of temperate agroforestry. Organic Research Centre, Elm Farm, UK

Sommariba, E. (1992). Revisiting the past: an essay on agroforestry definition. Agroforestry Systems 19: 233-240.

Statistics Denmark (2013). Official Statistics of Denmark. Available online: http://www.statistikbanken.dk/statbank5a/default.asp?w=1600

Statistics Sweden (2013). Yearbook of agricultural statistics 2013 including food statistics, Official Statistics of Sweden. Available online: http://www.jordbruksverket.se

Stevenson, A.C. and Harrison, R.J. (1992). Ancient forests in Spain: a model for land-use and dry forest management in south-west Spain from 4000 BC to 1900 AD. Proc. Prehistoric Soc. 58: 227–247.

Takács, V. and Frank, N. (2008). The traditions, resources and potential of forest growing and multipurpose shelterbelts in Hungary. In Rigueiro-Rodríguez, A., McAdam, J., Mosquera-Losada, M.R. (eds.) *Agroforestry in Europe*, vol 6. Springer, Dordrecht, Netherlands.

Thompson, D.B.A, MacDonald, A.J., Marsden, J.H. and Galbraith, C.A. (1995). Upland heather moorland in Great Britain: a review of international importance, vegetation change and some objectives for nature conservation. Biological Conservation 71: 163-178.

UK Biodiversity Action Plan (2008). Priority Habitat Descriptions. Available online: http://jncc.defra.gov.uk/PDF/UKBAP_PriorityHabitatDesc-Rev2011.pdf

Vainio, M., Kekäläinen, H., Alanen, A. and Pykälä, J. (2001). Suomen perinnebiotoopit - Perinnemaisemaprojektin valtakunnallinen loppuraportti [In Finnish: Finland's key-biotopes – Final Report of the National Key-Biotope Project]. Suomen ympäristö 527, 166 pp.

Weidema, B.P., Wesnæs, M., Hermansen, J., Kristensen, T. and Halberg, N. (2008). Environmental Improvement Potentials of Meat and Dairy Products Final Report. Sevilla: Inst. Prospective Technology Studies, 190 pp.