

# The History of Temperate Agroforestry



Figure 1. "Harvesting acorn to feed swine" from the Queen Mary Psalter, British Library

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Kindly supported by funding from  
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## SYNOPSIS

- ✿ Land use systems integrating trees and agriculture have been practised for thousands of years, and have traditionally been important elements of the agricultural landscape in tropical and temperate regions around the world.
- ✿ The shifting cultivation of early civilisations evolved into more settled systems of agriculture involving woodland grazing and silvopasture with transfer of fertility from woodlands to cultivated crops via manure. Traditional temperate systems include:

**Fruit tree silvoarable and silvopastoral systems.** Up until the last century, fruit and nut silvoarable systems covered large areas of central Europe, and are still widespread in certain countries.

**Woodland grazing and wood-pasture.** Pasturing in woodland is one of the oldest land use practices in human history. In northern Europe, mature woodland provided shelter to cattle and sheep during the winter months, while in Mediterranean regions woodland provided browse, forage and shade during early summer drought periods.

**Pollarding.** Cutting branches from trees two to three metres above ground is an ancient practice that provided fodder for livestock and/or wood for fuel and other uses.

**Pannage.** Since Roman times, pigs have been released into beech and oak woodlands to feed on the acorn and beech mast, and into fruit orchards to eat fallen fruit.

**The *Dehesa* (in Spanish) or *montado* (in Portuguese).** This is a Mediterranean land use system based on widely spaced oaks on shallow stony soils, which produce acorns, wood, charcoal and cork, with sheep, goats, pigs and cattle grazing and browsing beneath the trees.

**Hunting forests and parkland.** Woodlands have provided hunting grounds for wild pigs in eastern Europe and game birds in Britain and France, while parklands were developed in 18<sup>th</sup> century Britain for aesthetic reasons and later developed economic value.

**Hedgerows.** Traditional hedgerows provided many benefits; in addition to shelter, hedges provided stock-proof barriers, forage and browse for livestock, and food and medicinal plants for rural populations.

- ✿ Since the introduction of agroforestry as a concept in the late 1970s, the emphasis has been on the development of new systems designed to fulfil the potential benefits of increased productivity balanced with resource and environmental conservation.
- ✿ Modern systems of silvoarable (trees and crops) and silvopastoral (trees and pasture/livestock) agroforestry for food, fuel and timber have been developed, along with systems established for environmental protection such as riparian (riverside) buffers, shelterbelts and soil protection systems.

# 1 INTRODUCTION

The term 'agroforestry' was first coined in 1977 to describe the integration of trees and agriculture, and can be defined as follows:

*A collective name for land-use systems in which woody perennials (trees, shrubs, etc.) are grown in association with herbaceous plants (crops, pastures) or livestock, in a spatial arrangement, a rotation, or both; there are usually both ecological and economic interactions between the trees and other components of the system.*<sup>[1]</sup>

Though the term and its definition are recent, land use systems integrating trees and agriculture have been practised for thousands of years, and have traditionally been important elements of the agricultural landscape in tropical and temperate regions around the world.

The earliest stages of agricultural history were dominated by shifting cultivation, with alternating periods of agriculture and forestry. This evolved into more settled systems involving woodland grazing and silvopasture with transfer of fertility from woodlands to cultivated crops via manure.<sup>[2, 3]</sup> In Europe, tree fodder from species such as ash, elm and poplar was collected and stored to feed livestock, thus maintaining a close connectivity between agriculture, livestock and forestry. Eckert<sup>[1995, in<sup>21</sup>]</sup> has estimated that in Germany's Neidlingen valley up to the year 1500, 75 percent of the nitrogen and 90 percent of the phosphorus needed for arable production came from the forests via fodder residues, manure, litter and ash from domestic fires. Charcoal was also used as a source of potassium.

Trees of high value, such as fruit trees, oaks and beech trees for acorns and beech mast, and ash trees for fodder, were retained during forest clearance and formed the basis of early agroforestry systems.<sup>[4]</sup> These early systems integrating trees and agricultural production began to decline during the Middle Ages, when crop rotation was developed as a method to maintain soil fertility, replacing reliance on the transfer of nutrients from woodlands to croplands. The separation of cropland and woodland was further exacerbated by the introduction of chemical fertilisers during the 19<sup>th</sup> century.<sup>[2]</sup> Nevertheless, remnants of traditional agroforestry systems can still be found throughout Europe, and are often valued for their cultural significance.

## 2 TRADITIONAL SYSTEMS

### 2.1 Fruit tree systems

Up until the last century, fruit and nut silvoarable systems covered large areas of central Europe. Long-established systems remain in certain countries, such as 18,000 hectares of almond trees with cereals or fodder in Sicily, and 10,200 hectares of fig trees with cereals in Crete and the Aegean islands.<sup>[2]</sup> In north-east France, low density fruit tree plantations known as *pre-vergers* provide grazing land, and may be intercropped for the first five to 15 years of a 30-year cycle.<sup>[2]</sup> High-growing fruit trees (*boguards*) with an understorey of grass



Figure 2. Grazed orchard



which is mowed or grazed by cattle and sheep is an agroforestry system which has existed for a long period in the Netherlands.<sup>[5]</sup>

The *pomeradas* of humid areas of northern Spain have existed since the 13<sup>th</sup> century. Consisting of apple trees planted in lines or scattered throughout meadows and croplands, the system has declined dramatically over the last 35 years. Within the UK in the early 20<sup>th</sup> century, intercropping soft fruits or vegetables in the early years of developing full-stature orchards was common, especially in the Kent region. In southern Europe, mixed vineyards incorporated trees as mechanical support for the grapevines, with the added bonus of diversified economic return.



Figure 3. Streuobst

*Streuobst* are fruit trees grown under a traditional central European system: “tall trees of different types and varieties of fruit, belonging to different age groups, which are dispersed on croplands, meadows and pastures in a rather irregular association”.<sup>[2]</sup> *Streuobst* systems are subdivided into silvoarable (*Streuobstäcker*) and silvopastoral (*Streuobstwiesen*) forms. The silvoarable system generally consisted of paired rows of fruit trees, intercropped close to the tree trunks, with low branches to facilitate fruit harvest.

Eichhorn et al.<sup>[2]</sup> have described all of these systems, but observe that they are in rapid decline due to intensification and increased mechanisation. *Streuobst*, for example, declined by 50 percent during the last century, prompting the rollout of subsidised schemes for protection. The majority of remaining sites maintain the silvopastoral system, with small-scale silvoarable existing mainly in eastern Germany (such as in the Magdeburger Börde) for household consumption rather than as commercial systems.<sup>[2]</sup>

## 2.2 Olives

Dating back to pre-Roman times, when rows of olive trees were intercropped with wheat in alternate years to improve the olive yield the following year, olive groves still cover an estimated 650,000 hectares in Greece and 20,000 hectares in Italy.<sup>[2]</sup> Grown in rows or as scattered trees, the olive trees are intercropped with cereals, vegetables and fodder crops, and systems combining olives with grape vines are still found in Spain (46,600 hectares) and Greece.<sup>[2]</sup>

## 2.3 Shelterwoods and woodland grazing

Pasturing in woodland is one of the oldest land use practices in human history. In northern Europe, mature woodland provided shelter to cattle and sheep during the winter months, while in Mediterranean regions woodland provided browse, forage and shade during early summer drought periods, when grazing also reduced fire risks by controlling the understorey.<sup>[6, 7]</sup>

Wood-pasture remnants in England feature some of the oldest and widest trees in Europe, providing valuable resources for a wide range of associated biodiversity, as well as having historical and cultural value.<sup>[8, 9]</sup> The New Forest in southern England is one of the largest remaining areas of wood-pasture in

temperate Europe, with over 3,000 hectares of woodland grazed by ponies, deer, cattle and pigs. Recently designated a National Park, the New Forest pasture woodland has high biological and cultural value and must be grazed to maintain its unique nature.

## 2.4 Pollards

Pollarding is the practice of cutting branches from trees two to three metres above ground level, to obtain leaf fodder for feeding livestock and/or wood for fuel or other uses, and has been an important component of European agriculture over the centuries. Read, in *A brief review of pollards and pollarding in Europe*,<sup>[10]</sup> describes it as, “a way of getting a regular product from the trees while also obtaining a crop from the land underneath them; a sustainable system of agro-forestry.” Fodder pollards were often established in wooded meadows where a hay crop was cut from under the trees and grazed subsequently, while wood pollards were more widely found in wood pasture where grazing occurs for most of the year<sup>[10]</sup>. Pollarding has a long history in Europe: archaeological excavations have uncovered pollards dating back to the Iron Age,<sup>[11]</sup> and a fossil oak pollard found during gravel extraction in the UK has been carbon dated to 3,400 years old.<sup>[9]</sup>



Figure 4. Pollarded trees in wooded meadow, Norway

Pollarding for fodder was practiced across Europe, and was particularly common in northern Europe and mountainous areas such as the Pyrenees, Alps and high pasture areas of the Basque country<sup>[10]</sup>. According to Read, the predominant method for collecting leaf fodder was to cut away all leaf-bearing branches in summer, and dry them for use as livestock feed during the winter. Trees would be cut on a two to six year rotation.<sup>14</sup>

In *Pollarding in Western Norway*,<sup>[11]</sup> Austad and Hauge describe the very active management of pollarded trees and their branches to harvest twigs, leaves and bark for animal use as fodder and bedding (elm bark was even used as a substitute flour in ‘bark bread’ for human consumption in difficult years). They write of a well-developed culture around the use of trees, with sophisticated collection, stacking, drying and feeding practices. One ‘bunch’ of small branches of up to a metre in length and of a diameter decided according to the length of the carrier’s arm, might weigh up to 6kg for fresh elm (the most compact species), and during the winter would constitute a day’s ration for one dairy cow or five sheep. Interestingly, Austad and Hauge quote analyses indicating that leaves are of similar nutritional value to hay.<sup>1</sup>

Many species of deciduous trees used for fodder, in particular *Ulmus glabra* (Wych or Scots Elm), *Fraxinus excelsior* (ash), *Betula pendula* (silver birch), *Betula pubescens* (downy birch) and *Salix caprea* (goat willow)<sup>[11]</sup>. In Norway, cattle and pigs were primarily fed leaves of *Ulmus glabra* and *Fraxinus excelsior* while leaves of *Betula* sp. and *Alnus* sp. were given to sheep and goats.<sup>1</sup>

Reminders of lost skills and knowledge, fodder trees systems are still found in the Mediterranean. Deciduous oak leaves are shredded and dried for sheep fodder in Greece; in Crete and Sicily, carob pods

are stored for fodder.<sup>[2]</sup> There are still many fodder pollards in parts of Scandinavia (e.g. over 40,000 in the Åland Islands, Finland) but many of these have been neglected<sup>[10]</sup>.

Pollarding for wood was also widespread across Europe, though often concentrated in specific areas to meet special demands, such as in Epping Forest, England, where industrial scale pollarding was used to supply fuel to London. There used to be over 500,000 pollards at densities of between 390-740 stems per hectare in Epping Forest, mainly of *Quercus robur* (oak), *Fagus sylvatica* (beech) and *Carpinus betulus* (hornbeam), with pollarding rights extending back over 1,000 years.<sup>[12]</sup> Wood pollards were also important features of farming communities and were often located close to buildings or on rough-grazing common land belonging to a village.<sup>[10]</sup> In the northern plains of Italy, tree hedges of *Ulmus campestris* (elm), *Salix viminalis* (common osier willow) and *Morus alba* (mulberry) were cultivated and used as a source of firewood.<sup>[13]</sup>

## 2.5 Pannage

Pannage is a practice dating from Roman times, wherein pigs are released into beech and oak woodlands to feed on the acorn and beech mast, and into fruit orchards to eat fallen fruit. It was prevalent by the Middle Ages, when most forests in Central Europe were valued by surveyors according to the number of pigs that could be supported by the acorn and beech mast, with woods designated as 'one-hog' to 'hundred-hog'.<sup>[14]</sup> A similar approach was adopted in the Domesday Book.<sup>[15]</sup>



Figure 5. Pannage in the New Forest

Pannage was a legal term from Norman times describing the right to release swine into a woodland during a specified season.<sup>[15]</sup> It often involved movement over long distances; in 17<sup>th</sup> Century Denmark, for example, animals were driven from the treeless western Jylland to eastern forests across distances of over 50km.<sup>[16]</sup>

Although pannage as a legal term had mostly disappeared by the 1800s, the practice continues today in the New Forest of southern England. Common of Mast is the right of New Forest Commoners to turn out pigs during the pannage season, a period of around 60 days between September and November.

The timing is decided by the Forestry Commission in consultation with the verderers (officials responsible for common lands in certain royal hunting areas) according to seasonal variation in mast abundance and timing. In addition to fattening up for the winter, pigs provide a useful service in reducing the density of acorns which are poisonous to the cattle and ponies that graze in the forests. In the 19<sup>th</sup> Century, 5000 to 6000 pigs were turned out each year; this number has dropped to 200 to 600.<sup>[17]</sup>



## 2.6 Dehesas of Spain and montados of Portugal

*Dehesas*, or *montados*, are a Mediterranean land use system based on widely spaced oaks (*Quercus rotundifolia*, *Q. ilex*, *Q. pyrenaica*, *Q. suber*) on shallow stony soils, which produce acorns, wood, charcoal and cork, with sheep, goats, pigs and cattle grazing and browsing beneath the trees.<sup>[6, 18, 19]</sup> Studies of changes in the composition of pollen cores in Spain date the earliest records of *dehesas* to the Copper Age (c. 2500 BC) when oak/pine forests were replaced by scattered oaks and herbaceous vegetation including agricultural weed species, indicating a shift towards intermittent cultivation and grazing.<sup>[2]</sup> The system was developed primarily to produce fine hams: scattered oaks yield substantially more acorns than woodland trees, and this abundance of acorns combined with understory grazing of grasses and herbs creates a high quality of pork.<sup>[2]</sup>



Figure 6. Dehesa system, Spain



Figure 7. Pigs in dehesa, Spain

Wood products of *Dehesas* and *Montados*, however, have also been important; cork is produced from the bark of *Quercus suber* L. in these systems, contributing to the dominance of Portugal (54 percent) and Spain (26 percent) and Portugal in worldwide annual production of 340,000 tonnes of cork.<sup>[20]</sup> Firewood is also an important by-product, with farmers outsourcing pruning of the oaks to contractors who accept lopped branches in lieu of payment, to sell on for charcoal or firewood.<sup>[20]</sup>

*Dehesas* still cover around 2,250,000 hectares in south-west Spain, and *montados* cover 869,000 ha in Portugal, although there are

concerns over the long-term survival of the system as very few oaks have been planted over the last century.<sup>[2]</sup> Similar systems are also found in Greece, marginal areas of Italy and Sardinia (called *seminativo* or *pascolo arborato*), and also in South America, where a system known as *espinal* uses *Acacia caven*.

## 2.7 Hunting forests and parkland

Over the centuries, woodlands have provided hunting grounds for wild pigs in eastern Europe and game birds in Britain and France. Parklands were developed in 18<sup>th</sup> century Britain for aesthetic reasons, but later became a source of valuable open-grown timber for ship building.<sup>[6]</sup>

## 2.8 Erosion control and shelter belts

The value of tree planting for controlling soil erosion was recognised back in the 19<sup>th</sup> century, when the French forestry department planted pine trees on overgrazed steep slopes.<sup>[6]</sup> Some traditional European

landscapes have been shaped by the establishment of shelterbelts centuries ago, such as in the Rhône valley where trees were planted to protect against the Mistral winds, and the *bocage* regions of Normandy and Brittany where the removal of hedgerows in the 1950s and 1960s led to severe wind erosion.<sup>[6]</sup>

## 2.9 Hedgerows

Traditional hedgerows provided many benefits. In addition to shelter, hedges provided stock-proof barriers, forage and browse for livestock, and food and medicinal plants for rural populations. During the second half of the 20<sup>th</sup> century, hedgerows began to be removed to create larger fields for more efficient use of farm machinery. Within the UK, over 50 percent of hedgerows have disappeared since 1947.<sup>[21]</sup> Despite recent agri-environment schemes that have helped to slow this decline by introducing options encouraging hedgerow management, re-creation and restoration,<sup>[22, 23]</sup> the Countryside Survey reported that the length of ‘managed’ hedgerows decreased by 6.2 percent between 1998 and 2007, primarily due to neglect.<sup>[24]</sup>

## 2.10 Timber tree systems

Poplar intercropped with cereals became fashionable in France in the 18<sup>th</sup> century, and still covers about 6000 hectares in well-irrigated alluvial regions.<sup>[2]</sup> In the province of Noord-Brabant, in the Netherlands, poplar was integrated with livestock over an area of 3000 hectares for the production of matchstick veneer.<sup>[5]</sup>

## 2.11 Agroforestry systems in China

China has a long history of agroforestry; official records document recommendations for combining forestry with livestock and crops during the Han Dynasty (206 BC to AD 220), and the biological and ecological interactions between trees and crops appear in writings of the Yuan Dynasty (13<sup>th</sup> to 14<sup>th</sup> century AD).<sup>[25, 26]</sup> Systems often combined crops and trees to improve the form of the trees. Examples of this include the interplanting of Chinese scholar trees (*Sophora japonica*) with hemp to improve the trees for road-side planting; the interplanting of chestnut (*Castanea* spp.) with soybean to make the trees grow upright or for shade or shelter benefits; the use of hemp with paper mulberry (*Broussonetia papyrifera*) to prevent frost damage to the mulberry; or the undersowing of mulberry (*Morus* spp.) with tea (*Thea sinensis*).<sup>[25]</sup> Shifting cultivation was also practised during the Ming Dynasty (AD 1368-1644).<sup>[25]</sup>

### 3 THE DECLINE OF TRADITIONAL AGROFORESTRY SYSTEMS

Eichhorn et al., in their article *Silvoarable systems in Europe - past, present and future prospects*, identify seven basic factors responsible for the decline of agroforestry in Europe: <sup>[2]</sup>

- Increasing mechanisation leading to the removal of scattered trees to facilitate cultivations.
- The post-war demand for increased productivity through monocultures.
- A reduction in the agricultural work force prohibiting labour-intensive systems such as full stature fruit orchards.
- A shift from small, fragmented land holdings to larger single farms, with an increase in field sizes, the removal of boundary trees and landscape simplification.
- Policy regimes that favoured single crop systems over crop associations.
- For many years, wooded areas were ineligible for subsidy payments, and so trees were removed to maximise subsidy income.
- Stricter quality regulations for dessert fruit leading to intensification of orchard production.

Agroforestry systems are still important in several regions of the Mediterranean; often these are more marginal areas where the terrain and climate have prevented intensive agriculture. For example, in the Segura river basin in south-eastern Spain, an area of marginal agricultural land, agroforestry systems cover 60 percent of the basin territory and support 62 percent of the livestock population.<sup>[27]</sup> The greatest diversity of systems is in Greece, with agroforestry systems covering an estimated 3 million hectares or 23 percent of the whole country.<sup>[28]</sup>

Even in Greece, however, agroforestry has been under threat from lack of policy support and short land tenancies which discourage farmers from initiating long-term management plans. Eichhorn et al. found that in Spain, intercropped fruit tree systems declined by 97 percent between 1962 and 1999, and olive systems declined by 94 percent over the same period.<sup>[2]</sup> In addition to the factors listed above, these declines were also caused by irrigation projects that reduced the need for shade trees, and the migration of people from marginal agricultural lands so that *dehesas* reverted to woodland.

#### 4 WHY AGROFORESTRY SYSTEMS ARE NOW RELEVANT AGAIN

In Europe, agroforestry has the potential to address the three key themes of the European Commission's Rural Development Policy 2007-2013:

1. *Improving the competitiveness of the agricultural and forestry sector.* A central hypothesis of agroforestry research is that complementarity of resource capture by trees and crops should lead to increased yields in agroforestry systems compared to forestry or agricultural monocultures.<sup>[29]</sup> By combining crops or livestock with a tree component, it is possible to generate income in the short-term from the agricultural element in addition to long-term revenue streams from the trees, which should increase competitiveness over a forestry-only enterprise. Agroforestry can also bring marginal land into production, and by reducing reliance on synthetic inputs, could potentially improve efficiency.
2. *Improving the environment and the countryside.* Integrating trees into farmland has many environmental benefits including enhanced soil fertility, reduced nutrient leaching, reduced soil and wind erosion, improved water quality and more regulated hydrological cycles, enhanced biodiversity and landscape quality, increased aesthetic value, remediation of polluted land, mitigation of greenhouse gases and sequestration of carbon.<sup>[30]</sup> Agroforestry can also reduce resource-use pressure on native woodlands and slow rates of deforestation.<sup>[31]</sup> Being multi-functional and biodiverse, agroforestry systems are predicted to have greater resilience to the effects of climate change.<sup>[32]</sup>
3. *Improving the quality of life in rural areas and encouraging diversification of the rural economy.* There are several socio-economic benefits of agroforestry. It generates opportunities for skilled jobs in arboriculture, as well generating raw materials for other economic activities (such as bioenergy, fruit production, thatching and other craft products), supporting diversification of local economies and products.<sup>[33]</sup> It is also associated with non-market factor like aesthetics and recreation, since trees can provide wildlife habitat and create a pleasant sheltered environment for people.<sup>[20]</sup> Also, trees perform important ecosystem services such as the control of soil erosion and the regulating water, soil and air quality.<sup>[30]</sup>



## 5 MODERN SYSTEMS

Since the introduction of agroforestry as a concept in the late 1970s, the emphasis has been on the development of new systems designed to fulfil the potential benefits of increased productivity balanced with resource and environmental conservation. Modern systems of silvoarable (trees and crops) and silvopastoral (trees and pasture/livestock) agroforestry for food, fuel and timber have been developed, along with systems established for environmental protection such as riparian (riverside) buffers, shelterbelts and soil protection systems. In North America, *Pinus*-based silvopastoral systems are the most common form of agroforestry, and shelterbelts and riparian buffers have been established to protect the environment and modify the microclimate.<sup>[34]</sup> In New Zealand and temperate regions of Australia, agroforestry systems have been developed over the last 30 years to address the problems of land degradation including salinisation and soil erosion.<sup>[35]</sup> Agroforestry systems in Australia include scattered trees in pastures, tree belts and woodlots,<sup>[35]</sup> while degraded areas in New Zealand have seen the establishment of erosion-minimising systems that integrate the production of high grade *Pinus radiata* saw-logs with cattle and sheep, whose grazing in the understorey reduces fire risk and provides early returns from the land.<sup>[6, 36]</sup>

Mosquero-Losada et al. identified six basic types of agroforestry existing in Europe today: silvoarable, silvopasture, forest farming, riparian buffers, improved fallow and multipurpose trees.<sup>39</sup> A recent phenomenon is the development of several novel systems to investigate agroforestry's potential to address contemporary environmental concerns, for example, as a source of renewable energy. One such experiment is a 'combined food and energy' system that integrated bioenergy production from belts of alder, willow and hazel with crop and pasture production, established in Denmark at Taastrup in 1995.<sup>[37, 38]</sup> Also in Denmark, at Aarhus University, pigs have been released into energy crop systems with mutually beneficial effects for both crops and livestock.<sup>[39]</sup>

Within the UK, examples of modern agroforestry are rarer but interest may be increasing. Progress has been encouraged by the UK's Agroforestry Forum, now the Farm Woodland Forum. In their survey of British agroforestry in 2001, they documented a network of three silvoarable and six silvopastoral experimental sites, established in the late 1980s.<sup>[6]</sup> Later, in 1994, Prof. Martin Wolfe established Wakelyns Agroforestry on a 22.5 hectare site in eastern England. This is an organic silvoarable farm, incorporating a rotation of cereals, potatoes, field vegetables and leys into three systems of tree alleys: hazel coppice, willow coppice, and mixed timber and fruit trees. Sheepdrove Organic Farm in Berkshire runs a silvopoultry system which is integrated into the farm's organic rotation. Planted in 2002, five avenues of trees, hedges and shrubs with 40 metres between avenues provide a stimulating environment for broiler chickens as well as valuable habitat for farmland wildlife and opportunities for community involvement in hedgerow foraging for fruits and nuts.<sup>[40]</sup> An organic apple/arable system was established in 2009 on fenland in Cambridgeshire, by Stephen Briggs, with 4,500 apple trees planted in rows with 24 metre-wide alleys between them allowing for combinable cropping.



Figure 8. Silvoarable system, Wakelyns Agroforestry, Suffolk UK

## 6 MOVING AGROFORESTRY INTO THE MAINSTREAM

The potential of agroforestry as a sustainable land-use system that combines production with conservation of natural resources has not yet been fully realised in temperate regions. Addressing the issue of bringing agroforestry into the mainstream in a 2009 article, Current et al. raised three key questions:<sup>[41]</sup>

- Can agroforestry offer viable alternatives to monocropping systems?
- Where and to what extent is agroforestry feasible?
- What policies are needed to facilitate adoption and implementation of agroforestry to achieve both production and environmental benefits?

### *Can agroforestry offer viable alternatives to monocropping systems?*

For agroforestry to be adopted on a wider scale, economic viability needs to be demonstrated to farmers and landowners. Dupraz and Newman, in their review of European approaches to agroforestry, identified the most successful agroforestry systems as those that had a clearly defined market; consequently, the authors advocated placing a strong focus on the economic value of the trees.<sup>[4]</sup> The economics of a variety of agroforestry systems have been modelled,<sup>[42-44]</sup> but there remains a continued need for long-term research to provide empirical data. The extended time scale required for this research is a limiting factor, with very few studies yet available of complete cycles from tree planting to harvest. It is possible to demonstrate technical effectiveness and economic viability through research trials and modelling, but for these systems still not to appeal to farmers, so outreach support and effective extension projects are essential.<sup>[41]</sup>

### *Where and to what extent is agroforestry feasible?*

Reisner et al.<sup>[45]</sup> used a modelling approach to identify the potential for silvoarable agroforestry within 32 European countries and concluded that one of five commercial tree species (*Prunus avium*, *Juglans* sp., *Populus* sp., *Pinus pinea* and *Quercus ilex*) could grow productively in an agroforestry system on 56 percent of utilised arable land, while providing ecosystem services such as reducing soil erosion and N leaching on 6m and 30m hectares respectively. Research is needed to gain a better understanding of agroforestry function to facilitate appropriate site-specific species selection and agroforestry design and management so that negative interactions of trees and crops are minimised.<sup>[46]</sup>

### *What policies are needed to facilitate adoption and implementation of agroforestry to achieve both production and environmental benefits?*

Supportive policies are seen as instrumental in providing incentives and removing constraints to wider adoption of agroforestry.<sup>[41]</sup> Agroforestry systems often fail to qualify for subsidies under either agricultural or forestry policies, although this situation is now being remedied in some countries (notably France) thanks to policy reforms which enable payments for their establishment. There has also been increasing support for developing a market in environmental services such as carbon sequestration ('Carbon credits') and water quality protection as an incentive for adoption and management of agroforests.<sup>[47]</sup>

A major barrier to wider adoption of agroforestry is limited awareness among farmers and landowners of agroforestry practices. In a recent survey of European farmers' perceptions of agroforestry by Graves et al., only 33 percent of respondents correctly defined agroforestry as an association of trees with crops or livestock.<sup>[48]</sup> However, at the end of the interview, half of all the participating farmers indicated that they would be willing to attempt silvoarable agroforestry on a part of their farm. This suggests that with

promotion and support, agroforestry has the potential to become a more common land use system across Europe.<sup>[48]</sup>

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