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How is agroforestry perceived in Europe? An assessment of positive and negative aspects by stakeholders

Silvestre Garcia de Jalon[1*], Paul J. Burgess[1], Anil Graves[1], Gerardo Moreno[2], Jim McAdam[3], Eric Pottier[4], Sandra Novak[5], Valerio Bondesan[6], Rosa Mosquera Losada[7], Josep Crous-Duran[8], Joao HN Palma[8], Joana Paulo[8], Tania Sofia Oliveira[8], Eric Cirou[9], Yousri Hannachi[10], Anastasia Pantera[11], Regis Wartelle[12], Sonia Kay[13], Nina Malignier[14], Philippe Van Lerberghe[15], Penka Tsonkova[16], Jaconette Mirck[16], Mercedes Rois[17], Anne Grete Kongsted[18], Claudine Thenail[19], Boki Luske[20], Staffan Berg[16], Marie Gosme[21], Andrea Vityi[22].

(1) Cranfield University. Cranfield, Bedfordshire, MK43 0AL, United Kingdom
(2) Forestry Research Group, INDEHESA, Universidad de Extremadura, Plasencia Spain
(3) Agri-Food & Biosciences Institute (AFBI), Newforge Lane, Belfast, UK
(4) Institut de l'Elevage, France
(5) FERLUS, INRA, Les Verrines, F-86600 Lusignan, France
(6) Veneto Agricoltura, Legnaro 35020-Padova, Italy
(7) Crop Production Department, Escuela Politécnica Superior, Universidad de Santiago de Compostela, 27002 Lugo, Spain
(8) Forest Research Centre, School of Agriculture, University of Lisbon, Lisbon, Portugal
(9) Chambres d'Agriculture of Charente-Maritime, France
(10) Chambres d'Agriculture of France, France
(11) Forestry and Natural Environment Management, TEI Stereas Elladas, 36100, Greece
(12) Chambres d'Agriculture of Picardy, France
(13) Agroscope, Switzerland
(14) Association Française d'Agroforesterie (AFAF), France
(15) Institut pour le Développement Forestier (IDF-ACTA), France
(16) BTU Cottbus-Senftenberg, Cottbus, Germany
(17) European Forest Institute, Yliopistokatu 6, FI-80100 Joensuu, Finland
(18) Aarhus University, Denmark
(19) INRA, Rennes, France
(20) Louis Bolk Institute, Netherlands.
(21) INRA, Montpellier, France
(22) University of West Hungary, Hungary

Abstract

Whilst the benefits of agroforestry are widely recognised in tropical latitudes few studies have assessed how agroforestry is perceived in temperate latitudes. This study evaluates how stakeholders and key actors including farmers, landowners, agricultural advisors, researchers and environmentalists perceive the implementation and expansion of agroforestry in Europe. Meetings were held with 30 stakeholder groups covering different agroforestry systems in 2014 in eleven EU countries (Denmark, France, Germany, Greece, Hungary, Italy, Netherlands, Portugal, Spain, Sweden and the United Kingdom). In total 344 valid responses were received to a questionnaire where stakeholders were asked to rank the positive and negative aspects of implementing agroforestry in their region. Improved biodiversity and wildlife habitats, animal health and welfare, and landscape aesthetics were seen as the main positive aspects of agroforestry. By contrast, increased labour, complexity of work, management costs and administrative burden were seen as the most important negative aspects. Overall, improving the environmental value of agriculture was seen as the main benefit of agroforestry, whilst management and socio-economic issues were seen as the greatest barriers. The great variability in the opportunities and barriers of the systems suggests enhanced adoption of agroforestry across Europe will be most likely to occur with specific initiatives for each type of system.

Key words

Agroforestry; Adoption; Barrier; Opportunity; Europe

Introduction

From the 1960s to the beginning of the twenty-first century, crop yields per unit area in Europe have increased as a result of plant breeding, the use of external inputs such as fertilizers and pesticides, and the use of specialised field machinery (Burgess and Morris 2009). This change from traditional to modern agricultural systems has led to a simplification and standardisation of farming systems and to a substantial loss of landscape heterogeneity (Dupraz et al. 2005). At the same time, the area occupied by traditional agroforestry practices (mainly associated with the integration of trees and farming) has declined across Europe. However, agroforestry is still practised on 15.4 million hectares in Europe, about 3.6% of the total territorial area of the European Union (EU) (den Herder et al. 2017).

FAO (2015) defines agroforestry as "land-use systems and technologies where woody perennials (trees, shrubs, palms, bamboos, etc.) are deliberately used on the same land-management units as agricultural crops and/or animals, in some form of spatial arrangement or temporal sequence". The two main types of agroforestry on agricultural land are: i) silvopastoral systems that typically integrate trees with pasture and domesticated animals and ii) silvoarable (or agrisilvicultural) systems that integrate trees and crops. The combination of trees, animals and arable crops are sometimes referred to as agrosilvopastoral systems. In Europe, the AGFORWARD project identified four different categories of agroforestry in terms of the main focus of production and management (Burgess et al. 2015): i) agroforestry of high nature and cultural value (e.g. traditional systems such as the dehesa, montado and other forms of wood pasture and hedgerows which are widely recognised for their biodiversity and heritage), ii) agroforestry with high value trees (e.g. grazed or intercropped orchards or olive groves where tree crops is the primary focus), iii) agroforestry for arable farmers where the crop component is the main focus of the production (e.g. tree lines and windbreaks in arable systems), and iv) agroforestry for livestock farmers, when livestock is the main focus (e.g. fodder trees for ruminants or hens in woodlands).

In 2005, the establishment of agroforestry on agricultural land was supported by the EU Regulation 1698/2005, and the "high ecological and social value" of agroforestry was recognised. Although this support was supposed to increase adoption, farm-level decisions are ultimately made by producers, landowners or by other key stakeholders with relevant influence. Thus, a better understanding of stakeholders' perception of agroforestry is essential to design appropriate policy measures and tools.

Research has highlighted multiple benefits of agroforestry in Europe in terms of environmental benefits (e.g. ecological values and biodiversity), social benefits (e.g. rural employment and cultural practices) and economic benefits (e.g. diversified source of income) (Fagerholm et al. 2016; Eichhorn et al. 2006; Plieninger et al. 2015). However, agroforestry has also been associated with a loss in farm income, reduced labour productivity, and an increase in complexity of work (Graves et al. 2017; Graves et al. 2009; Pannell 1999; Burgess et al. 2016). The latter means that farm management and planning decisions become more critical in determining the economic performance of the system (Schroth et al. 2001). For example, the introduction of trees into arable fields, whilst providing an additional source of future revenue in the form of timber, also shades the crop and alters its capture and use of

soil water and nutrients (Schroth et al. 2001). Whilst the crop-tree interaction, if managed correctly, can improve the economic performance of the farm the system does become more complex. Consequently, agroforestry farmers need to consider more variables in their decision-making process including temporal and spatial factors. These, for example include decisions on the orientation of tree rows, the width of the rows, the timing of field operations, and the potential to damage the tree or crop when implementing field operations. Thus farmers' views on how they could deal with these agroforestry operations and how agroforestry would perform in economic terms on their farms, is likely to determine adoption.

Various studies have assessed farmer attitudes towards conservation practices (e.g. Howley et al. 2014; Barnes et al. 2009; Reimer et al. 2012). However, there are not many specifically focused on agroforestry, and in most cases, they refer to case studies in tropical climates (e.g. Babu and Rajasekaran 1991; Jerneck and Olsson 2013; Meijer et al. 2015). In Europe, the number of studies assessing farmer attitudes towards agroforestry is relatively small. Graves et al. (2009) analysed farmer perceptions of silvoarable systems in seven European countries. The study found that whilst in Mediterranean areas, farmers tended to feel that the principal benefit of silvoarable systems would be increased farm profitability, in Northern Europe farmers placed greatest value on environmental benefits. By contrast, when asked to identify the greatest negative attribute, Mediterranean farmers identified intercrop yield decline, whereas farmers in Northern Europe highlighted the general complexity of work and difficulties with mechanisation. Liagre et al. (2005) found that the majority of European farmers did not know who had planted the existing isolated trees on their farm and stated that they were present when they started to farm. They also showed that a number of farmers recognised that they often cut the trees without replacement as the trees age and only a small percentage of farmers had planted trees on their farm. Graves et al. (2017) evaluated farmers' views on the benefits, constraints, and opportunities for silvoarable systems in Bedfordshire, England. The study showed that most farmers felt that silvoarable systems would not be profitable on their farms and that benefits would tend to be environmental or social rather than financial. The study concluded that management and use of machinery is an important barrier to the adoption of silvoarable systems.

Using the framework used by Botha and Coutts (2011), the implementation of agroforestry depends on the motivation to change and the capacity to change. The motivation to change is dependent on the removal of barriers to adoption of new systems and the generation of, or existence of, capacity to execute that change. The main objective of this study is to assess how stakeholders and key actors perceive the positive and negative issues of implementing agroforestry practices in Europe and to explore possible methods for promoting agroforestry. The study presents the results of a survey carried out across Europe to analyse how stakeholders perceived the positive and negative aspects of implementing and expanding different agroforestry systems. This work assesses farmer attitudes towards agroforestry in Europe in line with previous studies (e.g., Liagre et al. 2005; Graves et al. 2009; Graves et al. 2017) but advances this by separately assessing the positive and negative aspects for each type of agroforestry system and making comparisons across Europe.

Methods

Data collection

Data were obtained from a survey and focus group discussions carried out in case-study workshops in Europe with stakeholders and key actors between June and December 2014. The survey was sent and/or handed out in 45 case-study workshops. Of these, participants in 30 of the workshops successfully completed the study, in six workshops the responses did not provide the disaggregated data necessary to make case-study comparisons and in nine workshops the survey was not undertaken. Each case-study workshop represented a different type of agroforestry system located in eleven countries (Denmark, France, Germany, Greece, Hungary, Italy, Netherlands, Portugal, Spain, Sweden and the United Kingdom). Table 1 describes the 30 case-study workshops used in this study and Figure 1 shows the geographical location.

In each case-study workshop, a focus group discussion was used to gather information on the barriers and opportunities of implementing and expanding a specific agroforestry system that was pertinent to the local region. Subsequently, a questionnaire was handed to each participant. In the questionnaire, stakeholders were asked to identify and rank the main positive and negative aspects of agroforestry in terms of production, environmental, management, and socio-economic aspects. A total of 45 aspects were evaluated (Table 2). Whilst the workshops were primarily focused on qualitative questions, the questionnaire was used to provide a quantitative estimate of the positive and negative attributes of agroforestry. The qualitative data collected in the workshops were used to better explain the survey results. Among the 30 workshops, 344 surveys were successfully completed and returned as presented in Table 1.

Workshop participants mainly included producers, landowners, agricultural advisors, members of NGOs, and researchers. Although most participants were local farmers with some experience in agroforestry practices the proportion of stakeholder groups varied in each case study (Table 1). Further information about each case-study workshop is presented in reports available on the website of the AGFORWARD project (www.agforward.eu).

< INSERT FIGURE 1 >

Description of the agroforestry systems evaluated

The survey was completed during the initial stage of the AGFORWARD project which seeks to promote appropriate agroforestry in Europe. The systems were grouped according to the aforementioned four agroforestry categories. There were eight surveys completed in the *high nature and cultural value agroforestry* group, nine in the *agroforestry with high value trees* group, and seven and six surveys were completed in the *agroforestry for arable systems* and *agroforestry for livestock systems* categories respectively. A detailed description of each agroforestry system is provided in Table 1.

< INSERT TABLE 1 >

Normalising stakeholders' responses

Each participant was given the same two pages (translated into the local language) which listed issues related to production (9 issues), management (8 issues), the environment (11 issues) and socio-economic issues (17 issues) (Bestman et al. 2014). On the first page, the participants were asked to indicate up to 10 issues that they considered were the most positive aspects of agroforestry (with 1 indicating the highest rank and 2 the second highest rank). On the second page, the participants were asked to indicate the 10 issues which they considered were the most negative. A limitation of this study was that the stakeholder groups used slightly different approaches to rank the positive and negative aspects of agroforestry systems. The groups in Denmark, France, Germany, Italy, the Netherlands, Portugal, Hungary and the UK answered the questionnaire as planned. However at the meetings in Greece (Groups 3, 12, 13, 14, 15, 21), Western Spain (Group 1 and 9) and Sweden (Group 6), most or all of the participants ascribed multiple issues the same ranking, e.g. a participant may have given, for example, ten issues the highest rank value of "1". The three groups in Galicia in North-East Spain (Groups 10, 19 and 27) also used a multiple ranking system, but the ranking was sometimes done within each of the production, management, environment and socio-economic categories, rather than considering the 45 issues as a whole.

The differences in the method of completing the questionnaire meant that it was inappropriate to simply aggregate the stakeholders' responses. To allow comparison between groups, we assumed that where participants only ranked the most positive or negative issues, all of the unranked issues had a low and equivalent rank. For example if the participant only ranked three positive aspects e.g. first rank for biodiversity, second for soil conservation, and third for rural employment then we assumed that participant's ranking scale ranged 1 to 4. We then assumed the ranks for biodiversity, soil conservation and rural employment would be 1, 2, and 3 respectively, and that all of the non-ranked issues were given a value of 4. In this way, all issues were given a rank although the range of ranks could vary with participant. Subsequently, the different ranking ranges were given a normalised rank between 0 and 1 (NR_i) derived from the rank (R_i) given by participant *i* and the lowest ($Rmin_i$) and highest ($Rmax_i$) rank given that participant (Equation 1). Hence in this example, biodiversity and rural employment would have NR values of 0 and 0.67 respectively.

$$NR_i = \frac{R_i - Rmax_i}{Rmin_i - Rmax_i} \qquad \text{Equation 1}$$

Finally each normalised rank (NR_i) was subtracted from 1 to create a normalised score (NS_i) so that in the positive issue assessment a higher score indicates a more positive issue and in the negative issue assessment, higher values indicated higher negative values.

$$NS_i = 1 - NR_i \qquad \text{Equation 2}$$

Results

This study describes how stakeholders scored the negative and positive aspects of implementing agroforestry practices. The results are presented first in terms of the overall mean result, and then in terms of four categories of agroforestry systems and the 30 individual groups.

Overall results

The results were first analysed in terms of the overall effect and the same weight was given to each system e.g. the response from the dehesa in Spain (67 respondents) is given the same weight as wood pasture in Hungary (1 respondent). A higher mean normalised positive score was achieved for environmental (0.31) and production (0.31) issues than management (0.20) and socio-economic (0.16) issues (Figure 2). In terms of specific issues, the highest normalised positive scores were achieved for biodiversity and wildlife habitat (0.53), animal health and welfare (0.48), landscape aesthetics (0.43), general environment (0.39), soil conservation (0.39) and diversity of products (0.37).

In terms of negative issues, the highest mean normalised score was obtained for management issues (0.23), followed by socio-economic (0.12) and production (0.10), with environmental issues (0.06) of lowest concern. The highest individual normalised negative scores were achieved for labour (0.35), administrative burden (0.32), complexity of work (0.31) and management costs (0.31).

< INSERT FIGURE 2 >

Results per agroforestry category

The mean normalised score received for each issue within each of the four categories of agroforestry system are described in Table 2. The three individual positive and negative issues receiving the highest normalised score in each of the 30 groups are presented in Tables 3 and 4.

< INSERT TABLE 2 >

< INSERT TABLE 3 >

< INSERT TABLE 4 >

Agroforestry of high nature and cultural value

In agroforestry systems of high nature and cultural value, the highest positive normalised score was received for enhanced biodiversity and wildlife habitat (0.61) (Table 2). This was the highest ranking issue in the hedgerow agroforestry systems in France and Germany and the wood pasture system in the UK (Table 3). The next highest score was for landscape aesthetics (0.45) and this was the highest ranking issue in the dehesa system in Spain. The broad term “general environment” received a score of 0.37, followed by diversity of products (0.37), animal health and welfare (0.35) and animal production (0.35). Animal health and welfare was ranked the highest positive issue in the silvopastoral

systems in Greece. Although not ranked highest across the eight systems as a whole, income diversity was the most important positive aspect in Portugal, rural employment was ranked highest in the reindeer silvopastoral system in Sweden, and disease and weed control was identified as the most positive aspect of wood pasture in Hungary.

In terms of negative aspects, agroforestry of high nature and cultural value was seen to result in losses due to predation (0.34) and this was the dominant negative issue in Greece and Hungary (Table 4). Management costs (0.33) and labour (0.26) were the main negative effects in terms of management, with labour being the highest ranked negative issue by the French and German group, and management costs ranked second in France, Germany, and Sweden. Administrative burden (0.31) was seen as the main negative socio-economic issue and it received the highest negative ranking in Spain. Other issues that were ranked highest by individual groups were complexity of work in the UK and regulation in Portugal.

Agroforestry with high value trees

For agroforestry related to high value trees, the mean normalised scores for positive issues tended to be greater than for the other three categories of systems. This is a result of the majority of these groups (primarily in Greece and Spain) allowing multiple first and second rankings. The highest positive values were again received for the enhancement of biodiversity and wildlife (0.60) and improved landscape aesthetics (0.58). Enhancement of biodiversity was ranked highest in Spain, and ranked second in France and by one of the Greek groups. Soil conservation (0.55), the general environment (0.53), and carbon sequestration (0.50) was also ranked high across the eight groups. Reducing runoff and flood control was ranked the most positive aspect by the orange intercropping group in Crete, Greece. High scores were also received for various aspects of production including the production of timber wood, fruit and nuts (0.51), diversity of products (0.51), and animal health and welfare (0.51). Production of tree products was the most important positive issues for one group in Greece and the group in France. Product diversity was ranked highest by the walnut intercropping group in Greece where the products included walnuts, timber, maize, vegetables, and beans. Animal welfare was considered the most positive issue with another group in Greece and the grazed orchard group in Northern Ireland in the UK. The other issue ranked highest by an individual group was animal production by the grazed orchard group in England, UK. The positive scores received for the individual management and socio-economic issues were less than 0.44.

In terms of negative issues, the most important aspect was the complexity of work (0.43). This was also individually identified as the greatest negative issue in North West Spain, and the two grazed orchard systems in the UK. The next most significant issues were the administrative burden (0.31) and management costs (0.30). The administrative burden was ranked as the most important negative issue in one Greek and one Spanish site. Management costs were considered to be the second most important negative issue by the French and one of the Greek groups. At an individual group level, a lack of knowledge was considered the most important negative issues by the French group dealing

with border trees, and losses by predation was ranked highest by one of the olive agroforestry groups in Greece. The lack of a marketing premium was also highlighted by the walnut intercropping group in Greece.

Agroforestry for arable systems

In terms of agroforestry for arable systems, each of the seven individual groups identified a different issue as the most important benefit of agroforestry. This suggests that the key advantage of agroforestry within an arable system is less clear than with the other categories. The highest positive normalised score was for soil conservation (0.50). Although no individual group identified this as the most important feature; it was ranked second or third in Southwest France, Western France, and Germany. The second highest score was achieved for crop production (0.47) and this was the most highly ranked issue with the German group and was ranked second by the groups in Southern France and Hungary. The third highest scores were for income diversity (0.41) and an enhanced biodiversity and wildlife habitats (0.41). Income diversity was ranked highest in southern France, and biodiversity benefits were ranked in the top three in south-west and western France. Other issues that were ranked highest by an individual group were timber, wood, fruit and nut production in South-West France and business opportunities in Northwest Spain. Climate moderation was ranked as the highest positive issue in Hungary where the focus was on the use of trees for shelterbelts. The highest ranked issue for the Greek group was improved animal health and welfare, which suggests that although the Greek group was included under "arable systems", the wide extent of mixed farms meant that animal welfare remains important on farms producing arable crops in Greece.

The five highest ranked negative issues all relate to management, namely labour (0.41), mechanisation (0.34), management costs (0.32), complexity of work (0.30) and project feasibility (0.30). Labour was ranked as the greatest constraint by the silvoarable group in southern France, and was ranked in the top three by the groups in Western France, Greece and Hungary. Mechanisation was ranked third in North-West Spain, and management cost was the most critical issue in Western France and Greece. Complexity of work was the major issue in Western France and North-West Spain. The other two negative issues that scored highest within an individual group was regulation in Germany and disease and weed control in Hungary.

Agroforestry for livestock systems

There were six groups focused on agroforestry for livestock and these groups generally gave similar responses. The highest positive score for an issue, and in fact the highest score for any issue across the four agroforestry categories, was for animal health and welfare (0.71). This was also the highest positive factor in four of the six groups i.e. two groups in Denmark and the groups in France and the Netherlands, and it was ranked second with the group from Italy. The second highest positive score was in terms of enhanced biodiversity and wildlife habitats (0.50) and this was identified as the most important issue in North-West Spain. Across the six groups the third highest score (0.44) was for

improved landscape aesthetics, which had a top three ranking from the group in the Netherlands and the free-range pig group in Denmark. The energy crops for free-range pigs group in Italy identified the diversity of products as the most important issue.

Increased labour (0.49) was seen as the most negative issue, and in fact this received the highest negative score for an individual issue within an agroforestry category. It was also the highest ranked constraint by the two groups in Denmark, and was ranked second in Western France and the Netherlands. This was also associated with increased administrative burden (0.39), which was ranked first by the group in North West Spain and second by the free-range pig group in Denmark. Across the category the third ranking was given to the complexity of work (0.33), and this was seen as a top three issue in Western France, Italy, and a group in Denmark. The fourth most important issue was disease and weed control (0.33), and this was particularly highlighted by the group in the Netherlands in relation to tree establishment. The group in Italy considered that tree survival was a major issue, and this was also identified by the group in the Netherlands working with goats.

Discussion

Motivations to undertake agroforestry

The study has highlighted four key drivers motivating the practice of agroforestry: biodiversity, soil conservation, enhanced animal health and welfare, and income diversity. These are discussed in turn.

Biodiversity and landscape aesthetics: in the agroforestry with high nature and cultural value and agroforestry with high value trees categories the enhancement of biodiversity and wildlife habitats was the dominant positive attribute. Most of the high nature and cultural value agroforestry systems were wood pastures which are widely recognised in Europe for their high ecological value (Plieninger et al. 2015). Campos Palacín and Mariscal Lorente (2003) showed that dehesa owners often value more self-consumption of recreational and environmental services such as landscape aesthetics and biodiversity than marketed farm products. Some of the systems considered as agroforestry for high value trees, such as the chestnut system in North West Spain, are also valued in terms of their biodiversity and are protected Natura 2000 sites. The high scores related to landscape aesthetics also highlight that these agroforestry systems are not just valued in terms of their ecology, but also their cultural importance. There is evidence that people prefer to see diversified landscapes with trees than without trees (Kaplan and Talbot 1988; Herzog et al. 2000; Gomez-Limon and Lucio Fernandez 1999).

Soil conservation: in agroforestry for arable systems, the key positive motivation was the combination of maintaining crop production with soil conservation. Particularly in silvoarable alley cropping systems soil conservation was seen as a key environmental benefit. Soil loss is a major factor determining the long-term productivity of many arable farms. For example a recent study in the UK has highlighted that soil degradation could have an annual cost of £1.2 billion with about half related to the loss of soil organic matter, 40% to compaction, and 12% to soil erosion (Graves et al. 2015). In

terms of supporting agroforestry, a focus on soil conservation may be particularly useful in that the benefits can be tangible at the farm level (e.g. improved productivity and reduced soil management costs) and, in addition, provide benefits at a wider landscape scale (e.g. reduced flooding and water purification costs).

Animal health and welfare: in agroforestry systems focused on livestock production (e.g., energy crops with free-range pigs and agroforestry with organic poultry), the key motivation was improved animal health and welfare. Broom et al. (2013) has highlighted the positive effect of trees on animal welfare by providing shade from hot sun and shelter from precipitation and extreme cold temperatures. Hens, which are a species adapted to tree cover, can also show more natural behaviour when given access to trees.

Diversity of products and income diversity: diversifying sources of farm income is a key motivation for more risk-averse farmers. Similar to our results, Graves et al. (2009) also found that stakeholders perceived diversity of products to be a major benefit of silvoarable systems.

Constraints to undertake agroforestry

The analysis demonstrates that the key constraints to implementing agroforestry often relate to management issues. In broad terms the same constraints occurred across the four categories of agroforestry namely: high labour requirements, complexity of work, management costs and administrative burdens. Loss by predation was also highlighted within the agroforestry for high nature and cultural value category.

Labour: A key driver in agricultural decisions is the need to increase labour productivity. For example between 1953 and 2000, whilst output per unit area in the UK doubled, the output per unit labour increased at least five-fold (Burgess and Morris 2009). In some situations, this increase in labour productivity resulted in higher wages, but there can sometimes be a cost to social interaction and the number of people employed on farms.

In silvoarable alley cropping systems and agroforestry systems focused on livestock production a key barrier to adoption was the increased labour requirements. Compared to livestock production with no tree cover, agroforestry can require more labour due to tree management operations and difficulties in machinery use (Brownlow et al. 2005). On the other hand, higher labour requirements can lead to an increase in jobs in rural areas which is an important goal of EU policies.

Complexity of work and management costs: these were perceived as important barriers to the implementation of agroforestry in Europe. The management of agroforestry systems can be more complex than conventional agriculture as managers need to consider a wider range of variables, for example the management of the tree component and the phasing of crop, livestock and tree operations (Pannell 1999).

Increased complexity can be an important aspect to consider when livestock are incorporated into high value tree systems such as fruit orchards and olive groves. For example, whilst the introduction of sheep to an apple orchard can increase overall revenue, the integrated management requires the manager to have both tree and livestock management skills or for the orchard manger to work with a sheep farmer. The orchard manager and sheep farmer also need to address management constraints such as the need to remove sheep from the orchard for approximately 60 days before apple harvest to prevent faecal contamination.

Administrative burden: several stakeholders identified that the Common Agricultural Policy (CAP) of the EU disadvantaged agroforestry relative to conventional agricultural systems. Eichhorn et al. (2006) also identified that the CAP played a major role in the recent decline of silvoarable agroforestry systems across Europe. The high administrative burden associated with agroforestry could be a result of the CAP itself or individual national interpretations of the CAP. For example, stakeholders in Spain highlighted that the management of the dehesa wood pasture system required higher levels of administrative input than conventional arable agriculture. Furthermore, they claimed difficulties for getting permission for pruning, an excess of permission for transhumance and lack of efficient green accounting systems for multipurpose systems.

Methods to promote agroforestry

Producers and landowners considering agroforestry need to believe that the benefits outweigh the extra costs involved in the implementation and maintenance of agroforestry systems. Four key methods for promoting agroforestry include i) national demonstration sites, ii) improved regulation, iii) providing a market for the positive externalities with agroforestry, and iv) increasing the opportunities for new profitable businesses.

National demonstrations and education: education, training programmes and use of demonstration sites could play a key role in overcoming the barriers associated with operational complexity. Following the requirements for adoption as identified by Pannell (1999), farmers first need to be able to select the most appropriate agroforestry practice, perceive that the practice is feasible to trial, perceive that the innovation is worth trialing, and feel that the practice promotes their objectives. The use of demonstration sites and field days organized by extension services could be used to introduce farmers to novel agroforestry practices and compare and show their advantages over other systems.

Improved regulation: some of the administrative burden associated with agroforestry can be addressed through simplified and/or improved policies. At present it is argued that there are complex regulations that lead to simplified landscapes; is it possible to have simplified regulations that lead to more diversed landscapes? For example in the dehesa, farmers highlighted the difficulty of retaining full eligibility of wood pastures for Pillar I CAP payments. One potential way forward is for managers of agroforestry systems to work with national farming associations to improve communication with policy makers at local, national and EU level.

Market for positive externalities: many of the benefits of agroforestry are environmental which are non-market benefits, and hence agroforestry farmers are not financially compensated for the societal benefits that they provide. Moreover, some of these "non-market benefits" occur not just on-farm but at a wider landscape or catchment scale. Since currently, it is often only market costs and benefits that are guiding decision-making it is argued that this has led to sub-optimal land uses from a societal perspective, and hence (with due care) there may be a case for government and, for example, utility companies to compensate farmers who integrate trees with farming. In some cases, awareness alone of the environmental benefits is insufficient to lead to the adoption of conservation practices (Knowler and Bradshaw 2007). Farmers need to perceive that the practice will provide benefits on their own farm or that they will be compensated for the extra costs (Greiner and Gregg 2011). To some extent, the magnitude of the environmental benefit perceived by each person depends on personal knowledge, awareness and attitudes towards the environment (Jacobsen et al. 2008). A farmer with low environmental awareness is therefore less likely to adopt agroforestry practices than a farmer with high environmental awareness (Reimer et al. 2012; García de Jalón et al. 2013). Thus, raising farmers' environmental awareness could be an additional approach to promoting agroforestry practices.

Profitable business opportunities: many agricultural innovations are founded on the business opportunity of improved profit. In this study, the business opportunities and the profit associated with agroforestry were not seen as key drivers. Workman et al. (2003) highlighted lack of markets as a barrier to the adoption of agroforestry. One of the key areas where agroforestry systems have recently been adopted in the UK is in relation to woodland eggs and chickens driven by an increase in societal concern about farm animal welfare (Jones et al., 2007). In this case, consumers and NGOs have perceived that a welfare benefit for hens and other poultry exists when they have access to a wooded environment, and hence specific labels or contracts may specify that that poultry owners need to provide access for their stock to woodland.

Conclusions

The main positive aspects of agroforestry as perceived by stakeholders in Europe were primarily environmental or production-based, with specific benefits being enhanced biodiversity and wildlife habitats, landscape aesthetics, soil conservation, and animal health and welfare. By contrast, the main negative aspects of agroforestry were primarily related to management and socio-economic issues, with the principal constraints being increased labour, complexity of work, management costs, the administrative burden and in some cases predation by wild animals.

Successful adoption and maintenance of agroforestry systems requires farmers to perceive that the net benefit provided by agroforestry is greater than alternative land use options. If there is clear quantification of the environmental benefits provided by agroforestry, then there is a case for national governments, NGOs and motivated individuals to use education, regulation, market mechanisms and marketing innovation to promote wider adoption and maintenance of agroforestry systems.

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Table 1. Description of the 30 agroforestry workshops

System	Description	Number and types of stakeholders and key actors
Agroforestry of high nature and cultural value		
1. Dehesa, South-west Spain	Agrosilvopastoral systems originating from clearing of evergreen woodlands where trees, native grasses, crops, and livestock interact positively under specific management. The tree species include holm oak (*Quercus ilex* L.) and cork oak (*Quercus suber* L.). Traditional breeds of pigs, cows, sheep and goats are reared at low stocking densities.	67: 26 farmers (livestock breeders), 9 landowners, 16 technical advisors, 5 agrarian administrators, 2 environmentalists, 7 researchers, 2 journalists
2. Montado, Portugal	Similar to dehesa in Spain but cork oak is usually more abundant	17: 7 technical advisors, 2 farm managers, 2 forest managers, 5 farm and forest managers, 1 other
3. Valonia oak silvopastures in Greece	Silvopastoral systems where livestock breeders (sheep and goat) use the valonia oak woodland (*Quercus ithaburensis subsp. macrolepis* (Kotschy)) for grazing. Some acorn cups are used the dye industry.	11: 4 livestock breeders, 2 farmers (livestock breeder) , 1 agronomy student, 4 farmers
4. Wood pasture and parklands in lowland UK	Characterised by veteran trees (often pollarded), grazing livestock, and an understorey of grassland or heathland. Typical tree species include oak, beech and hornbeam.	5: 2 Estate managers; 3 advisors
5. Bocage agroforestry in North-western France	Traditional hedgerow systems largely based on lines of pollarded high-stem trees such as oaks (*Quercus robur* L.), chestnut (*Castanea sativa Mill.*) and beech (*Fagus sylvatica* L.), and medium-stem trees such as hazel (*Corylus avellana* L.) and hornbeam (*Carpinus betulus* L.).	4: 2 farmers, 1 engineer of decentralized State services, 1 technician of a local administration
6. Wood pastures in Northern Sweden	Reindeer husbandry systems based on forest understorey resources. Private forest landowners and enterprises often interact with Sami people, who manage the reindeer, for land-management decisions.	3: 3 Njaarke Sami members (farmers)
7. Agroforestry in Spreewald of Germany	Systems characterized by closely-spaced hedgerows that demarcate individual fields. Common tree species are black alder (*Alnus glutinosa* (L.) Gaertn.), hackberry (*Prunus padus* L.), oak (*Quercus robur* L.) and black poplar (*Populus nigra* L.).	2: 2 farmers
8. Wood pasture, Hungary	Characterised by oak trees (*Quercus robur* L.) with traditional sheep herding.	1: 1 manager of major conservation district of national park
Agroforestry with high value trees		
9. Grazing and intercropping of walnut and cherry, Spain	Plantations of quality timber trees (walnut or cherry) are intercropped with arable crops or grazed by sheep.	27: 10 arable farmers, 7 timber producers, 6 technical advisors, 1 agrarian administrator, 3 academic/researchers
10. Chestnut agroforestry in North-western Spain	Chestnut production is the main focus, but mushrooms and high quality honey is also harvested. The system is protected by the Natura 2000 network as it is a priority area for birds.	21: 12 chestnut farmers, 2 chestnut processing employees, 5 chestnut association members, 1 expert, 1 rural development member
11. Border trees, South-west France	Managed trees found in rural hedges which often line the side of a road, in riparian forests, buffer strips (with woody vegetation) and wood edges.	10: 3 farmers with border trees, 2 timber producers, 3 riparian technicians, 1 chamber of agriculture, 1 arable farmer
12. Intercropping of walnut trees, Greece	Characterized by walnut trees (*Juglans regia* L.) growing at the edge of fields of maize, dry beans, cereals or pasture.	8: 1 retired farmer, 1 private employee, 6 farmers
13. Intercropping olive groves, Greece	Intercropping of olive (*Olea europaea* L.) groves with arable crops (cereals) to diversify production and income.	13: 1 agronomist, 1 forester, 10 farmers, 1 retired farming employee
14. Grazing and intercropping of olive groves, Greece	Intercropping of olive groves with arable crops (cereals) and grazing with sheep or chicken.	6: 5 farmers, 1 agricultural public servant

15. Intercropping of orange groves, Greece	Intercropping of citrus trees (*Citrus × sinensis* (L.) Osbeck) with intercrops (mainly vegetables) until the tree canopy fully develops, at which stage poultry production can be an option.	5: 3 farmer, 1 agronomist, 1 other
16. Grazed orchards, England, UK	Apple (*Malus domestica* Borkh.) orchards are grazed with sheep. The sheep usually need to be taken out of the orchard during some field operations such as spraying or harvesting. Pears (*Pyrus communis* L.) are also grown.	7: 7 farmers
17. Grazed orchards, N. Ireland, UK	Grazed bramley apple orchards with sheep.	2: 2 apple growers
Agroforestry for arable systems		
18. Silvoarable agroforestry, Western France	Integration of three to five tree species (e.g. *Juglans regia* L., *Sorbus domestica* L., *Sorbus torminalis* (L.) Crantz, *Prunus avium* L., *Fraxinus excelsior* L., *Acer pseudoplatanus* L., and *Quercus spp*.) in arable fields often with regional government support. Typical tree densities are 30-50 trees per hectare in 27 m rows (24 m cultivated area). Arable crops are often organically managed.	14: 4 farmers and 10 technical advisors
19. Silvoarable agroforestry, North-western Spain	Widely-spaced trees intercropped with annual or perennial crops.	13: 2 dairy farmers, 2 timber producers, 4 farming cooperative employees, 1 organic producers, 2 representative of rural development group, 1 counsellor in farming company, 1 other
20. Silvoarable agroforestry, South-Western France	Novel methods for integrating trees in crop fields, pastures and vineyards, often with regional government support.	11: 9 agroforestry farmers, 1 member of the chamber of agriculture, 1 local technician for agroforestry plantations
21. Trees with arable crops and grassland, Greece	Trees species such as walnut and poplars grown in the borders of arable fields producing field beans, cereals and grass	10: 3 farmers, 1 forester, 2 agronomists, 2 public servants, 2 farmers
22. Alley cropping, Germany	Experimental system integrating rows of fast growing trees such as poplar (*Populus spp.*) and black locust (*Robinia pseudoacacia* L.) with arable crops.	6: 1 farmer, 1 retired-farmer, 1 agricultural engineer, 1 landscape architect, 1 researcher, 1 other
23. Silvoarable agroforestry, Southern France	Integration of trees (e.g. *Populus* species) planted in rows with durum wheat, chickpea, and oilseed rape.	10: 6 farmers, 1 technician, 1 food industry member, 1 organic farmer, 1 seed production advisor
24. Alley cropping in Hungary	Protective shelterbelts, buffer strips and alley cropping on farmsteads or between arable lands	1: 1 managing director of agri-cooperative
Agroforestry for livestock systems		
25. Agroforestry with ruminants, Northern and mid-Western France	Integration of trees for timber production and as an alternative source of fodder on organic and non-organic grassland and mixed crop-livestock farms with dairy and beef cattle or sheep or goats.	28: 10 farmers, 5 researchers, 10 technical advisors (5 agriculture advisors and 5 agroforestry advisors), 3 others
26. Energy crops and free-range pigs, North-eastern Italy	Free-range pigs with poplar and willow trees for biomass production on paddock borders. The trees provide shade and reduce heat stress during summer months.	22: 9 farmers, 3 members of Dept. of agriculture, 2 veterinarians, 5 agronomist, 3 researchers (forestry and animal science)
27. Pigs with chestnut and oaks, North-western Spain	Semi-extensive or extensive systems focused on pork production in forest areas dominated by chestnut and oak trees.	16: 7 pig breeders, 5 employees in the technological centre of pig, 2 foresters, 1 veterinarian, 1 mushroom mycelia supplier
28. Agroforestry with organic poultry and pigs, Denmark	Organic pig or poultry production on small-holder farms integrated with pasture, fruit trees, bushes and vegetables.	5: 1 organic farmer, 1 private advisor, 1 animal protection member, 1 organic farmer, 1 researcher
29. Fodder trees for cattle and goats, the Netherlands	Fodder trees such as willow are planted for browsing by cattle and goats.	4: 4 farmers
30. Energy crops with free-range pigs, Denmark	Free-range pigs integrated with grass clover crops between rows of short rotation coppice willow (*Salix spp.*) or poplar (*Populus spp.*). Lactating sows are kept outdoors all year round in individual paddocks.	2: 2 organic pig producers

Table 2. Positive and negative aspects of the categories of agroforestry in Europe.

Criteria	Aspects	Positive assessment				Negative assessment			
		High Natural and Cultural Value systems	High Value Tree systems	Agroforestry for Arable systems	Agroforestry for Livestock systems	High Natural and Cultural Value systems	High Value Tree systems	Agroforestry for Arable systems	Agroforestry for Livestock systems
Production	Animal health and welfare	0.35	0.51	0.32	0.71	0.07	0.07	0.04	0.13
	Animal production	0.35	0.41	0.26	0.26	0.02	0.13	0.05	0.09
	Losses by predation	0.05	0.16	0.10	0.05	0.34	0.23	0.23	0.20
	Crop or pasture production	0.33	0.40	0.47	0.14	0.01	0.10	0.11	0.07
	Crop or pasture quality food safety	0.22	0.45	0.28	0.18	0.03	0.09	0.05	0.06
	Disease and weed control	0.30	0.45	0.19	0.17	0.24	0.10	0.25	0.31
	Diversity of products	0.37	0.51	0.24	0.34	0.04	0.07	0.07	0.04
	Timber wood fruit nut production	0.18	0.51	0.33	0.23	0.01	0.10	0.08	0.03
	Timber wood fruit nut quality	0.26	0.46	0.23	0.19	0.02	0.08	0.04	0.06
Management	Complexity of work	0.22	0.27	0.10	0.11	0.19	0.43	0.30	0.33
	Inspection of animals	0.14	0.21	0.07	0.09	0.23	0.27	0.10	0.24
	Labour	0.25	0.34	0.13	0.11	0.26	0.24	0.41	0.49
	Management costs	0.11	0.33	0.09	0.10	0.33	0.30	0.32	0.27
	Mechanisation	0.12	0.23	0.09	0.10	0.13	0.23	0.34	0.28
	Originality and interest	0.31	0.40	0.21	0.32	0.01	0.17	0.10	0.12
	Project feasibility	0.25	0.32	0.21	0.13	0.07	0.14	0.30	0.09
	Tree regeneration survival	0.30	0.41	0.16	0.14	0.10	0.14	0.16	0.23
Environmental quality	Biodiversity and wildlife habitat	0.61	0.60	0.41	0.50	0.01	0.06	0.04	0.06
	Carbon sequestration	0.31	0.50	0.26	0.19	0.00	0.07	0.02	0.05
	Change in fire risk	0.20	0.38	0.11	0.12	0.02	0.10	0.08	0.04
	Climate moderation	0.25	0.44	0.38	0.09	0.01	0.08	0.05	0.08
	Control of manure noise odour	0.15	0.44	0.09	0.10	0.08	0.08	0.10	0.11
	General environment	0.37	0.53	0.37	0.31	0.01	0.06	0.05	0.04
	Landscape aesthetics	0.45	0.58	0.25	0.44	0.00	0.08	0.10	0.05
	Reduced groundwater recharge	0.11	0.34	0.12	0.06	0.07	0.10	0.09	0.05
	Runoff and flood control	0.26	0.44	0.19	0.19	0.03	0.07	0.07	0.06
	Soil conservation	0.32	0.55	0.50	0.17	0.04	0.07	0.08	0.06
	Water quality	0.21	0.40	0.29	0.14	0.01	0.07	0.04	0.10
Socio-economic	Administrative burden	0.10	0.16	0.03	0.04	0.31	0.31	0.27	0.39
	Business opportunities	0.26	0.32	0.19	0.18	0.04	0.21	0.14	0.08
	Cash flow	0.15	0.20	0.08	0.06	0.15	0.18	0.22	0.08
	Farmer image	0.29	0.39	0.21	0.29	0.03	0.18	0.10	0.04
	Income diversity	0.25	0.43	0.41	0.17	0.01	0.11	0.06	0.05
	Inheritance and tax	0.14	0.11	0.06	0.05	0.06	0.17	0.17	0.09
	Regulation	0.12	0.09	0.08	0.05	0.15	0.27	0.20	0.24
	Local food supply	0.16	0.35	0.15	0.17	0.08	0.07	0.06	0.05
	Marketing premium	0.17	0.16	0.07	0.13	0.02	0.16	0.14	0.06
	Market risk	0.14	0.17	0.06	0.05	0.04	0.18	0.18	0.15
	Opportunity for hunting	0.19	0.22	0.13	0.06	0.02	0.16	0.10	0.03
	Profit	0.18	0.37	0.15	0.09	0.10	0.12	0.08	0.07
	Relationship between farmer hunter	0.13	0.16	0.10	0.08	0.05	0.18	0.10	0.08
	Relationship between farmer owner	0.14	0.17	0.12	0.12	0.05	0.15	0.11	0.08
	Rural employment	0.20	0.34	0.13	0.11	0.02	0.13	0.05	0.04
	Subsidy and grant eligibility	0.14	0.17	0.16	0.06	0.07	0.13	0.11	0.20
	Tourism	0.21	0.21	0.08	0.13	0.02	0.15	0.09	0.04

Table 3. Three issues receiving the highest normalised positive score in each of 30 studied agroforestry systems.

	Systems	Highest score	Second	Third	n
High nature and cultural value	1. Dehesa, South-west Spain	Landscape aesthetics	General environment	Soil conservation	67
	2. Montado, Portugal	Income diversity	Biodiversity and wildlife habitat	Diversity of products	17
	3. Valonia oak silvopastures, Greece	Animal health and welfare	Animal production	Diversity of products	11
	4. Wood pasture and parklands, UK	Biodiversity and wildlife habitat	Soil conservation	Landscape aesthetics	5
	5. Bocage agroforestry, France	Biodiversity and wildlife habitat	Carbon sequestration	Runoff and flood control	4
	6. Wood pastures in Northern Sweden	Rural employment	Business opportunities	General environment	3
	7. Agroforestry in Eastern Germany	Biodiversity and wildlife habitat	Crop or pasture production	Diversity of products	2
	8. Wood pasture in Hungary	Disease and weed control	Biodiversity and wildlife habitat	Runoff and flood control	1
Agroforestry with high value trees	9. Grazing and intercropping of walnut and cherry, Spain	General environment	Landscape aesthetics	Soil conservation	27
	10. Chestnut agroforestry, North-west Spain	Biodiversity and wildlife habitat	Diversity of products	Tree regeneration survival	21
	11. Border trees, South-western France	Timber, wood, fruit and nut production	Biodiversity and wildlife habitat	Landscape aesthetics	10
	12. Intercropping of walnut trees, Greece	Diversity of products	General environment	Landscape aesthetics	8
	13. Intercropping of olive groves, Greece	Timber, wood, fruit and nut quality	Biodiversity and wildlife habitat	Diversity of products	13
	14. Grazing and intercropping of olive groves, Greece	Animal health and welfare	Control of manure, noise and odour	Timber, wood, fruit and nut production	6
	15. Intercropping of orange groves, Greece	Runoff and flood control	Soil conservation	Crop or pasture quality food safety	5
	16. Grazed orchards, England, UK	Animal production	Labour	Management costs	7
	17. Grazed orchards, Northern Ireland, UK	Animal health and welfare	Profit	Crop or pasture production	2
Agroforestry for arable systems	18. Silvoarable agroforestry, Western France	General environment	Biodiversity and wildlife habitat	Soil conservation	14
	19. Silvoarable agroforestry, North-western Spain	Business opportunities	Originality and interest	Project feasibility	13
	20. Silvoarable agroforestry, South-Western France	Timber, wood, fruit and nut production	Soil conservation	Biodiversity and wildlife habitat	11
	21. Trees with arable crops and grassland, Greece	Animal health and welfare	Timber, wood, fruit and nut quality	Animal production	10
	22. Alley cropping, Germany	Crop or pasture production	Soil conservation	Landscape aesthetics	6
	23. Silvoarable agroforestry, Southern France	Income diversity	Crop or pasture production	Biodiversity and wildlife habitat	3
	24. Alley cropping, Hungary	Climate moderation	Crop or pasture production	Income diversity	1
Agroforestry for livestock	25. Agroforestry with ruminants, Northern and mid-Western France	Animal health and welfare	Farmer image	Biodiversity and wildlife habitat	28
	26. Energy crops and free-range pigs, North-eastern Italy	Diversity of products	Animal health and welfare	Timber, wood, fruit and nut quality	22
	27. Pigs with chestnuts and oaks, North-western Spain	Biodiversity and wildlife habitat	Project feasibility	Tree regeneration survival	16
	28. Agroforestry with organic poultry and pigs, Denmark	Animal health and welfare	Diversity of products	Biodiversity and wildlife habitat	5
	29. Fodder trees for cattle and goats, the Netherlands	Animal health and welfare	Landscape aesthetics	Biodiversity and wildlife habitat	4
	30. Energy crops with free-range pigs, Denmark	Animal health and welfare	Biodiversity and wildlife habitat	Landscape aesthetics	2

Table 4. Three issues receiving the highest normalised negative score in each of 30 studied agroforestry systems.

	Systems	Highest score	Second	Third	n
High nature and cultural value	1. Dehesa, South-west Spain	Administrative burden	Subsidy and grant eligibility	Mechanisation	66
	2. Montado, Portugal	Regulation	Tree regeneration survival	Complexity of work	15
	3. Valonia oak silvopastures, Greece	Losses by predation	Reduced groundwater recharge	Soil conservation	7
	4. Wood pasture and parklands, UK	Complexity of work	Inspection of animals	Management costs	5
	5. Bocage agroforestry, North-western France	Labour	Management costs	Cash flow	4
	6. Wood pastures in Northern Sweden	Disease and weed control	Management costs	Losses by predation	3
	7. Agroforestry in Germany	Labour	Management costs	Administrative burden	2
	8. Wood pasture in Hungary	Losses by predation	Administrative burden	Inspection of animals	1
Agroforestry with high value trees	9. Grazing and intercropping of walnut and cherry, Western Spain	Administrative burden	Subsidy and grant eligibility	Mechanization	27
	10. Chestnut agroforestry, North-western Spain	Complexity of work	Animal production	Losses by predation	21
	11. Border trees, South-west France	Lack of knowledge	Management costs	Mechanisation	10
	12. Intercropping of walnut trees, Greece	Marketing premium	Cash flow	Business opportunities	8
	13. Intercropping olive groves, Greece	Administrative burden	Management costs	Complexity of work	10
	14. Grazing and intercropping of olive groves in Greece	Losses by predation	Opportunity for hunting	Relationship between farmer hunter	7
	15. Intercropping of orange groves, Greece	NA	NA	NA	5
	16. Grazed orchards, England, UK	Complexity of work	Inspection of animals	Management costs	7
	17. Grazed orchards, N. Ireland, UK	Complexity of work	Cost of fencing boundary	Inspection of animals	2
Agroforestry for arable systems	18. Silvoarable agroforestry, Western France	Complexity of work	Labour	Cash flow	14
	19. Silvoarable agroforestry, North-western Spain	Complexity of work	Losses by predation	Mechanisation	13
	20. Silvoarable agroforestry, South-Western France	Management costs	Project feasibility	Administrative burden	10
	21. Trees with arable crops and grassland, Greece	Management costs	Losses by predation	Labour	10
	22. Alley cropping, Germany	Labour	Business opportunities	Cash flow	3
	23. Silvoarable agroforestry, Southern France	Regulation	Administrative burden	Management costs	3
	24. Alley cropping, Hungary	Disease and weed control	Project feasibility	Labour	1
Agroforestry for livestock	25. Agroforestry with ruminants, Northern and mid-Western France	Complexity of work	Labour	Mechanisation	28
	26. Energy crops and free-range pigs, North-eastern Italy	Tree regeneration survival	Inspection of animals	Complexity of work	22
	27. Pigs with chestnuts and oaks, North-western Spain	Administrative burden	Losses by predation	Animal production	12
	28. Agroforestry with organic poultry and pigs, Denmark	Labour	Complexity of work	Administrative burden	5
	29. Fodder trees for cattle and goats, the Netherlands	Disease and weed control	Labour	Tree regeneration survival	3
	30. Energy crops with free-range pigs, Denmark	Labour	Administrative burden	Management costs	2

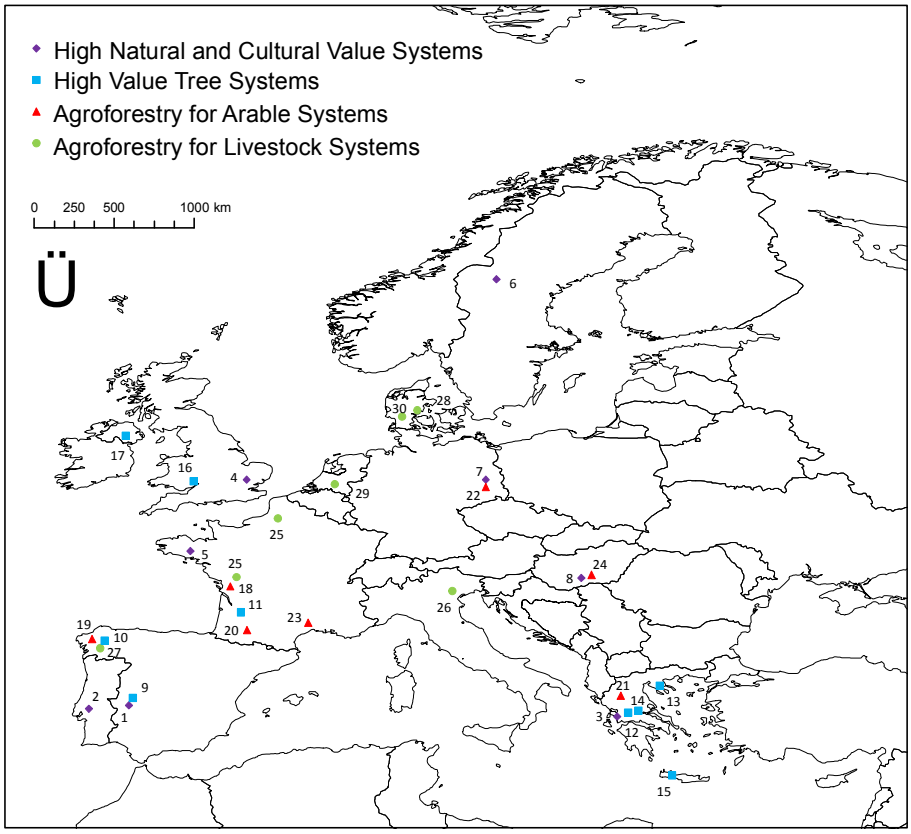

Figure 1. Location of the stakeholder workshops.

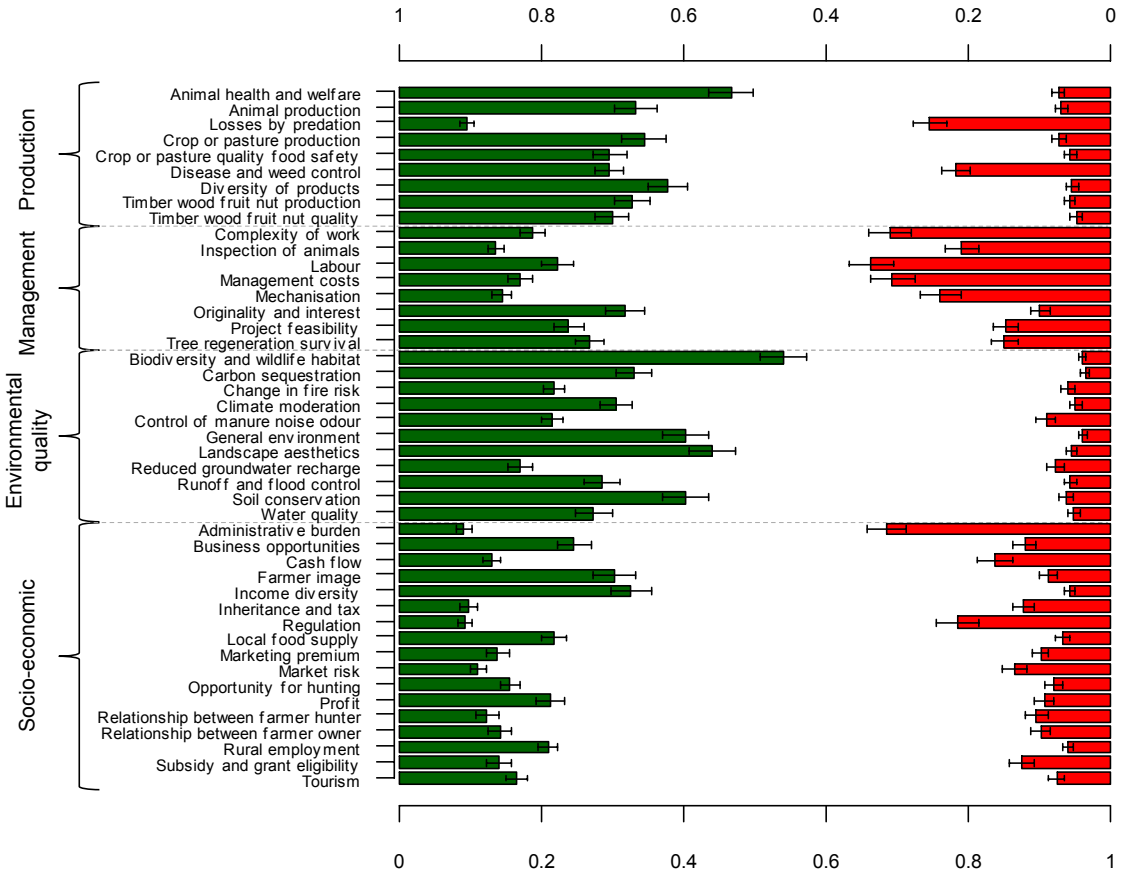

Figure 2. Mean normalised scores received from 30 stakeholder groups (comprising 344 stakeholders) on the positive (green bars on the left) and negative issues (red bares on the right) related to selected agroforestry systems across Europe. Error bars indicate the 95% confidence interval for the estimated mean.

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García de Jalón, Silvestre

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