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Farmer perception of benefits, constraints and opportunities for silvoarable systems: preliminary insights from Bedfordshire, England

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Abstract

Silvoarable agroforestry integrates the use of trees and arable crops on the same area of land, and such systems can be supported by national governments under the European Union's (EU) Rural Development Regulations (2014-2020). In order to improve understanding of farmers' perceptions of such systems, detailed face-to-face interviews in 2003 were completed with fifteen farmers in Bedfordshire, England. Most of these farmers thought that silvoarable systems would not be profitable on their farms and that benefits would tend to be environmental or social rather than economic. Most also thought that management and use of machinery would become more difficult. They felt that the tree component could potentially disrupt field operations and drainage, and expressed concern over the uncertain and long-term nature of timber revenue, and the effect of intercrop yield reductions on crop revenue. Even so, 20% of the farmers stated they would use silvoarable systems if convinced that they were more profitable than conventional arable farming. A further 20% said they would farm the intercrop area belonging to someone else, if the rent was reduced to compensate for crop yield reductions. These results suggest that for most arable farmers, an economic advantage over current practice needs to exist before silvoarable systems are likely to be adopted. However a minority might rent the crop component of a silvoarable system from another party, or implement a full system for perceived environmental or social benefits.

*Keywords***:** Social survey, adoption, attitudes, risk, positive, negative

Introduction

Recent EU Rural Development Regulation 1305/2013 allows support to be provided for the establishment of agroforestry systems on agricultural land in the European Union. The European Commission (2004) has stated that such systems should be encouraged, because of their "high ecological and social value". Previous research supports this position (Palma et al., 2006). However, relatively little is known about how European farmers regard agroforestry systems. Most research regarding farmers' perceptions of agroforestry has been undertaken in tropical countries where it has sought to understand local practice (Barrance et al., 2003), opportunities for improvement (Fischler and Wortmann, 1999; Dreschel and Rech, 1998), and the reasons for success or failure (Graves et al., 2004, Franzel, 1999).

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Research on farmers' perceptions of agroforestry in temperate areas has focused on riparian strips (Ducros and Watson, 2002), hedgerows (Morris et al., 2002), windbreaks (Matthews et al., 1993), or silvopastoral systems (McAdam, et al., 1997). For example, Matthews et al. (1993) used a postal questionnaire of landowners in Wellington County in Canada. The majority of those surveyed were familiar with windbreaks, woodlots and plantations and interest in adopting such techniques was relatively high; but fewer were aware of the practice of incorporating widely-spaced trees in cropped fields or displayed an interest in doing this. Most felt that there would be little economic benefit in adopting such systems because of the increased need for management. Although a minority stated they would be interested in establishing agroforestry systems despite anticipated increases in labour and overheads, widespread adoption would depend primarily on perceived economic benefits.

Lawrence and Hardesty (1992) also used a postal questionnaire in Washington State in the United States of America, to survey three groups of land managers: employees of the Soil Conservation Service, employees of the Washington State University Cooperative Extension Service, and a group comprising university faculty members, private, state and federal land managers, and owners of natural resource businesses. Of the 45% who responded to the survey, 94% were aware of agroforestry and of these, 55% had given advice on or implemented an agroforestry system themselves. The most frequently cited potential application for agroforestry was in "government mandated" soil conservation plans (100%), range and pasture land (84%), management of non-commercial forest land (84%), commercial forest plantations (83%), and orchards (61%). The perceived benefits were land use diversity (25%), enhanced productivity (18%), aesthetics (13%), and income diversity (13%). The identified constraints were lack of information (28%), lack of technical assistance (18%), establishment costs (14%), and the fact that it was not an established practice (14%).

Workman et al. (2003) reported on a survey of landowners and extension professionals in Florida, Alabama, and Georgia in the United States of America. Most farmers indicated that they used at least one form of agroforestry practice, for example, riparian buffers or windbreaks. A small proportion, who had established nut trees such as Pecan (*Carya illinoinensis*) and peach (*Prunus persica*) indicated they had used the intercrop area for vegetables and cut flowers. Given a list of 16 potential benefits, farmers in Florida and Alabama indicated that they felt the main advantages of agroforestry were aesthetic value, shade, wildlife habitat, and soil conservation, increased land value and long-term investment value. The same farmers identified the main constraints as competition between trees crops and animals, lack of equipment, lack of information and markets, expense of management, lack of familiarity with agroforestry, and lack of land and demonstrations.

This paper describes the results derived from a sample of farmers in Bedfordshire, England. The principal objectives were to determine farmers' current awareness of silvoarable systems, to understand their perception of the potential benefits and constraints, to understand what would motivate them to use a silvoarable system, and finally to understand how they would then design and implement it.

Method

The interviews took place in Bedfordshire in Eastern England in 2003 (Figure 1) around the county town of Bedford (52°08' N, 0°27' W; 95 m above mean sea level). The mean annual temperature in Bedfordshire (1971-2000) is about 9.6°C, and the mean annual rainfall is about 580 mm (The Meteorological Office, 2005). Bedfordshire covers 119,208 ha with a population of approximately 381,600. The agricultural area of 87,000 ha comprises 73% of the total area. In 2003, the agricultural area was devoted principally to arable production comprising wheat (39%), oilseed rape (10%), barley (7%) and field beans for stock feed (6%) (Defra, 2003). Set-aside (12%) (land taken out of crop production to reduce crop surpluses and provide environmental benefits), and grassland (16%) were also substantial. Woodlands comprised only 2% of the agricultural area and 7% of the total area (i.e. including non-farm woodlands). In June 2003, 535 out of a total of 1,414 farm holdings were involved in cereal production (Defra, 2003). The pre-dominance of arable agriculture with relative low levels of tree cover means that there are potential opportunities for silvoarable agroforestry.

An open and closed format questionnaire (Neuman, 2000), also described by Liagre et al. (2005), was used as a schedule (Wilson, 1996) for individual face-to-face interviews with farmers, farm managers and land owners. Quantitative and qualitative data collected during the interviews were entered directly onto a laptop computer. The interviews were semi-structured since questions were not always asked in the order on the questionnaire because farmers often volunteered information that answered un-asked questions. This flexibility helped to maintain the flow of the interview. The questionnaire was divided into several sections. The first two sections aimed to determine background information on the farmer and farm business, their understanding of silvoarable systems, and their attitude to trees. The third section included a demonstration of silvoarable systems using images on the computer so that farmers were aware of the general nature of silvoarable agroforestry. The fourth section aimed (i) to establish if the images corresponded to farmers' preconceptions of silvoarable systems, (ii) to determine the perceived positive and negative aspects of the silvoarable systems shown, and (iii) to determine what might motivate them to implement silvoarable agroforestry. The final three sections aimed to determine how farmers would design a silvoarable system, how they would implement it, and to determine if, after the interview, they would be interested in using silvoarable agroforestry themselves.

A sampling frame (Schofield, 1996) of commercially active arable farmers in Bedfordshire was used to select 15 farmers for interview between January and March 2004. Bedfordshire was divided into four areas (north-west, north-east, south-west and south-east) to ensure even geographical coverage of the interviewees. Farmers' positive and negative perceptions of silvoarable systems and the reasons given for possible use of a silvoarable system were first examined in terms of the frequency of response. They were also characterised using a weighted index (Neuman, 2000), here called the "aggregate weighted rank" (R_a). This gave greater weight to a response if the farmer gave it a higher rank and the value of R_a was calculated by aggregating the ranked importance of each perception (Equation 1), so that:

$$R_a = \sum_{s=1}^{s=n} R_i^{-1} \qquad \text{Equation 1}$$

Where R_i is the integer rank given to a perception by the farmer during interview, and n is the number of farmers in the sample (s).

The responses to open format questions and comments volunteered by the farmers during the interviews, which had been entered on a computer, were disaggregated and coded (Strauss and Corbin, 1998) according to thematic content and collected in tabular summaries. They were then used to substantiate responses to closed format questions, i.e. triangulation of method (Neuman, 2000), introduce new themes and explanations in the analysis, and illustrate the discussion with direct quotes from the farmers.

Results

Farmer sample

The sample consisted entirely of male farmers, ranging in age from 36 to 63 years old. The mean age was 45, with most between 45 and 49 years of age. Eight farmers had potential successors, most of whom were younger than 20 years old. Twelve owned at least part of the farm business, two were tenants, and one was a non-owner manager. Decisions made regarding the farm were mostly made by the individual farmer. The area cropped by the sample farmers ranged from 42 to 2000 ha, with a median area of 200 ha; the mean value of 410 ha was skewed by two large farms. Eleven farmers owned and rented land, two only rented land, and two were farm-business managers who neither owned nor rented land. The mean owned area was 155 ha (range: 42 to 315 ha) and the mean rented area was 66 ha (range 12 to 202 ha). Ten farms specialised in crop production whilst five farms included livestock enterprises. Most of the farms employed fewer than two workers, but the two largest employed 13 and 19 people.

Attitude to trees and knowledge of agroforestry

All 15 farmers indicated that they “liked” trees and each farm had hedgerows (range: from less than 5 km to more than 20 km). On most farms, trees and crops were separated; nine had no trees at all in arable areas, three had 1 to 19 trees, and three had more than 30 trees. Most were mature trees planted by previous owners; only one farmer had recently planted trees in the cropped area of the farm as part of a demonstration project (Burgess et al. 1999). On eleven farms, individual trees had been removed to allow machine access (4 cases), improve crop productivity (4 cases), and to deal with tree disease (4 cases). Of the five farmers who had not removed trees, three stated this was for landscape benefit, and one farmer specified production benefits because the trees helped to dry “heavy” soil. Eight out of the 15 farmers said they had already heard of agroforestry either through technical papers (2 cases), newspapers (1 case), personal experience (2 cases) or other unspecified sources (3 cases). Five said they

had seen agroforestry and three that they knew someone using agroforestry. However, the farmers had different definitions of agroforestry; two said that it was an association of trees and crops, four that it was tree-planting on arable land, and one that it could be both of these.

Positive and negative perceptions of silvoarable systems

Most farmers thought that benefits of silvoarable agroforestry would be social and environmental, rather than economic. The most frequently mentioned benefits were for farmer image, biodiversity, landscape, farm diversification, soil conservation, and timber production (Figure 2a). Two farmers mentioned intercrop productivity as a benefit, since silvoarable systems allowed farmers to maintain crop production whilst creating a tree-based environment, whereas this was not possible with forestry. The aggregate weighted rank showed that farmer image was seen as the most important benefit (R_a = 3.5), as well as most frequently mentioned benefit (Figure 2a). Soil conservation was given almost as much importance (R_a = 3.4) as farmer image. Other benefits given high importance included landscape benefits, production of timber, high quality timber production, farm diversification, biodiversity, and general environment.

Negative perceptions of silvoarable agroforestry revolved around management, feasibility and production issues (Figure 2b). The most frequently mentioned negative perceptions were linked to use of farm machinery, complexity of work, general project feasibility and the effect of the trees on crop productivity. The greatest aggregate weighted rank (R_a = 5.5) was for mechanisation (Figure 2b) suggesting that farmers anticipated difficulties with machinery use in silvoarable systems. The value this achieved in terms of aggregated weighted rank was greater than any of the positive perceptions. Project feasibility (R_a = 3.9), complexity of work (R_a=3.9), and intercrop productivity (R_a = 3.4) were also given high aggregate weighted ranks in terms of negative perception.

Reasons for using a silvoarable system

When asked to state the reasons, in an imaginary situation, for using silvoarable systems on their farm, the most frequently stated reasons were the general environment, biodiversity, timber production, profit, and the benefit from subsidies (Figure 3). The reason with the highest aggregate weighted rank was profit (R_a = 3.0). The frequencies and aggregate weighted ranks were generally lower than those for negative perceptions of silvoarable systems, indicating that farmers placed greater emphasis on negative aspects than anticipated reasons for implementing silvoarable agroforestry.

Implementation of a silvoarable system

Most farmers said they would use poor land (7 cases) and avoid planting along the contours (11 cases). Approximately half envisaged a secondary product from the trees in addition to timber (6 cases) and most stated this would be fruit (4 cases); firewood, grass, and bio-fuels were also mentioned. The greatest difficulties with farm machinery dimensions were related to spray widths (9 cases) and the height of the combine harvesters (5 cases). Farmers identified oak, poplar, and wild cherry as the

preferred species. The other tree species mentioned more than once were ash, walnut, and willow. Most farmers were keen to maintain their current choice of crops and the preference was for autumn- rather than spring-planted crops. The crops most likely to be used were wheat, oilseed, barley, field beans and grass.

Farmers were divided evenly on whether or not irrigation would be possible in silvoarable systems. Eight farmers said they would avoid some agrochemicals because of the trees, compared to six who said they would not alter their agrochemical use. Decreasing intercrop width over time was not considered to be viable by most farmers. Three explained this because of machinery restrictions and one because of a desire to maximise crop return. By contrast two farmers stated that they would reduce the intercrop width, by blocking lines in the seed drill, to save on management costs or to minimise obstruction and damage to machinery as the trees grew. Most farmers said they would turn the intercropped area to pasture when an arable crop was no longer profitable.

Twelve of the fifteen farmers said they would undertake the tree operations themselves. Farmers said they would manage the tree row at planting by leaving it bare (5 cases), seeding it (4 cases), using a plastic mulch (3 cases), natural regeneration (2 cases), and using herbicides (1 case). The most commonly stated maintenance practice for the tree row was herbicide use (8 cases), rather than mowing (3 cases), or integrated herbicide and mowing strategy (4 cases).

Most farmers said they would plant less than 15 ha of land to silvoarable agroforestry. This was equivalent to a mean of 13% of the land of each farm (Table 1). Most farmers (6 cases) said they would plant one contiguous area. Three said they would use a tree row distance of less than 20 m, but most (9 cases) said they would use a tree row distance of between 20 and 34 m. Five selected an in-row distance of less than 4 m and four said they would use an in-row tree distance of 5-9 m. These dimensions result in a tree density of less than 100 trees ha^{-1} for seven farmers, and 100-200 trees ha^{-1} for five farmers. The mean planting density was 102 trees ha^{-1} (range 17 to 333 trees ha^{-1}). Most farmers (11 cases) said they would use an intercropping width of less than 30 m (mean 25 m, range 12 – 72 m). The majority (6 cases) preferred a headland width of 15-19 m, but four said they would use headlands of more than 35 m (mean 27 m, range: 3 to 60 m). Finally, most farmers (10 cases) said that the minimum width of the plot would be between 50 and 150 m (mean 122 m, range 40 to 316 m) and that the minimum practical length for a plot of land would be between 100 and 250 m (mean 198 m, range 100 to 450 m). The tree-row distance, intercrop widths, and headland widths were generally related to machine requirement (Table 2). However, the in-row tree distances were based on tree needs and the minimum plot width and length were justified for reasons of "plot area".

When the farmers were asked how they would undertake the project, they were divided on whether they would opt for a collective or individual project, but the majority were ready to share machine and worker costs. Those wishing to work in a joint project suggested other farmers (7 cases), family (3 cases), enterprises and local group (1 case each). Most said they would make planting decisions alone,

although some said they would discuss it with family. Six farmers said that under the right circumstances they would consider using the intercrop area on another farm if it was proposed to them; five said they would not and four were undecided. Seven opposed the idea of a landlord establishing a silvoarable project on the land they rented, but four said they would agree under the right circumstances, and five didn't know. Of the seven farmers who responded regarding tree establishment costs, four said they would not be willing to pay more than 50% of the establishment costs. All but one farmer said they would need technical advice on tree and crop husbandry in a silvoarable system.

Finally, when asked to score an opinion of silvoarable systems on a scale of zero (low) to ten (high) most farmers gave low scores. Ten said they would not consider establishing a silvoarable system themselves, but three said they might consider it under the right conditions. Most stated that age was not a deciding factor in this decision; three stated that it was with one farmer saying he "would like to be alive when the trees are harvested".

Discussion

Field management constraints

Many farmers felt there would be difficulties in managing the system. One stated, "Why change the separation of crops and trees which is practical?" Another said that, "fields are the factory floor of the farm and trees in fields are obstacles".

Machinery: Farm machinery is fundamental to conventional arable farming and successful silvoarable systems need to be designed accordingly. There was a consensus that intercrop widths would have to be a multiple of common widths of sprayers, combine harvesters and seed drills to avoid overlapping. One farmer was concerned about inflexibility, stating that once the intercrop width was set, increasing sprayer width in the future would be impossible. One farmer noted that even after tree harvest, the stumps or the hollows left after their removal could be problematic for machinery. There was also a general consensus that operating machines in silvoarable systems would lead to increased difficulties and costs and reduced speed of operations. Several stated that combine harvesters could be damaged by tree branches, leading to expensive repairs. Most stated they would not plant along the contour, because field shape could make this impractical and because moving across slopes was more difficult in farm machines. One farmer stated that tree rows would make it impossible to work the soil in different directions. This would result in soil compaction along vehicle tracks running up and down the slope and increased soil erosion. Interestingly, one farmer who had established a silvoarable plot on his own farm in the mid 1990s did not mention mechanisation problems or raise issues concerning complexity of work during the interview.

Crop and tree growth: farmers were concerned about growth of trees and crops in mixed systems. Most felt that the trees would reduce crop yields because of competition for light, and the possibility that arable production might be curtailed before the end of the tree rotation was untenable to some. They

often said that the system's spatial-design should prevent this, and some suggested harvesting the trees prematurely, before crop yields were significantly reduced. Some farmers also considered that arable operations would reduce tree growth. For example, ploughing might damage trees roots, and herbicides used on the crop could damage the trees. Several farmers therefore stated that they would avoid using non-selective herbicides and several mentioned avoiding the use of insecticides that might kill beneficial insects in the tree strip.

Socio-economic and environmental constraints

Although some farmers felt that silvoarable agroforestry was an attractive and interesting idea, the majority thought it was inappropriate. One said that it was "not the right idea for this part of the country" and another that it had "limited application in the eastern part of England". Particular concerns related to land value, landscape, biodiversity and flexibility.

Land value: One farmer said "putting trees on arable land could render the land almost valueless" because potential buyers would see the trees as a hindrance and would want them cleared. Another said that if the land was bound in a long-term commitment after receiving grants, it would make sale to developers and other landowners difficult.

Landscape and biodiversity: Two farmers stated that single rows of trees in the landscape were "ugly" and would not consider using silvoarable systems because of this. Although the farmers stated that they liked trees, and many had planted them on their farms, they felt that they belonged to woodlands or hedgerows. Several commented that silvoarable systems appeared to support less biodiversity than conventional woodlands with dense tree cover, and that herbicide operations would create sterile tree strips.

Flexibility: Many farmers felt that silvoarable agroforestry was inflexible and were worried about long-term limitations if "circumstances changed". Several farmers felt that there were too many uncertainties regarding the system. One stated that he would prefer others to be "guinea-pigs" as he was not "a leader in new ideas". Another was concerned that policy could change and that support for the system could be withdrawn, once he was committed. For example, trees could have preservation orders put on them, as the public might start to feel the trees were important landscape features. He cited the case of a local farmer who had difficulties felling trees that had been planted to produce timber. Another stated that deliberate vandalism could be a long-term problem. Two farmers suggested that the only planting of trees on arable land farmers would contemplate related to making the field a more regular shape so that it could be farmed efficiently with machinery. Otherwise, planting of trees was restricted to unproductive or low quality land. These issues were summed up by one farmer who said, "You put trees and woodland where you can't grow a crop, or for hunting or the environment or to make a field square".

Profitability: Most farmers perceived that silvoarable systems would be less profitable than current arable cropping. They were concerned with a potentially poor market for timber and increased costs of crop production. One farmer stated that silvoarable systems would make marketing timber difficult with "small amounts (of timber) in small places". Another stated that in England, there was no longer any market for low quality wood. Another stated "timber the world over is cut for less than the cost of production". He concluded that timber trees can only make money "if they are inherited or have grown naturally". Concern about increased crop production costs was attributed to the trees reducing light availability in the intercrop area. One farmer indicated that shading by trees would also cause differential ripening which would make harvesting problematic.

Several stated that damage to machinery caused by collisions between, for example, combine harvesters and the trees could be expensive. Several farmers considered that the area at the base of trees would lead to additional costs, partly because of weed and pest invasion. One farmer said that root encroachment into drains would impede field drainage which would be expensive to remedy.

Opportunities for silvoarable systems

Although farmers were open to the benefits of using trees on farms and many stated that they had a role to play, few felt that in England, this would be in an integrated tree-crop system on arable land. However, several mentioned that they could see advantages of such systems in a Mediterranean context where annual crops were obtained from the trees. Nevertheless, seven farmers (46%) were willing to use a silvoarable system in some form. Three farmers (20%) (Table 3: Q.2) were willing to use it on their own land if convinced it was more profitable than their current enterprise, and a further four farmers (26%) (Table 1: Q.1) were willing to use an intercrop area rented from another party. A subset of these two groups (Table 3: Q.3) was also willing to accept the implementation of silvoarable agroforestry on land they rented from a landlord. However, this willingness came with the proviso that such use should be profitable, either due to the inherent financial performance of the system, the availability of grants, or because of satisfactory adjustments to rent.

Most farmers stated that they would establish a silvoarable system on their worst land because they would not want to reduce the income from their best land. One farmer felt that the system would be most appropriate for an organic farm, where spray damage was not an issue and suggested an entire chronology for the intercrop. Cereals could be grown for the first five years, then the intercrop area used for grass production for silage, because "greenness" doesn't matter in silage production. Because grass doesn't need spraying, the tree component would not be damaged. Most farmers however said they would continue to use cereals as this was what the farm business was already equipped to do. Several stated that they would stop using oilseed rape owing to bird problems.

Many had suggestions regarding the tree component. Several thought that integrating trees with farming was most appropriate where there were livestock and where it was possible to obtain an annual harvest

from the trees. Christmas trees and hops were suggested as options. Two suggested that trees should be selected on the basis of canopy architecture to minimise their impact on crop yields. One felt that rather than planting single rows of trees, several rows of mixed species could be planted with wider intercropping areas. This would preserve the per hectare density of the trees, be more suited to modern farm machinery, and enhance biodiversity, because the tree habitat would be superior. There were two potentially divergent objectives regarding tree species, either they should provide rapid returns from timber production or be planted for landscape value and long-term quality timber production. One farmer suggested that returns from the tree component could be reduced to just several years by growing ornamental standards for use by town developers. This would provide an earlier return on the money invested and reduce shading of the crop, because trees would be harvested before the canopy became dominant.

Opportunities for adoption

Pannel (1999) reported that four conditions were necessary for adoption of new systems. Farmers must (i) be aware of the system, and they must consider that, (ii) it can be trialled, (iii) that it is worth trialling, and (iv) that it meets important components of "self-interest" such as profit. The results suggest that these conditions are some way from being fulfilled in Bedfordshire. Only a few of the farmers are aware of silvoarable agroforestry. In addition, the long-term nature of silvoarable agroforestry makes it difficult for an individual farmer to trial, because of the long-term commitment of land, labour, and capital. Finally, the results demonstrate that most farmers do not believe that silvoarable agroforestry can increase profitability and the last condition suggested by Pannel (1999) is therefore also lacking. The sampled farmers considered that the major benefits of silvoarable agroforestry would be environmental and social rather than financial. Although wider factors of "self-interest" such as stewardship, or farmer image might motivate a small number of farmers to use silvoarable systems, if required on a wider scale, it appears that silvoarable systems will need to be encouraged through agri-environment schemes such as proposed by the European Council in their Rural Development Regulations.

Conclusions

Previous research has shown that silvoarable agroforestry can provide greater environmental and social benefits than arable cropping (Palma et al. 2006). Such benefits are sought by the European Union and these can be provided whilst maintaining crop production and diversifying into timber production. Moreover, appropriate application of agroforestry provide the EU with a potential approach to helping the EU achieve more resource efficient, sustainable, low emission food and fibre production as outlined in the Europe 2020 strategy (EC 2011) whilst providing an improved quality and diversity of rural life (EC 2005), reducing deforestation (EC 1999), and reducing biodiversity loss (EC 2011). However, the

interviews reported here suggest that use of silvoarable agroforestry is unlikely to increase significantly amongst arable farmers in Bedfordshire and beyond, since the appropriate conditions for adoption, as described by Pannel (1999), are lacking. A coherent effort of research, promotion, and support will be required for silvoarable agroforestry to be seen as a viable option by farmers. Future research needs to quantify the public as well as private benefits of silvoarable agroforestry, whilst successfully tackling the issues that farmers see as important. This study helps to identify such key areas for future research. Specifically, there is a need to revisit the on-farm economics of agroforestry demonstration sites such as those established in Bedfordshire in the late 1990s (Burgess et al., 1999). From this survey, it appears that particular concerns relate to understanding the implications for mechanised arable operations, long-term timber values, and the effect of trees on land value. Suggestions made by farmers for the tree component could also be investigated. For example, growing ash, cherry, or short rotation willow coppice as short-term trees, and hops or fruit trees to provide an annual income could be examined. Further options include examining the combined use of short and long-term trees in the tree row and use of several tree rows instead of single trees rows. It would also be useful to determine if there are regional variations in perceptions of silvoarable agroforestry in England and Europe, and if certain types of farmer (e.g. organic farmers), or farmers in areas with certain environmental problems (e.g. treeless areas with high wind erosion) are more receptive to using silvoarable agroforestry. Such areas and groups of farmers could potentially become focal points for promotion of silvoarable agroforestry. A major new EU sponsored agroforestry project, the AGFORWARD project (https://www.agforward.eu/index.php/en/) is examining some of these issues and readers can refer to this to find more on the latest research on different types of European agroforestry systems.

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446 **Table 1** Summary of plot dimensions that farmers would use in a silvoarable system (n = 13-15).

	Median	Mean	Minimum	Maximum
Area of plots (ha)	10	20	2	100
Proportion of farm area (%)	6	13	0.1	100
Number of plots (n)	2	3	1	10
Distance between tree lines (m)	26	26	15	50
Distance between trees on line (m)	5	7	2	20
Tree density (trees ha^{-1})	71	102	17	333
Intercropping width in first year (m)	22	25	12	72
Intercropping width in last year (m)	22	25	9	72
Width of headland (m)	20	27	3	60
Minimum width of plot (m)	100	122	40	316
Minimum length of plot (m)	200	199	100	450

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450 **Table 2** The number of times that eight possible criteria were used by farmers to justify the plot
451 dimensions shown in Table 1 (n = 14 - 15).

Criteria used to justify plot dimensions								
	Machine priority	Tree priority	Plot area	Crop priority	Field surface	Association optimisation	Other	Rules
Plot dimensions								
Tree row distance	12			1			1	1
In-row tree distance	3	9		3	1			1
First year intercrop width	13	3		2				
Last year intercrop width	10	1		3		1		
Headland width	12	1				1		
Plot minimum width	5		5		2	1	2	
Plot maximum width	6		5		2	1	1	
Total	61	14	10	9	5	4	4	2

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455 **Table 3** The responses of the sample of farmers (n=15) to questions concerning the use of silvoarable
456 systems in various hypothetical situations.

	Farmer (n)														
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. If a neighbour proposed an intercrop area for you to use, would you accept?	?	X	X	√	?	X	X	√	X	√	√	?	?	√	√
2. Would you implement silvoarable agroforestry on your own land?	X	X	X	X	√	?	X	√	X	X	?	X	X	X	√
3. If your landlord proposed to implement silvoarable agroforestry on land you rent, would you agree?	?	X	X	X	√	X	X	?	X	√	√	?	?	X	√

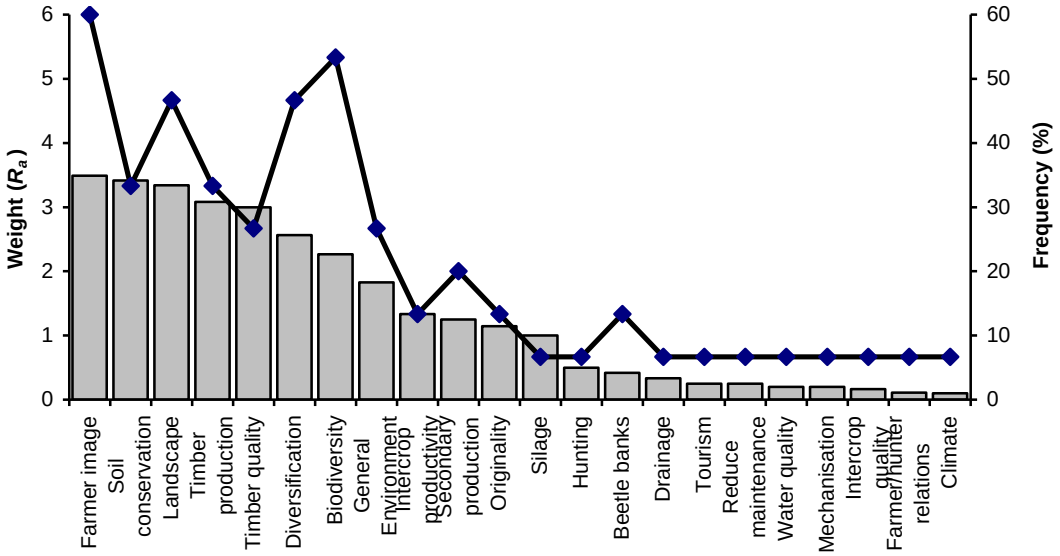
457 Note: √ = yes, X = no, and **?** = don't know.
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Figure 1 The location of Bedfordshire in England.



Figure 2 The aggregate weighted rank (R_a) and frequency of response for (a) positive and (b) negative perceptions of silvoarable systems given by the sample of farmers in Bedfordshire (n = 15).

a) Positive perceptions



b) Negative perceptions

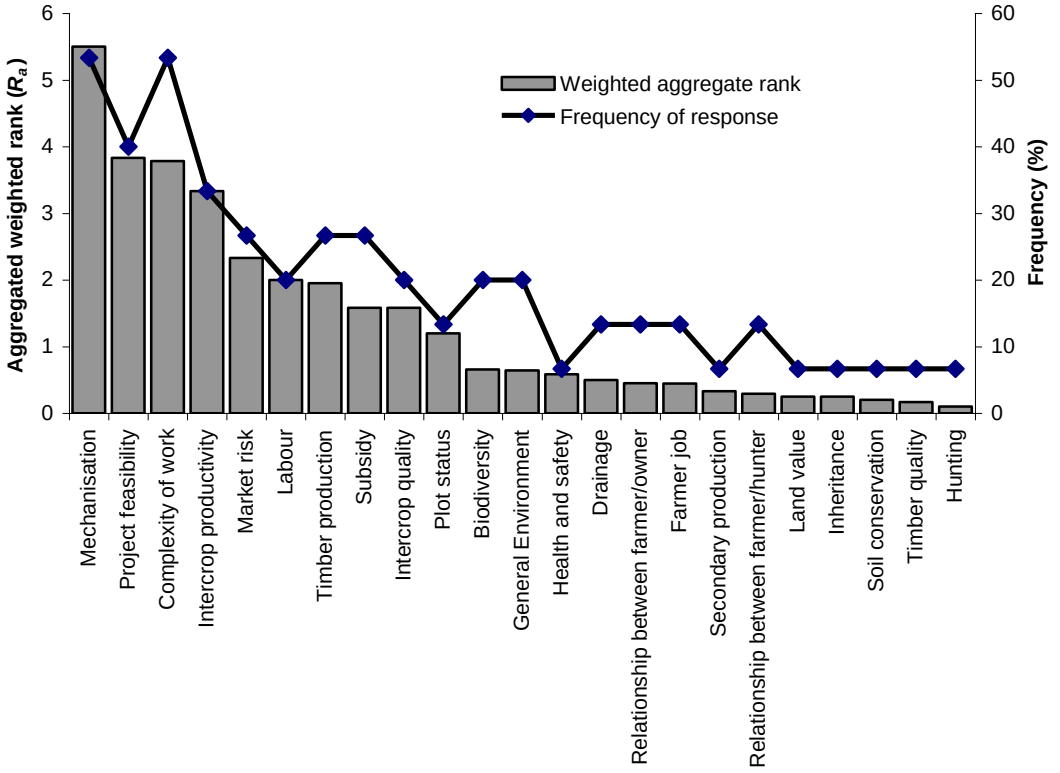


Figure 3 The weighted aggregate rank (R_a) and frequency of response for perceived objectives of undertaking a silvoarable system given by the sample of 15 farmers in Bedfordshire.

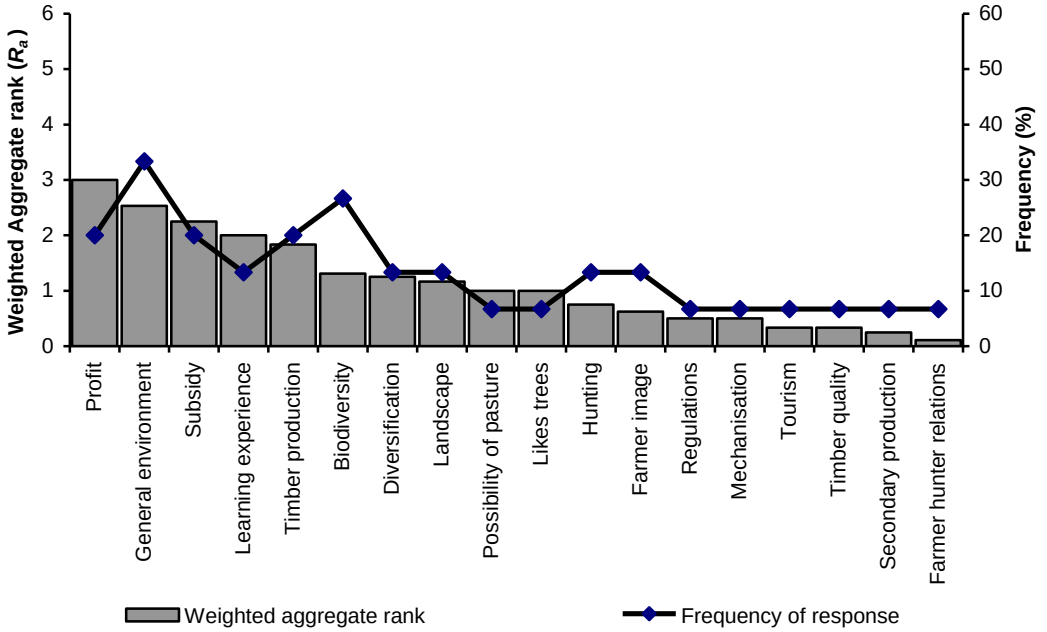
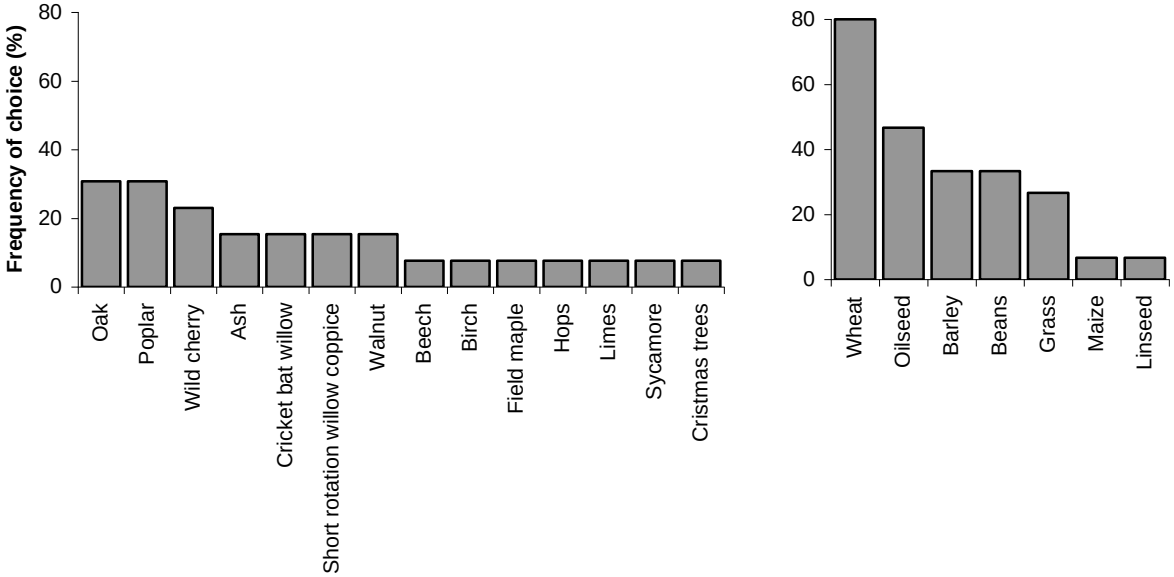


Figure 4 Choice of a) crop and b) tree species that farmers would use.

a) Tree species

b) Crop species





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