The UK Agroforestry Forum Newsletter

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This is the second issue of the UK Agroforestry Forum Newsletter. The aim of the Newsletter is to circulate items of interest amongst Forum members. As well as the annual summary of silvopastoral and silvoarable network site data, we will be pleased to receive correspondence and news items.

The previous bulletin *Agroforestry Forum* has been amalgamated with *Agroforestry Systems*, published by Kluwer. It is available to members of the IUFRO agroforestry group and AFTA at a reduced annual subscription of £40 per annum: please go to http://www.kluweronline.com/issn/0167-4366 for more information or to subscribe.

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C.J. Doyle

Role of agroforestry in rural economic development

Introduction

Rural areas in the UK have had to adapt to the long-term relative decline in agriculture and other primary industries. Thus, although agriculture accounts for around 70% of the land area, economically it only accounts for about 1% of GDP (MAFF, 2001). The total income from farming has been declining in real terms for many years (Figure 1) and is now as low as at any time since the 1930s depression. Even re-structuring activity and continued public financial support have failed to sustain income per full-time (FT) worker in the industry (Figure 1). Thus, among the challenges facing UK farmers is the need to identify the opportunities for diversification of land use and income, while ensuring environmental sustainability and maintenance of employment. Among the opportunities for diversifying land use recognised in the recently published England Rural Development Plan (MAFF, 2001), is the afforestation of agricultural land. Specific provision in the plan is made to invest £237 million between 2000 and 2006 in forestry, of which £172 million is connected with the afforestation of agricultural land. Some of this investment (£27 million) is to be achieved by 'modulating' (top-slicing) direct aid payments to farmers, reflecting the government's determination to expand funding for rural development, as opposed to agriculture.

Provision is made in the England Rural Development Plan to invest £172 million in 2000-2006 in afforestation of agricultural land

Certainly, these measures, when set against the economic context of farming, will help to stimulate future interest in afforestation of agricultural land. However, whether forestry in general and agroforestry in particular will play a significant role in providing new jobs in rural areas will depend on three factors: i) the willingness of farmers to plant trees; ii) the wider income and employment effects of forestry and agroforestry; and iii) public attitudes to afforestation of agricultural land.

Environ-mental and recreational benefits are likely to be more important determinants of farmland tree planting than the revenue from timber

Farmer attitudes to forestry and agroforestry

A number of recent studies, undertaken to examine farmer attitudes to establishing farm woodlands, have suggested that the majority of farmers regard forestry as an 'inappropriate' use of productive land and as 'irrelevant' as an alternative source of income (Thomas and Willis, 1997). Consequently, the rate of conversion of agricultural land to trees has been slow with only 7500 applications being recorded under the Farm Woodland Premium Scheme (FWPS) between 1992/93 and 1997/98 and an average area planted of merely 6.5 ha (The Forestry Industry Council of Great Britain, 1999). However, with farm incomes having fallen by 70% in real terms since 1995 (Figure 1), the attitudes of farmers are changing. Moreover, negative attitudes to conventional forestry are probably not directly applicable to agroforestry, as the latter involves the diversification of existing grassland and arable systems, rather than the total displacement of agriculture.

Attitudes are also compounded by a lack of knowledge among farmers about agroforestry systems (Thomas and Willis, 1997; McAdam *et al.*, 1997) and the existing system of grants equally militates against the adoption of agroforestry compared to conventional forestry (Willis *et al.*, 1993; Bullock *et al.*, 1994; Thomas and Willis, 1997). First, agroforestry is not eligible for support under the FWPS, but only for establishment grants under the Farm Woodland Grant Scheme. Second, the grant rates for agroforestry are generally paid on a pro-rata basis, relative to conventional forestry, depending on the planting densities.

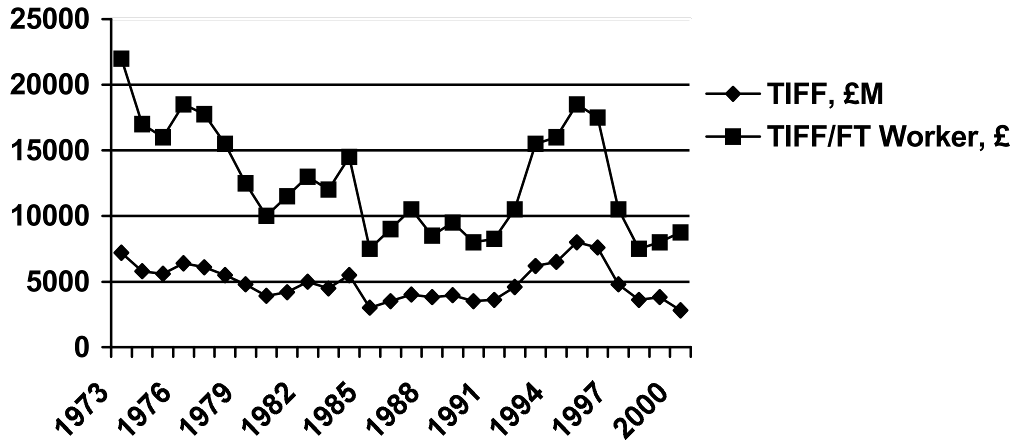

Figure 1. Trends in total income from farming (TIFF) in the UK at constant 2000 prices.

This arguably acts as a disincentive, because it fails to recognise the true production costs of agroforestry systems (Thomas and Willis, 1997). Only in Northern Ireland, where agroforestry schemes qualify for 50% of the grant eligible for conventional forestry, are farmers reported to be satisfied with the grant levels (McAdam *et al.*, 1997). However, purely concentrating on financial subsidies fails to recognise that the reasons why farmers plant trees are varied. A study by Appleton and Crabtree (1991) of Scottish farmers participating in the Farm Woodland Scheme showed that considerations relating to landscape, wildlife conservation, game and shelter were all more important than increasing farm income, when deciding whether to plant trees. A later study by McAdam *et al.* (1997) of a group of Northern Ireland farmers, who had adopted agroforestry systems, also revealed that environmental, recreational and animal welfare benefits were likely to be the key determinants of planting, as the revenue from timber was a very minor component from the land use system. Thus, expansion of the area under agroforestry may not be totally dependent on public subsidy.

Wider income and employment impacts of agroforestry

Attitudes of government and regional development agencies to agroforestry are likely to be as important as those of farmers, as the willingness of government agencies to increase financial incentives to agroforestry will depend strongly on the perceived benefits in terms of rural incomes and employment. Any expansion of agroforestry will be expected to have social and economic benefits beyond the farm gate, especially in the more remote rural areas. However, estimating these socio-economic benefits is difficult, because of the complex nature of the land-use system and the absence of actual studies. One way to gauge the impacts is to consider agroforestry as an agricultural system, based predominantly on grassland farming, with timber as a 'minor' component. A measure of the wider social and economic benefits could then be assessed from the employment directly and indirectly supported by a grass-based, livestock system. On this basis, Doyle and Thomas (2000) reported that for every person employed in agroforestry on farms, between 0.5 and 1.3 were employed in allied industries. However, whether the implied total (gross) employment effects of agroforestry of 2 to 4 jobs per 100 ha of agroforestry can be regarded as a measure of the net benefits to society is debatable. If, in the absence of agroforestry, the land had no alternative productive use, then the *gross* employment effects would be a correct measure of the wider socio-economic gains. However, if the land used for agroforestry primarily displaces traditional grass-based livestock farming, the *net* social gains from the introduction of agroforestry will largely be linked to the 'added' forestry component of the system.

The net job creation from agroforestry may be small, but it should boost farm incomes

An approximate estimate of the socio-economic gains that may be realised from the 'forestry' component of agroforestry systems can be obtained by reviewing the work done on conventional forestry systems. Studies commissioned by the Forestry Commission in England, Wales and Scotland have shown that for every job in forestry a further 0.8 jobs are created elsewhere in the economy (http://www.forestry.gov.uk). Based on the evidence that 1 man is directly employed in managing timber production for every 100 to 250 ha of woodland (Central Statistical Office, 1997), this suggests that every 100 ha of forestry creates 0.7 to 1.8 jobs in total. This is only 35 to 45% of the estimated gross employment effects of livestock farming. However, the relatively small observed employment impacts associated with conventional forestry may underestimate the potential gains from agroforestry. In particular, recent estimates of the employment impact of farm woodland planting in Scotland suggest that for every person employed full-time in farm woodland production a further 1.8 are engaged elsewhere in the economy (Table 1). This is consistent with an earlier study by Slee and Snowdon (1996) that suggested that farm-based forestry schemes supported 1 to 2 additional jobs per man employed in forestry. They also showed that, where employment creation was a specific objective of the rural development programme, then figures of 3 to 4 jobs per person employed in forestry were achievable. Based on these observations, the potential employment impacts of farm woodland planting schemes may be nearer to 2 to 4 people per 100 ha.

Table 1. Additional income and employment generated beyond the farm-gate by farm woodland planting.

Type of woodland planting	Additional income per £1 of farm income generated	Additional jobs per job created on farms
Commercial coniferous planting and maintenance	0.54	0.58
Farm woodland planting and maintenance	1.67	1.79
Timber harvesting	1.97	0.77

Source: http://www.forestry.gov.uk/website/oldsite.nsf/byunique/HCOU-4U4JMJ

Until farmers are better informed about it and the present system of grants is modified, the uptake of agroforestry is likely to be limited

However, regardless of whether agroforestry leads to direct job creation on farms, in so far as it increases the incomes of farm households, it will have an economic effect on the wider local economy. Recent studies commissioned by the Forestry Commission in Scotland (http://www.forestry.gov.uk) indicate that farm woodland planting and maintenance increases incomes outside farming by £1.7 for every additional £1 of farm income. The corresponding figure for timber harvesting is £2 for every additional £1 of farm income. For agroforestry, the benefits may be proportionately larger, in that the trees could add value to existing grassland systems by either increasing agricultural output or increasing returns per unit of output (Doyle and Thomas, 2000). Especially in hill areas, the presence of agroforestry may increase the shelter provided for animals with benefits in terms of output. Nevertheless, the potential socio-economic gains from agroforestry may be difficult to realise. Despite local successes, the majority of farmers still do not expect woodland planting to boost their incomes significantly (Brown, 2001).

Public attitudes to afforestation of agricultural land

The implication of this is that, unless the present system of grants and subsidies is modified, the area under agroforestry will grow slowly. Acceleration in the pace will depend on a more attractive structure of grants and this in turn will depend on changes in public attitudes to farm afforestation. Such changes are likely to hinge on agroforestry delivering significant non-market benefits in the form of enhanced landscape value, wildlife conservation and recreation. In 1993, the House of Commons (1993) questioned whether there were unequivocal environmental gains from farm forestry, but the evidence is growing that it can generate environmental and amenity benefits (McAdam, 2000). The significance of these non-market benefits is that they form a very significant part of the total social value attached to farm woodlands. Pearce (1991) estimated that the non-market benefits of forests, assessed at a discount rate of 8% over a 30-year rotation, were worth between £330 and £875 per ha. In contrast, the discounted net benefits of the timber production were negative and worth between minus £1000 and minus £1700 per ha. Thus, non-market benefits appear to represent an important social justification for any public funding for agroforestry.

Looking to the future

From the viewpoint of rural development, agroforestry has the potential to help sustain farm employment and boost rural incomes. This, coupled with the need to diversify land use on farms, has prompted the UK government to increase the total level of grants for farm woodland planting in the next 6 years. However, notwithstanding the potential of agroforestry to assist rural economic regeneration, until farmers are better informed about it and the present system of grants and subsidies is modified, the uptake of agroforestry is likely to remain limited.

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A.Waterhouse, C. Morgan-Davies and I.A.R. Hulbert

The development of an integrated hill sheep and woodland system – relative contributions of sheep and woodland to FARM AND regional economics

Large-scale establishment of woodland and extensive hill sheep production are usually seen as mutually exclusive. Yet, with the economic and environmental sustainability of hill sheep systems under scrutiny, integration with woodland offers potential to alleviate these concerns. This paper describes progress of a system-scale study of a new 220 ha native woodland amidst 850 ha of land occupied by a 680 ewe flock. This flock is not being reduced, with the aims of maintaining the income and viability of the sheep system and meeting the aspirations of sheep farmers who want to continue being sheep farmers. The woodland is being established via fenced exclosures with the medium term aim of controlled re-introductions of sheep once the trees are safe from significant damage. This first phase has thus required two processes; (1) the establishment of the woodland and (2) the modification of sheep management to maintain the flock once land was lost to the woodland. As a result of a bio-economic modelling exercise, it was determined that the existing flock could be retained on the reduced land during the summer months when grass supply is typically excessive, but in winter reductions in forage and shelter necessitated the off-wintering of the flock. However, as a result of this off-wintering, both costs and output of lamb were predicted to be substantially increased such that turnover from the flock has increased by 30%. The woodland establishment phase has had, and is predicted to have, further significant income and expenditure. Overall turnover passing 'through the glen' will have quadrupled over the six year period.

Introduction

Current systems of extensive sheep production cover large areas of the UK and are vital to the viability of rural areas. However, such systems are economically and environmentally limited, extremely fragile and much of farmers' incomes depend on a range of agricultural and environmental support schemes. Large scale planting of commercial exotic woodlands is often the only other viable land use in the uplands of Scotland. Native woodland schemes are accepted to have an overall positive environmental impact (Macmillan and Duff, 1998). However, such planting schemes still do not favour integration with agriculture. Sheep farming becomes untenable because planting consumes lower or middle land essential for sheep in winter.

Establishment of the project

An innovative integrated system has been established in SAC's farm at Auchtertyre in West Perthshire. The sheep system is intimately integrated with the establishment of extensive and diverse native woodland within the same block of land, to combine the benefits of both enterprises for the farmer and the local economy. The key practical element in the early years of the new system is the need to off-winter the sheep. Within a glen of 850 ha, entirely barren of woodland, a central block of 220 ha has been planted with native trees. Sheep have been excluded from the planted area but the remaining 630 ha are available to grazing by the 680 ewes and their lambs during the summer. The native woodland has been designed to be a patchwork mosaic of open glades and trees at various planting densities, to create natural looking native woodland (Figure 1).

The woodland was planted under a Woodland Grant Scheme (WGS). As part of the application process, an Environmental Impact Assessment was carried out, together with a forest design plan. Ground preparation, fencing of the area and planting started in October 1998. By April 1999, 220 ha of trees were planted and 9 500 m of fences erected. The woodland is composed predominantly of birch species, as well as Scots pine, willow and hazel. Large areas of open ground within the woodland have been developed specifically as grazing lawns. Once the woodland is properly established, a new controlled grazing system will be implemented, where sheep will be allowed in the woodland during summer.

Results and Discussion

The new sheep system was implemented in November 1999. Six hundred ewes were sent for off-wintering on lowland farms. They were brought back to the hill farm in February 2000, for ultrasound scanning and careful management of pregnancy and lambing. The twin-bearing ewes were housed until lambing, while the single-bearing ewes were sent to the hill. The

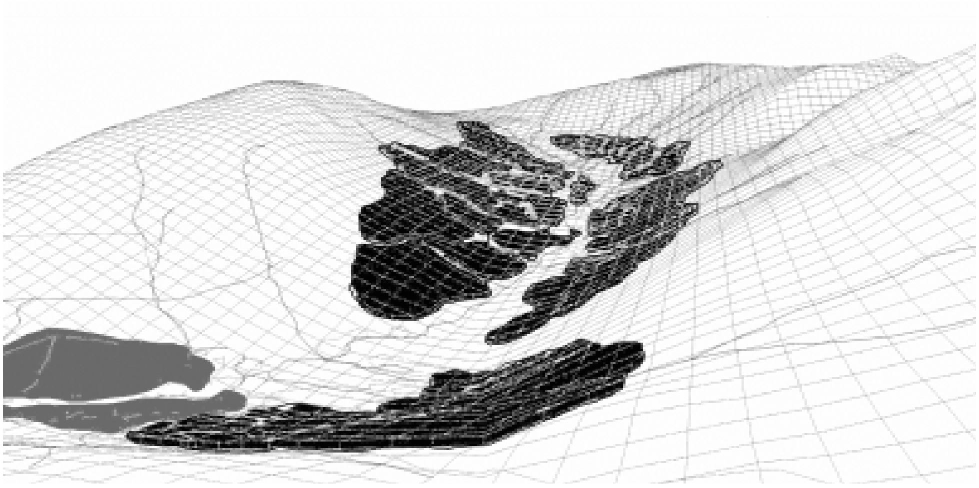

Figure 1. Design of new woodland.

Table 1. Inputs and outputs for the sheep systems before and after woodland establishment

	Previous system	New system (first year results)	
Outputs			
Total number of weaned lambs	**552**	**724**	
Lamb birth weight (kg)		**Blackface**	**Crossbred**
Single	**3.8**	**4.3**	**4.7**
Twin	**3.3**	**3.4**	**3.5**
Lamb weaning weight (kg)	**25.3**	**26.6**	
Sales value (lambs and ewes)	**£3,754**	**£13,638**	
Inputs			
Feed costs (£/ewe)	**3.1**	**5.2**	
Haulage costs (£/ewe)	**0**	**2.3**	
Off-wintering costs (£/ewe)	**0**	**7.8**	
Additional veterinary costs (£/ewe)	**0**	**1.2**	
Market expenses (£/ewe)	**1.1**	**1.9**	
Total extra costs		**£8621**	

results for 1999-2000 are presented in Table 1. The outputs for this new system were higher than for the previous one, in conjunction with higher input costs. Overall, the new system is little different in terms of gross margin and profitability but both quality and quantity of lambs increased.

The first full year of the new 'integrated' system of sheep and woodland has been successful. The sheep results exceeded those predicted by the modelling exercise and the woodland is well established. As seen in Table 1, increases in financial throughputs to the rural economy from the sheep system are substantial. Cumulative income from the sheep is predicted to be £166,000 during the establishment period, while costs are projected to be £87,755. Whilst there is no change in sheep support payments, the proportion of total sheep income falls from 0.81 to 0.54 due to increased sale values. The actual income and costs to date and projective income and costs for the balance of the establishment years are shown in Figures 2 and 3.

Income for the woodland is projected to be £288,000, while costs are predicted to be £227,000 (Figure 2). Public access is also a significant element of the project, with incorporation of a Forestry Commission's 'Walker's Welcome' within the main Woodland Grant Scheme area and link to a network of footpaths lower down the farm. Creation of these footpaths will produce a turnover of £3,500. Deer control is important and projected to provide another £9,000 net over the next six years. At the end of the establishment period, the integrated system is projected to have an income flow of £454,235, compared to £116,863 (Figure 2), thus almost quadrupling income flow into the rural economy.

Cumulative surplus (income minus costs) of the integrated system is presented in Figure 4. It shows that at the end of the six years, a potential surplus (cumulative gross margin) of almost £140,000 would be available to the farmer, instead of £72,000 in the previous 'sheep only' system. Cashflow problems occur during the first year of establishment as woodland grant is not paid until all works are successfully completed and inspected. Smaller, but similar problems occur in the middle years before release of the final payment of the WGS grant. Nevertheless, for

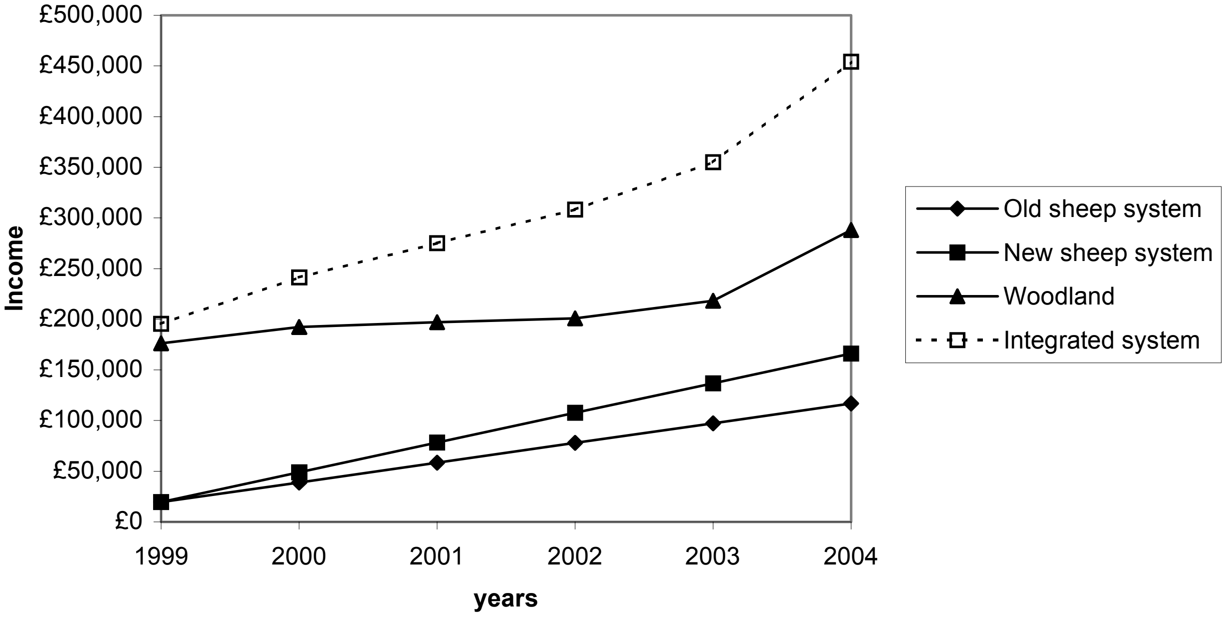

Figure 2. Predicted cumulative income.

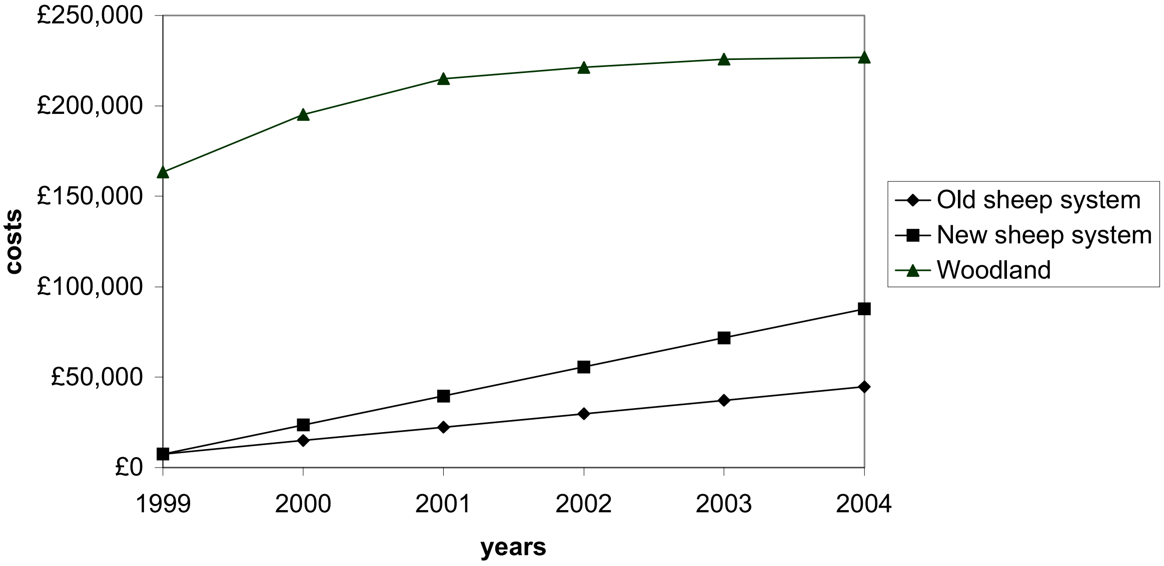

Figure 3. Predicted cumulative costs.

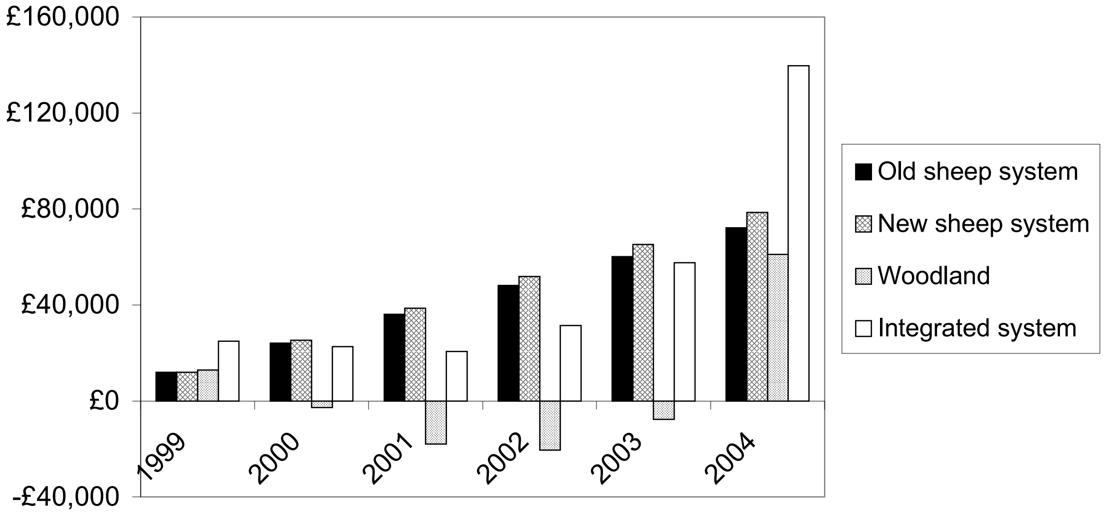

Figure 4. Potential cumulative surplus over six years.

a large woodland, maintained without high costs, the surplus from the woodland in the sixth year has attractions.

Local rural enterprises and small business have mainly carried out the work created by the establishment of the woodland. Figure 5 represents the geographical source of goods (trees) and services (location of fencers, tree planters and forest design specialist) provided, as well as the amount of money involved. It shows that such establishment would be a major boost for rural and local economy. It also highlights a lack of qualified workers in the direct area. For example, tree planters were coming daily from as far away as the island of Mull.

Conclusion

In conclusion, although such a project seems to be very attractive for the rural economy and the farming community, it must be said that there is still some uncertainty over the future income generation capacity of woodlands. Indeed, timber value in native woodland has yet to be assessed, sheep benefit might change radically in the next few years and tourism is a fluctuating parameter.

However, such integrated production has already shown that it does reduce dependency on agri-support mechanisms and has proved to have increased quality and quantity of sheep output; both being very attractive in the actual economic context. It will also facilitate economic development for the farming community and the local economy, giving them a much-needed boost. Finally, such a system should enhance the environment and the landscape, in line with the environmental policies and incentives and will impact on local tourism.

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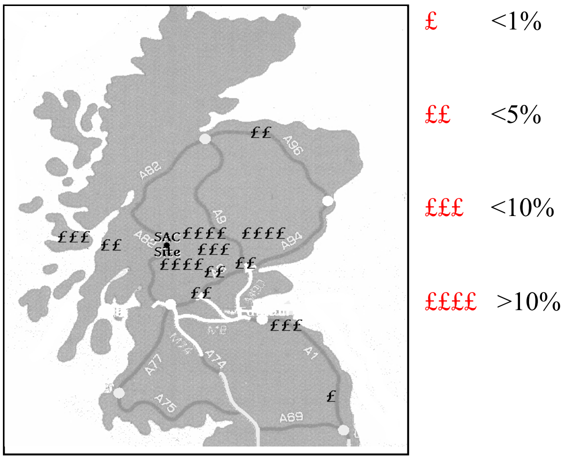

Figure 5. Map of the labour involved.

Silvopastoral National Network Experiment - Annual Report 2000

Project period

The experiment is designed to run for a complete harvest cycle of 40 to 60 years according to site. More details of the sites, including planting dates, can be found in Sibbald (1990) and Sibbald and Sinclair (1990).

Funding

The experiment is managed by scientists from a range of institutions (see Sibbald, 1990) and as a consequence is funded for differing periods by a number of agencies. The five sites reported here formed a significant part of the UK contribution to a European Commission DG VI-funded research project from 1993-96. The background to the project is given in Sibbald *et al.* (1993) and a more up-to-date account is given in Auclair (1996). Funding provided for the site at Glensaugh by the Scottish Executive Environment and Rural Affairs Department through the Macaulay Land Use Research Institute ceased on 31 March 2001.

Objectives

To provide knowledge, information and experience on the establishment of silvopastoral systems over a range of climatic and edaphic conditions in the UK using, wherever possible, common treatments and management protocols.

Background

The experiment has been described in some detail in previous issues of *Agroforestry in the UK* (for example, Sibbald, 1990). Originally, sycamore was planted at all five sites in the common agroforestry and woodland treatments; sycamore at 100 stems ha^{-1} (SYC 100), sycamore at 400 stems ha^{-1} (SYC 400) and sycamore woodland control at 2500 stems ha^{-1} (SYC 2500). There is an un-planted agricultural control (AGR CONT) comprising only pasture. All treatments and controls are replicated three times. However, as has been reported in previous years (see for example, Sibbald and Agnew, 1995) at North Wyke sycamore appeared to be intolerant of local site conditions (e.g. during periods of water logging). Sycamore agroforestry treatments (SYC100, SYC400) were therefore removed from the North Wyke site during 1995, although the sycamore woodland control (SYC2500) plots were retained as a common basis for comparison of tree growth across all of the sites. Results reported here for North Wyke are for ash at the same planting densities (ASH100, ASH400 and ASH2500) but these data have been omitted from the calculation of treatment means across all sites.

The agroforestry plots are grazed by sheep and the trees are protected individually. Tree shelters supported by strong stakes were originally used at four of the sites (Bronydd Mawr, Glensaugh, Loughgall and North Wyke) but these have been replaced by wider Netlon™ plastic net guards on sites where the original tree shelters were found to be causing problems with tree growth form. The shelters were replaced as the trees emerged from them. The net guards are wide enough to allow movement of the stems of the trees. At Loughgall, the trees were treated with Wobra™, a browsing repellant, in 1996 and 1997. Problems were experienced with the adherence of this product and Netlon™ net guards are now used as tree girth exceeds that of the original tree shelters. On the more recently planted site at Bangor (Henfaes), trees are individually protected by a spiral guard and a 1x1 m fence made of posts, rails and sheep net (for background see the National Network Annual Report for 1991; Sibbald, 1992). This form of protection is expected to have a 15-year life span.

Woodland control plots are not grazed and the trees are not individually protected though the plot areas are fenced to exclude sheep, rabbits and, where appropriate, deer.

Data have been analysed using ANOVA (Genstat) on un-transformed data.

Results and discussion

Of the five sites reported here, Henfaes was planted in 1992, Loughgall was planted in 1989 and the other three sites were planted in late 1987 or early 1988.

A summary of meteorological data is presented for site comparison (see Table 1).

One of the common management protocols used throughout the experiment is the control of sward height within an agreed range over the grazing season. The seasonal sward height profile is set to maximise the efficiency of growth and utilisation of the swards independent of external variables such as the weather and independent of treatment effects on the swards as the trees grow. Sward heights are measured regularly and adjustments are made to stocking rates on individual plots in response to changes in sward height, which reflect changes in sward growth rate.

Table 1. Summary of meteorological data for 2000.

	Upland sites		Lowland sites		
	Glensaugh	Bronydd Mawr	North Wyke	Loughgall	Henfaes
Total precipitation (mm)	1218	1573	1361	896	1338
Total radiation (MJ m^{-2})	3001	1125$^{\#}$	1343$^{\#}$	N/A	N/A
Mean annual soil temp. at 100 mm (^{o}C)	8.7	8.9	11.2	9.1	N/A

$^{\#}$sunshine hours

As a consequence of this sward height control, individual animals are presented with sward conditions, which should be similar across all sites and between treatments within sites. Individual performance of animals should therefore be directly comparable both across sites, allowing for breed differences, and across treatments within sites.

Individual lamb growth rates for the period from turnout (normally within a week of lambing) to weaning in mid-July have previously demonstrated consistency within sites and in the overall means for treatments. There were no significant differences ($P>0.05$) between the overall means of the agroforestry treatments and agricultural control in the year 2000 or at four of the five individual sites (Figure 1). There was a significant difference between the agricultural control and the agroforestry treatments ($P<0.05$) at Bronydd Mawr (233 ±7.0 *vs* 199.4 ±7.6 g lamb^{-1} d^{-1} for agricultural control and agroforestry treatments respectively). While these data might indicate that the agroforestry treatments were having an impact on individual animal performance, the trend within the agroforestry treatments was for higher lamb growth rates to occur with the higher tree density (188 ±18.5 *vs* 207 ±1.3 g lamb^{-1} d^{-1} for SYC100 and SYC 400 respectively) indicating that the cause of the reduced lamb growth rates on the agroforestry plots was due to some factor other than tree density.

Differences in lamb growth rate between the sites classified as upland and lowland (see Table 1) have been evident in earlier years (higher growth rates at lowland sites) because of differences between the growth potential of the different sheep breeds at these sites (Greyface at Glensaugh and Loughgall, Beulah at Bronydd Mawr, Masham at North Wyke and Welsh Mountain at Henfaes). The difference between upland and lowland was not significant in 1997, nor was it significant in 1999 (Sibbald and Dalziel, 2000). In 1998, the difference between upland and lowland was significant but the higher rate was on the upland sites (see Sibbald and Dalziel, 1999) and this pattern ($P<0.05$) was repeated in 2000 (222 ± 4.7 *vs* 198 ±6.4 g lamb^{-1} d^{-1} for upland and lowland sites respectively).

Results for the annual animal stock carrying capacity of the grazed areas were calculated from the number of grazing days (length of the season), the stocking densities carried on each of these days (a measure of pasture growth rate based upon sward height control as described above) and the live weight of the animals (which takes account of the breed of sheep). This calculation provided an integrated value of tonne-days per hectare of animals carried throughout the season (Figure 2). There was trend ($P<0.1$) for the upland sites (222 ±6.8 tonne-days ha^{-1}) to have a lower stock carrying capacity than lowland sites (246 ±9.1 tonne-days ha^{-1}). This difference would result from differences in the length of the grazing season and herbage growth rates between the sites and has been evident in earlier years. There were still no statistically significant differences ($P>0.05$) between the overall means for the agroforestry treatments and agricultural control. This observation is surprising given that on some of the sites the trees are already thirteen years old.

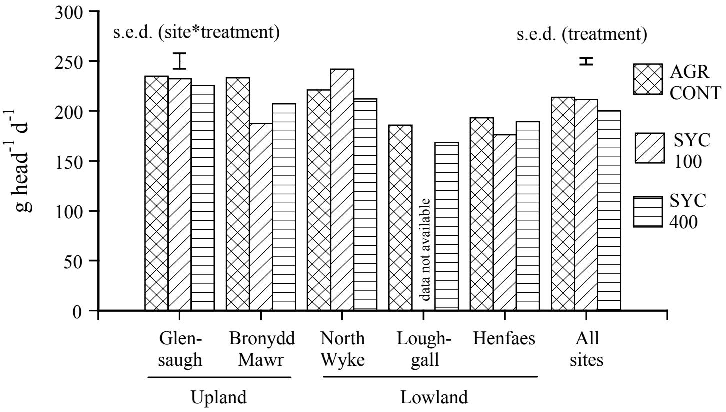

Figure 1. Individual lamb growth rate, turn-out to weaning, 2000.

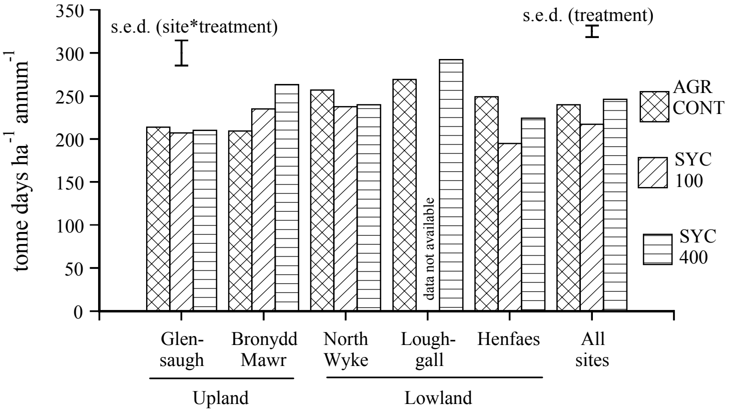

Figure 2. Mean animal liveweight carried over the season, 2000.

Table 2. Annual tree survival (%).

	Upland sites		Lowland sites			
	Glensaugh	Bronydd Mawr	North Wyke*	Loughgall	Henfaes	Mean of all sites #
SYC100	100.0	100.0	100.0	98.7	100.0	99.7
SYC400	100.0	100.0	100.0	98.7	100.0	99.7
SYC2500	100.0	100.0	100.0	98.7	100.0	99.7
Site mean	100.0	100.0	100.0	98.7	100.0	99.7

* Ash; # Excludes North Wyke

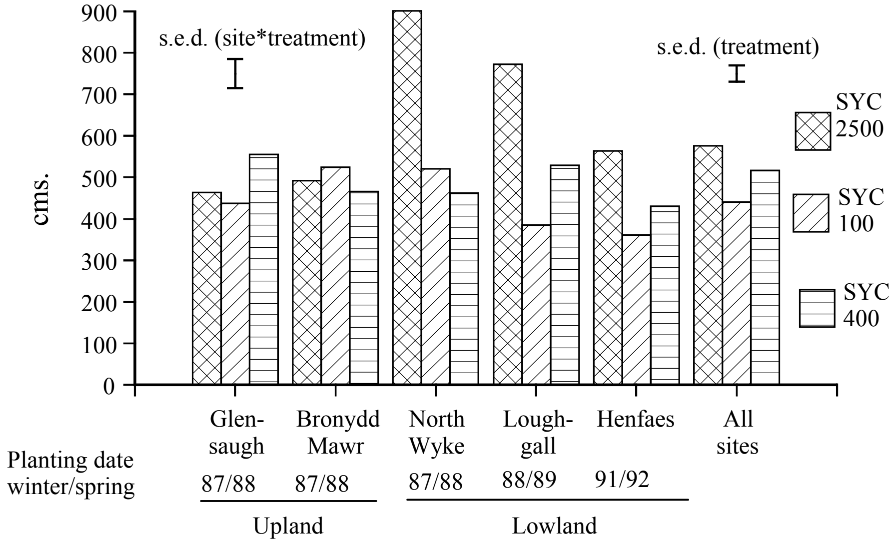

Figure 3. Tree height at end of 2000 (all sites mean excludes North Wyke and Henfaes).

Tree survival in 2000 was high at all sites (Table 2); North Wyke results are for ash. Mean tree heights at the end of 2000 are shown in Figure 3. The data in this figure are, wherever possible, based upon trees from the original planting (ash at North Wyke). Even though the Loughgall site was planted one year later than the other three older sites with sycamore, the mean height of trees on the SYC2500 treatment was greater than for sycamore at the other sites; this could of course be due to differences in the height of planting material. Using the plot means of tree height (excluding the North Wyke and Henfaes sites, the latter because of the age of the trees) in an analysis of variance indicates that there was a significant effect of tree spacing ($P<0.05$), confirming the differences which emerged for the first time in 1999. The trees on the SYC2500 treatment were taller than the most widely spaced trees (SYC100). The more densely planted agroforestry trees (SYC400) were intermediate and not significantly different from the SYC2500 and SYC100 treatments. On two of the three lowland sites (North Wyke and Loughgall), the trees on the woodland controls (ASH2500 and SYC2500) were significantly taller ($P<0.001$) than those on agroforestry treatments. On the lowland site at Henfaes, the trees on the SYC2500 treatment were taller than those on treatment SYC100, the trees on treatment SYC400 were intermediate and similar to both SYC2500 and SYC100. The upland site at Glensaugh, which, in earlier years, has shown the opposite trend with the shortest trees on SYC2500, had trees of similar height on agroforestry treatments and SYC2500 in 1999 and in 2000. This has been the case for some years at Bronydd Mawr.

The mean increments in tree height between 1999 and 2000 are shown in Figure 4 (ash at North Wyke). There was a significant difference ($P<0.01$) in the height increment of sycamore between the sites. Least growth occurred at Bronydd Mawr (26.4±13.6 cm annum^{-1}) and Loughgall (24.2±7.62 cm annum^{-1}), most growth occurred at Glensaugh (54.0±6.23 cm annum^{-1}) and Henfaes (72.6±11.46 cm annum^{-1}). There was a significant difference ($P<0.05$) between treatments across all sites (excluding North Wyke, see Figure 4); SYC2500 and SYC400 were similar and had a greater rate of height extension than SYC100. This difference between treatments in the annual height increment was not consistent within sites, only at Henfaes was the difference between treatments in the annual height increment significant ($P<0.001$). In previous reports it has been suggested that, for the upland sites, the greater rate of height extension of SYC2500 trees would result in them eventually catching up with the agroforestry treatments and this has proved to be the case (see Figure 3). Height increments on the ash at North Wyke showed no treatment differences during 2000.

The relative increase in tree height from 1999 to 2000 (i.e. the percentage increase over height in 1999, see Figure 5) shows similar patterns to the absolute height increment data shown in Figure 4. There were significant differences between the sites with sycamore ($P<0.001$). The lowest relative increases in top height occurred at Bronydd Mawr (6.3 ±3.06%) and Loughgall (5.0 ±1.42%) which were similar, an intermediate level of relative increase in height occurred at Glensaugh (12.6 ±1.36%) and the greatest relative increase was at Henfaes (18.9 ±2.43%). There were significant differences ($P<0.01$) between treatments at Glensaugh ($P<0.10$) and Henfaes ($P<0.05$) with the SYC2500 treatment showing a greater relative increase than the agroforestry treatments.

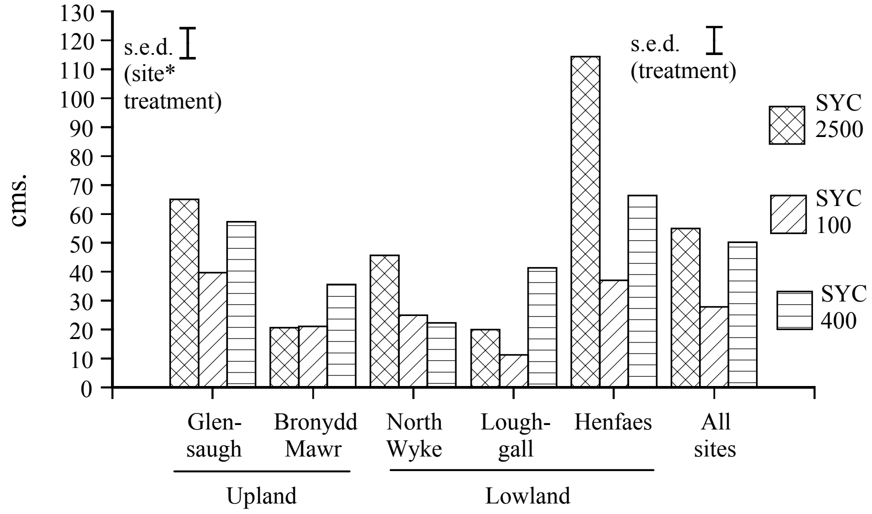

Figure 4. Mean increment in tree height 1999-2000 (all sites mean excludes North Wyke).

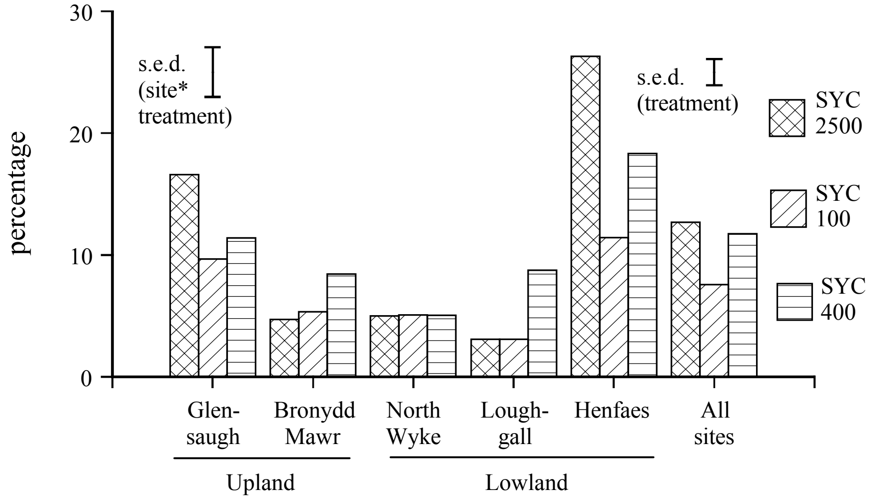

Figure 5. Relative increase in tree height 1999-2000 (all sites mean excludes North Wyke).

For the first time, there were no significant treatment differences for ash at North Wyke in the relative increment of the trees. In previous years (see, for example Sibbald and Dalziel, 2000) it has been argued that the higher relative growth rate of the trees on the treatment ASH2500 was due to the improvement of drainage through root penetration of indurated soil layers creating micro-channels for effective drainage. This effect would have been greater on the treatment ASH2500 than on the agroforestry treatments because of its greater root mass. It was anticipated, however, that improvement of drainage would eventually take place on the ASH400 and ASH100 treatments. The similarity of the relative height increments in 2000 might indicate that this has now happened, however, the height increment of trees on treatment ASH2500 in 2000 (5.0 ±1.86%) was much less than in 1999 (18.0 ±2.07%) while the mean relative height increments for the two agroforestry treatments were similar in the two years (4.1 ±1.95 *vs* 5.05 ±0.34% for 1999 and 2000 respectively). It is therefore unlikely that an improvement in drainage on the agroforestry treatments explains the results.

A comparative analysis of data from the whole network experiment for 1999 and 2000 indicates that while lamb growth rate was similar (207 ±4.0 *vs* 208 ±4.6 g lamb^{-1} d^{-1} for 1999 and 2000 respectively), there were highly significant differences between the years in the other reported parameters. Annual stock carry capacity was significantly higher (P<0.001) in 1999 (280 ±6.4 tonne-days ha^{-1}) than in 2000 (236 ±6.2 tonne-days ha^{-1}). Mean annual increment in tree height was significantly (P<0.001) higher in 1999 (70.4 ±5.92 cm tree^{-1} annum^{-1}) than in 2000 (44.8 ±5.88 cm tree^{-1} annum^{-1}) and relative increase in tree height was similarly greater (P<0.001) in 1999 (19.0 ±1.62%) than in 2000 (10.8 ±1.39%). The similarity of lamb growth rate in the two years was expected since sward height was controlled to the same level in both years. The differences between years in stock carrying capacity and in the height increments of the trees indicate generally poorer growing conditions in 2000 than in 1999, however the annual summary of meteorological data (Table 1) does not indicate significant differences between the years and the causes will be further investigated.

Conclusions

It has been proposed that, in the first few years of the establishment phase of the experiment, animal pressure on trees planted in individual shelters at high animal:tree ratios resulted in significantly lower survival rates of trees planted at 100 than at 400 stems per hectare. The fact that this effect has now disappeared supports the suggestions made in earlier reports (see for example, Sibbald and Agnew, 1997) that trees are able to withstand the pressure after only four to five years, if a beating-up policy is pursued. The previous difference in tree height between 100 and 400 trees ha^{-1} (see Sibbald and Agnew, 1997) is no longer evident. The carry-over effect of early differences, proposed by Sibbald and Agnew (1997), appears to have disappeared.

The earlier advantage in terms of height increment of the individually protected trees when compared to woodland control (SYC 2500) has now disappeared at all sites. The greater relative height increment of the woodland control trees in previous years has resulted in taller trees than those in agroforestry treatments, a fact that was very evident on lowland sites in 1997 and is now evident on the two upland sites.

Future developments

Reviewing the results from the use of conventional farm woodland methods in the Network in earlier years indicates that further research is required on the establishment phase of silvopastoral systems. The use of conventional tree shelters has produced what may, in the long-term, be an inappropriate growth form; the use of herbicide-treated spots around trees may exacerbate the effects of animal treading and the use of agricultural rates of nitrogen fertilizer may further modify tree root:shoot ratio. There is evidence, through a network-wide root-measurement protocol, that patterns of root and shoot development are affected in agroforestry treatments (Eason *et al.*, 1994). These differences may help to explain some of the effects of treatments on tree growth and early survival. The Network Managers' Group is currently debating the setting up of a networked trial and demonstration of a variety of tree protection methods in combination with selected tree species and cultivars.

The loss of funding at the Glensaugh site has resulted in the experiment being reduced in size by terminating the sycamore 100 trees ha^{-1} treatment, in line with an agreement made by the managers of all the sites in the experiment. The remaining treatments, the agricultural control and the sycamore 400 trees ha^{-1} treatment, will be managed on a care and maintenance basis; Forest Research will continue to monitor the trees on a regular but less frequent basis than in the past.

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