The UK Agroforestry Forum Newsletter

Number 1 December 2000

Welcome to the first 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 but available from the University of Wales at a reduced annual subscription of £40 per annum. Contact Fergus Sinclair (address given below) for more information or to subscribe.

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The UK Agroforestry Forum Newsletter is an informal newsletter collated and produced by Fergus Sinclair at the School of Agricultural and Forest Sciences at the University of Wales, Bangor. To join the UK Agroforestry Forum mailing list and receive future copies of the Newsletter, please contact Alan Sibbald, Secretary, UK Agroforestry Forum at the following address: Alan Sibbald, Macaulay Land Use Research Institute, Craigiebuckler, Aberdeen, AB15 8QH; email a.r.sibbald@mluri.sari.ac.uk.

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Copy date for next issue: 10 May 2001.

Silvopastoral National Network Experiment - Annual Report 1999

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).

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 waterlogging). Sycamore agroforestry treatments (SYC100, SYC400) were therefore removed from the North Wyke site during 1995, while 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 are being replaced by wider plastic net guards on sites where the original tree shelters were found to be causing problems with 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. However, 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 1999.

	Upland sites		Lowland sites		
	Glensaugh	Bronydd Mawr	North Wyke	Loughgall	Henfaes
Total precipitation (mm)	1099	1733	1245	929	1198
Total radiation ($MJ\ m^{-2}$)	3020	1109#	1489#	N/A	3035
Mean annual soil temp. at 100 mm (^{o}C)	8.8	8.9	11.6	9.4	11.6

#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 demonstrate consistency within sites and in the means for treatments (Figure 1). There were no significant differences (*P*>0.05) between the overall means of the agroforestry treatments and agricultural control or at individual sites. Differences between the sites classified as upland and lowland have been evident in previous 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 (overall mean, 207 ±4.0 g hd^{-1} d^{-1}). In 1998, the difference between upland and lowland was significant but the higher rate was on the upland sites (see Sibbald and Dalziel, 1999).

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 a statistically significant difference (*P*<0.001) between the sites classified as upland (252 ±5.5 tonne-days ha^{-1}) and lowland (299 ±8.3 tonne-days ha^{-1}), resulting from differences in the length of the grazing season and herbage growth rates between the sites. 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 twelve years old.

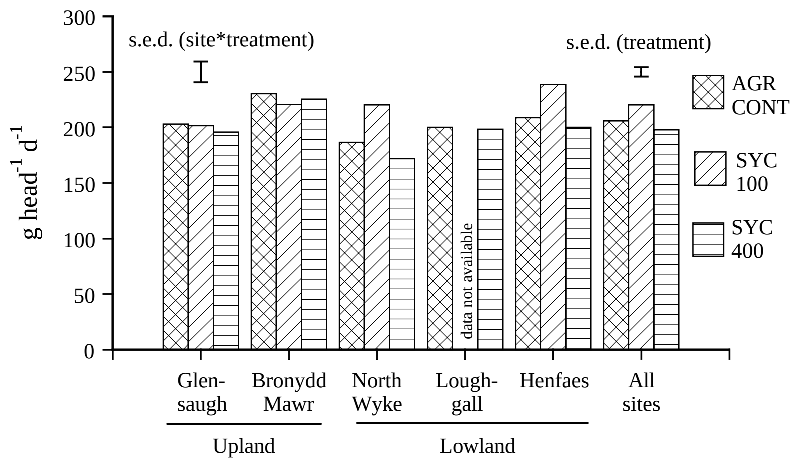

Figure 1. Individual lamb growth rate, turn-out to weaning, 1999.

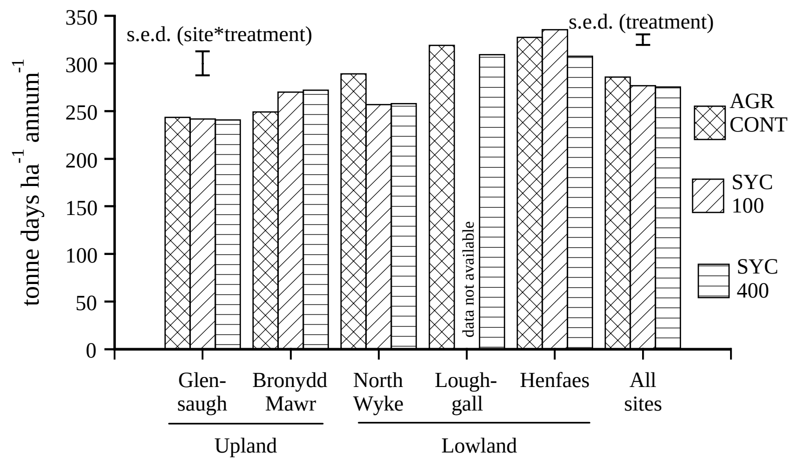

Figure 2. Mean animal liveweight carried over the season, 1999.

Tree survival in 1999 was high at all sites (see Table 2); North Wyke results are for ash.

Mean tree heights at the end of 1999 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, 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, for the first time, a significant effect of tree spacing ($P<0.05$). The trees on the SYC2500 treatment were taller than the most widely spaced trees (SYC100). The more densely planted agroforestry plots (SYC400) were intermediate and not significantly different from the SYC2500 and SYC100 treatments. On each of the three lowland sites, the trees on the SYC2500 treatment were significantly taller ($P<0.05$) than those on agroforestry treatments. The upland site at Glensaugh, which has previously shown the opposite trend with the shortest trees on SYC2500, had trees of similar height on agroforestry treatments and SYC2500 in 1999. This has been the case for some years at Bronydd Mawr.

The mean increments in tree height between 1998 and 1999 are shown in Figure 4 (ash at North Wyke). There was no significant difference in the height increment of sycamore between the sites (mean 70.4±5.92 cm annum^{-1}). There was a highly significant difference ($P<0.001$) between treatments across all sites (excluding North Wyke); SYC2500 had a greater rate of height extension than both agroforestry treatments, although this trend was not significant at Henfaes ($P=0.308$). 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). There was a highly significant difference ($P=0.001$) between ASH2500 and the ash agroforestry treatments at North Wyke.

The relative increase in tree height from 1998 to 1999 (i.e. the percentage increase over height in 1998) show similar patterns (Figure 5). There were no significant differences between sites that have sycamore (mean 19.0 ±1.62%). There was a significant difference ($P<0.01$) between treatments across all sites (excluding North Wyke) with the SYC2500 treatment showing a greater relative increase than the agroforestry treatments. There was also a significant site by treatment interaction ($P<0.01$). The trees on the SYC2500 treatment on the upland sites had significantly higher relative growth rates than the agroforestry trees ($P<0.01$) while there were no differences between treatments on the lowland sites (see Table 3).

Table 2. Annual tree survival (%).

	Upland sites		Lowland sites			
	Glensaugh	Bronydd Mawr	North Wyke*	Loughgall	Henfaes	Mean of all sites #
SYC100	97.1	100.0	100.0	97.8	100.0	98.7
SYC400	100.0	100.0	99.8	100.0	100.0	100.0
SYC2500	100.0	100.0	100.0	100.0	100.0	100.0
Site mean	99.0	100.0	99.9	99.3	100.0	99.6

* Ash; # excludes North Wyke

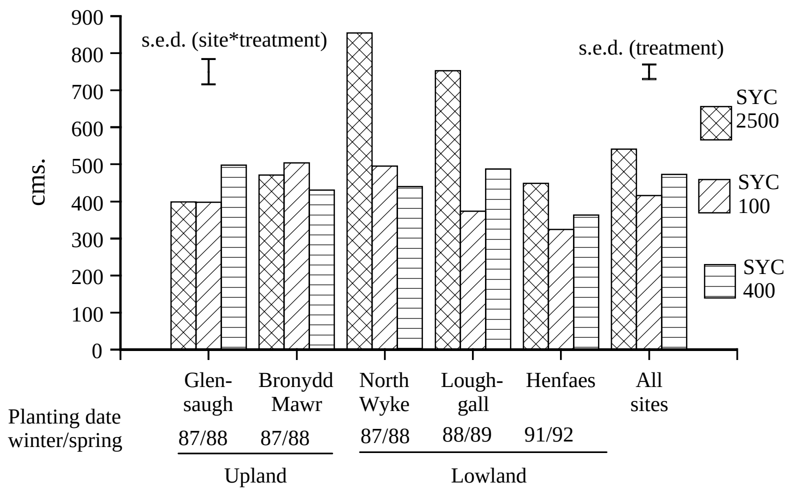

Figure 3. Tree height at end of 1999 (all sites mean excludes Henfaes and North Wyke).

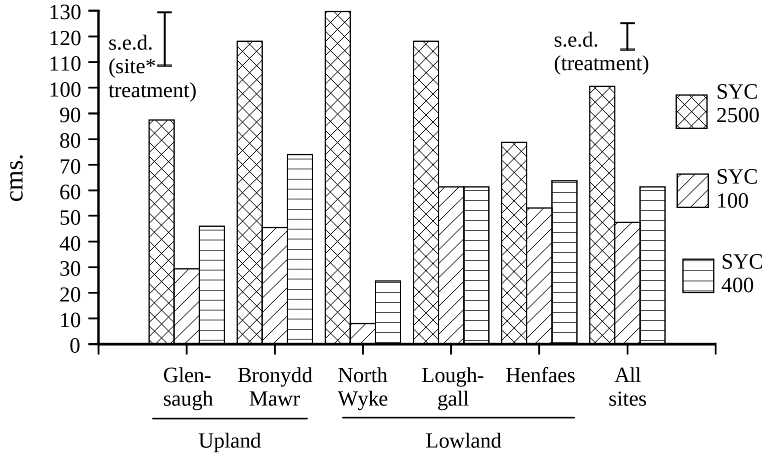

Figure 4. Mean increment in tree height 1998-99 (all sites mean excludes North Wyke).

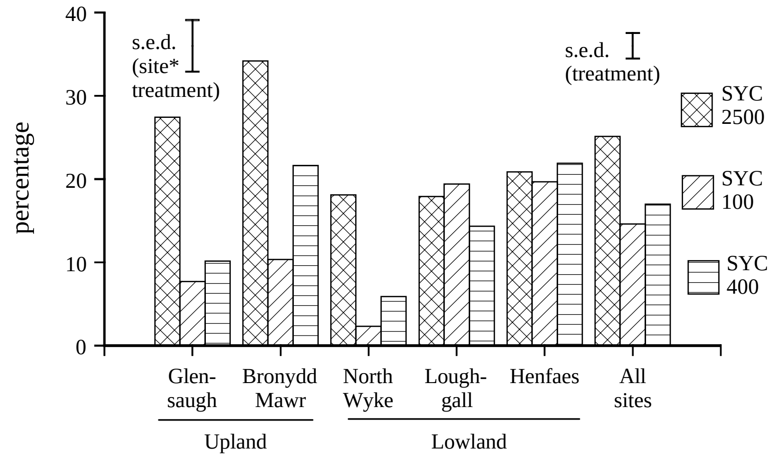

Figure 5. Relative increase in tree height 1998-99 (all sites mean excludes North Wyke).

Table 3. Relative annual height increments 1998-1999 (percentage over 1998, and s.e.m.) for treatments at the upland and lowland sites.

	SYC2500	SYC100	SYC400	Site type means
Upland	30.8 (4.99)	8.8 (1.07)	15.9 (4.15)	19.1 (3.16)
Lowland	19.4 (2.11)	19.5 (1.79)	18.1 (2.55)	19.0 (1.19)
Treatment means	25.1 (3.10)	14.6 (1.99)	17.0 (2.35)	19.0 (1.62)

The trees on the ASH2500 treatment at North Wyke had a greater relative increment ($P<0.05$) than the agroforestry treatments (see Figure 5). The site at North Wyke is characterised by a soil type that is prone to periods of waterlogging as it is poorly drained. Previous studies have indicated that drainage may have been improved by tree planting in the ASH2500 woodland control, probably as a result of root penetration of indurated layers creating micro-channels for effective drainage. This is particularly evident from measurements of soil water content during winter months when the site is prone to periods of water-logging. The ASH2500 treatment had much lower recorded soil moisture levels (Penn *et al.*, 1994). The much higher tree root density in these conventional woodland plots is likely to have resulted in a more effective improvement in drainage across the whole plot area. In agroforestry treatments, root systems of individual trees do not overlap and their root systems will still be exposed (at least in part) to the original poorly drained soil conditions. It is anticipated that there will also be an eventual improvement in drainage in these treatments as the developing root systems continue to modify soil conditions.

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 ha^{-1}. 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. Evidence from Henfaes, where the annual relative height increments (Figure 5) are more similar across treatments than at any other site, suggests that the individual protection of trees by small fences rather than by shelters may alleviate this problem. 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 has resulted in taller trees than those in agroforestry treatments, a fact that was very evident on lowland sites in 1997. It is likely that, at current rates of height increase, this will soon be the case for the two upland sites. The relative height increments of the trees at Loughgall, which has the tallest sycamore in the experiment, may indicate, however, that there is a third phase of comparative development. It is possible that the agroforestry trees, which currently have similar growth increments to the woodland control trees, may subsequently exceed the growth rates of the trees on the woodland control again.

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.

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Glensaugh Silvopastoral National Network Site - Annual Report 1999

Funding details

The MLURI contribution to the running of the project comes from core research funds received from the Scottish Executive Rural Affairs Department (SERAD). The project is in the third year of the fourth phase of a rolling 3-year review programme. Depending on the research priorities of both SERAD and MLURI, an application will be made to SERAD for funding to continue the project into a fifth 3-year phase. Additional funding was received over the period 1993-96 from the AIR Programme of the European Commission. Forestry Commission Research Agency involvement comes from Forestry Authority funding. Reductions in the resources available for agroforestry research through both MLURI and FC resulted in a reduced programme of data collection in 1997.

Project dates

Project start: Summer 1987

Project end: Depends on medium to long-term research priorities (see above). Continued external funding will also be sought in the longer term.

Background

The background to the full National Network Experiment and detail of treatments, replication, site descriptions etc. are given in Sibbald (1990) and in Sibbald and Sinclair (1990).

The site was planted in spring 1988. Results to date have been presented in the Annual Reports of the National Network Experiment published in *Agroforestry Forum*. Results for the treatments which are in common to all of the sites in the National Network Experiment for 1999 (the sycamore and agricultural control treatments) are presented in this issue of *Agroforestry Forum.* The treatments that are additional to the common national treatments at the Glensaugh site are shown in Table 1.

Table 1. Treatments additional to those common to the National Network.

Planting density (trees ha^{-1})	Tree species	
	Hybrid larch *(Larix x eurolepis)*	Scots pine (*Pinus sylvestris)*
400	✔	✔
2500 (woodland control)	✔	✔

As a consequence of the reductions in resources available for agroforestry research, the treatments with Hybrid larch at 100 trees ha^{-1} and 200 trees ha^{-1} were removed from the experiment at the end of 1997. The Scots pine at 400 trees ha^{-1} (SP400) treatment remains on a care-and-maintenance basis and with a much reduced level of data collection.

Results

Animal performance

The only additional treatment on which animal performance and output are now routinely monitored is Hybrid larch at 400 trees ha^{-1} (HL400). In 1999 there was, for the first time, a significant difference in lamb growth rate from turnout to weaning (P<0.05) between the agricultural control treatment (AGR_CONT) and the HL400 treatment (203±6.1 vs 183±5.7 g hd^{-1} d^{-1} for AGR_CONT and HL400 respectively). This is the first time since the experiment was started that individual animal performance has been affected by an agroforestry treatment.

Stock Carrying Capacity (SCC) reflects the annual agricultural production of each treatment. For an explanation of SCC and its calculation, see the National Network Experiment annual report in this issue. During 1999, the HL400 treatment carried only 88% of the livestock carried by AGR_CONT treatment (P<0.05). This is an identical level of reduction to that measured in 1998 and is only the second time in eleven years that agricultural productivity has been reduced by agroforestry.

Tree performance

Tree survival remained high during 1999. There were no losses of Hybrid larch, and none on Scots pine woodland control (SP2500). Annual survival on Scots pine agroforestry (SP400) was 96.7±1.67 %.

Table 2 shows the top heights of the trees in 1999, the annual height increment and percentage height increment from 1998 to 1999. The Hybrid larch trees on the woodland control (HL2500) were significantly taller (P<0.05) than those on the HL400 treatment but the difference between relative height increments was not statistically different. Heights of Scots pine were not significantly different in 1999 although there was a trend (P<0.10) for height extension to be greater on the SP2500 than SP400 treatment, there was no difference in relative height extension.

Discussion

The reduction in individual animal performance on the HL400 treatment, measured as lamb growth rate from turnout to weaning, indicates that there may be changes taking place in pasture structure such that the maintenance of a standard seasonal sward height profile can no longer guarantee similar levels of animal performance across treatments. Change in pasture structure could arise from changes in botanical composition which, in turn, could result from the impacts of shading by the tree crowns or may be caused by a covering of larch needles in autumn creating changes in the litter layer or in soil chemistry, for example in soil pH. Another impact on animal production may be the direct ingestion of fallen larch needles reducing diet quality. It is hoped that these possibilities will be investigated in the future.

Table 2. Mean top height in 1999, annual increment and percentage annual increment 1998-99 for trees planted in 1988. (Data with different superscript letters (a, b) within columns are significantly different (P<0.05). Data with different superscript letters (x, y) within columns show a difference trend (P<0.10)).

	Hybrid larch			Scots pine		
Trees ha^{-1}	Top height (m)	Annual increment (m)	Annual increment (%)	Top height (m)	Annual increment (m)	Annual increment (%)
400	6.78^{a}	1.07	19.2	3.54	0.38^{x}	11.9
2500	8.14^{b}	1.23	17.9	4.53	0.52^{y}	13.1

Stock carrying capacity on the HL400 treatment was significantly less than on the AGR_CONT treatment for the second year in succession; the levels of reduction were identical in 1998 and 1999. It was argued in last year's report (Sibbald *et al*., 1999) that this could be the first sign that competition from trees was reducing pasture growth and it was assumed, because of their large crowns, that shading was the main cause. In many cases the branches of neighbouring trees were already overlapping. The trees on the HL400 treatment were, as a consequence, pruned during winter 1998/1999. The lowest whorl of branches above the 1.8 m-tall net guard was removed, provided that the remaining crown was not less than 50% of the total height of the tree. It is likely that the pruning prevented a further fall in agricultural production from the 1998 level. Consequently, it was decided to further prune the trees on the HL400 treatment in winter 1999/2000. Branches were removed to leave a crown height 50% of the top height of each tree.

Tree survival is no longer a problem, though individual trees on the SP400 treatment have been lost through stem breakage in strong winds. Trees in the HL2500 treatment are still taller than those in the HL400 treatment and the lack of a difference in their relative height increments suggests that this will continue to be the case. The Scots pines show no differences in top height between treatments. However, in earlier years the trees on the SP2500 treatment were significantly shorter than those in the SP400 treatment. The fact that there is now a trend for the height increments on the SP2500 treatment to be greater suggests that in the future they may exceed the top height of the trees in the SP400 treatment.

Prognosis

The experiment is entering the phase in which the trees will increasingly have an effect on agricultural productivity. The reduction in agricultural productivity on the HL400 treatment, which appeared for the first time in 1998, has continued in 1999, despite some light tree pruning. However, the level of reduction did not increase and it is likely that a pruning strategy can be designed which will enable a high level of agricultural production to be maintained for several further years under the tree canopy provided that irreversible change in pasture structure has not taken place.

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Temperate silvoarable agroforestry with quality hardwood timber species - report for 1997-2000

Project dates

Start date September 1987; finish date uncertain.

Funding details

Funding has come from various sources (see *Agroforestry Forum* **4**(2): 23-24 for details).

Background

The background to the experiment is described in detail in *Agroforestry Forum* **4**(2): 23-24. This is a field experiment with silvoarable, arable control and forestry control treatments replicated four times. The arable alleys of the silvoarable treatment are 14-m wide, containing a 12-m wide strip of crop and subtended by trees in rows in a 2-m wide uncultivated strip. The trees (ash, cherry, sycamore and walnut) are 4 m apart in the rows and 2 m apart in a square planting in the forestry control plots. The arable rotation is winter wheat, winter wheat, winter barley and threshing peas.

The project aims to measure the effects of agroforestry on crop yields, tree growth, faunal populations and diversity and on microclimate and soil hydrology. The practical problems in the management of a temperate silvoarable system are also being monitored.

The most recent annual report for this experiment (for 1996) to be published was in *Agroforestry Forum* **8**(2): 9-11 (1997).

Results

Growth of trees

Within treatments (silvoarable and forestry control), heights of ash, cherry and sycamore remained not significantly different in 1997/98. In 1997 however, for the first time the diameter at breast height of cherry trees was significantly greater than that of both ash and sycamore (which were not different from each other). Although walnut is one of the tree species in the tree rows, it is not grown at forestry densities, so its response to being grown in a silvoarable system is not being comparatively assessed. However, it has done less well than the other species, being about 67% of their mean height in 1997/98. The measurements of trees in the 1997-98 winter were the last to be made.

Between treatments, the faster growth in height of the trees in the forestry control which was apparent in earlier years, was not maintained in 1997/98 (Table 1), despite their greater height, because the annual increment in height was 0.6 m for forestry control trees versus 0.7 m for agroforestry tree rows.

In recent years, in contrast, the girths of the tree row and forestry control trees have converged (having been originally less in the tree rows), so that for cherry and sycamore there were no differences in girth in 1996/97. In 1997/98 the girths of ash, cherry and sycamore in tree rows were greater than those in forestry control plots for the first time. Ratios between treatments show the differential effect on diameter compared with that on height (Table 2).

Table 1. The mean height[1] (m) of trees in agroforestry tree rows and forestry control plots since the winter of 1990/91. Figures in brackets are heights as a percentage of the forestry control.

Year	Treatment: Forestry control	Treatment: Agroforestry tree rows
1990/91	2.8 (100)	2.6 (93.0)
1991/92	3.4 (100)	3.0 (89.1)
1992/93	3.9 (100)	3.3 (85.5)
1993/94	4.4 (100)	3.7 (82.3)
1994/95	4.8 (100)	4.0 (83.0)
1995/96	5.1 (100)	4.3 (84.2)
1996/97	5.6 (100)	4.7 (85.3)
1997/98	6.2 (100)	5.4 (87.1)

[1] Mean of three species - ash, cherry and sycamore

Table 2. The ratios, for the measured variables of height and diameter at breast height, for trees in the agroforestry tree rows to those in forestry control plots in the winter of 1997/98.

Species	Ratio / tree row: control: Height	Ratio / tree row: control: Girth
Ash	0.82	1.05
Cherry	0.87	1.20
Sycamore	0.91	1.11

Arable cropping

In the early years of the experiment, yields in the arable alleys exceeded those of the arable control areas by as much as 23% in 1993 (Table 3), but between 1993 and 1996 yields dropped below those of the conventional crop by as much as 22%. In 1997, however, the agroforestry treatment had little effect, whereas in 1998 it yielded 20% less than the arable control again.

Strips of crop, 20 m long and 1.5 m wide, were harvested alongside each set of five trees (of the same species) in the tree row. Within the width of the alley, six parallel strips were harvested, three each side of the tramlines which lie down the middle of the alley. Within the agroforestry treatment, there have never been significant differences in yield between whole alleys. However, yields have always been highly significantly different with position within the alley. From 1994 to 1996, the yields in the outer strips closest to the tree rows, were significantly lower than the rest. This reduction also applied in the crops of 1997 and 1998. In 1997 the inner four strips had a similar yield to the arable control yields, whereas in 1998 they were lower than the control yields.

The species of tree has only occasionally (two years in nine) been shown to significantly affect yield of adjacent crop; in 1993 and 1995, yields were lower next to ash. It is of interest that yields next to the markedly smaller walnut trees have never been greater than those next to the taller trees of the other three species.

Small mammal fauna

The benefits of a silvoarable system as a habitat for small mammals has already been reported by Wright (1994). From December 1994 to August 1997, Klaa (1999) investigated the distribution, use of space and population dynamics of small mammals in this experiment, with particular attention to the most abundant small mammal in the system, *Apodemus sylvaticus* L., the woodmouse.

For the small mammals collectively, the highest density of captures (live trapping by Longworth traps) was found in the agroforestry tree rows and the least in open arable crop, with both arable alleys and forestry control areas having intermediate values (Table 4). Among the small mammals, *A. sylvaticus* preferred the agroforestry habitats of tree rows and arable alleys rather than the control habitats of forestry and open arable crop; the densities of captures in tree rows and arable alleys were not significantly different. Densities of captures of all small mammals were greater in the autumn of 1995 and 1996 than in the other three seasons of each year; the latter were not significantly different from each other. *A. sylvaticus* showed no preference for any one habitat in spring. In autumn it preferred wooded to cropped areas. Within the agroforestry system of tree rows and arable alleys it preferred the tree rows in summer, autumn and winter.

The population dynamics of the woodmouse (*Apodemus sylvaticus*) were studied by live trapping and the Mark-Release-Recapture technique. Population densities in the combined agroforestry/forestry environment were comparable with those of previous research in farmland, varying from 1 to 36 mice ha^{-1} (Table 5).

Table 3. Mean yields (t ha^{-1}) of arable crops in the arable control areas, and the arable alleys of the silvoarable system since 1990, expressed per unit cropped area. Figures in brackets are yields as a percentage of the arable control.

		Treatment	
Year	Crop	Arable control	Arable alley
1990	Threshing peas	5.9 (100)	5.3 (90.8)
1991	Winter wheat	7.6 (100)	8.3 (108.4)
1992	Winter wheat	6.6 (100)	6.8 (103.4)
1993	Winter barley	5.1 (100)	6.3 (122.7)
1994	Threshing peas	4.5 (100)	4.2 (94.2)
1995	Winter wheat	9.3 (100)	8.8 (95.0)
1996	Winter wheat	10.4 (100)	8.1 (78.1)
1997	Winter barley	5.7 (100)	5.6 (98.0)
1998	Spring barley	4.7 (100)	3.8 (80.0)
1999	Set-aside	-	-
2000	Spring barley	Not sown	Not measured

Table 4. Density of captures (number per 100 trap nights) of all small mammals (woodmouse, voles, shrews and other mice) in relation to habitat between December 1994 and August 1997.

Habitat	Density of captures
1. Agroforestry tree rows	15.0
2. Arable alleys (arable crop between tree rows)	9.1
3. Forestry control trees	9.2
4. Arable control areas (open arable crop)	4.3

Table 5. Comparison of published ranges of estimates of density of A. sylvaticus *populations (mice ha^{-1}).*

	Habitat				
Source of data in order of publication	Woodland	Farmland	Set-aside	Sand dune	Agroforestry system
Gurnell (1978)	75-225				
Green (1979)		0.46-17.54			
Flowerdew (1985)	0.25-100				
Akbar and Gorman (1993)				1-13	
Rogers and Gorman (1995)		0-36	0-11		
Klaa (1999) – this project					1-36

The use of space by the small mammal, *Apodemus sylvaticus*, was assessed by night time radio-tracking 15 animals. Home range was estimated by cluster analysis, giving mean home ranges of 0.18 ha for males (n=8) and 0.08 ha for females (n=4). The value for males is less than those previously reported and suggests that, in the patchy agroforestry environment, woodmice do not have to range over large areas. All animals had patchy home ranges, with between 1 and 21 nuclei, and the Simpson Index of diversity (ranging from 1.42 to 8.34) showed that clusters were of different sizes within each home range. Core ranges for males were also larger (0.09 ha) than those for females (0.03 ha), and their area varied with season and sex. Males increased their core ranges in the breeding seasons; females reduced them. Only two of the 12 animals with stable home ranges used the forestry control area as their preferred habitat. Females used the tree rows more than expected by chance (Figure 1). Males were positively associated with arable areas and forestry control areas but negatively with tree rows. There was no association between density of cover and the habitat content of home ranges.

Discussion

There are a number of possible explanations for the slower growth in height of trees in the agroforestry tree rows. Exposure to wind is greater for the isolated trees than the forestry control plantings. The effect of wind on reducing extension growth and strengthening stems is well known (Grace, 1977). The differential effect of agroforestry treatment on height versus diameter at breast height probably reflects this phenomenon.

The 1997 and 1998 crops differed in the temporal distribution of their growing periods. The winter crop of 1997 grew for much of its life without competition from trees when the trees were not in leaf. In contrast, the 1998 spring crop competed with the trees in leaf for most of its life. The greater effect of the agroforestry treatment on yield in 1998 may reflect that difference. (The reduced yield close to the tree row was discussed in the last report.)

In conclusion, the population dynamics of woodmice in the complex agroforestry/forestry environment were similar to those described for arable land but differed from those reported for woodland, set-aside and sand dune habitats.

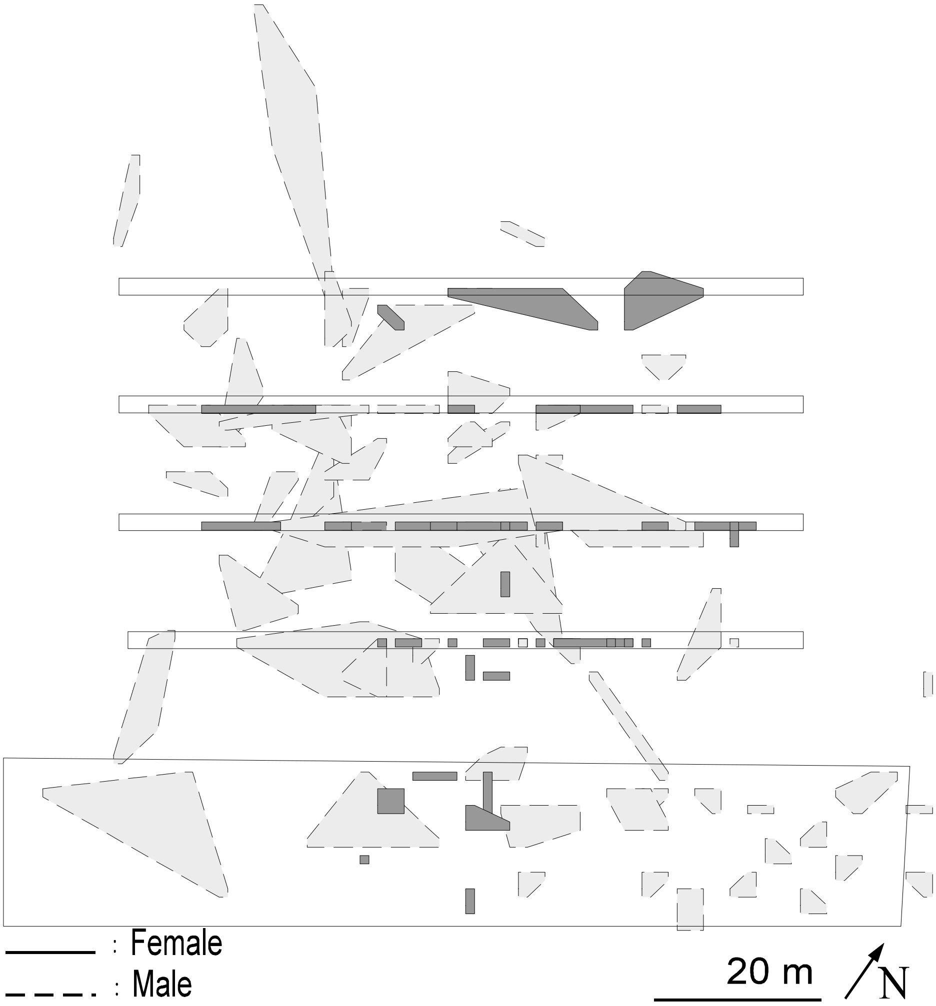

Figure 1. Distribution of core ranges of both sexes of A. sylvaticus *in Block 3. The diagram shows four tree rows (long thin rectangles) separated by three arable alleys and one forestry control area (large long rectangle at the bottom of the diagram). Female ranges (n=3 animals) are dark shaded and male ranges (n=9 animals) are light shaded.*

Clearly the system is a favourable combination of habitats for the woodmouse, with the uncultivated grassed understoreys of the tree rows providing undisturbed habitat for shelter and for breeding females to nest.

Prognosis

The future of this experiment is a matter for concern because it would now cost £4000 per annum in land rental charges alone to continue it as a cropping system. We are unable to obtain funding of this order. Consequently the arable alley areas have been put into set-aside since the harvesting of the 1998 crop. Block 1 was returned to cropping for the 1999/2000 cereal growing season (at an annual rental charge of £1000) as a public service - the site is visited each year by groups of university and college students because of its uniqueness as an experimental silvoarable agroforestry system. However, crop yield in Block 1 was not measured in 2000.

The trees and bounding hedges are under care and maintenance. Agroforestry trees will be pruned this winter to give a 50% canopy (the cherries have already been pruned in the late summer of 2000) and the trees in the forestry control areas are being thinned (the largest ash trees in Block 1 have already been thinned once in 1999) and badly diseased cherries removed; all for firewood. Hazel bushes will be topped where their branches reach into the tree row canopy. Tree heights and diameters at breast height of the remaining trees will be measured again this winter.

We are now considering the conversion of the experiment to woodland by planting trees in the arable alleys.

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