Forest Research

Short Rotation Forestry Trials in Scotland

Progress Report

2014

The Research Agency of the Forestry Commission

Contents

List of Figures

List of Tables

Forest Research is the Research Agency of the Forestry Commission and is the leading UK organisation engaged in forestry and tree related research. The Agency aims to support and enhance forestry and its role in sustainable development by providing innovative, high quality scientific research, technical support and consultancy services.

Executive Summary

Six Energy Forestry trial sites are now established in Scotland; four planted in 2010, one in 2011 and one in 2012. In addition, two further trials were planted in Orkney in 2013. The 2010 trials have now had five full growing seasons and it is possible to identify some emerging trends in species performance and site suitability from the height and survival assessments to date.

Despite early heavy losses caused by the extremely severe weather conditions in the first two years after planting, survival since beating up is much improved for most species.

Based on performance to date, hybrid aspen appear to have the most potential for use in SRF systems on these sites as it is tolerant of site conditions and able to grow fast. Hybrid larch also performed very well, but future planting may be limited due to *Phytophthora ramorum*. Common alder, silver birch and Sitka spruce may also have potential on certain site types, but do not appear to be universally suitable for SRF.

Although red alder had extremely large height increments on most sites, it is not able to tolerate the site conditions and survival was very poor making it unsuitable for SRF on these sites. Survival of Italian alder was also poor.

In contrast, ash and sycamore (and sweet chestnut at some sites) had high survival rates and appear to be the most tolerant of site conditions, but growth rates were very low. Further monitoring will show whether growth rates of these species improve as the trees become fully established.

Severe winter weather conditions caused very heavy damage to all Eucalyptus species in the 2010 planting, including *E. glaucescens* which was thought to be hardier. The initial sites were replanted in September 2011, and have now had three full growing seasons.

In the second planting, which had more favourable weather conditions, *E. gunnii* had the highest survival and largest mean height increment of Eucalyptus across all sites. On the more southerly sites *E. pauciflora* and *E. subcrenulata* had reasonable survival rates. The improved survival of these later plantings to date may be due to the relatively mild winters in recent years, or to the different species planted.

Where Eucalyptus species have survived growth rates are good, often in the region of 50 cm per year, but not as large as the increments achieved by red alder, hybrid larch and hybrid aspen.

For most species, performance at the younger two sites, Aros (a Sitka spruce restock site) and Auchlochan (a higher altitude and relatively exposed site) appears at this stage to be comparable with that at the better quality ex-agricultural sites.

Further monitoring and assessment of the trials will confirm whether these early trends continue, and will allow volume to be calculated indicating which species are the most likely productive SRF candidates.

The opportunity is being taken to replace some of the species at the Sibster, the most northerly site, with alternatives that may be better able to tolerate the exposed site conditions, based on experience from SRF trials in similar conditions in Orkney.

The trials are starting to make a significant contribution to improving our knowledge of SRF in Scotland. The demonstration value of the sites is increasing, with a greater visual impact to practitioners, researchers and policy makers throughout Scotland. The trials are now providing information on which species are most likely to be suitable for SRF in Scotland. As the rotation progresses, this value will continue to be built upon.

This report summarises recent progress made up to March 2015, and gives an overview of the programme for the coming year, 2015/16.

Background

Wood fuel has an important role in contributing to the Scottish Government's climate change and renewable energy targets, particularly the target for renewable heat. Currently the majority of the wood fuel used in Scotland comes from the conventional forest resource (waste wood is around one third of total wood fuel use) and there may be a role for Short Rotation Forestry (SRF) to produce wood fibre specifically for the wood fuel market with the benefit of obtaining the fibre on a reduced rotation.

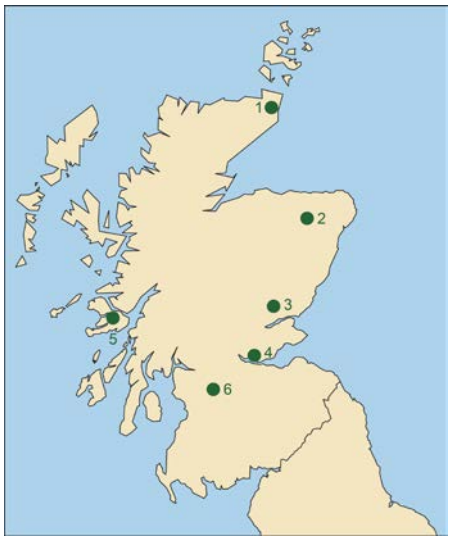
However, there was little current knowledge of SRF in the UK and so in 2007 Forestry Commission Scotland (FCS) and Forest Research (FR) began developing a network of Energy Forestry (EF) exemplar sites. The aim was to address the important information gaps on the growth of short rotation forestry in Scotland, as well as being a practical, operational demonstration of its potential. As these trials mature, information from the exemplar sites will highlight the opportunities for these new crops to foresters and farmers as well as providing useful new data on the growth of tree species in their early years.

Establishment of the trial sites

Six trial sites have now been established in Scotland. These are all ex-agricultural sites with the exception of Aros which is a restock site, previously a Sitka spruce crop (Table 1; Fig 1).

Table 1. Location and land use history of the six trial sites.

Site	Altitude (m)	Aspect	NGR	History
Sibster	30-40	West	ND147597	Ex-arable
South Balnoon	180-210	North east	NJ645428	Livestock farming
Alyth	210-220	South	NO235493	Ex-agricultural
East Grange	45-60	South	NS993891	Ex-agricultural
Aros	30-90	South	NM541456	Sitka spruce restock
Auchlochan	225-245	West	NS829404	Ex-agricultural



1. Sibster, North Highland FD
2. South Balnoon, Moray & Aberdeenshire FD
3. Alyth (Westfield), Tay FD
4. East Grange, Scottish Lowlands FD
5. Aros (Mull), West Argyll FD
6. Auchlochan, Scottish Lowlands FD

Figure 1. Map showing location of the six experiment sites.

At each of the six sites a fully replicated randomised block experiment was established trialling species likely to have fast early growth of high-density timber suitable for use in SRF. The following 10 species were planted:

Sycamore (SY)	*Acer pseudoplatanus* L.
Italian alder (IAR)	*Alnus cordata* Desf.
Red alder (RAR)	*Alnus rubra* Bong.
Silver birch (SBI)	*Betula pendula* Roth.
Sweet chestnut (SC)	*Castanea sativa* Mill.
Ash (AH)	*Fraxinus excelsior* L.
Hybrid larch (HL)	*Larix x marschlinsii* Coaz
Common alder (CAR)	*Alnus glutinosa* (L.) Gaertn.
Hybrid aspen (ASP)	*Populus tremula* L. *x tremuloides* Michx.
Sitka spruce (VPSS)	*Picea sitchensis* (Bong.) Carr. (from vegetative propagation)

A second experiment at each of the sites planted in 2010 trialled a range of Eucalyptus species with potential for growth in SRF:

E. glaucescens
E. gunnii
E. nitens (NSW)
E. nitens (Vic)

The experiment sites were fenced and ground preparation and weed control were carried out prior to planting. Species plots were 20 m x 20 m, planted at 1 m spacing along the rows and 2 m spacing between rows, giving 200 trees per plot. Assessments were carried out in the central 12 m x 15 m area containing 96 trees.

After heavy losses during the first two winters, which were extremely severe, the plots were beaten up to 100% stocking with trees of the original species and batch (grown on in a nursery until required). Throughout this report the survival figures presented are post beating up, and mean height figures include those of beat up trees.

Orkney Trials

Two further short rotation forestry trials were established in Orkney by the Agronomy Institute, Orkney College, University of Highlands and Islands, also funded by Forestry Commission Scotland. These are located in Muddisdale (Orkney Mainland) and Newfield (on Shapinsay) and were planted in Spring 2013.

The trials are based on a very similar design to the mainland trials, and contain some of the same species:

Sycamore (SY)	*Acer pseudoplatanus* L.
Italian alder (IAR)	*Alnus cordata* Desf.
Common alder (CAR)	*Alnus glutinosa* (L.) Gaertn.

As well as some additional species suited to Northerly climates:

Downy birch	*Betula pubescens* (Ehrh.)
Beech	*Fagus sylvatica* (L.)
Aspen	*Populus tremula* (L.)
Goat willow	*Salix caprea* (L.)
Mountain ash	*Sorbus aucuparia* (L.)
Whitebeam	*Sorbus intermedia* (Ehrh.) Pers.

As the most Northerly trial at Sibster was lost due to severe herbicide damage, the results of the Orkney trials may provide important additional information to supplement the mainland network. The summary results are presented here for comparison, and a report presenting the full results for the end of the second growing season by Dr. Peter Martin, University of Highlands and Islands, is included in Appendix 2.

Update on the past year

There was a severe outbreak of the common leaf weevil (*Phyllobius pyri*) in early May at Alyth, affecting both the Forest Research trials and adjacent FES wider area (Fig. 2). This was a particularly heavy infestation causing severe defoliation of young developing leaves in early May and was probably related to the heavy weed growth on the site which has not been well controlled. Hybrid aspen, birch and alder species were particularly badly affected, while numbers were far fewer on hybrid larch and spruce causing little damage. Although weevils were numerous on sweet chestnut and sycamore, the buds had not fully broken and so damage was limited to these species. However, by the third week of June new leaves were seen on the hybrid aspen, red alder and birch, and by mid summer little evidence of the attack could be seen.

Figure 2. Images of weevil damage at Alyth in early May, and recovery of hybrid aspen trees in late June (bottom right image).

Weed growth has been an ongoing challenge on these comparatively rich soils (compared to standard forestry sites) and still requires further control until canopy closure is achieved for the slower growing species.

Ash trees on Alyth and East Grange continue to show signs of *Chalara fraxinea* with a large number of trees in some of the plots showing symptoms (Fig. 3). Current policy is to leave the trees in place and progress of the disease will be monitored, however, this may have affected growth and survival rates this year.

Figure 3. Ash tree at Alyth in November 2014 showing signs of *Chalara fraxinea*

The Sibster site which was badly damaged by herbicide in June 2013 has been prepared for replanting by Scottish Woodlands and planting is currently ongoing (March 2015). The opportunity has been taken, based on previous experience at the site, to replace sweet chestnut with downy birch (*Betula pubescens*). In addition, hybrid larch will be replaced with balsam poplar (*Populus balsamifera*) and ash with native aspen (*Populus tremula*) due to disease. The original plots of hybrid aspen and red alder, which escaped herbicide damage due to their larger size have been retained and will continue to be assessed for comparison with the other 2010 trials. Scottish Woodlands will continue to maintain this site for five years after planting.

All sites were assessed in winter 2014/15 and the results are presented below.

Results

Fast-growing broadleaves

East Grange (Kincardineshire)

This site is the most southerly of those planted in 2010 with a low elevation, and the five-year results continue to show some of the best growth and survival rates (Fig. 4). In addition, as ex-agricultural sites, the soils at most of the trial sites are likely to be richer and better drained than the 'natural' soil of the site. This has resulted in mean height of hybrid aspen, the tallest species on the site, of almost 6 m at age 5, with that of red alder approaching 5 m. Hybrid larch also continues to perform well, with mean height over 4 m (Fig. 5). Italian alder has performed better than in 2013 with an

increment of almost 1.5 m, remaining a little taller than common alder. Sycamore, sweet chestnut and ash continue to perform very poorly, with silver birch and Sitka spruce slightly better with a mean height of over 2 m. There has been little change in survival over the past year.

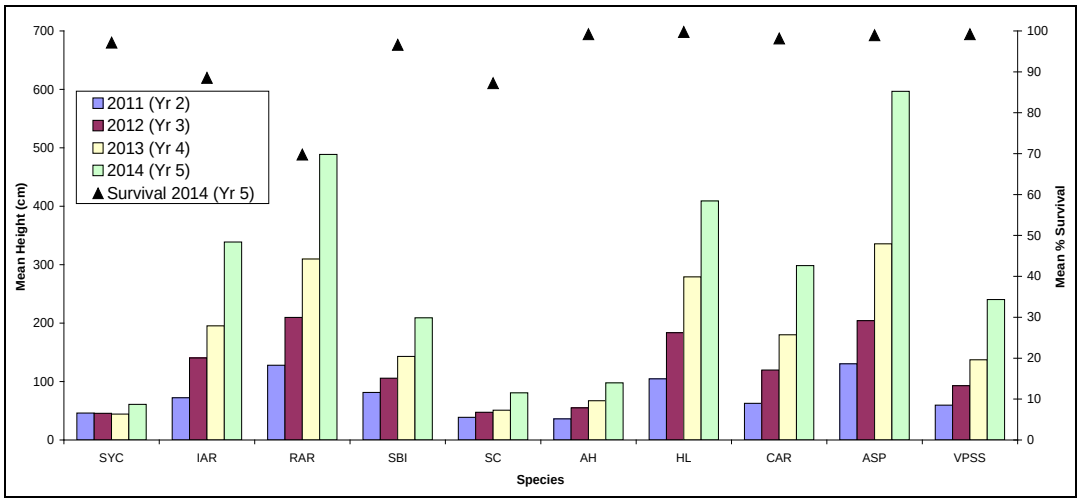


Figure 4. Mean end of year height and survival after five years at East Grange.

Figure 5. Hybrid larch and hybrid aspen at East Grange in March 2014 at the start of the growing season.

Alyth (Perth and Kinross)

This site remains one of the best for all species, including eucalyptus (see later section) despite its relatively high exposure. The south facing slope and freely-draining brown earth soil provide good conditions for growth and survival. Although the tallest species are not as tall as at East Grange, the others are broadly similar and survival is also generally high.

Hybrid larch remains the tallest species on the site at around 3.5 m, with the increment being particularly large during 2014 (Fig. 6 & 7). Although red alder and hybrid aspen are still among the tallest species on the site, their increment in 2014 was not as large as might have been expected, probably due to the attack by common leaf weevil, which was particularly severe on these species. Sitka spruce, which was not affected by the weevil attack is also now approaching 2.5 m, having performed very well during the year (Fig. 7).

Growth rates of sycamore and ash have improved slightly after a slow start, although the many of the ash trees are infected with *Chalara*. Sweet chestnut has not shown signs of improved growth rate. Survival is similar to last year for all species.

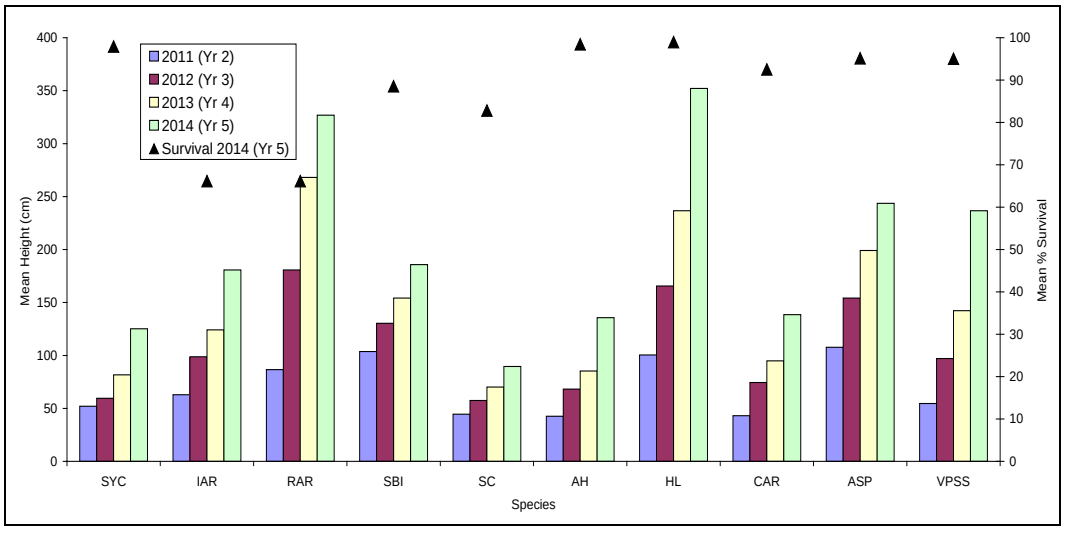


Figure 6. Mean end of year height and survival after five years at Alyth.

The soil depth on this site is only around 30 cm, making it susceptible to drying out during periods of low rainfall. The water availability monitoring that has been carried out

on the adjacent operational site since planting (see Appendix 1 for full report) demonstrates that soil moisture under grass decreases more than under ash or sycamore during dry periods, such as the summer of 2013. This is likely to be caused by the well developed deeper root system of the grass and high transpiration requirement compared to that of the young trees.

Monitoring of water resources on this site will continue and will provide further information as the site matures. However, one of the water monitoring arrays is within the ash block of the operational area and this would become redundant if the ash was to be cleared.

Figure 7. Hybrid larch and ash, Hybrid aspen, and Sitka spruce at Alyth in November 2014 (clockwise from top left)

South Balnoon (Aberdeenshire)

Despite the severe weed competition on this site initially, survival has remained reasonable since beating up except for the alder species and sweet chestnut, probably due to poor seedling quality and less ability to compete with other vegetation. Survival of Italian alder may also be poor due to low accumulated temperature, which is likely to limit the species on the site.

Red alder, hybrid aspen, hybrid larch and silver birch are performing well with good height growth increments for the year (Fig. 8). The early growth of hybrid aspen was not as good on this site as on others, but growth rates have now improved and the increment in 2014 was large. Sycamore, sweet chestnut and ash continue to grow extremely slowly and increments have improved little compared to those in previous years (Fig. 9).

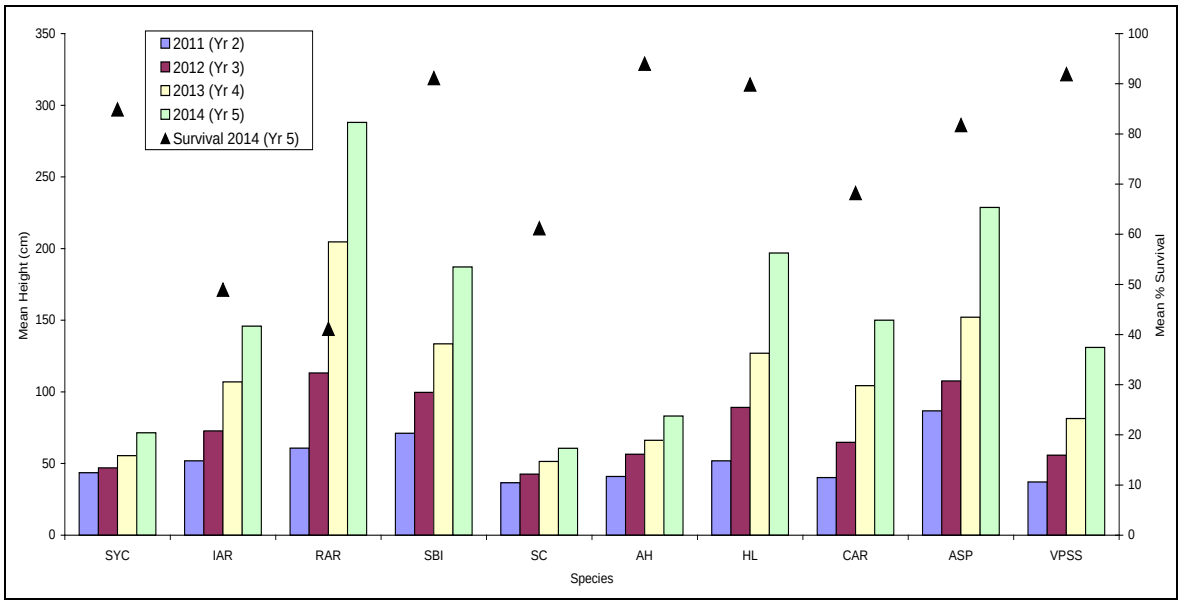


Figure 8. Mean end of year height and survival after five years at South Balnoon.

Figure 9. Common alder and ash at South Balnoon in August 2014

Sibster (Caithness)

Planted in 2010, this site is the most northerly and the most exposed of all the trials. The site was chosen for its geographical location, and relatively fertile ex-arable land such as this would not normally be planted. However, despite the higher than normal fertility, early growth was slow in all species. Frequent cold winds and gales resulted in shoot die-back and foliage damage in most species. The storm-force winds of May 2012 were particulary damaging and severely affected newly emerging broadleaf foliage and larch needles, resulting in both physical damage and scorching. Many trees had a multi-stemed and 'stag-headed' appearance.

Regardless of damage and slow growth, survival to Spring 2013 was good overall, with most species >70% (after beating up). Only red and Italian alders had lower survival, although the survivors were among the best performing trees on the site. The quality of initial seedling stock of these species was not as good as some other species, being small and relatively thin. This combined with the exposure will have contributed to low initial survival.

Unfortunately, in June 2013, the Sibster plots were mistakenly treated with glyphosate herbicide. This resulted in major damage to most species except the red alder and hybrid aspen, which were sufficiently tall to avoid most of the spray.

Figure 10 below shows end of growing season height and survival for each species at Sibster, with only the remaining red alder and hybrid aspen assessed in 2014. Although survival of red alder at Sibster is now very low (possibly due to herbicide damage), the

few remaining trees had a very large mean increment of 80 cm during 2014. Survival of hybrid aspen is 69% and these trees also grew well during 2014, with a mean height increment of 49 cm. The early results from Sibster suggest that SRF is unlikely to be very successful on such sites without additional wind breaks.

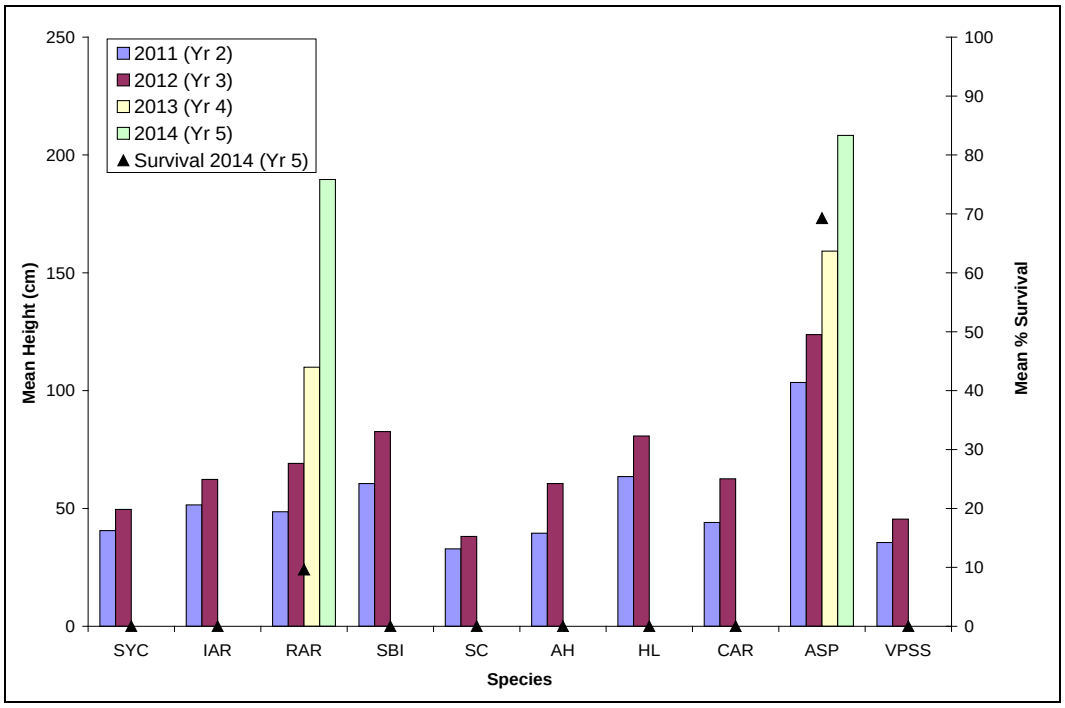


Figure 10. Mean end of year height and survival after five years at Sibster (red alder and hybrid aspen only).

Aros (Mull, Argyll)

This site was planted one year after the initial planting at East Grange, Alyth, South Balnoon and Sibster in spring 2011. It is a relatively sheltered 6.0 ha restock site with a south-facing slope, between 30-90 m elevation and an upland brown earth soil. The site has recovered well from early Hylobius problems and survival of most species is reasonably high.

The same general species growth responses can be seen as at the initial four sites. Red alder and hybrid aspen grew extremely well at Aros during 2014, with increments of 1.0 m or more, and reached a mean height of 3.0 m at the end of year 4 (Fig. 11 & 12). Hybrid larch, common alder and Italian alder also grew well during 2014, and mean heights are now over 1.0 m. Ash, sycamore and Sitka spruce remain slow growing, with sweet chestnut and silver birch performing slightly better (Fig. 12).

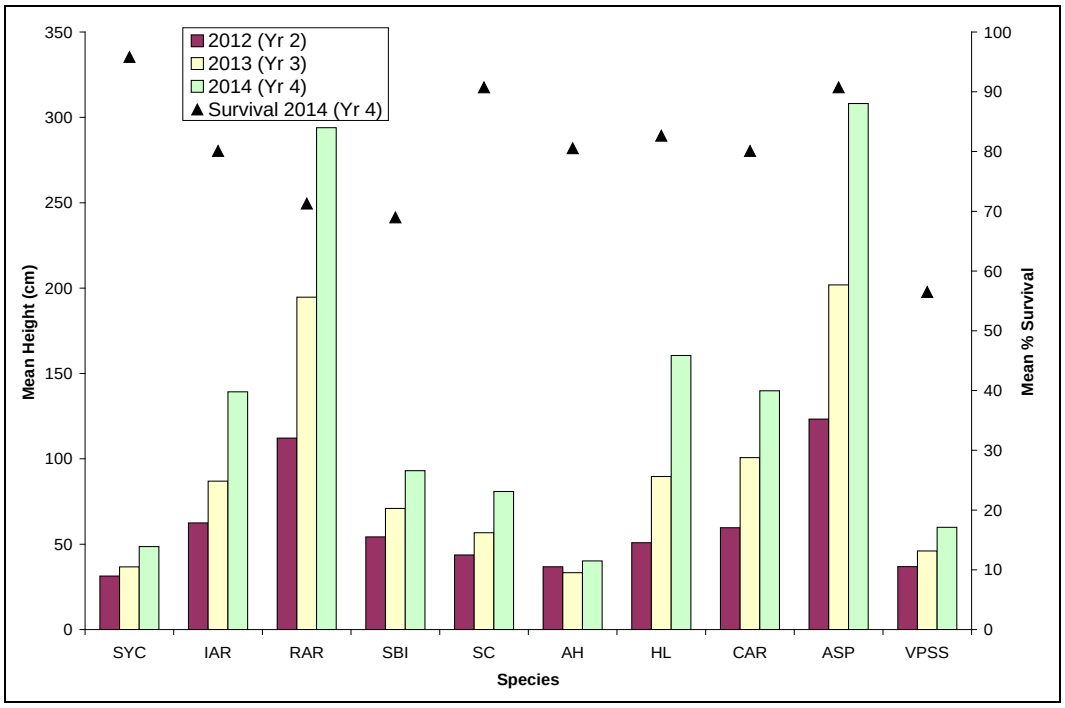


Figure 11. Mean end of year height and survival after four years at Aros.

Figure 12. Hybrid aspen and ash at Aros, June 2014.

Auchlochan (South Lanarkshire)

This site, near Lesmahagow in South Lanarkshire, was planted in the spring of 2012, two years after the initial four sites, and one year after Aros. Delays in site acquisition and determining the location of mains water pipes forced changes in the ground preparation and the ultimate layout of the site. Way-leaves for the pipes and also overhead cables reduced the usable area of the site by about a third. As a result, fewer trees could be planted here than at the other EF trial sites, although it still remains a substantial trial.

Survival of all species during the first year was very good (>90%) compared to the sites planted in 2010, probably because winter weather conditions after planting were much less severe than for the first four sites. Minor beating-up was carried out in April 2013.

Survival of most species remains high at the end of the 3rd growing season, with the exception of Italian alder (Fig. 13). In contrast to the 2013 growing season, all species at Auchlochan had large height increments during 2014, a particular increase being seen for sycamore and ash, which were previously growing very slowly. As at the other sites, red alder and hybrid aspen had the largest height increments, and mean height of these species is now over 2.0 m. Hybrid larch and common alder also remain among the tallest species at the site, both with mean height over 1.5 m.

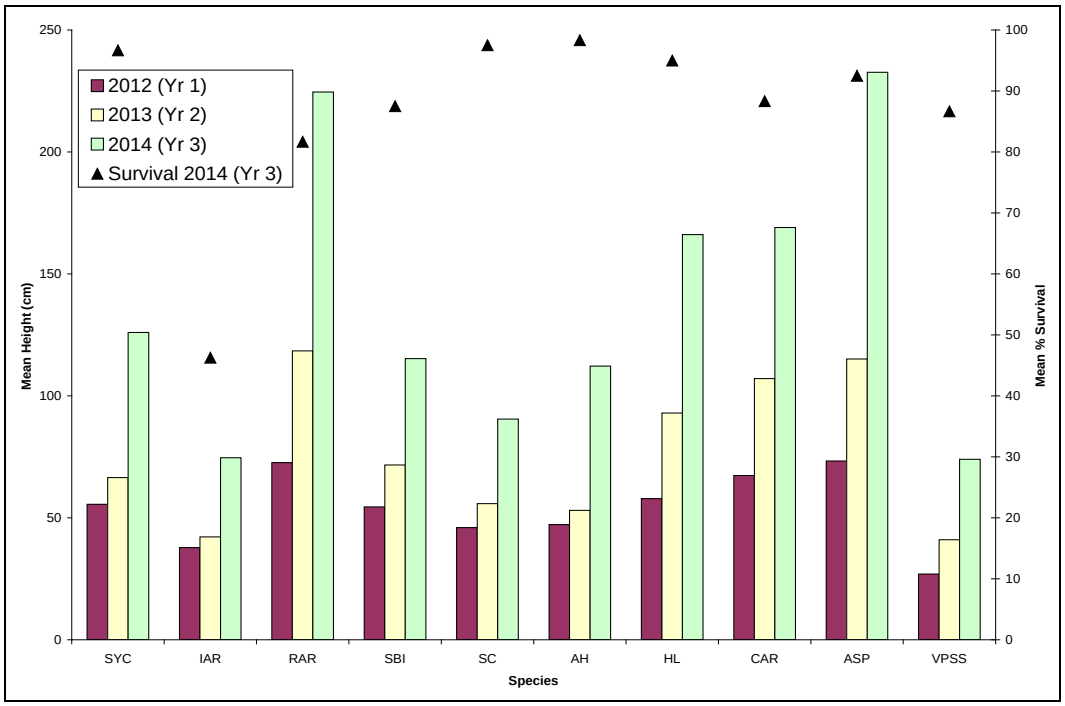


Figure 13. Mean end of year height and survival after three years at Auchlochan.

Orkney sites

In addition to the trials described above, Forestry Commission Scotland also funded two SRF trials in Orkney, established in 2013 and managed by the Agronomy Institute, Orkney College, University of Highlands and Islands. These trials are on ex-agricultural land, located at Muddisdale (Orkney Mainland, HY 435 110) and Newfield (Shapinsay, Balfour Mains Farm, HY 516 181). The windy, exposed conditions of these northerly sites make them a good comparison for the Sibster site, which was lost due to herbicide damage.

Rabbit/hare damage was a serious problem at the Muddisdale site during the first growing season and trees were protected with guards shortly after planting. At the Newfield site dry weather conditions in the spring and early summer following planting resulted in some defoliation and scorching in trees that were not protected by guards.

At the end of the first growing season survival of all species was very high. Goat willow (not planted in the mainland SRF trials) was the tallest species with the largest height increments of 60-80 cm at both Orkney sites.

At the end of the second growing season survival of all species remained high, but sycamore had the lowest survival at both sites (Fig 14 and 15). Goat willow remained the tallest species at both sites, with aspen, common alder and downy birch also performing well at both sites. The largest height increment was achieved by aspen at the Muddisdale site. Italian alder and whitebeam both grew very well at Muddisdale but not at Newfield. Beech, mountain ash and sycamore did not perform well at either site.

For some of the species that are in common with the mainland sites two-year performance at the Orkney sites has been markedly better than at the Sibster site (Fig. 10). Common alder achieved heights of over 1 m at both Orkney sites at the end of the second growing season, compared with just 44 cm at Sibster, and Italian alder at Muddisdale achieved 1.3 m compared with 51 cm at Sibster. These species may have been severely affected by the very cold winters of the two years following planting at Sibster. The two-year heights of sycamore were similar at Sibster and the Orkney sites.

Common aspen and downy birch, which have both performed well at the Orkney sites are being planted at the Sibster site in spring 2015. As they appear to tolerate the exposed weather conditions it is hoped that they will also be well suited to the Sibster site.

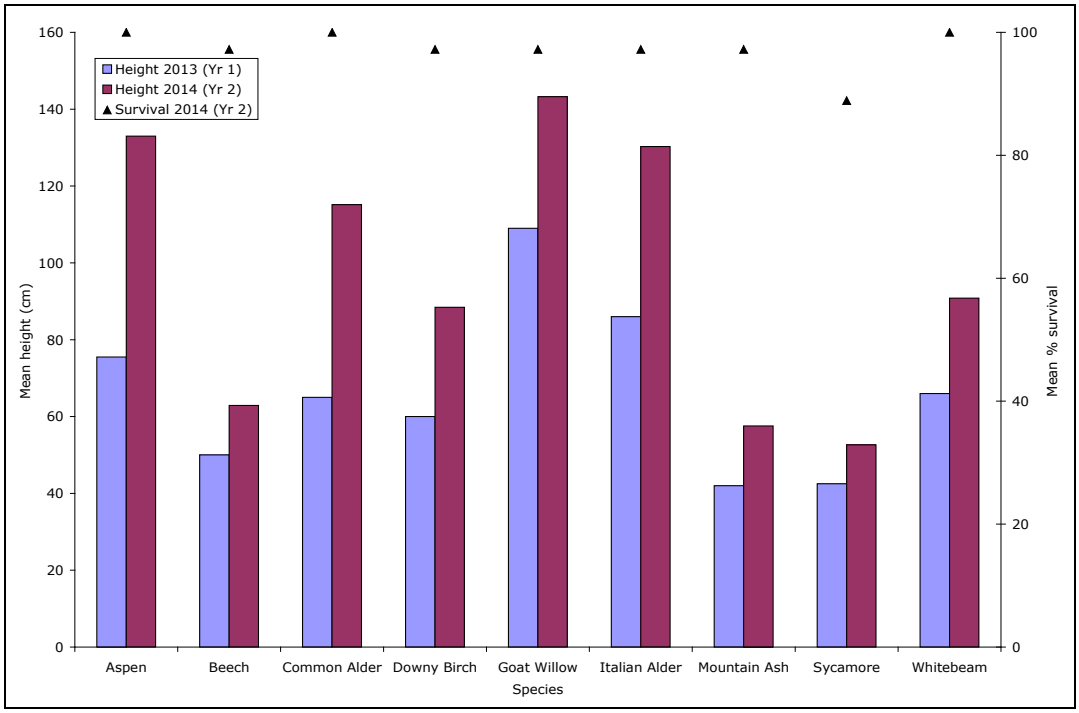


Figure 14. Mean end of year height and survival after two years at Muddisdale

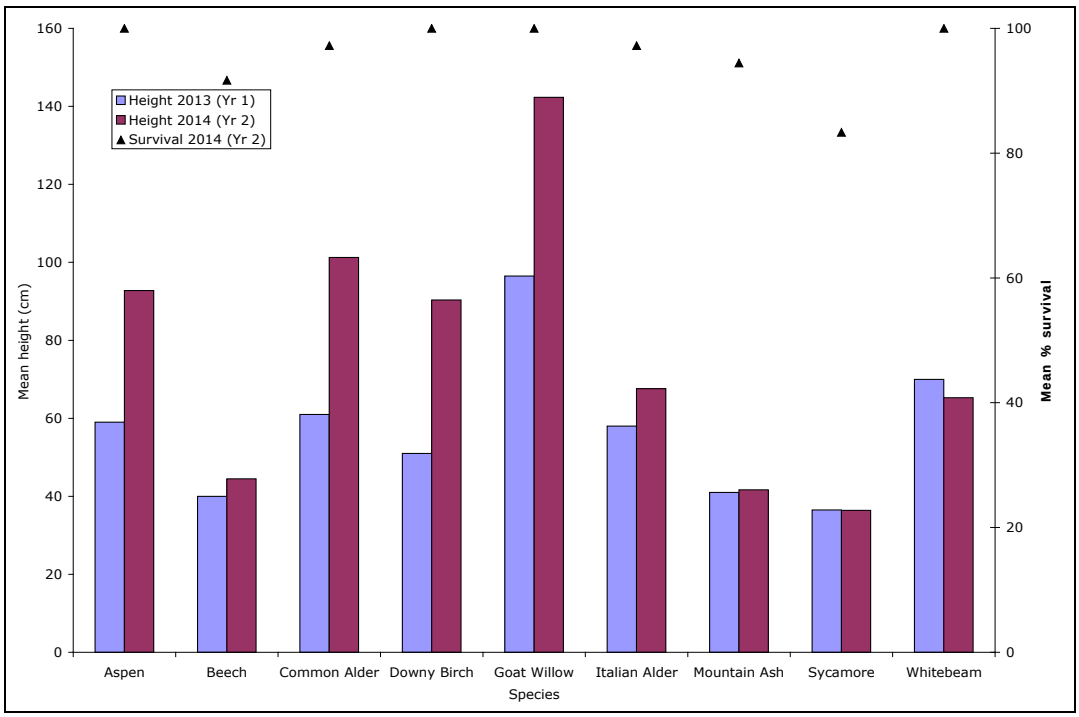


Figure 15. Mean end of year height and survival after two years at Newfield

Eucalyptus species

Surviving plots from first series of sites

Of the original four sites (replanted in Sept 2011) only East Grange and Alyth have eucalyptus plots that are worth assessing; survival at Sibster and South Balnoon is virtually zero. The eucalyptus species continue to survive and grow faster at Alyth than at East Grange.

At both East Grange (Fig. 16) and Alyth (Fig. 17) the few remaining individuals of *E. nitens* have the best eucalyptus growth rates on the site, with mean height of over 1.3 m and 2.6 m respectively after 3 growing seasons. However, their very poor survival rates make them unsuitable species for the sites.

At both sites *E. gunnii* has the highest survival rates of the eucalyptus species, with survival of *E. pauciflora* and *E. subcrenulata* being lower. Annual increment of *E. gunnii* at both sites during 2014 was large, 43 cm at East Grange and 76 cm at Alyth.

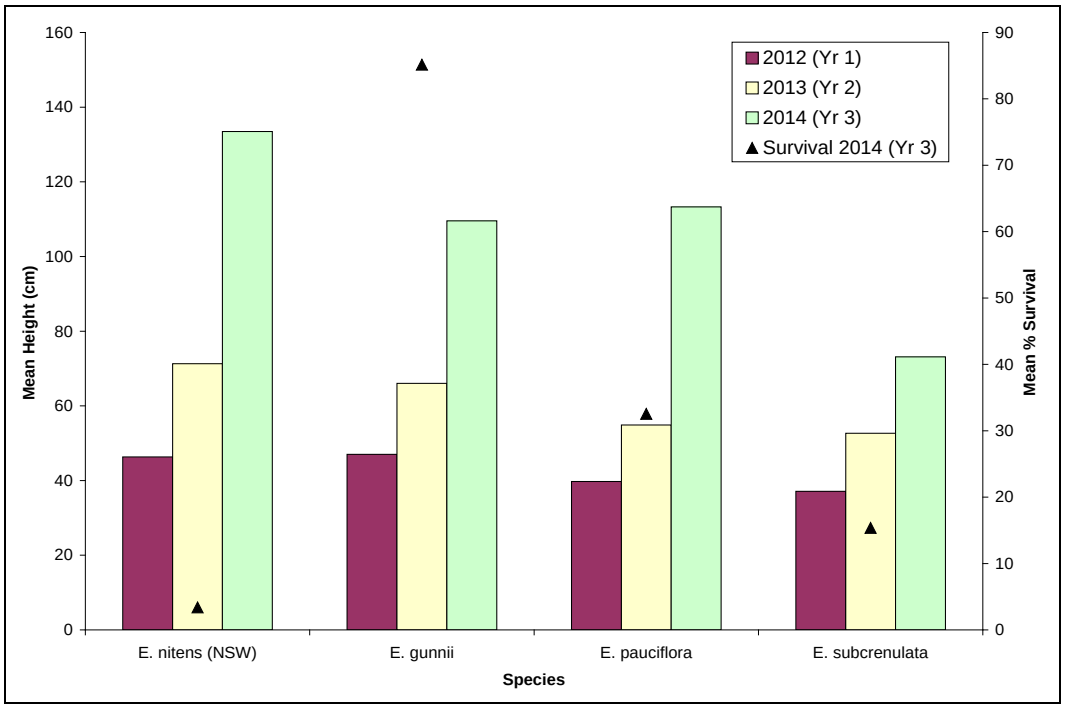


Figure 16. Mean end of year height and survival of Eucalyptus species after three years at East Grange

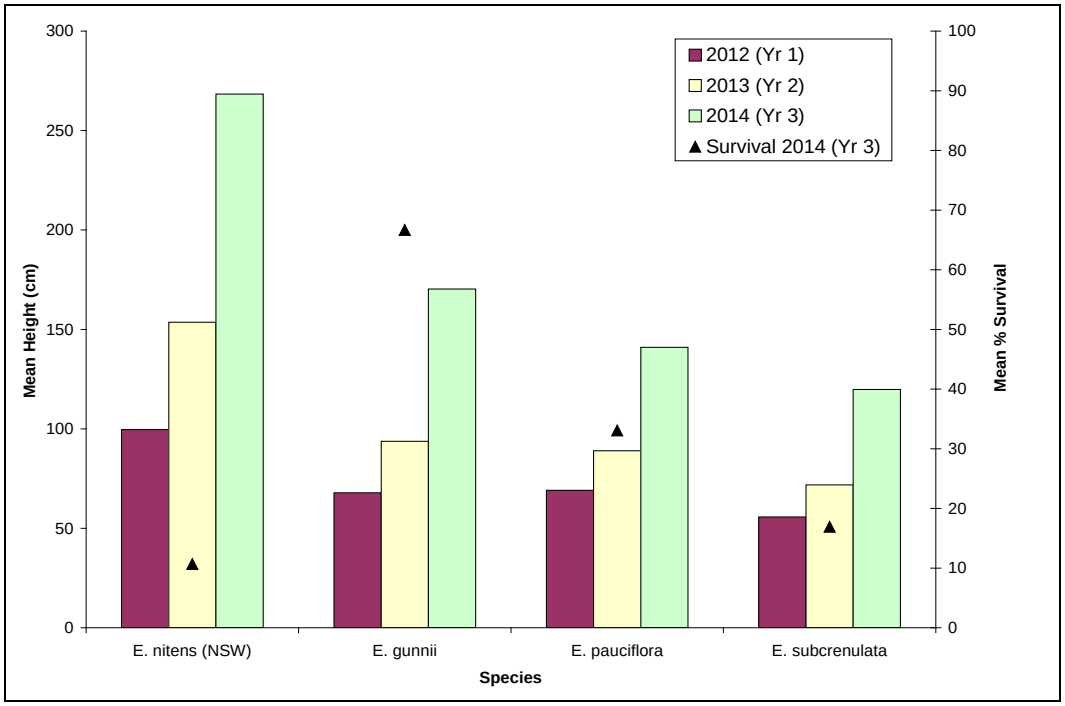


Figure 17. Mean end of year height and survival of Eucalyptus species after three years at Alyth

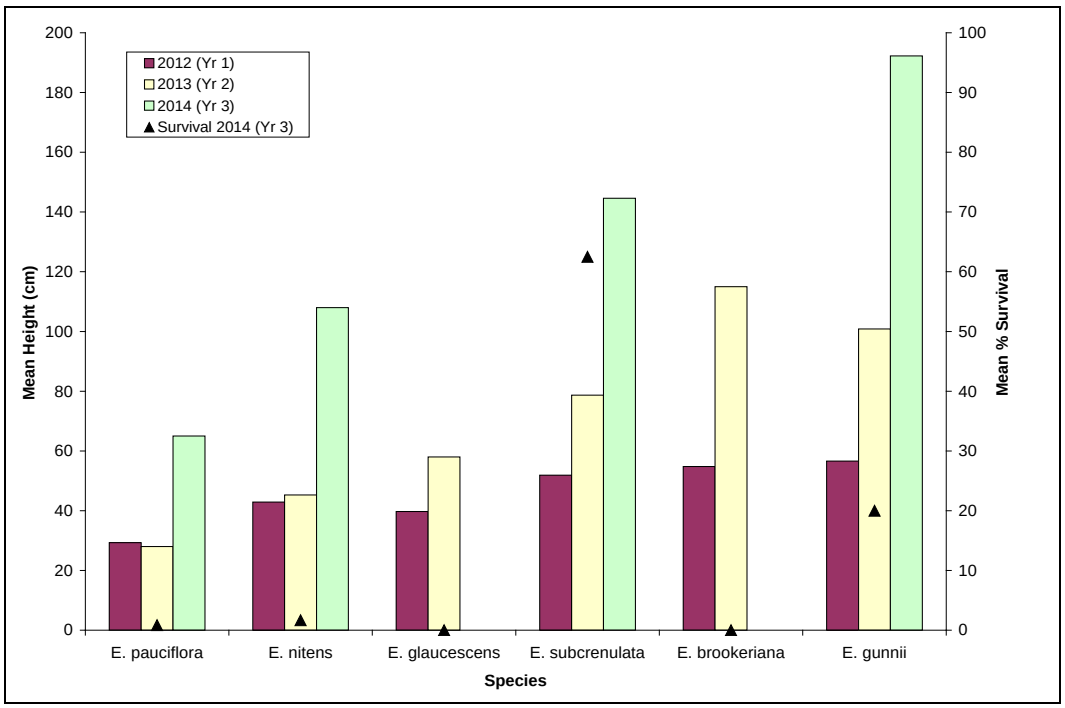


Figure 18. Mean end of year height and survival of Eucalyptus species after three years at Auchlochan

Auchlochan

At Auchlochan only *E. subcrenulata* and *E. gunnii* survive, with 62% and 20% survival respectively (*E. pauciflora* and *E. nitens* have 1 and 2 individuals surviving respectively and their heights have been plotted on Fig. 18 for comparison). Growth rates of surviving individuals remain high, but only *E. subcrenulata* has shown reasonable survival on this site (Fig. 18).

Early conclusions from the sites

Comparison of 5-year height across sites

A comparison of mean height at the end of the fifth growing season across the four sites that were planted in 2010 (Fig. 19) demonstrates that there is a clear growth gradient from north to south for some species. This is particularly strong for Italian alder, red alder, hybrid larch and hybrid aspen. For all species except downy birch and common alder growth was better at Alyth than at Balnoon, as would be expected for the latitude and southerly aspect at Alyth. Sycamore and ash have grown better at Alyth than at East Grange, despite being further north, perhaps due to the south facing slope and freely-draining soil.

Despite this general latitudinal trend across the Scottish mainland sites, two of the three species grown at both Sibster and the Orkney sites had much better two-year height growth at the Orkney sites. This highlights the importance of the weather conditions during the early establishment years, which were particularly severe in winter 2010 and 2011.

To summarise performance across all sites the ranked height at the end of 2014 and the mean percentage survival of each species is presented in Table 2. The best performing species at each site received a score of 1, and the poorest a score of 10. The overall score across all five sites is shown in Table 2, with the best performing and worst performing species highlighted in green and red respectively.

Hybrid aspen had the best height performance across all sites, ranking 4th in terms of survival (91.8%). Hybrid larch also had good height growth and survival across all sites. Both of these species appear able to tolerate a range of site conditions and to grow fast, having potential for use in SRF systems on these sites.

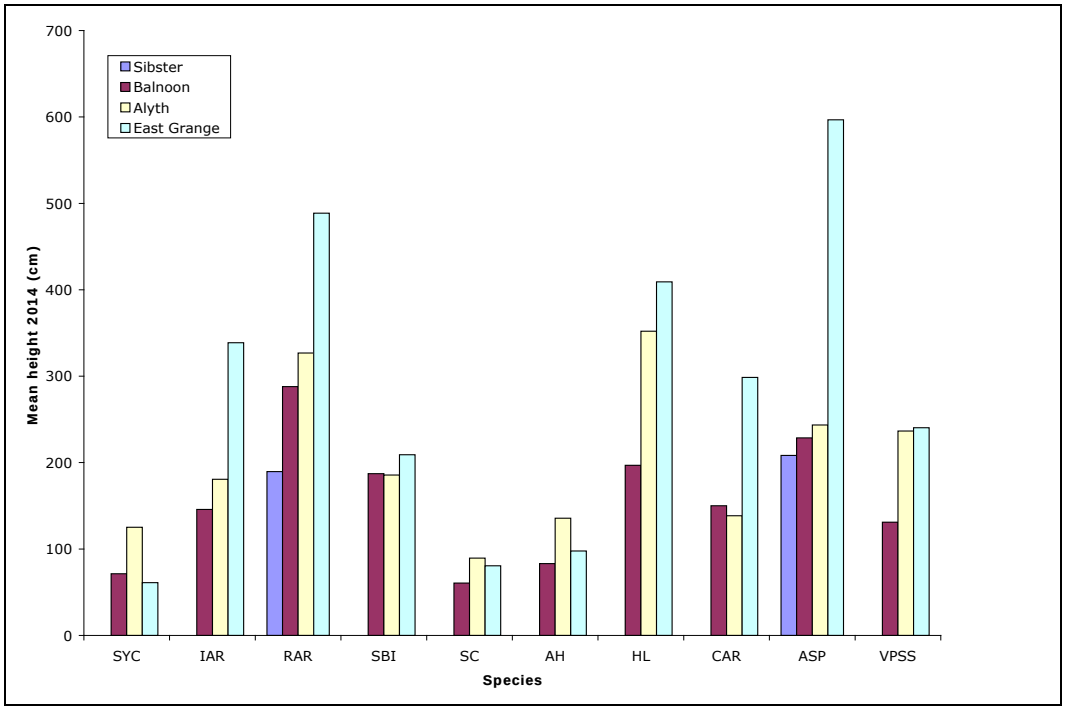


Figure 19. Comparison of mean height at the end of 2014 across the four sites planted in 2010.

Despite good height growth rates, red alder had poor survival across all sites, suggesting that the potential of the species is difficult to achieve and that it may not be suitable for SRF systems on these sites. The poor survival of Italian alder also suggests that it is not able to tolerate the conditions on these site types and is not suitable for SRF systems. Common alder also had good height growth on most sites, and although survival was a little better than that of red alder and Italian alder, it was lower than for some other species, particularly at Balnoon. Common alder may be more appropriate for use in SRF systems on sites where conditions are relatively sheltered.

The height growth and survival of silver birch was moderate across all sites, but the species performed better at Balnoon than at other sites, suggesting that it may have potential where other species are limited by exposure but is not universally suitable for use in SRF systems.

Despite being improved stock, the growth and survival of Sitka spruce was not good overall and establishment has been slow. However, there are now signs that growth rates are increasing, particularly at Alyth, and the species may have potential for use in SRF systems on such site types.

Sycamore, sweet chestnut and ash grew consistently slowly across all sites compared to other species. However, survival of ash and sycamore was very good across all sites (and sweet chestnut survived well at Aros and Auchlochan). Ongoing monitoring will

determine whether longer term growth rates of these species increases after establishment.

Table 2. Ranking of species across 5 sites according to height and survival at the end of 2014.

Species	Height ranked across sites	Mean % survival ranked across sites
ASP	1	4
RAR	2	9
HL	3	3
CAR	4	7
SBI	5	5
IAR	6	9
SS	7	6
AH	8	2
SY	9	1
SC	10	8

For a species to be a suitable choice for use in SRF systems in Scotland it must be able to tolerate the site conditions and achieve good growth rates. The results to date show that some of the species found to have high growth rates (red alder, Italian alder and on some sites common alder) are unable to tolerate the site conditions and have very low survival rates; these would be high risk choices for SRF. In contrast, some of the species which appear to be the most tolerant of site conditions and have the highest survival rates (ash and sycamore) are currently growing very slowly, although this may improve once the trees are fully established.

The species that currently appear to have the most potential for use in SRF systems on these sites based on performance to date are hybrid aspen and hybrid larch (depending upon the development of *Phytophthora ramorum*). Common alder, silver birch and Sitka spruce may also have potential on certain site types, but do not appear to be universally suitable for SRF.

Eucalyptus species

Eucalyptus species have not survived well at any of the trial sites and do not appear to be appropriate choices for use in SRF systems in Scotland. Severe winter weather conditions in the first two years caused very severe damage to all species in the first planting, including *E. glaucescens* which was thought to be hardier. In the second planting, which had more favourable weather conditions, *E. gunnii* appeared to have

reasonable survival rates and good height growth; however heavy beating-up was still required during the early establishment phase. On the more southerly sites *E. pauciflora* and *E. subcrenulata* had reasonable survival rates. The improved survival of these later plantings to date may be due to the relatively mild winters in recent years, or to the different species planted.

Where Eucalyptus species have survived, height increments are good, often over 50 cm per year at the most suitable sites, but not as large as the increments achieved by red alder, hybrid larch and hybrid aspen.

Future plans for the sites and work due in 15/16

Annual assessments will continue to the end of the 6th growing season for each site. For East Grange, Alyth and Balnoon this will mean one further annual assessment in winter 2015/16. For Aros there will be two further annual assessments, finishing in winter 2016/17 and for Auchlochan three further assessments, finishing in winter 2017/18. Some ongoing weed control and maintenance will be required at these sites for slower growing species until canopy closure is achieved.

Sibster will be assessed during summer 2015 shortly after planting to confirm planting size and also to monitor survival for beating up in winter/spring 2016. Annual assessments will be carried out at the end of the first 6 growing seasons, finishing in winter 2020/21. Establishment operations and ongoing maintenance will be provided by Scottish Woodlands until the end of year five.

Longer-term assessments at all sites are recommended at years 10, 15 and perhaps 20 for each site according to the schedule in Table 3. These later assessments would include measurement of diameter at breast height and calculation of volume.

Table 3. Assessment schedule for the six trial sites.

Calendar year	15/16	16/17	17/18	18/19	19/20	20/21	21/22	24/25	25/26	26/27	29/30
East Grange	6	/	/	/	10	/	/	15	/	/	/
Alyth	6	/	/	/	10	/	/	15	/	/	/
South Balnoon	6	/	/	/	10	/	/	15	/	/	/
Aros	5	6	/	/	/	10	/	/	15	/	/
Auchlochan	4	5	6	/	/	/	10	/	/	15	/
Sibster	1	2	3	4	5	6	/	10	/	/	15

Values are age in years. / indicates no assessments scheduled.

Appendix 1: Studies to Assess the Hydrological Impacts of Energy Forestry

Dr. Nadeem Shah, Northern Research Station, Forest Research

Objectives

To quantify the impacts of short rotation forestry (SRF) on water resources and assess the effects on water quality.

Background

Concern has been raised that the establishment of energy forest crops could have an adverse impact on water resources due to the potential high water use of SRF, which could lead to reduced water supplies and ecological flows. Another issue is the effect on water quality; energy crops are expected to benefit water quality compared to the previous agricultural land use due to reduced soil disturbance and chemical and pathogenic inputs. However, there is a need to assess the impacts of the final harvesting phase and to confirm that the pollution risks associated with harvesting can be minimised by best practice measures.

1. The impacts of SRF on water resources

The field experiment on water resource impacts is being carried out at Alyth, Tayside (Figure 1). The two experimental plots were planted with Ash (*Fraxinus excelsior L.)* and Sycamore (*Acer pseudoplatanus*) in April 2010; the grass control was left unplanted.

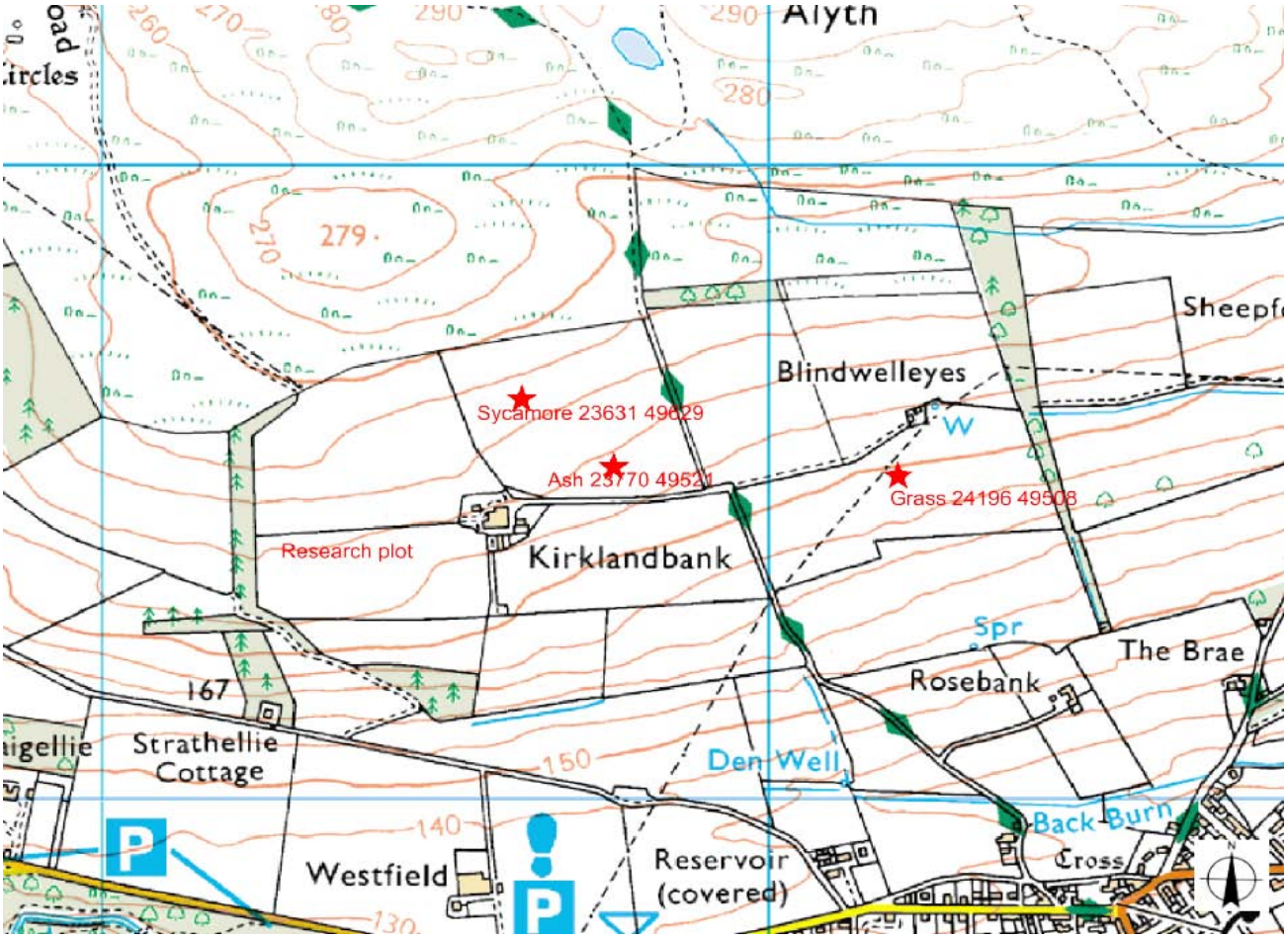


Figure 1 *Alyth water use experiment – location of monitoring equipment within experimental plots planted with Sycamore and Ash, and grass control unaffected by SRF planting.*

Monitoring equipment was installed at all three plots in July 2010, consisting of soil moisture probes to measure volumetric soil moisture content and tensiometers to measure soil water potential. A network of rainguages was put in at the two planted plots and an automatic weather station was installed at the grass control plot. With the exception of the weather station all monitoring equipment was connected to data loggers that were programmed to collect data every 10 minutes. The measurements will allow estimates to be made of water use via transpiration and interception processes.

Following installation electronic problems were identified with the logger box setup and this together with the heavy snowfall over winter 2010 led to a delay in baseline data collection from some of the probes; most of the problems have been resolved and data has been collecting from the three sites since early 2011.

Figure 2 *Soil moisture probes installed at various depths in soil profile to measure soil moisture content (left) and tensiometers to measure soil water potential.*

Fortnightly visits are made to the site to download data and maintain equipment; we considered reducing the frequency of sampling but have kept the current sampling regime due to large amount of data generated and the sensitive nature of the equipment, which requires regular checks and maintenance. The intention is to continue measurements throughout a complete SRF rotation.

Results

From the soil moisture and tensiometer data we can calculate the total amount of water in the soil and the availability of water for vegetation growth, which then allows us to assess the effects of the growing trees on soil water. The water potential measurements at different depths can also be used to calculate the gradient in pressure with depth in order to determine whether water is stationary or moving up or down the soil profile.

Figure 3 shows the change in soil moisture content at the three sites from 2010 until 2014; fluctuations are generally seasonal - the effects of the dry summer of 2013 can clearly be seen.

Soil moisture content is similar at all sites at 5 cm and 10cm depth but is considerably lower at the grass site at 15 cm, 20 cm and 30 cm depths. The effect, which can be seen in the annual mean plots (Figure 4) and the depth plots shown in Figure 5, could be due

to differences in the soil and subsurface conditions under the grass and tree fields; alternatively the lower moisture content could be due to the presence of a more developed and deeper rooting system under the grass, which allows the grass to use more water. At 40 cm depth the moisture content is similar at all sites, which is perhaps a function of the lower moisture content at the grass site than the ash and sycamore sites at this depth.

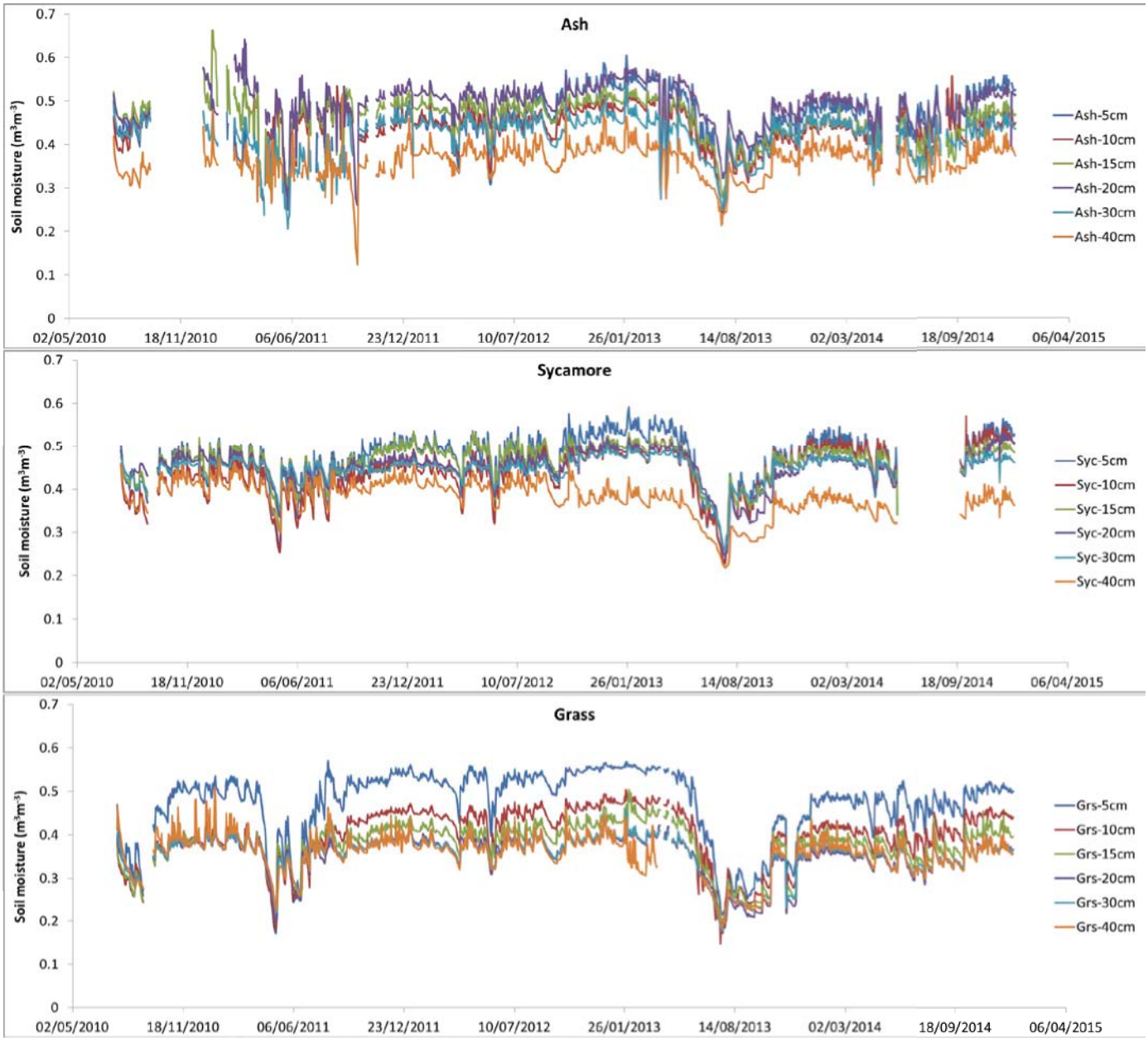


Figure 3 *Soil moisture content measured by subsurface soil moisture probes at the Ash and Sycamore SRF sites and at the grass control. Gaps in data are mainly due to electronics malfunctions.*

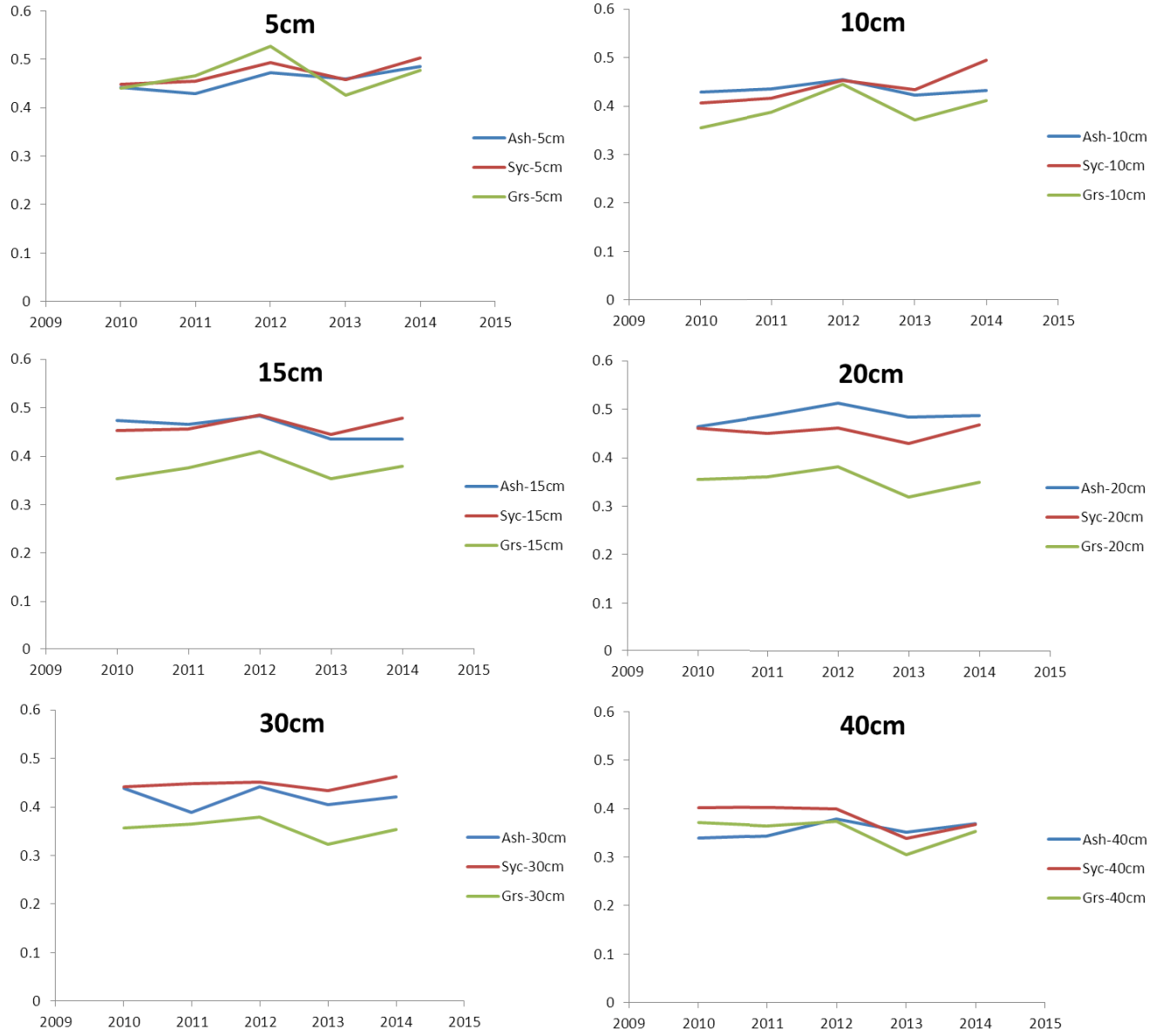
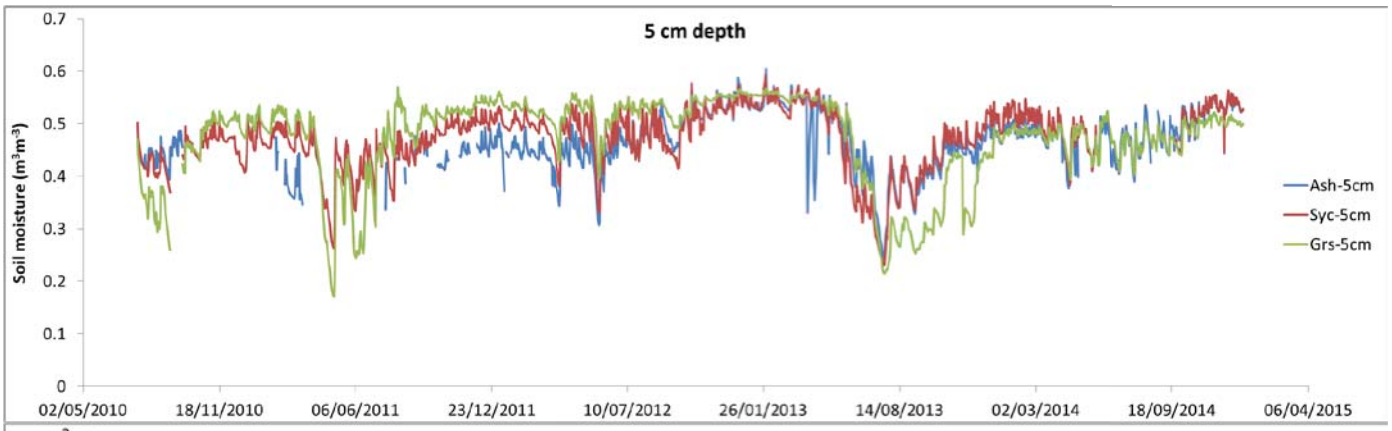
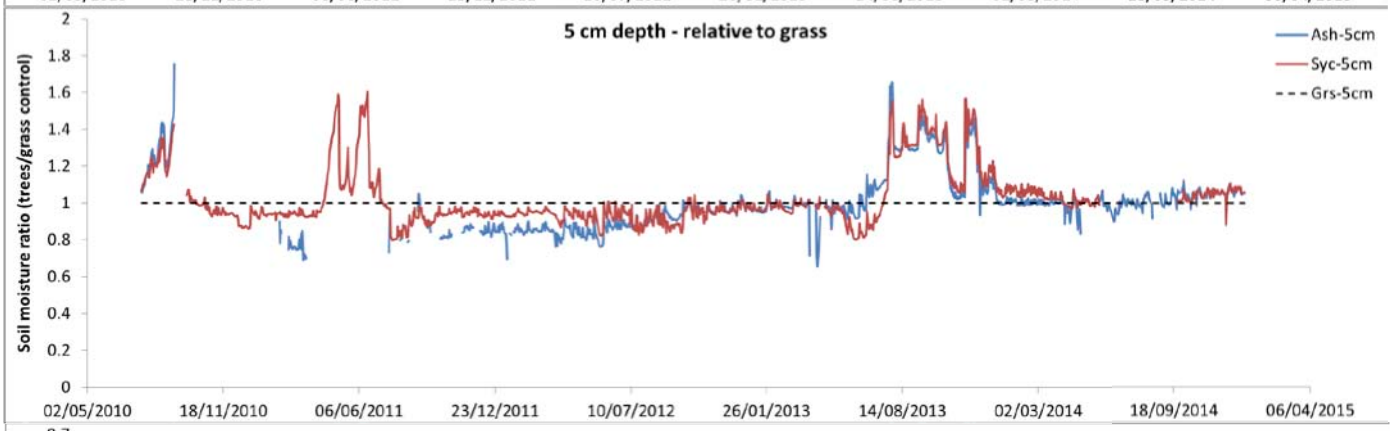
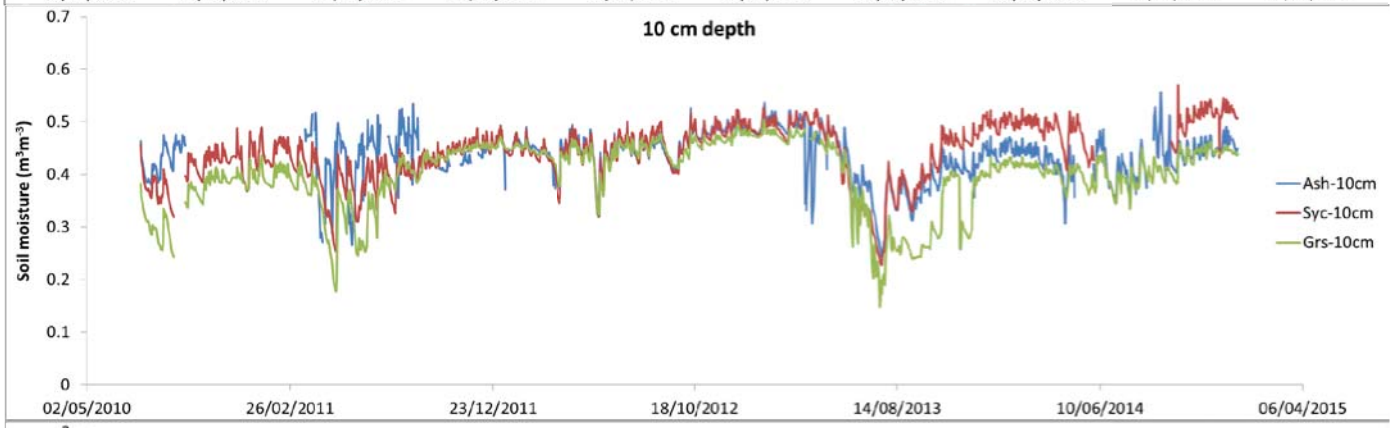
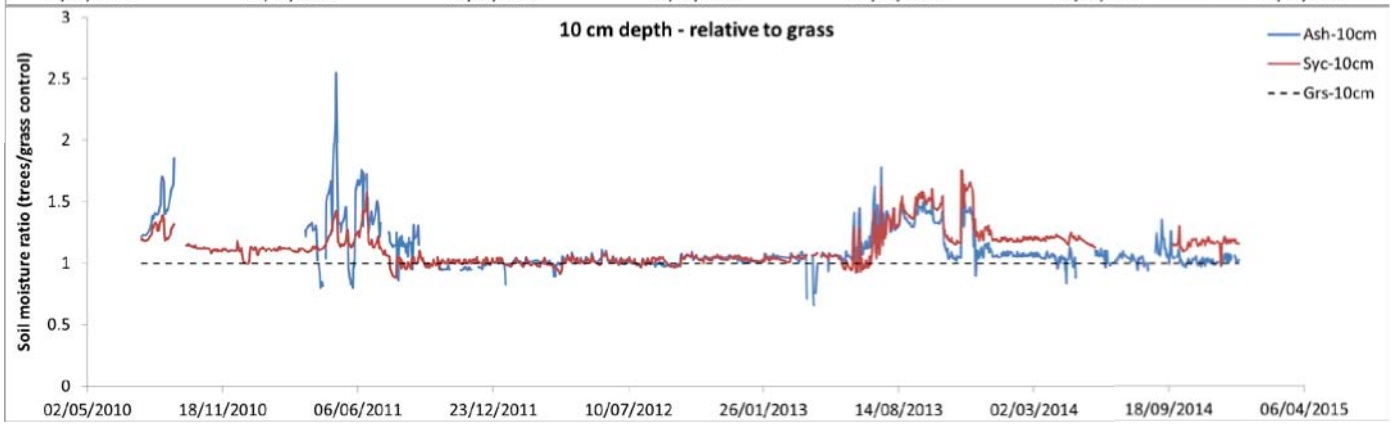


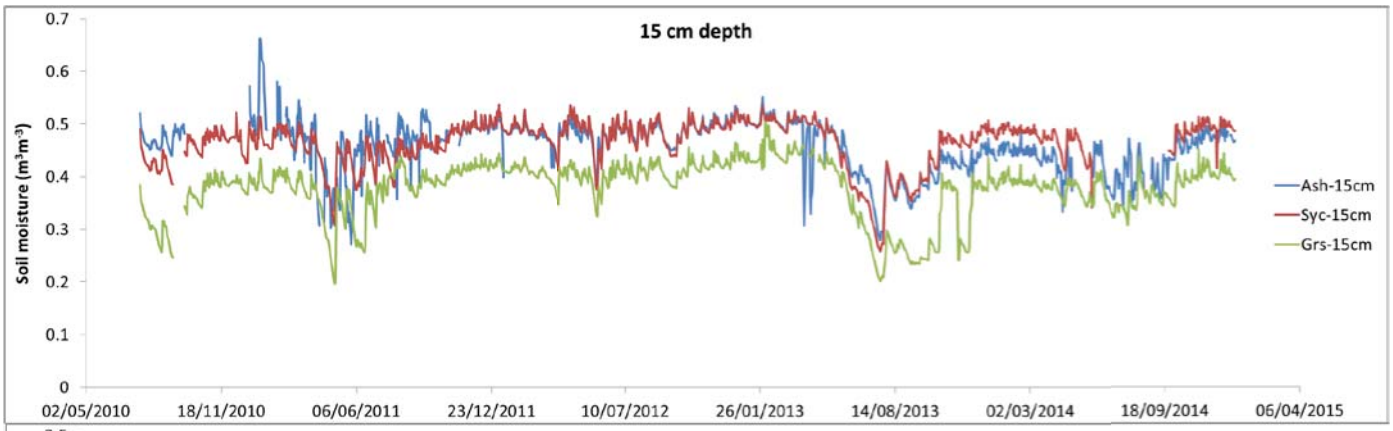
Figure 4 *Annual means of soil moisture content at the various depths measured by subsurface soil moisture probes at the Ash and Sycamore SRF sites and at the grass control.*

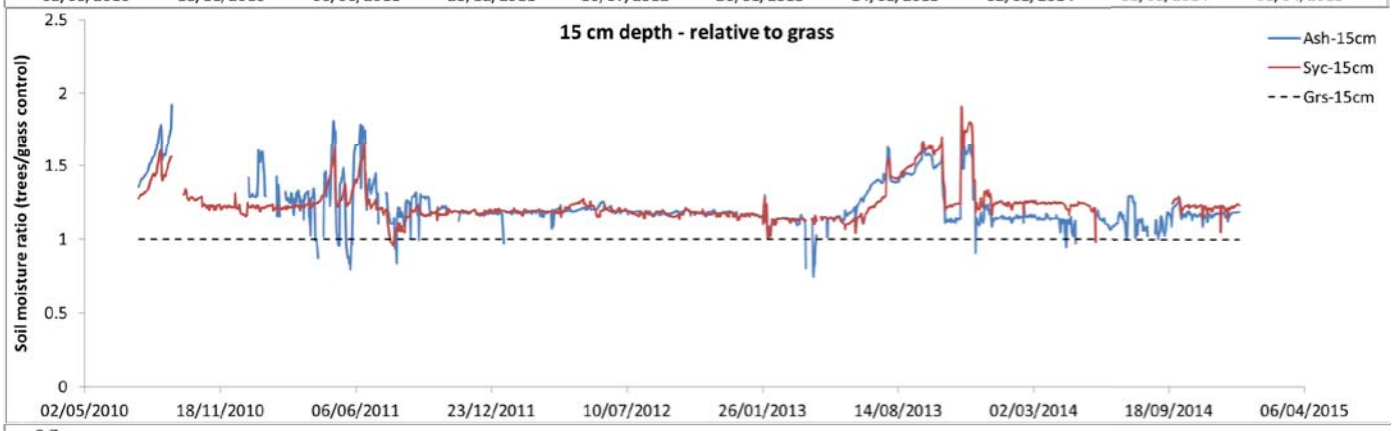

5 cm depth
Soil moisture (m³m⁻³)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
02/05/2010
18/11/2010
06/06/2011
23/12/2011
10/07/2012
26/01/2013
14/08/2013
02/03/2014
18/09/2014
06/04/2015
Ash-5cm
Syc-5cm
Grs-5cm

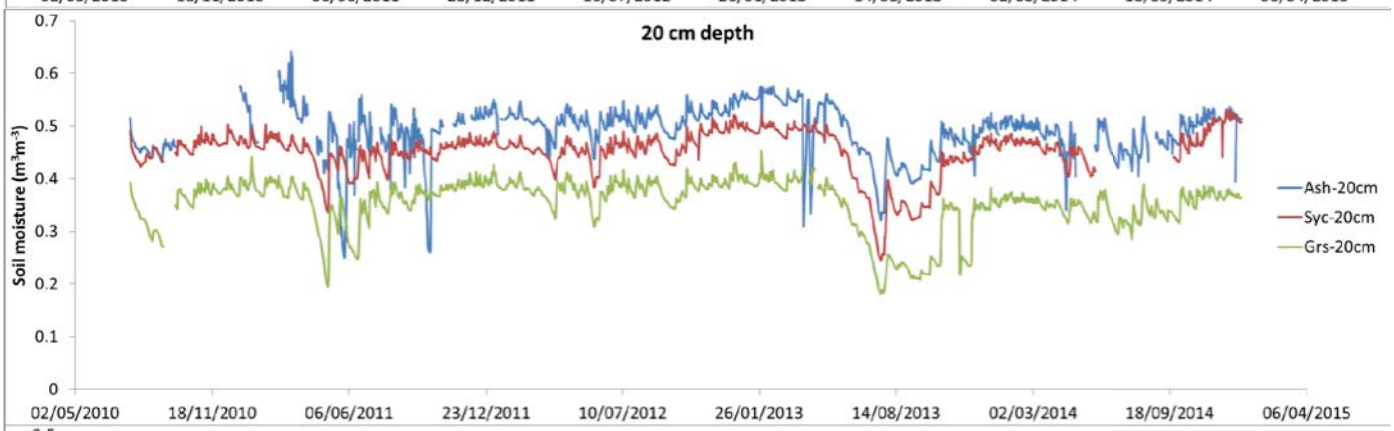

5 cm depth - relative to grass
Soil moisture ratio (trees/grass control)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
02/05/2010
18/11/2010
06/06/2011
23/12/2011
10/07/2012
26/01/2013
14/08/2013
02/03/2014
18/09/2014
06/04/2015
Ash-5cm
Syc-5cm
Grs-5cm

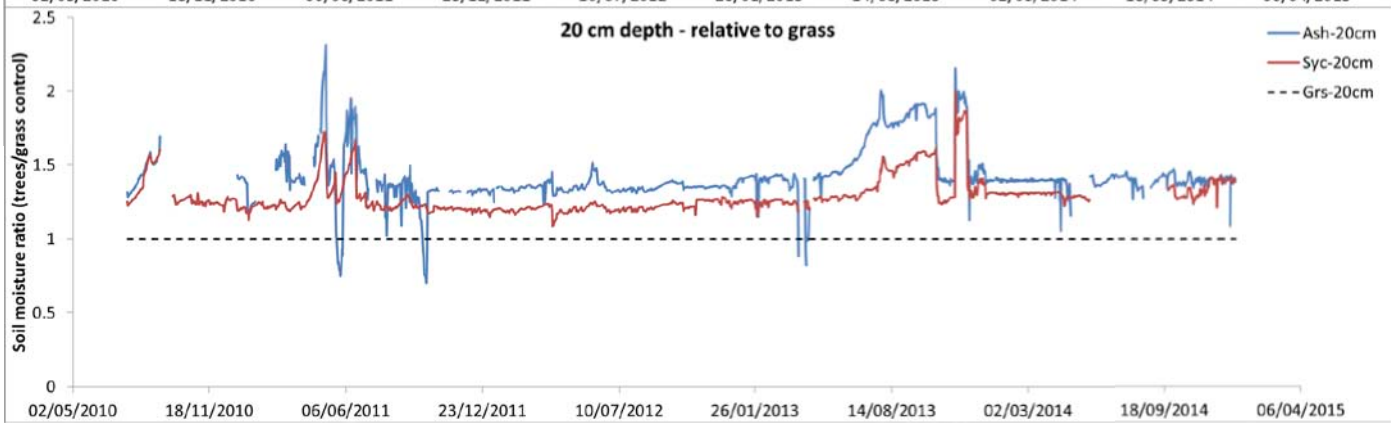

10 cm depth
Soil moisture (m³m⁻³)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
02/05/2010
26/02/2011
23/12/2011
18/10/2012
14/08/2013
10/06/2014
06/04/2015
Ash-10cm
Syc-10cm
Grs-10cm


10 cm depth - relative to grass
Soil moisture ratio (trees/grass control)
3
2.5
2
1.5
1
0.5
0
02/05/2010
18/11/2010
06/06/2011
23/12/2011
10/07/2012
26/01/2013
14/08/2013
02/03/2014
18/09/2014
06/04/2015
Ash-10cm
Syc-10cm
Grs-10cm


15 cm depth
Soil moisture (m³m⁻³)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
02/05/2010
18/11/2010
06/06/2011
23/12/2011
10/07/2012
26/01/2013
14/08/2013
02/03/2014
18/09/2014
06/04/2015
Ash-15cm
Syc-15cm
Grs-15cm


15 cm depth - relative to grass
Soil moisture ratio (trees/grass control)
2.5
2
1.5
1
0.5
0
02/05/2010
18/11/2010
06/06/2011
23/12/2011
10/07/2012
26/01/2013
14/08/2013
02/03/2014
18/09/2014
06/04/2015
Ash-15cm
Syc-15cm
Grs-15cm


20 cm depth
Soil moisture (m³m⁻³)
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
02/05/2010
18/11/2010
06/06/2011
23/12/2011
10/07/2012
26/01/2013
14/08/2013
02/03/2014
18/09/2014
06/04/2015
Ash-20cm
Syc-20cm
Grs-20cm


20 cm depth - relative to grass
Soil moisture ratio (trees/grass control)
2.5
2
1.5
1
0.5
0
02/05/2010
18/11/2010
06/06/2011
23/12/2011
10/07/2012
26/01/2013
14/08/2013
02/03/2014
18/09/2014
06/04/2015
Ash-20cm
Syc-20cm
Grs-20cm

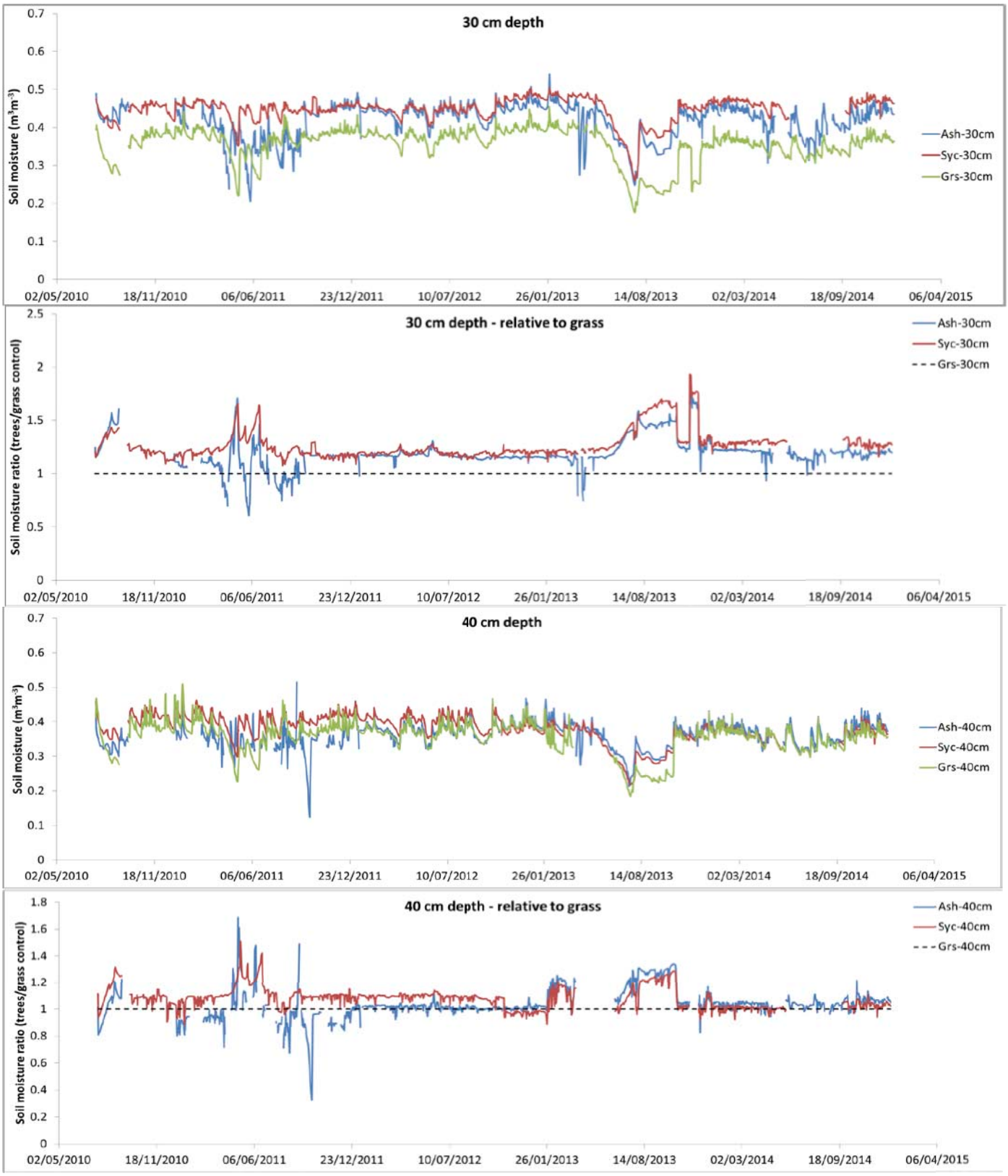


Figure 5 *Soil moisture content by depth and relative to the grass control.*

The year 2013 was a particularly dry year with rainfall at only 787 mm compared to over 1000 mm in each of the other years of the experimental record (Figure 6). This gives rise to an interesting trend in summer 2013 where soil moisture decreases more under the grass than under the sycamore or ash (Figure 5). This is most likely because the grass grows fairly long in the summer months and has a higher transpiration requirement than that of the young trees; moreover, the rooting system is likely to be more developed under the grass than the trees and so it's able to access water from deeper and hard to reach places. It will be interesting to see how the soil moisture regime changes as the trees and their roots grow, although in relation to this we need to be careful to control competing vegetation within the experimental plots, otherwise it will be difficult to isolate the effects of tree growth on soil moisture. Therefore, some sort of site management is recommended at least in the experimental area if not the entire site.

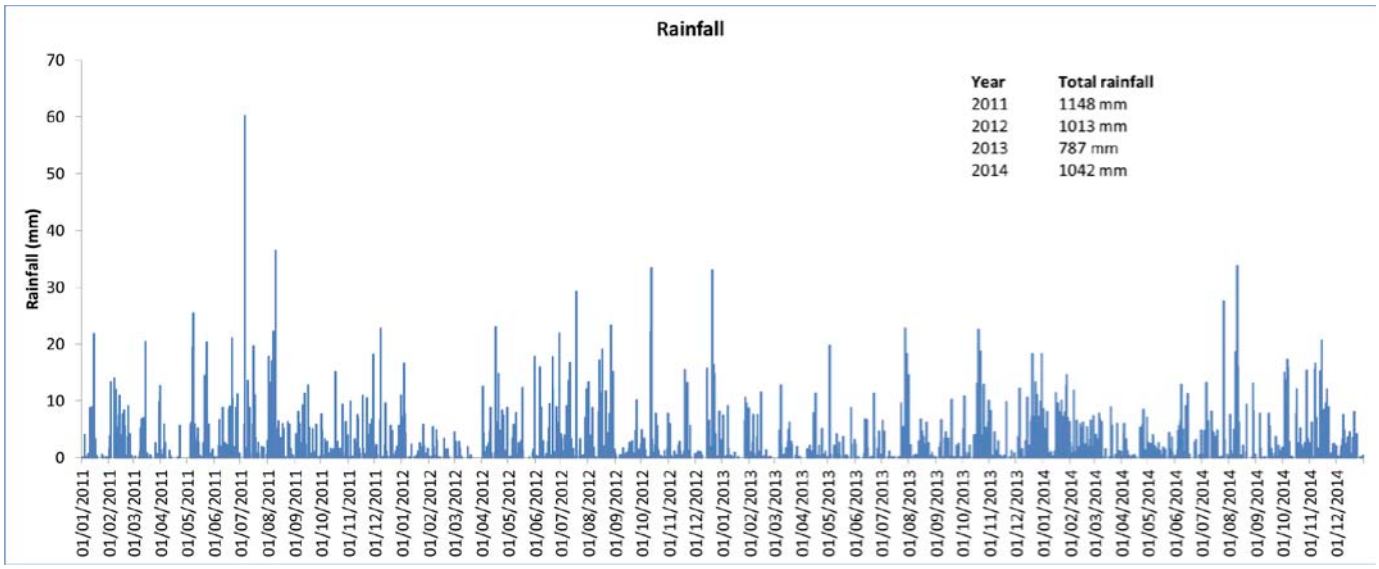


Figure 6 *Daily rainfall as measured by raingauges in the sycamore plot.*

The tensiometer equipment has suffered from a number of setbacks including subterranean damage by burrowing animals (possibly moles) and electronic malfunctions; therefore further time is required to process this data. An example of the data generated can be seen in Figure 7, which is a plot of the volumetric soil moisture at the sycamore site; dry periods are clearly indicated by increases in soil water tension.

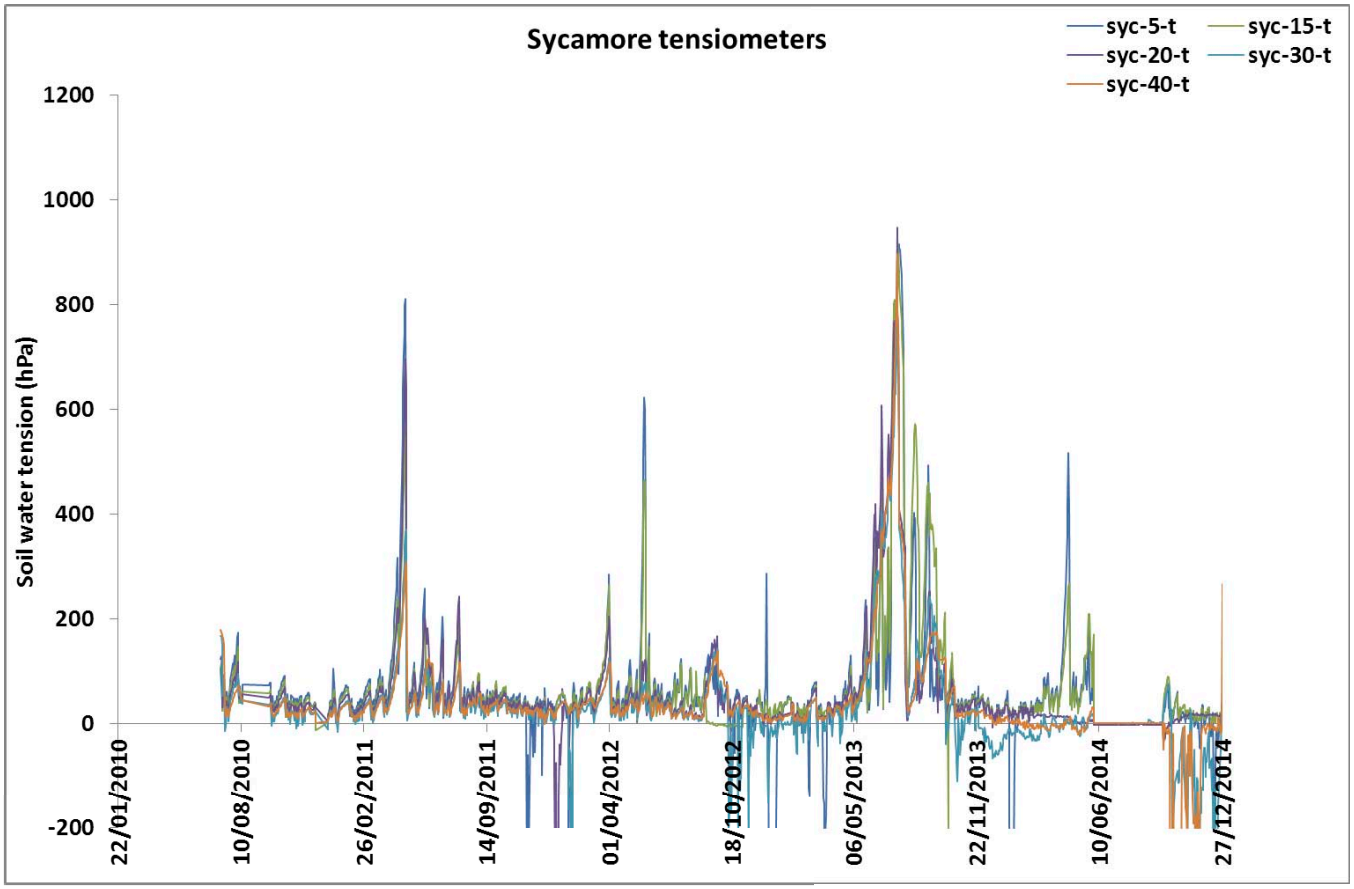


Figure 7 *Volumetric soil moisture content measured by tensiometers at the Sycamore SRF site*

2. The effects of SRF on water quality

The water quality experiment is located at Sibster Farm, Caithness; two water sampling points were selected, one in a stream draining the experimental area (dominated by the proposed SRF trial) on Sibster Farm and the other in the Achingills Burn, a stream unaffected by the SRF planting and therefore suitable as a control (Figure 8). Sampling began in September 2009 to provide baseline data prior to planting with SRF species; initially water samples were taken fortnightly for water quality analysis at our laboratory in Alice Holt and same day microbiological analysis at Scottish Water's laboratory in Inverness – sampling frequency was reduced to monthly in November 2013 and we intend to continue at this sampling rate until the SRF crop reaches harvesting age.

Early results from the microbiological data showed relatively high numbers of Coliforms, Escherichia coli and Enterococci at the Sibster Farm site, most likely due to the presence of livestock (Figure 9). Microbial numbers fell when the livestock were removed in October 2009 but increased again when livestock were returned to the site in April 2010. Livestock were again removed in October 2010, and again the microbial numbers were reduced; the results show a direct relationship between microbial contamination of the stream and the presence of livestock.

In general, nitrate concentrations are low but were found to be higher at Sibster Farm compared to the control site when sampling began, perhaps reflecting the previous practice of cereal farming. Nitrate concentration at Sibster Farm fell following livestock removal (Figure 10).

We took the decision to cease the microbiological analysis in December 2014 mainly because there is little chance that livestock will be put back on to the site. Moreover, the farmer in the adjacent field now pastures livestock on a field adjacent to the Sibster Farm sampling point and this is likely to cause interference with our data. The analysis can be reintroduced if needed.

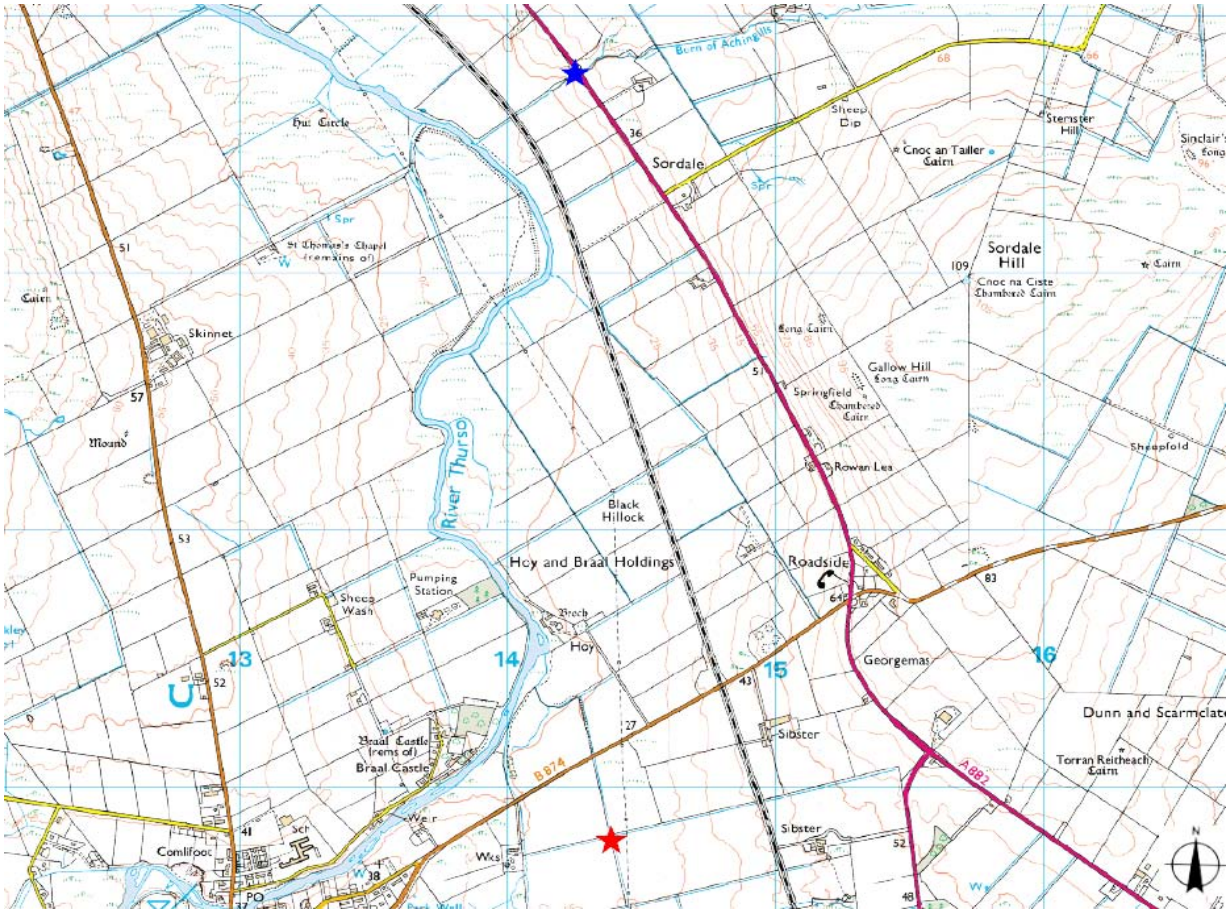


Figure 8 *Sibster water quality experiment – Location of water sampling points and water level recorders in operational area on Sibster Farm (ND143 597) and control catchment unaffected by SRF planting (ND142 627).*

Automatic water level recorders were installed in March 2010, which gives us the option to estimate the volume of runoff and convert chemical concentrations (mg/l) to fluxes (kg/ha). Operations carried out by the farmer adjacent and immediately downstream to the experimental site has led to a change in the flow regime at the Sibster Farm site, which in turn has caused erosion of the river bank where our recorder is located. Site characteristics are such that there are few alternative locations for the recorder; therefore it will remain where it is unless data quality is severely affected.

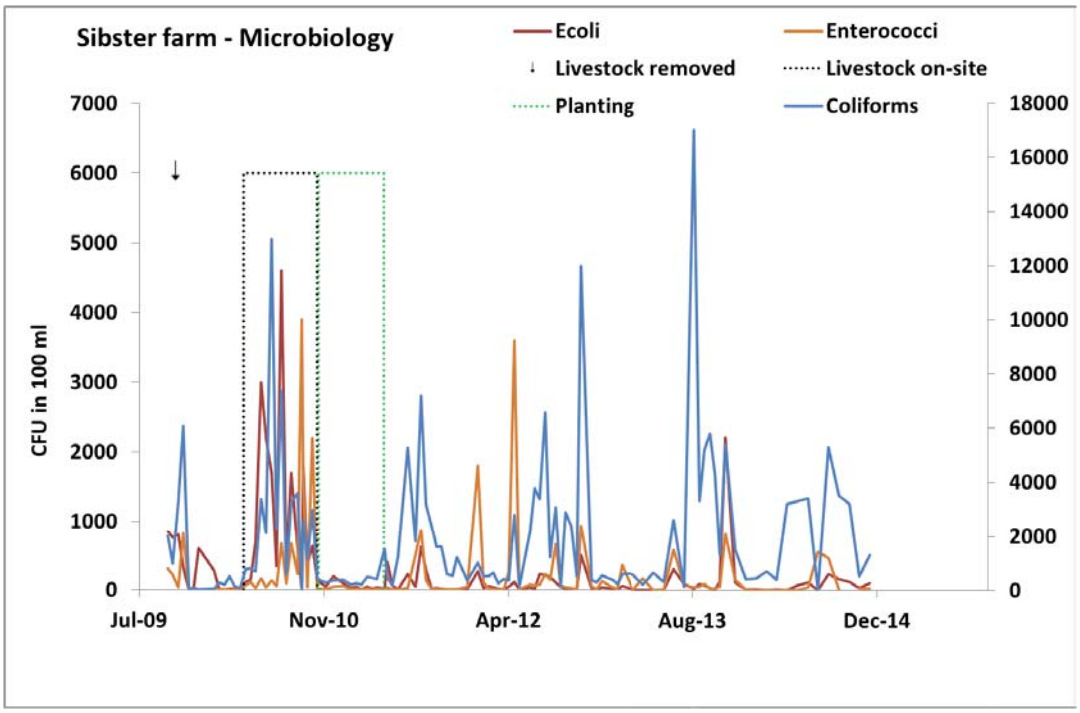


Figure 9 *Microbial concentrations in colony forming units per 100ml at the Sibster Farm SRF site.*

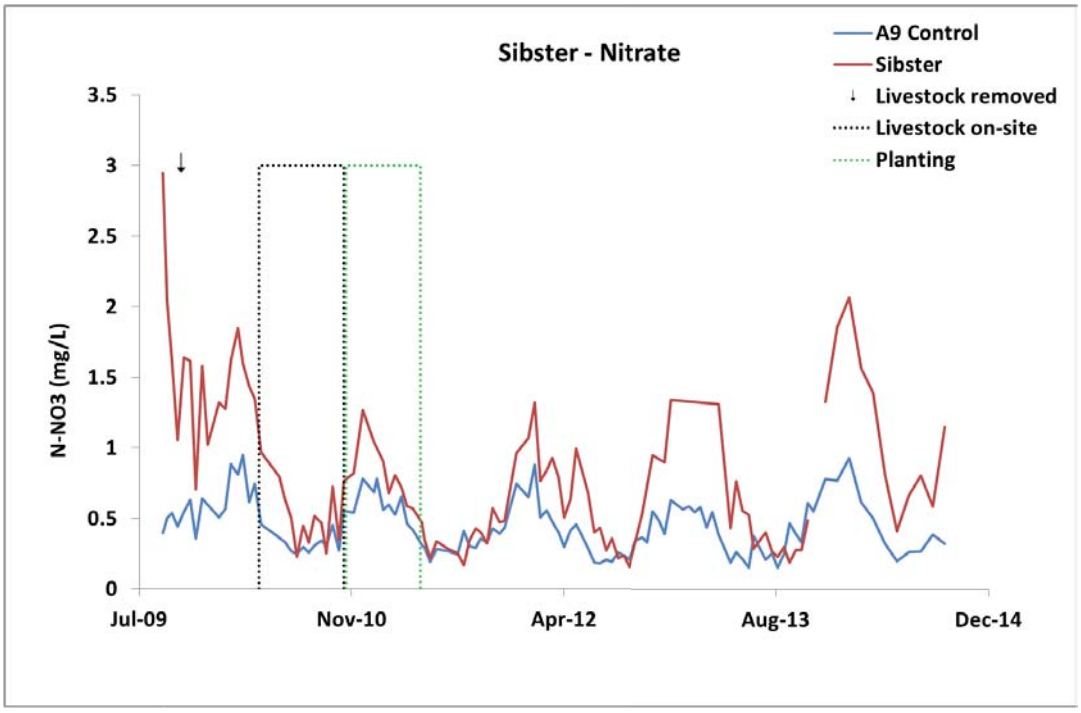


Figure 10 *Nitrate concentrations at the Sibster Farm SRF site and the A9 control site.*

Appendix 2: Full report on the Orkney SRF trials

REPORT TO FORESTRY COMMISSION SCOTLAND ON MONITORING OF SHORT ROTATION FORESTRY TRIALS IN ORKNEY DURING 2014

Muddisdale Short Rotation Forestry Trial in Orkney in July 2014

By
Peter Martin
Agronomy Institute
Orkney College (University of the Highlands and Islands)
December 2014

Executive Summary

- Monitoring of two short rotation forestry (SRF) trials, established in Orkney in 2013, was carried out in 2014 by the Agronomy Institute at Orkney College UHI. The trials are located at Muddisdale (Orkney mainland) and Newfield (on Shapinsay),
- Both trials contain the same tree species: sycamore, *Acer pseudoplatanus*; Italian alder, *Alnus cordata*; common alder, *Alnus glutinosa*; downy birch, *Betula pubescens*; beech, *Fagus sylvatica*; aspen, *Populus tremula*; goat willow, *Salix caprea*; mountain ash, *Sorbus aucuparia*; whitebeam, *Sorbus intermedia*.
- At each trial there are 6 plots (each containing 25 plants) of each of the 9 tree species, arranged in 6 randomised blocks (54 plots in total). Four of the blocks comprise a species trial and the other blocks are observation blocks on i) planting at 1.0 x 1.0 m (instead of the 1.5 m spacing used in the rest of the trial) and ii) use of a polythene mulch square (0.6 x 0.6 m) at planting to reduce weed competition.
- Tree survival and growth were recorded on the 9 innermost plants of each plot at the end of the 2014 growing season.
- Tree mortality has continued to be low (3.2% over the two trials) but is higher at Newfield (3.9%) than at Muddisdale (2.5%). Amongst the tree species, mortality (over the two trials) has been highest in sycamore (11.1%), followed by mountain ash (6.5%) and beech (5.6%).
- Averaged over all species, trees in the species trial are taller at Muddisdale than Newfield (97 cm compared with 76 cm). At both sites, goat willow was tallest (143 and 142 cm at Mudisdale and Newfield, respectively), followed at Muddisdale by aspen (133 cm), Italian alder (130 cm) and common alder (115 cm) and at Newfield by common alder (101 cm), aspen (93 cm) and downy birch (90 cm). At both sites, sycamore, mountain ash and beech were the shortest species (all less than 65 cm).
- At both sites, the changes in heights during 2014 of species in the 1.0 x 1.0 m planting and polythene mulch observation blocks were similar to those in the main species trial.
- A small trial using the guard trees in each plot was also monitored to compare the survival and growth of 5 trees of each species which had no tree guard with that of the same number with i) spiral guards and ii) rigid plastic net guards. Mortality at both sites was high in the absence of any tree guard (58% at Muddisdale and 38% at Newfield) and has increased since 2013 when it was 42% at Muddisdale and 22% at Newfield. Heights of surviving trees are variable in this trial but are broadly in line with those measured in the species trial.
- The following are a number of observations made on the trials during the year:

- Weed control was considerably better at Muddisdale than at Newfield and it is likely that this, together with its greater shelter contributed to the higher survival and taller growth of trees at Muddisdale over the year.
- Trees of sycamore, mountain ash and beech which were shorter than the spiral guards had difficulties in growing out of them and this may have contributed to the poorer growth of these species.
- By September, there was considerable rust on downy birch at Muddisdale and rust was also present on aspen and common alder.

Introduction

Between November 2011 and December 2013 Forestry Commission Scotland (FCS) provided funding to the Agronomy Institute (AI) at Orkney College UHI to work with local stakeholders to start investigations into the potential of short rotation forestry (SRF) in Orkney. Protocols for establishing trials, including the selection of species, were developed with the Orkney Woodland Group (OWG) and FCS and in 2013 two trials were established - one at Muddisdale (near Kirkwall on Orkney mainland) and one at Newfield (on Shapinsay). Survival and growth of the trees in their first year were monitored and reported at the end of 2013[1]. The current report provides information on the growth and survival of trees in 2014, their second field season.

Trial sites, Management and Observations on Species

Trial Sites and Management

The two trial sites were located at Muddisdale (HY 435 110) and Newfield (Balfour Mains farm) in Shapinsay (HY 516 181). Over the winter 2013/14 (before 31st January 2014), the residual herbicide Kerb Flo was applied at both sites at 3.75 l ha^{-1}. At Muddisdale, weeds were further controlled by topping, strimming and spot applications of glyphogan (at 4.0 l ha^{-1}) in June-July 2014 so that weed control was good for all of the growing season (see cover photo and Photo 1). No further weed control was carried out at Newfield and, even by July, there was a dense cover of grass (Photo 2).

Observations on Trials

Frequent visits were made to the Muddisdale site but Newfield was only visited in July and October. By the end of May, at Muddisdale, leaf-eating caterpillars started to defoliate whitebeam, birch and goat willow, but were particularly bad on the latter, causing complete defoliation of some of these trees by mid-June. It is likely that these caterpillars are the same as those which cause regular

[1] Martin, P. (2013). Report to Forestry Commission Scotland on phase two of a project to establish short rotation forestry trials in Orkney. Agronomy Institute Report.

defoliation to the adjacent short rotation coppice (SRC) willow. Caterpillars did not appear to be a problem at Newfield when the site was visited in July.

At Muddisdale, by mid-June, it was clear that several plants of sycamore, mountain ash and beech which had not completely grown out of their spiral guards, were having difficulties to emerge and the new growth was becoming trapped inside the guards (Photo 3). To help plants emerge properly, the upper section of spiral guard was removed. The same problem was observed at Newfield but Balfour Mains did not have sufficient staff available to rectify this in the 2014 growing season. It is scheduled to be done over the winter.

By September 2014, there was considerable rust on the downy birch at Muddisdale (Photo 4) and rust was also noticed on aspen and common alder.

Experimental Design and Methods

Experimental Design and Methods of Measurement

These were described fully in the 2013 report and only a brief summary is provided here.

Both trials (see Appendices 1 and 2) had the same layout and consisted of plots of 25 trees (5 x 5) of 9 different species (sycamore, *Acer pseudoplatanus*; Italian alder, *Alnus cordata*; common alder, *Alnus glutinosa*; downy birch, *Betula pubescens*; beech, *Fagus sylvatica*; aspen, *Populus tremula*; goat willow, *Salix caprea*; mountain ash, *Sorbus aucuparia*; whitebeam, *Sorbus intermedia*). Plots were arranged into 6 randomised blocks (each containing one plot of each species) set up as follows:

- A species trial consisting of 4 randomised blocks.
- An observation block with trees planted at a closer spacing (1.0 x 1.0 m, instead of the 1.5 x 1.5 m used in the remainder of the trial).
- An observation block with each tree planted in the middle of a polythene mulch square (0.6 x 0.6 m) to reduce weed competition.

As in 2013, tree height was measured from ground level to the tip of the top leaf or shoot. For the main species trial, the 1x1m planting and mulched trees, tree height and survival were recorded on the 9 plants in the centre of each plot. Data were collected on 21 September at Muddisdale and 16 October at Newfield. For data analysis, the average height of surviving trees was calculated for each plot. Height data from each of the species trials were analysed by ANOVA using GenStat (version 9) and least significant differences between the species means calculated at $P<0.05$. These are shown in Fig 1A, Fig 1B and Table 3.

In the species trial and the 1.0 x 1.0 m observation block, 3 guard trees were selected in each plot for inclusion in a small trial comparing the effect of different tree guard treatments (i. none; ii. spiral guard; iii. net guard) on the growth and survival of trees. In this trial there were 5 plants of each species in each tree guard treatment.

Results

Tree Mortality

Table 1 shows the number of dead trees at the end of 2014 at Muddisdale and Newfield by species and by the main treatment blocks (species trial, 1.0 x 1.0 m block and mulch block). Overall mortality is still low (3.2% for the two trials) but is higher at Newfield (3.9%) than at Muddisdale (2.5%). Amongst the species and over both trials, it is highest in sycamore (11.1%) followed by mountain ash (6.5%) and beech (5.6%).

Table 2 shows the number of dead trees at both trial sites within the tree guard trial. While the number is low for trees with a spiral or net guard, at both trials there has been high mortality amongst trees with no tree guard (57.8% at Muddisdale and 37.8% at Newfield). The higher mortality at Muddisdale can be attributed to rabbit damage in 2013 (before rabbit netting was erected). At both sites there were additional deaths in 2014, but while these were only one tree in the net guard treatment at each site, 7 trees died at each site in the unguarded treatment. The highest number of deaths have been amongst sycamore, mountain ash, Italian alder and beech.

Tree Height

Species trial

Averaged over all species, tree height at the end of the season continued to be higher at Muddisdale than Newfield (97 cm compared with 76 cm), probably reflecting the greater exposure at Newfield and the greater competition from grass. Fig 1 compares tree heights (Fig 1A) and change in tree height (Fig. 1B) at Muddisdale and Newfield in 2014. For reference, the same data are presented in Table 3. At both sites, goat willow was tallest at the end of the season followed by aspen, Italian alder and common alder at Muddisdale and by common alder, downy birch and aspen at Newfield. At both sites, sycamore, mountain ash and beech were the shortest species. At Muddisdale, aspen, common and Italian alder showed the greatest increase in height over 2014 compared with goat willow, common alder, downy birch and aspen at Newfield. Growth of goat willow at Muddisdale, however, was checked by defoliation early in the season. At Newfield, there was hardly any increase in height of sycamore and mountain ash over 2014 and whitebeam showed a decline in height.

1 x 1 m Planting and Mulch Trial

Fig. 2 shows changes in height of trees in the 1 x 1 m planting and mulch blocks at the two trial sites over 2014. For comparison, changes in height of trees in the species trial are also shown. Increases in height of the different species show the same trends across the three treatments at each site suggesting that, so far, the 1.0 x 1.0 m spacing and mulch treatments are not having a major effect on the growth of the trees.

Growth of Trees in the Tree Guard Trial

The change in height of trees in the tree guard trial over 2014 is summarised in Table 4. Unlike the mortality data for these trees (described above and Table 2), there is no convincing suggestion from Table 4 that growth of the surviving trees has been affected by the tree guard treatments.

Table 1. Number of dead trees in October 2014 by species, trial site and treatment.

	Muddisdale					**Newfield**				**Both Trials**
	Species Trial	1x1m	Mulch	Total		Species Trial	1x1 m	Mulch	Total	Total (% in brackets)
Italian Alder	1	0	0	1		1	0	0	1	2 (1.9)
Common Alder	0	0	0	0		1	0	0	1	1 (1.0)
Downy Birch	1	0	0	1		0	0	0	0	1 (1.0)
Beech	1	0	2	3		3	0	0	3	6 (5.6)
Aspen	0	0	0	0		0	0	0	0	0 (0)
Goat Willow	1	0	1	2		0	0	0	0	2 (1.9)
Mountain Ash	1	0	0	1		2	2	2	6	7 (6.5)
Whitebeam	0	0	0	0		0	0	0	0	0 (0)
Sycamore	4	0	0	4		6	2	0	8	12 (11.1)
Total dead	9	0	3	12		13	4	2	19	31
Number of trees monitored	324	81	81	486		324	81	81	486	972
% Dead trees	2.8	-	3.7	2.5		4.0	4.9	2.5	3.9	3.2

Table 2. Number of dead trees in October 2014 by species, trial site and tree guard treatment.

	Muddisdale					**Newfield**				**Both Trials**
	Spiral Guard	No Guard	Net Guard	Total		Spiral Guard	No Guard	Net Guard	Total	Total
Italian Alder	0	4	0	4		0	3	0	3	7
Common Alder	0	2	0	2		0	2	0	2	4
Downy Birch	0	2	1	3		0	2	0	2	5
Beech	0	4	0	4		0	3	0	3	7
Aspen	0	2	0	2		0	2	0	2	4
Goat Willow	0	3	0	3		0	1	0	1	4
Mountain Ash	0	4	0	4		1	2	1	4	8
Whitebeam	0	1	0	1		0	1	0	1	2
Sycamore	0	4	2	6		0	1	1	2	8
Totals	0	26	3	29		1	17	2	20	49
Number of trees monitored	45	45	45	135		45	45	45	135	270
% dead trees	-	57.8	6.7	21.5		2.2	37.8	4.4	14.8	18.1

Table 3. Height and changes in height over the 2014 growing season of trees in the SRF species trials at Muddisdale and Newfield.

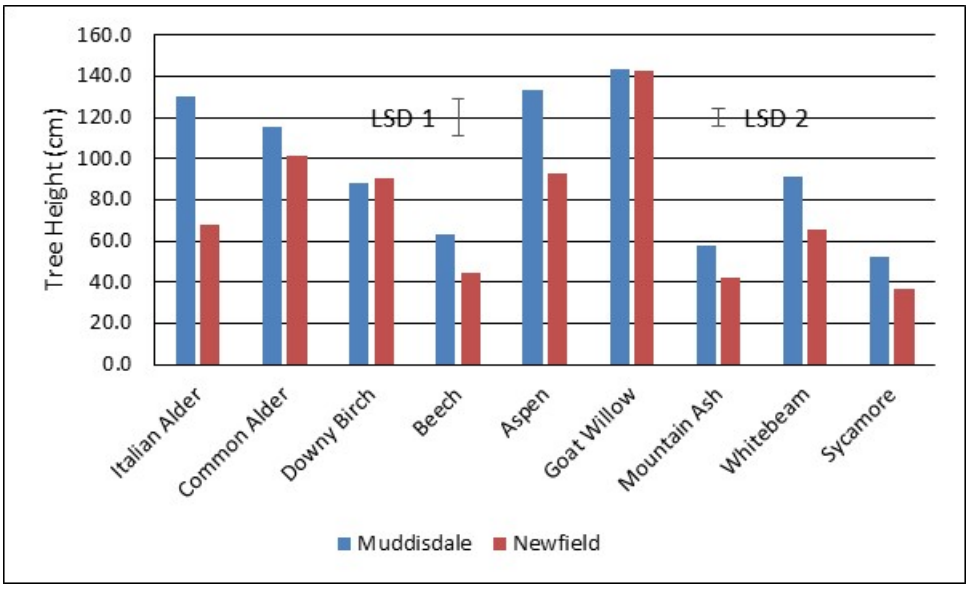
	Tree Height (cm)			Change In Height (cm)	
	Muddisdale	Newfield		Muddisdale	Newfield
Italian Alder	130.3	67.6		43.8	9.4
Common Alder	115.2	101.3		49.6	39.1
Downy Birch	88.4	90.4		28.0	39.1
Beech	62.9	44.5		12.9	5.0
Aspen	133.0	92.8		56.1	33.8
Goat Willow	143.3	142.3		34.4	45.7
Mountain Ash	57.6	41.7		15.0	-0.2
Whitebeam	90.8	65.3		24.9	-4.1
Sycamore	52.6	36.4		9.8	-0.4
LSD[1]	9.2	4.5		10.4	4.7

[1] Least significant difference between the species means at each site.

Table 4. Average changes in tree height (cm) over the 2014 growing season for trees in different tree guard treatments at Muddisdale and Newfield.

	Muddisdale			Newfield			Averages across both sites
	Spiral Guard	No Guard	Net Guard	Spiral Guard	No Guard	Net Guard	
Italian Alder	30.0	10.0	53.0	22.4	19.8	15.2	25.1
Common Alder	55.8	67.3	60.6	35.6	21.3	34.8	45.9
Downy Birch	16.2	41.1	25.3	34.4	27.3	27.2	28.6
Beech	13.6	29.0	21.8	2.6	7.0	11.0	14,2
Aspen	52.8	44.7	48.6	40.0	19.0	36.6	40.3
Goat Willow	10.4	47.0	39.0	47.2	51.8	62.2	42.9
Mountain Ash	19.6	16.0	23.8	2.8	9.1	5.7	12.8
Whitebeam	20.8	13.0	14.4	-6.4	-2.3	-5.4	5.7
Sycamore	6.0	8.0	11.9	-1.0	-7.9	-4.3	2.1
Averages:	25.0	30.7	33.2	19.7	16.1	20.3	

A.



B.

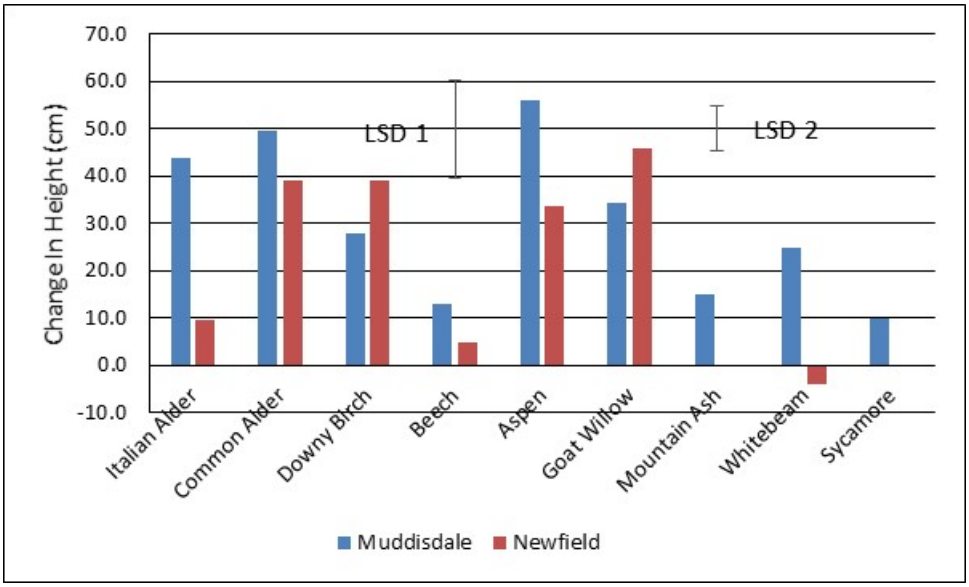
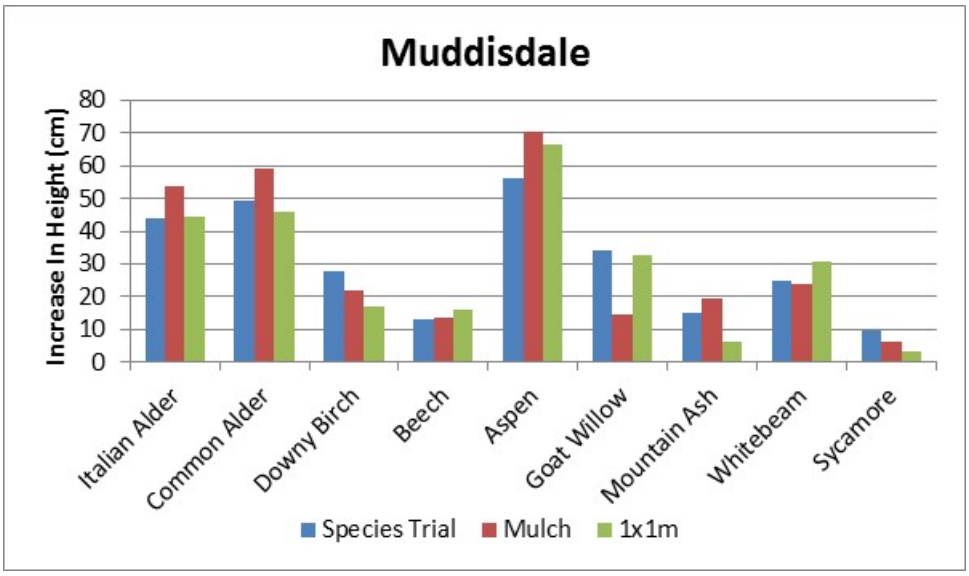


Fig. 1. *Height (A) and change in height over the 2014 growing season (B) of trees at the Muddisdale and Newfield trial sites. Bars indicate the least significant difference (P<0.05) between species means at each site (LSD1, Muddisdale; LSD 2, Newfield).*



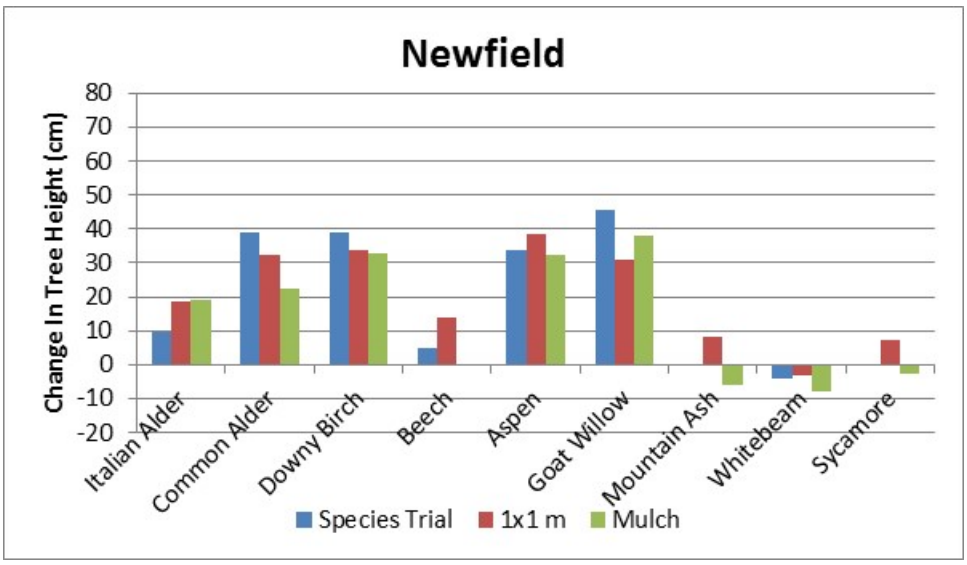


Fig. 2. *Change in tree height over the 2014 growing season of tree species in the different planting blocks at Muddisdale and Newfield.*

Discussion

Since establishing the two Orkney SRF trials in 2013, weed control has been consistently better at the Muddisdale site and it is also likely that this site is less exposed than that at Newfield. These are probably the two main factors which have contributed to the lower mortality at Muddisdale and the better growth of plants (as measured by plant height). Interestingly, there is a suggestion that differences are starting to appear in the relative performance of the species at the two sites. While

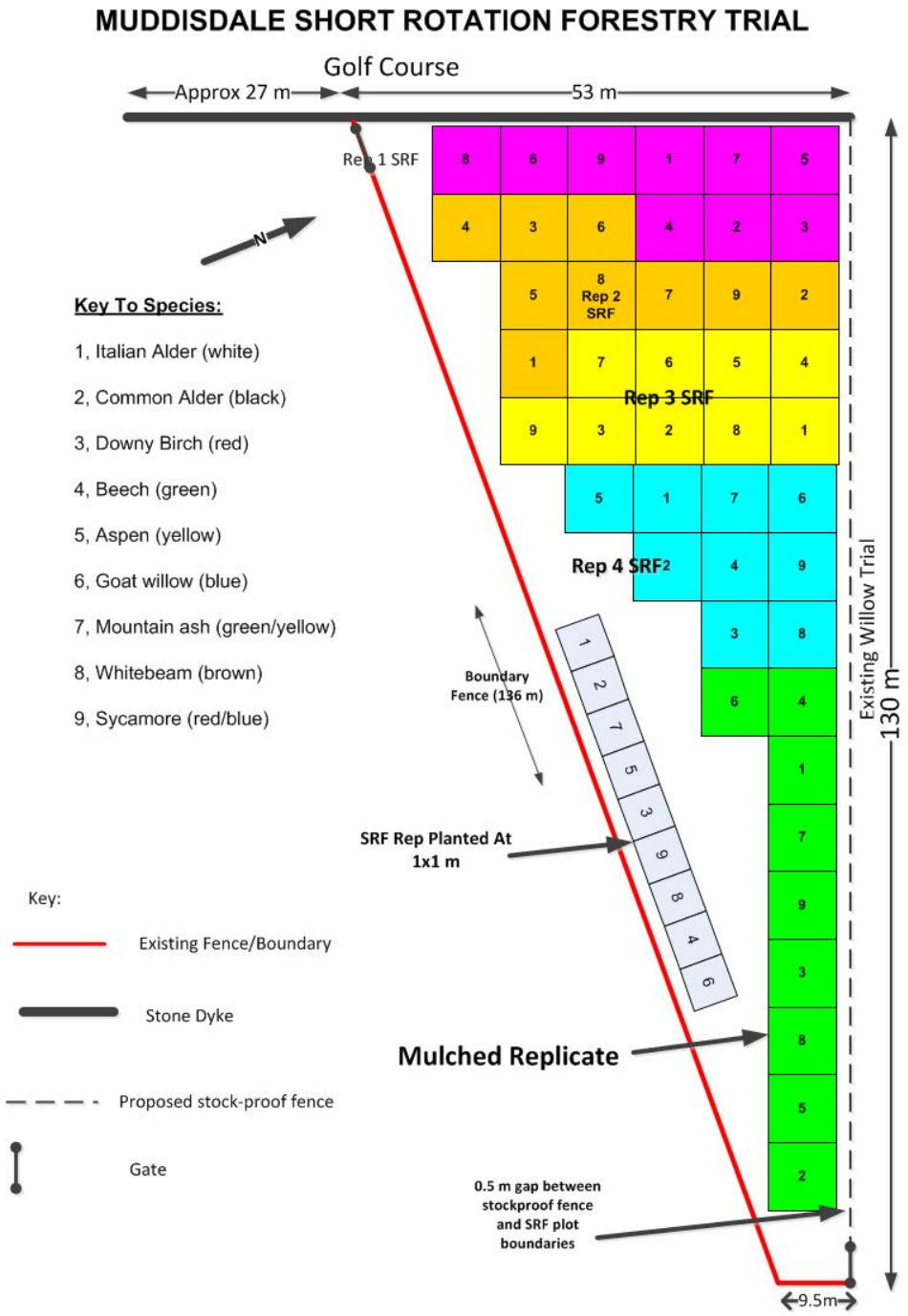
goat willow is the markedly tallest species at Newfield, followed by common alder, downy birch and aspen, at Muddisdale there is less difference between goat willow, aspen, Italian alder and common alder. At both sites, however, the smallest species are beech, mountain ash and sycamore. These species are also the ones which have had difficulties emerging from the spiral tree guards.

Notwithstanding the difficulties some species have had in emerging from spiral guards, the trial investigating different tree guard treatments has shown very convincingly the beneficial effect of using tree guards to increase survival. It is likely that the death of unguarded trees is caused by voles since the Newfield site does not have a rabbit problem and since June 2013 the Muddisdale site has been protected by rabbit netting.

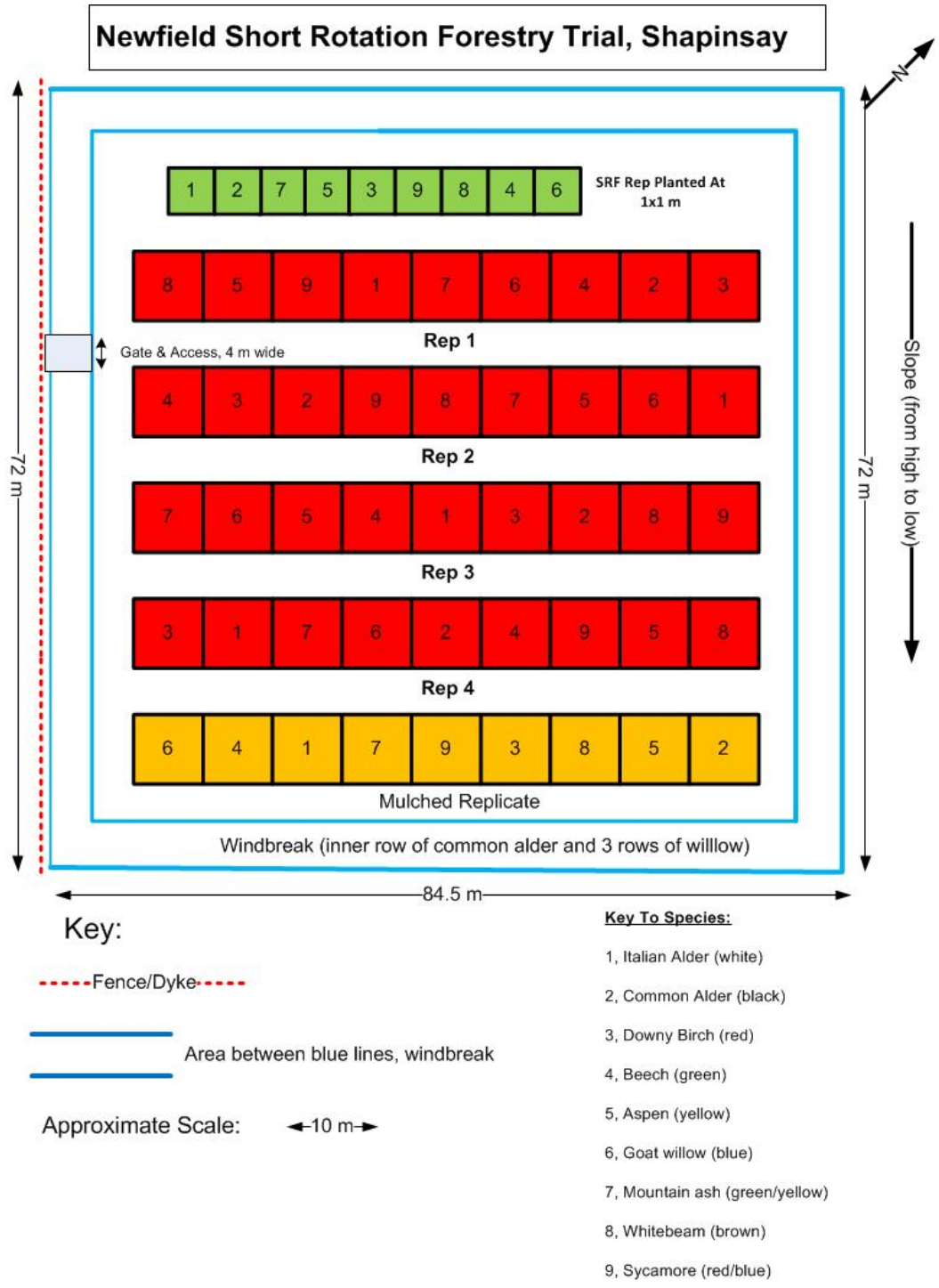
Acknowledgements

The author is very grateful to Forestry Commission Scotland and, in particular, John Risby for his enthusiastic support and interest in these trials. He would also like to thank John Wishart for management of the Muddisdale trial and Jean-Baptiste Bady at Balfour Castle for his help during visits to the Newfield trial.

Appendix 1: Plan of the SRF Trial at Muddisdale



Appendix 2: Plan of the SRF Trial at Newfield



Appendix 3: Photographs

Photos 1 (top), 2 (bottom). *General photographs of the Muddisdale (Photo 1) and Newfield (Photo 2) trial sites in July. Note the denser weed cover at Newfield.*

Photos 3 (top) and 4 (bottom). *Beech tree with its leaves and shoot trapped by the spiral guard (Photo 3). Rust (Photo 4) on downy birch at Muddisdale in September 2014.*