Forestry Commission Scotland

Energy Forestry Exemplar Trials

Establishment Guidelines

Energy Forestry Exemplar Trials

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INTRODUCTION

The Energy Forestry (EF) exemplar sites are being set up in support of the recommendations given in the *Scottish Forestry Strategy* (2006), the *Scottish Government Woodfuel Taskforce Report* (2008) and the *Climate Change Action Plan* (2008 -2010). These documents recognise that there is an important information gap with regard to the growth and development of Short Rotation Coppice (SRC) and Short Rotation Forestry (SRF) in Scotland. Though some significant work had been done on SRC, mostly in England, SRF is largely untried, and both require more thorough testing in a Scottish context.

The trials have been under development since September 2007, aided by close collaboration between FC Scotland and Forest Research. Broad proposals for both research and operational practice were published in spring 2008. These have now been refined and are presented here as a broadly generic package that can be applied, in whole or part, to any current or future EF trial site.

2. AIMS

The aims of these trials are:

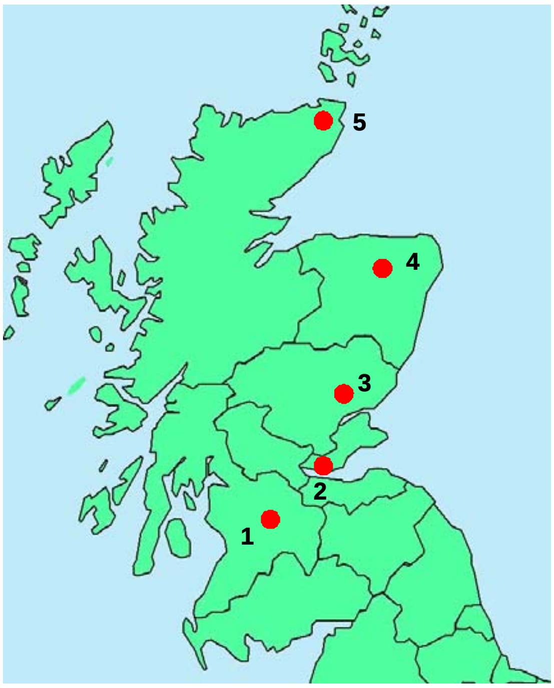
- To maximise the yield of information on SRC and SRF through an embedded programme of targeted research, development and monitoring.

- To be an educational resource by demonstrating best practice on an operational scale under realistic conditions.

it is considered essential to engage with all potential stakeholders in energy forestry to ensure that the information gained and demonstrated meets the need. Dissemination of information will necessarily be phased as the sites develop and will become increasingly fact based, rather than notional as d2ata is recorded and analysed.

3. THE TRIAL SITES

FCS has acquired several farms with the intention of planting these for the purposes of carbon sequestration. Of these, five of have currently been selected for inclusion in the trial series:



1. Auchlochan, S. Lanarkshire
2. East Grange, Scottish Lowlands FD
3. Alyth, Tay FD
4. South Balnoon, Aberdeenshire FD
5. Sibster, Dornoch FD

Though these choices give a good geographic and climatic spread, and they encompass a wide range of site characteristics, they clearly have an eastern bias. The final tally of trial sites is expected to be 6, with one additional site in SW Scotland and the other towards the West Coast, or possibly on one of the islands.

The diverse nature of the sites available for the trials will affect the overall forest design and the suitability for SRF and SRC. Field boundaries are likely to be retained and will constrain block size, as will landscape and environmental issues. However, an overall trial size of between 15 - 25 hectares is the target.

The design of the trials comprises 3 area elements:

Operational:

These are large single/mixed species blocks (>5.0 ha) established and maintained as commercial crops by the FD/FE Ops. Therefore, the number of these blocks is dependent upon the number and scale of species planted, but it is unlikely that more than 4 will occur on any one site.

Intensive:

This is a self-contained area, of around 4.0 -5.0 ha, which has a range of small research plots looking at aspects of SRF/SRC not included within the operational trial blocks e.g. alternative species and spacing. Statistical considerations, necessary to improve the quality of information gained from the trials, dictate the need for small replicated blocks (Figure 1). As various plots within this area will be directly compared with each other, it is important that site conditions (soil, exposure, slope, aspect) across the area are as uniform as possible. Also the area should be representative of the site as a whole. Shape is not so critical, but to reduce edge effects and fencing costs an approximate rectangle with a side ratio of no more than 2:1 is preferred.

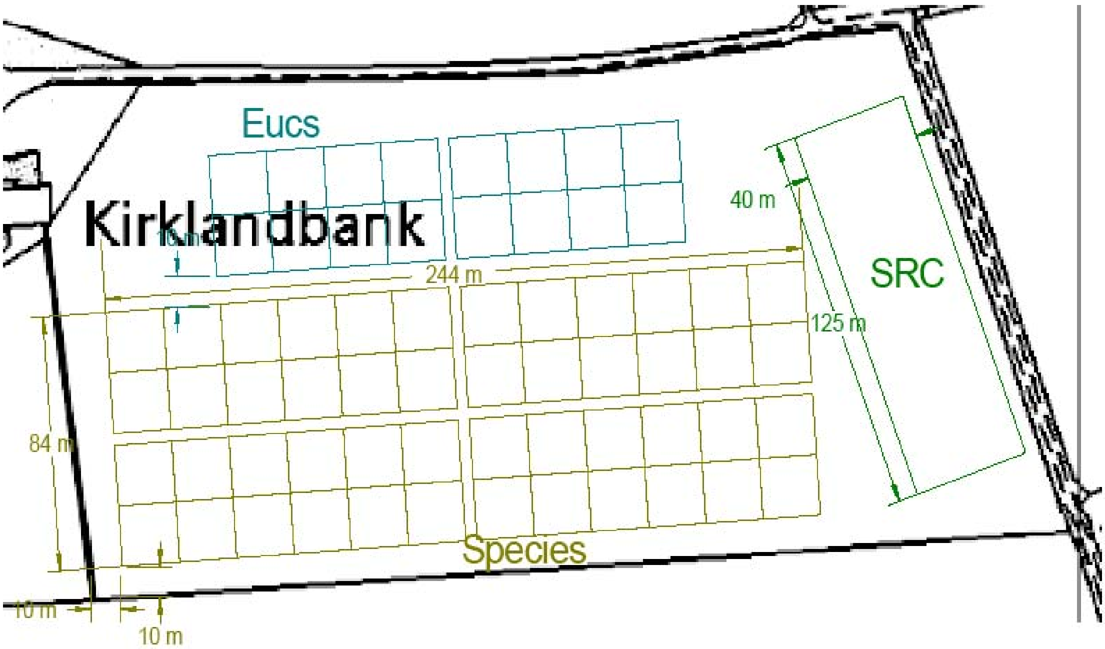


Figure 1: Expected layout of trial plots at Alyth (Westfield). Individual species plots are 20m x 20m and contain 200 trees. The *Eucalyptus* plots are separate and to the north side because of the potential for shading effects from their likely rapid growth rate compared to the other species

Control:

A representative area of 2 - 3 ha in extent should be left as an unplanted control. This will be used to compare factors such as hydrology, biodiversity, soil nutrition and carbon, etc. with the changes that occur within the planted blocks. On most sites the inclusion of this area should be possible within the 'open space' of the landscape plan.

The potential location of these elements and the species they will contain, and particularly the location of the intensive area, needs to be decided upon early in the site planning process between the FD and the Trials Project Manager. This should also include alternatives should landscape or environmental factors make the original choice unsuitable. A basic initial site survey will be necessary to ensure the required uniformity of site conditions.

4. GENERAL SITE MANAGEMENT

- **Cultivation**

The degree of cultivation will depend upon the information gained from the baseline soil survey. Some of these ex-agricultural sites are likely to have a compacted plough or stock pan that will impede root growth and would benefit from rip cultivation. This level of cultivation should suffice on most sites for SRF.

SRC sites will be complete ploughed with an agricultural plough then power-harrowed flat.

- **Weed control**

For SRC there is a well-tried sequence of contact and residual herbicide use at establishment that is unlikely to be bettered, though it may need revising as chemical approvals change. Mechanical or passive methods have not proven suitable.

For SRF the use of mechanical or passive control is possible but has proven more expensive and less effective than the correct use of herbicides. The use of herbicides, timed and targeted as required, will be the norm on the SRF sites.

Where the planting of trial sites is delayed and arable field areas are currently bare, the intention will be to sow low-productivity rye-grass as a way of stabilising the soil surface and restricting the growth of more aggressive weeds e.g. docks and thistles (Appendix 3).

- **Protection**

The avoidance of damage from browsing mammals, both wild and domesticated, including voles, squirrels, rabbits, sheep, deer and cattle, is essential to the integrity of the intensive research plots. Even a minor incursion can be very destructive to small plots. Therefore, all intensive areas will be protected within a combination deer and rabbit fence, and individual planted trees will be vole-guarded

Chemical protection from insect pests during the establishment phase may need to be considered but seems unlikely to be a major problem, at least during the first rotation.

5. SRC and SRF

An Energy Crop is defined (DTI, 2007) as: *A plant crop planted after 31st December 1989 and which is grown primarily for the purpose of being used as fuel.*

SRC can be defined as: *Woody vegetation grown on a repeated coppice cycle of 3 – 4 years* ***specifically*** *for the production of biomass.*

SRF can be defined as: *Single stemmed trees of fast growing species grown on a reduced rotation length (8 – 20 years)* ***primarily*** *for the production of biomass.*

Apart from the rotation length, the key difference in these definitions is that SRC is only fit for biomass, whereas SRF embodies a degree of flexibility. Though its initial objective may be biomass, it has the potential to be grown on as a timber crop should the market dictate that this is a better option at the end of the 'short' rotation.

SRC is becoming a less-favoured crop within Scotland as it requires higher value, arable land for good growth and, though productive, the calorific value and properties of biomass produced are relatively poor compared to other sources. SRF has the potential to utilise more marginal agricultural land and, provided that the right species are grown, can produce a high energy, quality product. This makes SRF a more appropriate woody biomass source for growing in most parts Scotland.

The majority of the trial sites will not have operational plantings of SRC. However, each site will have a O.5 ha plot of SRC within the intensive area as a comparison with the SRF.

6. RESEARCH, DEVELOPMENT AND MONITORING

The target for research is to provide information that will enable outputs to be maximised in the most economic way, while providing social, business and environmental benefit.

The factors requiring investigation for both SRC and SRF can be broadly categorised as:

- Environmental
- Silvicultural
- Carbon balance
- Economic

And have 4 main phases of development:

- Baseline
- Establishment
- Growth
- Harvest & Utilisation

Appendices 1 - 7 are detailed plans or protocols of the elements that will be assessed to provide information on these factors throughout the rotation phases. Resource constraints allied to site suitability will inevitably result in choices having to be made. Targeted detailed assessments on a smaller number of sites for some of the more intensive measurements e.g. hydrology, are considered more cost effective and likely to result in higher quality information than making general assessments on all sites.

A broad summary of the research that will be undertaken is given below:

6.1 Environmental research

It is essential that the sites be assessed for baseline environmental values before operations start so that any changes occurring later have a datum against which to be compared. This also provides a useful between site comparison. Following this, many of the elements will require continuous or periodic monitoring. Those that will be assessed are:

- **Site factors**

Basic **climatic data** (rainfall, temperature, windiness, etc) is available as mean values that are likely to remain broadly unchanged on a landscape scale throughout the life of the crop. However, variation does occur annually and may impact upon growth performance. To capture this variation, each site will have an automatic weather station, which will continuously record air and soil temperature, rainfall, wind speed and light intensity. This data will also help to isolate specific events that could cause direct damage e.g. frost, or others that indirectly may affect disease resistance e.g. cold and wet.

Historic landuse is an important but often overlooked element. All of these sites have been intensively managed for agriculture in the past, so in order to understand current site conditions and subsequent effects on crop establishment and growth, as much past landuse information as possible should be gathered. This will be done in conjunction with FD planners as part of the initial site survey.

- **Soils**

A detailed soil survey is an essential prerequisite to any planting scheme. On these sites, the top of the soil profile is likely to have been significantly altered by agricultural practice and may belie the inherent soil type and nutritional status. In addition, a 'pan' may have been formed due to compaction by machinery and/or livestock, which will impede rooting and may need an increased level of cultivation. Any soil survey needs to be thorough and systematic in order to capture site variation.

Soil investigations on the trial sites will be in two parts:

Firstly, an overall, **pre-planting survey** will be done to map the whole site. This will find the major soil types and lithology, and will identify their boundaries. A small number of samples will be taken and analysed to provide nutrient status and pH information. The data gathered will feed into the site planning process, informing species selection, cultivation, etc. In addition, this will help identify the best area for the intensive plots.

Secondly, there will be a **detailed soil assessment** (Appendix 1) within the intensive area, which will investigate the effect that the various SRF and SRC species have on soil carbon, nutrients and soil structure. This will be done by analysing samples taken at various depths down the soil profile from a series of points within individual species blocks. The samples will be taken pre-planting, and then repeated at the rotation end.

Soil carbon is important in deciding the overall efficacy of carbon sequestration, yet little is known about the long-term effects of most tree species on this aspect. This work will provide a unique insight into the topic.

- **Hydrology**

A fast growing crop of SRC or SRF requires a significant volume of water to sustain it. Depending upon water availability, this may reduce water flows and have other, allied environmental impacts. In areas more prone to summer drought e.g. Eastern Scotland, lack of available water may well be a limiting growth factor.

Hydrological **assessment** (Appendix 2) falls into two main areas: water resources and water quality. The types of site where these assessments can be made most effectively are not necessarily the same. Given the expensive nature of the equipment necessary for hydrology work, each element will only be assessed on a single site.

To test for the effects of SRF on **water resources** requires a site where water supply is likely to be limited. The eastern location of Alyth, with its sloping site and only 35 – 40 cm of soil depth to bedrock is easily the best of the currently available sites for this. A large block of trees, preferably >1.0 ha is needed to measure an overall effect; therefore this assessment will be done in the larger operational blocks of ash and sycamore, compared with an open field control. A series of probes will continuously assess the soil moisture content at various depths, commencing with a baseline study before the crop is planted and carrying on throughout the life of the crop.

To examine the effects of SRF on **water quality** requires a site with two self-contained, micro-water-catchments, one planted and one open. Sibster appears to meet this requirement and is likely to become the test site, though more detailed investigation is required. The method will be to continuously monitor stream flow and to take periodic samples for chemical analysis throughout the life of the crop. The invertebrate stream fauna will also be monitored to assess ecological changes.

- **Biodiversity**

The effect on biodiversity of planting trees is an important indicator of environmental change, as well as being of high public and political concern. Most trial areas are largely relatively sterile agricultural fields, where the greatest biodiversity is concentrated in field boundaries and small pockets of less managed land. The planting effects will be considered on two levels: changes in existing biodiversity on an overall site basis and the new biodiversity associated with the crop species.

Assessments (Appendix 3) will be done mainly through the spring and summer months, when biodiversity is most apparent, commencing with a pre-planting baseline survey, followed by periodic monitoring as the crop growth progresses. Assessments will include:

Ecosystem function - monitoring species abundance of *Syrphidae* (hoverflies), which are particularly niche-specific and therefore good indicators of ecological change.

Tree species biodiversity - assess diversity of species found on samples of canopy leaves of SRF species, based upon visible evidence of invertebrate activity, e.g. galls, leaf miners, leaf rollers, spiders' webs, etc.

Charismatic species - breeding bird and butterfly surveys, to be done in colaboration with the British Trust for Ornithology (BTO) and Butterfly Conservation.

Existing biodiversity value - monitoring the habitats present on site for changes directly or indirectly attributable to SRF, particularly with reference to vegetation change.

- **Landscape and social issues**

Largely outside the remit of the EF trials and controlled by the consultation and environmental impact assessment procedures. However, the site constraints generated will affect the type and amount of EF crop planted, the available land for the trials, and the level of research input applicable. All research proposals will need to be worked into the planning process at an early stage to ensure the best possible outcome.

6.2 Silviculture - Short Rotation Forestry (SRF)

Effective growing and management of SRF is not well understood and the trial sites have great scope for improving our knowledge of this system. The following research topics will be investigated:

- **Species choice**

When choosing species for SRF (Appendices 4 & 5)it should be borne in mind that high volume yield alone is not a clear indicator of biomass productivity, or for that matter carbon sequestration.. The density and moisture content of wood are critical considerations as they indicate the actual amount of woody material in a log. For example, green Sitka has an indicative moisture content of 69% and ash of 48% (weight of water content divided by dry timber weight), and their green densities (weight per volume) are for Sitka, 481 kg/m^3, and for ash, 801 (Laver, 1983). Therefore, ash can produce more biomass per unit volume than Sitka by a factor of greater than two, though this is unlikely to happen on the same site. Effectively this means that an ash crop at GYC 8 is as productive for biomass as a Siitka crop at GYC 16, with the additional advantages of easier handling and transport. Similar comparisons can be made between other species and lead to the conclusion that, where possible, fast growing, high density broadleaved species are preferable to conifers, with the possible exception of larch, which has a green density of 609 kg/m^3**.**

Selected for the criteria of fast growth and higher density, the following species will be planted in replicated plots at all sites.

Improved Sitka spruce will be planted as the standard control against which the relative performance of the other species can be compared.

Seed origin is an important consideration in determining site suitability and productivity. Trees from more southerly origins tend to flush earlier and set bud later, thus making them more prone to damage from late and early frosts. However, these trees adapted to a longer growing season will grow more productively, provided that cumulative site temperature is adequate. So choice of seed origin needs to be a balance between growth rate and survivability. For most natives, origins from registered seed stands in Mid-North England will out-perform Scottish ones, survive well and generally be of good form (Hubert, 2006), hence the choice of English origins of ash, sycamore and birch.

Common Name	**Scientific Name**	**Origin**	**Seed Zone**
*Sycamore	*Acer pseudoplatanus*	Middle England	402/403
Silver birch	*Betula pendula*	Welsh Marches	403
Ash	*Fraxinus excelsior*	Middle England	402/403
*Italian alder	*Alnus cordata*	UK	n/a
*Red alder	*Alnus rubra*	Alaska	n/a
Shining gum	*Eucalyptus nitens*	Central Victoria	n/a
Shining gum	*Eucalyptus nitens*	Talleganda, NSW	n/a
*Tingiringi gum	*Eucalyptus glaucescens*	Central Victoria	n/a

*Cider gum	*Eucalyptus gunnii*	Central Tasmania	n/a
Rauli	*Nothofagus procera*	Cautin/Malleco	8331/8332
*Hybrid aspen	*Populus tremula x tremuloides*	Sweden/Latvia	n/a
*Sweet chestnut	*Castanea sativa*	UK	n/a
Sitka spruce (VP)	*Picea sitchensis*	VP (Delamere)	n/a
Hybrid larch (pure)	*Larix x marschlinsii*	VP (Bush)	n/a

Table 1: SRF trial species choice and origins. Those species suffixed with (*) have high coppicing ability and could be regenerated through this mechanism.

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To obtain a worthwhile comparison between sites and species, it is essential that the same seed origins are repeated across all the sites. Given the number of plants required and the vagaries of seed supply and nursery production, it is not possible for the operational plantings to achieve this. Therefore, all the listed species (Table 1) will specifically grown by either FR or Delamere nurseries from known seed origins in sufficient numbers to allow them to be planted within the intensive research plots on every trial site.

- **Spacing**

SRF will be planted at a target stocking density of 5,000 trees/ha, with the assumption being that trees will be planted as single species blocks. Mixtures may be tried but there are doubts that differences in growth rate between species could result in suppression of one species thus reducing the unit area productivity for biomass. Actual spacing may be dictated by the planting method used e.g. South Balnoon will have a spacing of 1.65 m between rows and 1.35 m along rows giving a stocking of 4,490 trees/ha. A potentially better spacing would be 2.0 m between rows and 1.0 m along the row (5,000 trees/ha), which would allow for easier operational access. This is the spacing that will be applied to the intensive research plots.

The decision to use denser rather than conventional stocking in SRF is based upon maximising site utilisation over a short rotation. There is a complex balance between spacing and yield that depends upon competition for light, nutrients and water within a particular species on a site. In general it can be said that site productivity is finite and that total yield is constant. Using denser spacing, the biomass crop 'captures' site productivity more rapidly. Previous studies have proven that this increases the productivity in the short term, but that yield increment slows more quickly than in a wider spaced crop. Therefore, maximum productivity is reached at an earlier rotation age, which is exactly as required by SRF. There are also additional benefits from closer spacing of improved form, finer branching, a reduction in the less dense juvenile wood component and earlier weed suppression.

In order to test the effects of spacing on biomass yield, ash and birch will be planted out in a series of Nelder plots (Appendix 6). This system allows a wide range of spacing variation to be tested in a small area.

- **Planting**

Planting in the intensive plots will be done by hand and, because of the need to accurately layout plots, cannot be assessed as a true reflection of operational technique. Therefore, planting effectiveness and efficiency, including carbon life cycle analysis will be assessed by Technical Development in the large scale operation plantings.

- **Growth rate**

Assessment of this will include measuring the standard factors of height, diameter and form on an annual basis at the end of each growing season. In addition there will be more periodic assessments (every 5 years) of the biomass allocation in stems, branches and roots. From these measurements biomass volume can be calculated, and by extrapolation the amount and rate of carbon sequestered. Work on this topic (BSORT) is already in progress for commercial forestry species by Robert Matthews of Biometrics, but this does not yet include many of the species being considered here for SRF.

- **Thinning**

It is unlikely that thinning will increase the overall productivity for biomass and, if maximising biomass is the sole objective, thinning will probably have no crop benefit. However, it could provide a mid-rotation income stream and could render the crop more suitable for continuation into productive high forest if this was the option preferred to SRF later in the rotation.

An option to thin half of the intensive trial plots and compare the subsequent growth is included in the experiment plan trials. This will be considered as the crop progresses.

- **Phenology**

The growth cycle of the trees, and particularly the time of bud burst in the spring and bud set/shoot dormancy in the autumn, is critical factor in the adaptation of trees to seasonal climate changes. This will be monitored as part of the species trial.

- **Carbon cycling**

The accumulation and decay of leaf litter is an important element in both the carbon and nutrient cycles within a woodland. The rate of decay varies with species e.g eucalyptus slow, birch fast, and site conditions. Where the accumulation rate is greater than decay, significant amounts of carbon may be locked up in the litter or subsumed into soil organic matter. Monitoring levels of leaf litter through the growth phase of the trials will inform soil carbon assessment and give a fuller picture of carbon sequestration.

- **Nutrition**

With SRF the assumption would be against the use of fertiliser, relying on inherent site fertility to meet nutritional needs. Nutrient levels will be part of the soil assessment but will also be monitored in the shoots/foliage of the crop to inform growth and yield assessments.

- **Damage**

This includes any factor that results in a loss of vigour and subsequently a loss of yield. It may be abiotic or biotic in nature, but, whatever the cause, it will be monitored and logged as a crop performance variable.

Abiotic factors include operational damage e.g. chemical or mechanical, and climatic damage e.g. frost. Operational damage should be readily apparent and can be assessed as part of growth measurements. Climatic damage may be obvious or less so, depending upon the severity, but will be linked to an event e.g. wind, snow, frost, therefore assessments should be made following these events. Although, the effects of frost damage may not become apparent until sometime after the events e.g. bud damage, root freezing, it should be possible to link climatic damage with weather events recorded by the weather station.

Biotic factors are pests and diseases, ranging from large browsing mammals to virus infections. Damage can often be seasonal and sporadic, but can impact heavily on yield. The damage from larger pests is normally obvious and can again be assessed as part of the growth measurements. Assessment of insect, mite and disease damage is more problematic as it is often seasonal and rapid. The species plots will be routinely inspected during the summer for signs of damage. Significant amounts will trigger a reactive assessment.

- **Yield**

Yield assessment is linked to the continuous growth measurements throughout the rotation. However, other elements of yield are important to our understanding of carbon sequestration and substitution value. These include sampling the green and dry weights of wood, their calorific value and their carbon content relative to species and volume per unit area Also, given recent concerns regarding atmospheric pollution from woody biofuel, an examination of other chemical constituents in the wood may be appropriate.

This data will be the main commercial imperative and will link back to all the other assessments and practices during establishment and growth.

6.3 Silviculture - Short Rotation Coppice (SRC)

The basic establishment system for SRC is already well tried and tested. It may be possible to look further at fertiliser rates and one or two-year initial coppicing, but the spacing, plant type, subsequent treatment and cropping cycle are all well defined. The most important considerations are the performance and yield of specific clones relative to site and location.

- **Species and clonal choice**

For SRC, willow (*Salix* spp) is the preferred crop. Though poplar (*Populus* spp) can grow as productively, it is more site demanding and prone to rust

(*Melampsora*) infection. Planting material is clonal cuttings normally around 20 - 25 cm in length, which is often supplied as 'rods' of 2 –3 m length. A mixture of clones should be planted to allow for site adaptation and disease tolerance differences. In the trials, the aim would be to plant certain fixed clones for comparison between sites.

Currently, the most widely planted willow clones are:

From Sweden:

- Tora
- Torhild
- Olof
- Sven
- Tordis

From the European Breeding Programme:

- Ashton Stott
- Resolution
- Endurance
- Discovery
- Endeavour

Many of these clones are closely related but do show differences in growth and disease tolerance. Their performance in Scotland is largely untested. A 0.5 ha block containing these clones will be planted at each trial site within the intensive area and assessed for growth and yield.

- **Planting**

All SRC is planted mechanically as cuttings at a pre-defined spacing, resulting in 15,000 plants per hectare. This dependence upon machine planting is a major constraint on site suitability as slopes >15% (8.5°) are generally considered unsuitable, though planting slightly steeper slopes (20%) is possible if there are sufficiently wide flatter areas at the top and bottom of the slope for turning the machine.

Clones may be planted in either an intimate mixture or in clonal blocks. Pathologists consider that planting an intimate mixture of clones reduces the risk of disease, but slower growing clones may get shaded out. The trial block in the intensive area will be planted as half intimate mixture and half clonal blocks for comparison.

- **Nutrition**

Previous trials of SRC have shown that the effect on yield of additional fertiliser (organic or inorganic) during the first rotation depends upon the inherent nutrient status of the agricultural land used. The current sites are all sufficiently high in nutrients to support the first rotation, though subsequent rotations may tend to become more dependent upon fertiliser to maintain yield levels. There are standard recommendations (DEFRA, 2002) for additional nitrogen, which seem a reasonable baseline for the trials and will be compared against unfertilised controls.

6.4 Carbon Balance

Assessing this will be the culmination of the trials at the end of a rotation and will show how effective SRC and SRF is in holistically reducing atmospheric CO_2. The assessment will incorporate data from other assessments e.g. soil carbon, biomass yield and carbon content, to which will be added operational fuel use and transport miles for all the elements of the rotation, brought together in a comprehensive life-cycle analysis.

The carbon balance will depend upon product type and end-use efficiency, as well as the potential to substitute for less carbon efficient products and materials. Comparison with other landuse options e.g. agriculture or high forest will also be considered. Overall carbon accounting will be complex and dependent upon how many levels removed from biomass production one wishes to go. However, it is essential to the understanding and justification of SRC and SRF. For this study, it is the intention to draw the boundary at the trial site level, so that only those factors that directly effect growth and on-site operations will be considered.

The assessing operational carbon efficiency e.g. transport, machinery use, product conversion and utilisation, will be Technical Development's remit and will run in conjunction with methodology studies (Appendices 7 & 8).

6.5 Regeneration or reinstatement.

These are issues that we will need address down the line, though reinstatement in particular is likely to a difficult and may have large environmental and cost implications, which might negate the carbon gains of the crop.

The longer-term effects of repeated short rotations on the environment and the yield of both SRC and SRF are not clearly known. This will mean revisiting most of the factors looked at during the first rotation and comparing overall performance.

It seems likely that nutrition will change, pests and diseases may become more prevalent, climate change may have a greater impact upon species choice and yield, etc. We need to look at these systems in the longer term, which is easy enough for SRC on a 3 –4 year rotation, but will require long-term commitment for SRF.

7. Conclusion

This suite of trials and the associated research is a major step towards fulfilling the biomass energy objectives of FCS policy. The range of sites involved and the intended research will greatly enhance our understanding of both SRC and SRF in Scotland and provide a solid, factual basis for future development and policy on woody biofuel production.

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Appendix 1a: Soil sampling and analysis

FOREST RESEARCH

[Name of Division] EXPERIMENT PLAN

Experiment Title:	**ENERGY FORESTRY (SCOTLAND) – SOIL SAMPLING AND ANALYSIS**
Key Words:	SRF, soil carbon, soil nutrients
Background:	Planting Short Rotation Coppice (SRC) and Short Rotation Forestry (SRF) for use in fossil fuel substitution is increasingly seen as having a significant contribution to make to climate change mitigation. Pressure is already growing to extend planting of SRC and SRF as a way of maximising woody biomass yields. Intensive SRF plantations have raised concerns about environmental, biodiversity, hydrology and landscape issues. Although the land for SRF is ex-agricultural land and fairly rich in base cations, nitrogen and phosphorous, growing short rotation forest (SRF) crops for biomass will, over time, potentially lead to significant soil nutrient depletion and soil acidification. A simple model of carbon cycling within bioenergy plantations has predicted that short rotation plantations have significant potential to sequester carbon in the soil at comparable or greater levels than for naturally regenerating woodland (Defra's project NF0418, 2004). The removal of carbon in biomass from plantations was more than compensated by the faster growth rate of trees and higher planting densities compared to traditional woodland. The model highlighted an inverse correlation between the yield of bioenergy crops and carbon sequestration. Other studies also provide some support for carbon accumulation in SRF. However, much uncertainty remains and there is an urgent need to validate and improve models by quantifying actual soil carbon sequestration rates by bioenergy crops. Another key need is to consider carbon-offset through production of bioenergy crops. Although some studies and preliminary modelling provide estimates of C sequestration rates for SRF and SRC, the

impact on soil carbon and nutrient status remain largely unknown, especially for SRF. There is a need to compare systems and the effects of different tree species and rotation lengths on C sequestration efficiency, as well as to assess the wider environmental issues associated with them.

Environmental issues/questions:

1) What are the effects of SRF and SRC on soil carbon and the potential and overall capacity for carbon sequestration?

2) What are the effects of tree species, soil type and soil nutrient status on soil carbon dynamics and soil potential/capacity for C sequestration?

What are the overall impacts of SRF on soil carbon, nutrient status and biological status as compared to SRC?

Objectives:

1. To establish a baseline of soil carbon and soil nutrient status, and an estimate of soil biological status, prior to planting in two SRF and SRC trials – at East Grange in upslope intensive SRF/SRC field site (6 ha) and at Alyth in intensive SRF/SRC field (4.5 ha).

2. To evaluate the effect of different SRF species on soil carbon and nutrient dynamics.

Location: Various FCS- owned farmland sites.

Specific test conditions: N/A

Species:

Sycamore	*Acer pseudoplatanus* L.
Italian alder	*Alnus cordata* Desf.
Red alder	*Alnus rubra* Bong.
Silver birch	*Betula pendula* Roth.
Sweet chestnut	*Castanea sativa* Mill.
Ash	*Fraxinus excelsior* L.
Hybrid larch	*Larix x marschlinsii* Coaz.
Rauli	*Nothofagus procera* Oerst.
Hybrid aspen	*Populus tremula* L. *x tremuloides* Michx.
Sitka spruce	*Picea sitchensis* (Bong.) Carr.

	Eucalypt	*Eucalyptus* spp	

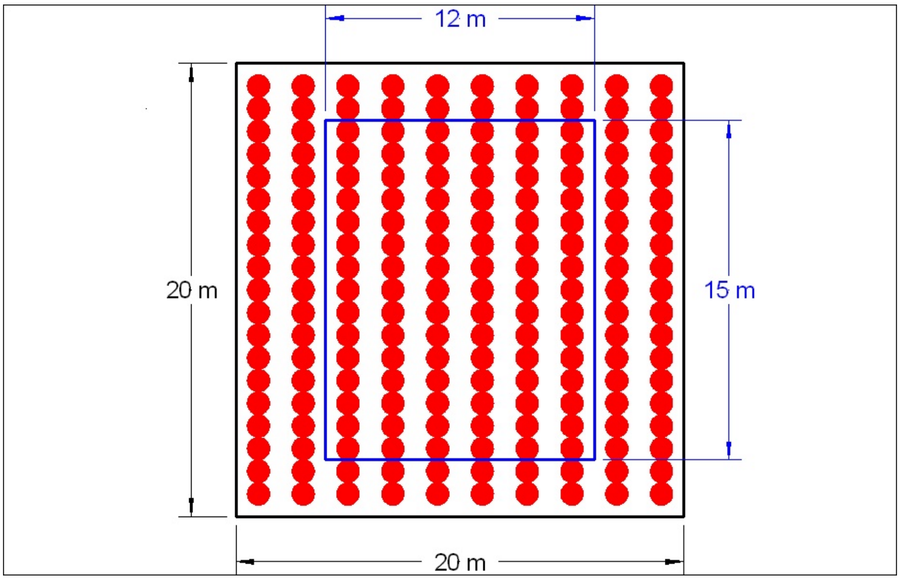
Products & Active Ingredients: No proprietary treatments used in this experiment.

Experimental Treatments:

1. SY	Sycamore	6. AH	Ash
2. IAR	Italian alder	7. HL	Hybrid larch
3. RAR	Red alder	8. PRN	Rauli
4. SBI	Silver birch	9. ASP	Hybrid aspen
5. SC	Sweet chestnut	10.SS	Sitka
		11.C	Unplanted control
		12. Euc	Eucalypt

Design: 11 species +control x 4 blocks = 48 plots (4 Control + 44 species plots) + 4 plots in SRC = total of 52 plots for soil assessment

Plot size - each plot will be 20m x 20m in extent and be planted at 1m spacing along the rows and 2m spacing between rows, giving 200 trees per plot. The assessment plot for tree species will be the central 12m x 15m area containing 96 trees, leaving a 2 tree buffer.



Methods: The purpose of the soil assessment is to establish a baseline of soil C and soil nutrient status so that the impact of planting SRF/SRC on these soil properties can be assessed by repeating measurements at the end of crop rotation (e.g.

3-4 years in SRC and 15-20 years in the case of SRF). The assessment plot for establishing the soil baseline will be the central 12m x 15m area containing 96 trees, leaving a 2 tree buffer. GPS will be used to map the plots and locate the sample points. The effects of different tree species and differences between SRC and SRF on soil C and nutrition will also be evaluated. A rigorous assessment of the impact of the proposed planting on soil conditions requires that the baseline assessment captures very well the within-site spatial variability in soil C and nutrients; this will greatly enhance the ability to statistically detect even small changes at the end of the measurement period. Generally, soil survey data is collected as composite samples. However, in composite sampling, the spatial reference of sampling locations and information on within-site variance in soil C amounts is lost. Recent studies show that spatial autocorrelation of the carbon stock is lost at distances greater than several metres between measuring points. Depending on the site, the distance between non-correlated sampling points should be up to 8m (Mäkipää et al, 2007). Studies suggest that more than 20 sub-samples per site should be taken in order to obtain a reliable plot-level estimate of the mean carbon stock in the topsoil.

Baseline of soil C and nutrients carried out before tree planting:

1) Based on the expected soil variability and the size of the plots, the proposed sampling design is to use a 3 x 4 m grid to provide a total of **12 soil samples per plot x 3 depths x 52 plots = 1872 soil samples in total.**
2) Soil sampling will be carried out by soil coring in all 52 plots.
3) Samples will be taken from the topsoil layer at 0-20 cm depth, 20-40 and 40-80 cm soil depth, overall 3 sample per sampling point.
4) Bulking of samples for carbon analysis will be avoided in the top 0-20 cm layer in order to capture the spatial variability as much as possible, producing in total 624 samples from all plots. The rest of the samples taken from 20-40 cm and 40-80 cm soil depth will be bulked in the ratio of 4 into 1 sample so total of 156 per sampling

depth samples for all plots will be analysed. ***For soil carbon assessment***, the overall **total number of samples is 1248** (624+156+156) samples per one SRF site to be analysed.

5) *For nutrient assessments,* 624 soil samples per site per depth (0-20 cm, 20-40 and 40-80 cm) will be bulked into 156 samples per depth (3 bulked soil samples per plot) for analysis for nutrients per site. *For soil nutrient assessment*, **the overall total number of samples is 468** (156+156+156 for the three soil depths).
6) **Bulk density sampling will be carried out at 156 sampling points per site** (1 samples per depth x 3 depths x 52 plots = 156) to allow concentrations to be converted to quantities per unit volume of soil.

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Duration & Responsibilities: 20 years, then review.

Drafted by: Elena Vanguelova

Date: 11.01.09

Appendix 1b: Investigating hydrological impact

FOREST RESEARCH
ENVIRONMENTAL AND HUMAN SCIENCES DIVISION

EXPERIMENT PLAN

Experiment Title: Energy Forestry (Scotland) - Investigating hydrological impact

Keywords: Short rotation forestry, water use, water quality, catchment management.

Background: Concern has been raised that the establishment of energy forest crops could have an adverse impact on water resources (LTS International, 2006). This arises from the potential high water use of SRF, which could reduce water supplies and ecological flows. While there is a reasonable understanding of the water use of SRC, little information is available on that of SRF. Studies of oak, ash and beech woodland in southern England have shown that broadleaved trees have the potential to increase or decrease water resources, depending on species, soils/geology and regional climate (Nisbet, 2005). Initial modelling of trees grown as energy crops indicates that ash could significantly increase water resources compared to grass, while the opposite is the case for exotic species such as Eucalyptus or Notofagus (Calder *et al.* 2009). No information is available for other potential SRF species such as sycamore. There is therefore a need to collect data on the water use of key species to test model predictions and clarify the risk or benefit to water resources.

A second water issue is the impact on water quality. Both SRC and SRF are expected to benefit water quality compared to an agricultural land cover due to lower chemical inputs and reduced soil disturbance. However, while some information is available for SRC, there is little on SRF. Data is required to check and quantify the expected benefits of SRF for water quality. There is also a need to confirm that the potential pollution risks associated with the final harvesting phase can be minimised by best practice measures.

Objectives: 1. To quantify the effects of different SRF species on water resources.
2. To evaluate the impact of SRF on water quality.

Location: Field experiment on water use at Alyth, Tayside and on water quality at Sibster Farm, Caithness, Scotland.

Species:

Water Use:	Ash	(Fraxinus excelsior L.)
	Sycamore	(Acer pseudoplatanus)
	Grass	
Water quality:	Mixed SRF species plus grass control	

Design: Water use: operational trial blocks involving 2 species and one control (grass) (3 plots). Each plot will be a 10 m X 10 m central area within main operational block, lying a minimum of 20 m from block edge. Trees planted at standard 2 m X 1 m spacing. Control plot sited at least 100 m from edge of SRF blocks.

Water quality: Two streams draining separate micro-catchments; one dominated by SRF operational trial and one a grass/arable control.

Methods:

Evaluating impact of SRF on water resources

The planned approach is to estimate species water use by monitoring changes in soil water content. Changes will be separated into evaporation (water use) and drainage by monitoring change in soil hydraulic potential gradient. Measurements will allow soil moisture deficits to be compared between species and the grass control. Interception loss will be directly measured for each SRF species using a network of recording rainfall gauges installed within each plot, which will be compared with open rainfall. Details as follows:
Soil water content: Install six soil moisture (Theta) probes (smp) at 5 cm, 10 cm, 25 cm, 40 cm, 55 cm and 70 cm depths in each of four depth transects per species and control plot. Probes inserted into face of soil pit and then back-filled.
Soil hydraulic potential: Install six tensiometers at same

depths as per smp) in one depth transect per species and control plot.
Smp and tensiometers connected to data loggers.
Interception: Install one set of 10 recording rain gauges in each species plot.
Rainfall and Penman potential evapotranspiration: Install an automatic weather station, including recording rain gauge, within control plot.

Evaluating impact of SRF on water quality at Sibster

Stream/drain water samples will be collected from the planted and control micro-catchments for full chemical analysis. More frequent sampling will be undertaken during years 1-3 and 20-22 to capture the effects of planting and harvesting. A flume will be installed in each stream plus a water level recorder to monitor the volume of runoff and allow chemical concentrations to be converted to fluxes. Gauge boards will be installed at each monitoring location in order to take manual records as a check against instrumental drift/error. Benthic macroinvertebrate population will be sampled using standard kick-sampling approach and identified to family level. This will allow the impact of any water quality changes to be assessed in terms of ecological quality.

Requirements: Area: Water use: Measurements made within a 10 m x 10 m central SRF block surrounded by a minimum buffer of 20 m (ideally 50 m). Control plot should be 100 m distant from crop/forest edge.

Water quality: catchment area of planted stream/drain should have a minimum cover of 20% SRF and preferably 50%. Remainder of land use should remain relatively unchanged during period of study. Control catchment should reflect 'typical' agricultural land use. Catchments should be >10 ha in area.

Records & Assessments: Water use: The recording resolution of the smp and tensiometers will be set at 15-minute intervals, while the interception and rainfall gauges will record the time of every event. The AWS will record hourly measurements. Data from all of these will be downloaded every two weeks.

Water quality: Water samples will be collected every fortnight for years 1-3 and 20-22 (monthly in between) and delivered by courier to Alice Holt laboratories for chemical analysis. Samples will be analysed for pH, conductivity, colour, suspended solids, turbidity, TOC, DOC, TON and all main cations and anions The water level recorders will record stage height every 5 minutes and the data will be collected every 6 weeks. Benthic macroinvertebrate samples will be taken from each stream/drain in autumn of years 1-3 and 20-22. Ideally, samples will be repeated at three-year intervals during intervening period, depending on available funding.

Statistical Analysis:

Water use: The soil water content data will be processed to give daily mean profile water content, allowing daily change to be estimated. Changes will be apportioned into evaporation and drainage using the hydraulic potential gradient data. Summer soil moisture deficits will be calculated, along with period rainfall and interception totals. The data will be compared between species and the control, as well as between years, to estimate the impact of planting SRF on evaporation/water use and water yield.

Water quality: The water chemistry data will be analysed to assess any breaches of water quality standards and to compare responses between SRF and control streams through time pre and post planting up to eventual harvesting. The water level data will be processed to provide daily discharge and used to convert chemical concentrations to period fluxes. The discharge data will also be analysed to assess any changes to water yield or to low and high flows through time. The benthic macroinvertebrate data will be compared with ecological standards to assess water status and extent of change through time.

Reporting:

Interim reports for first three years will be submitted at annual intervals giving progress to date, achievements for that period and recommendations and planned work for the next period.

Main reports will be submitted every three years detailing the methodology used, results and findings of the monitoring programme, with recommendations on further work required and actions to be taken.

	Presentation of the results will be given to relevant stakeholders and feed into review of SFS Implementation Plan. Publication of the interim and final results in a recognised hydrological and/or forestry journal at 5, 10 and end of rotation stages.
Duration & Responsibilities:	The project will run from 1st January 2009 until site is harvested at 10-22 years.
Data Storage:	Data and all associated work including reports will be stored in electronic format on personal hard drive as well as on Forest Research storage space. Hard copies of the data, results and reports will also be kept at NRS.
Collaboration:	The data will be shared with SEPA, the EA and other relevant bodies to improve understanding of impacts of SRF on water.
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Written by	Tom Nisbet
Date	5th November 2008

Appendix 1d: Recommended Methodologies for Biodiversity Monitoring of Energy Forestry

Background

Forestry commission Scotland (FCS) has acquired a number of sites on which they propose to trial on the development of energy forestry (EF) both short rotation coppice (SRC) and short rotation forestry (SRF). This will involve the planting of a range of different species managed in under a range of silvicultural practices across the sites. Understanding the potential impacts of EF on the existing biodiversity and changes to biodiversity on these may determine the species selection and management of sites. Public and political perceptions of the impacts of energy forestry on biodiversity will also be informed based on this understanding.

Aims

The overall aim of the monitoring strategy is to assess and understand changes in biodiversity on the FCS EF sites in a way that is cost effective and scientifically robust. This aim can be distilled into the following objectives:

- To assess **woodland ecosystem development** - e.g. the emergence of woodland structure, woodland habitats/micro-habitats and the presence of species that indicate that the new woodland areas are functioning as habitat

- To assess change in the **existing valued conservation features** of the site - e.g. condition of semi-natural grassland of wet habitats that could be detrimentally affected by woodland development

To provide a robust methodology that can assess changes in biodiversity on as a result of land use changes. That can monitor changes to

- Ecosystem function
- Biodiversity value of selected tree species
- Charismatic species
- Existing biodiversity value

Methods:

Ecosystem function: Syrphidae monitoring

The relationship between biodiversity and ecosystem function (the degree to which an ecosystem is working effectively) has been of interest to ecologists for some time (Shultz et al 1993). Various indicators for assessing how well an ecosystem is working have been proposed such as; indicator species, keystone species, species richness, diversity indices, functional species and functional diversity. There is continuing discussion about the effectiveness of such indicators and the most appropriate method of assessment of ecosystem function but the consensus would appear to fall in favour of the use of what are termed 'functional species groups'. Davic, R.D. 2003. (Patchley 2002)

The monitoring of the sites should assess

- A range of functional species groups representative of key woodland niches
- Temporal changes in these functional species groups
- Functional diversity within the ecosystem (site)

Key woodland niches (KWN) that represent a range of microhabitats within an ecosystem are identified with species groups representing their functionality. The assumption is that the KWN are functioning if the representative species of that niche are present. These species should have known, similar evolutionary and ecological traits (i.e. are in intraspecific competition with each other) and are grouped to form a functional species group.

The challenge is to find practical, cost effective, field methodologies that are able to measure this functionality without assessing the complete biodiversity resource within an ecosystem. The methodology is based on the premise that changes in species composition reflect changes in habitat functionality. Changes in open ground invertebrates to woodland invertebrates will indicate that the woodland structures are "functional" in the sense that they support the species that require these niches. Rather than recording changes in composition of all species, groups of species with known ecological requirements are selected to reflect ecological change. Detailed work on this has been undertaken on hoverflies (Syrphidae) and snails (Shelled Gastropoda) (Falkener et al 2000) and there is a tried and tested methodology that can be used to provide information on ecological function and change. (Spieght M. C.D., Castella E. and Ordlick, P. 2000)

Tree species biodiversity: Canopy leaf activity

A simple effective way of measuring the biodiversity value of the different selected EF species is by assessing the diversity of species found on a sample of canopy leaves. This is a rapid field assessment of biodiversity change that can be made by non-specialists. Here, absolute numbers of different signs of activity are recorded on a known unit of habitat and converted into a diversity index. Changes in the diversity index over time will used as a measure of woodland ecosystem development. The field methodologies for the evidence of activity are fairly straightforward, as they require total counts of all the different signs of activity within a defined area. It is proposed that the following are investigated within the research. The principle of this approach has been outlined by Oliver & Beattie (1993) and further developed by Angelstam and Donz-Breuss (2004). The leaf activity approach has been developed within Forest Research and used in the Scottish Forest Alliance biodiversity monitoring

- Evidence of invertebrate activity on 100 leaves of canopy branch, such as galls, leaf miners, leaf roller, spiders' webs etc.

In this way the contribution to ecosystem function that the different tree species make is assessed by its derived diversity index.

Charismatic species: Breeding bird survey

The importance of monitoring charismatic species (those that are easily recognisable and widely acknowledged as being important) cannot be underestimated as public and political perceptions are often based round the presence or absence of these species. The presence of breeding birds will highlight changes to populations of this suite of charismatic species. It is important to look at breeding birds on the sites as these are making use of the niches, structures and micro-habitats that are present as a result of EF. Therefore in a similar way to that of the invertebrates changes in bird species composition will also reflect changes in ecosystem development in those different groups of bird species have different ecological requirements. The point count method to be followed is based on the RSPB bird reserves woodland survey methodology and requires three visits to a series of randomly selected points with the birds counted for five minutes at each point. Monitoring will need to be carried out both within the EF site and the surrounding countryside to allow for comparisons to be made

Butterfly diversity and abundance will be estimated by 'butterfly walks' during weather suitable for butterfly activity. These samples should be done as often as possible (but no more than once per week) so that species only present at particular times of the year are seen. In practice, suitable weather may only occur once or twice per month. After discussions with Butterfly Conservation is proposed that this is done in collaboration with Rothamsted Research. This organisation is responsible for butterfly populations monitoring across the UK and so this would allow the EF sites to be compared directly with the general UK trends.

Existing biodiversity value: JNCC site condition monitoring for habitats present on site

Changes in the open, non wooded habitats on the EF sites will be monitored to asses changes that arise as a result of changes in management required to facilitate the development of the EF on the site. It is proposed for areas of habitat over 0.25ha that this is done using the JNCC common standards monitoring (CSM) methodologies for SSSI's of the particular habitat (available at www.jncc.gov.uk) in question in conjunction with more detailed vegetation monitoring using presence and absence mini quadrats. For smaller areas of habitat individual CSM plots should be undertaken also with the mini quadrats. The change in Syrphidae species as described for ecosystem function applies to open habitats as well as afforested areas so this methodology can also assess ecosystem function of the open habitats.

Sampling strategy

A sampling strategy will need to be devised for each site so that the variation within each site can be assesses both in terms of treatments applied and pre existing land-use and vegetation type. It is proposed that plots are located within the pre existing ecological units e.g. arable field, hedgerow, pond margins etc and within different treatments applied within these. The different methodologies outlined above should be nested within these plots. Each individual site will require its plots tailored individually to ensure the range of habitats and management practices are being monitored. This will require a pre-monitoring visit to identify these ecological units. This should be undertaken in the summer and can be undertaken post-planting since these unimproved remnants will not be planted. The pre monitoring visit is essential as based on the visit to East Grange many of these important small features of high biodiversity value within the agricultural landscape have gone unrecorded in the existing site survey. The pre monitoring visit will determine which elements of the monitoring as outlined above will be carried out on each site based on the features present on each site the geographical location of the site and the similarity of the site with other sites (both in terms of ecological and proposed management similarities). The same will be true for the bird monitoring which will a require specialist pre monitoring visit to determine the sampling strategy.

Mike Smith
3/11/08

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Syrphidae field sampling

In the case of Syrphidae, field-sampling is dependent upon collection of the flighted adults. For operating the database, sampling procedure has been standardised around use of Yellow sticky trap as the sample unit. In deciding upon the Yellow sticky trap as the standard sampling unit to use for Syrphidae, the following points were taken into consideration:

a) Analysis of results is dependent upon adequate samples of the local fauna, not a complete inventory of the local fauna,

b) The analysis procedures employed depend primarily upon use of presence/absence data

c) Ease of transport of trapping equipment to and from possibly remote sites, rapidity of installation and removal of trapping equipment and ease of servicing of equipment installed are all of primary concern,

d) Rapidity and simplicity of sample handling is important.

Placing of Yellow sticky traps.

Where and whether insects fly is determined by many factors, including climate, time of day and site topography. Basically, Yellow sticky traps can be positioned either on or off flight lines and either orientated or not along a north/south axis. Flight lines are largely dictated by local micro-topography and the location and direction of many of them can be detected by human eye, from juxtaposition of site features. Yellow sticky trap across a flight line maximises the catch of syrphids flying through a site from elsewhere (including migrators). Conversely, placing a trap off flight lines maximises the catch of syrphids engaged in local, on-site movements. Orienting a trap north/south, maximises catches of insects liable to fly towards the point of highest light intensity (i.e. the sun) on contact with a trap (i.e.heliophile, day-flying insects like syrphids). Trap alignment in a north/south direction can be achieved using a compass.

Site factors operating over short periods can also have a significant effect on trap catches, for instance a large patch of some low-growing plant which comes into bloom in the vicinity of a trap during a trapping campaign can greatly increase the number of syrphids caught. Conversely, the efficiency of Yellow sticky traps left in situ for an entire flight season (i.e. spring to autumn) can be reduced by change in the condition of the ground vegetation as the growing season progresses

In conducting a short duration (e.g. ten-day) field campaign, it might be considered self-evident that Yellow sticky traps should be positioned to obtain the maximum quantity of data in the minimum time. However, as indicated in the previous paragraph, maximising the trap catch is not necessarily synonymous with maximising the catch of species, which have developed locally, for instance, and the questions to be answered by conducting the trapping programme require to be considered carefully in deciding trap placement. In order to overcome the potential influence of trap placement on trap catch it is advisable to use traps in pairs, the two traps of a pair being placed close to each other (though sufficiently far apart that they do not interfere with each other's action) at the chosen trapping station. The degree of similarity between the catches made by two traps installed at a trapping station can be ascertained, and compared with the catches of traps from other trapping stations, to verify that the catch of a particular trap is less affected by its placement than by the character of its surrounding habitats.

The need to sample the fauna of each principal habitat type observed on-site determines the minimum number of Yellow sticky traps to be positioned there - it being advisable to place at least one pair of traps within the area occupied by each of the observed habitats in this case each plot.

Field Sampling Strategy: obtaining representative samples of site faunas

There are various factors that require to be considered in designing a fieldwork campaign aimed at obtaining a representative sample of the syrphid fauna of a site, using Yellow sticky traps. Survey aimed at inventorising the syrphid fauna of a site requires less rigorous consideration of optimal sampling periods, but is more demanding of man-power and time.

Choice of sampling period

Over most of Europe, adult syrphids are on the wing between April and September (inclusive), so sampling outside this period is not practical. Within the period April-September the various species are in flight at different times, and unless sampling can be carried out throughout that period, choice has to be made of when to sample. Most univoltine species are only in flight at the beginning of the summer, whereas polyvoltine species recur again later in the year. So, to sample univoltine species the optimal period is April/beginning June, that a second sampling campaign, in July/August, might be expected to show which polyvoltine species move into a site during the summer, though absent there earlier in the year. The periods of the year optimal for sampling can also be influenced by the type of habitat in which sampling is being carried out. For most habitats in atlantic parts of Europe, the most opportune time for sampling a syrphid fauna is end May/beginning June. However, this can be a period of very variable weather and in years in which spring is retarded the fauna is as well, reducing sample catches. Under such conditions, sampling should be postponed to mid-June, if possible. The pasture species might also reasonably be sampled through into July/August, whereas the forest species would be only half as well represented during this period as in end May/beginning June. In order to optimise a sampling programme it is necessary to have a clear understanding of which habitats in the target area are the particular objects of concern. In the event that free choice of sampling period cannot be exercised, it is necessary to take into account the flight period profile of the fauna associated with each habitat observed on site when analysing results. This can be achieved using the database.

Duration of field campaigns

A ten-day sampling period, which allows for the occurrence of flight-inhibiting weather (e.g. high wind or rain) for part of the period. Two such field campaigns, carried out within the period beginning June/end August and giving together a total of 20 days of sample collection, have similarly been taken as the minimum required to amass an adequate sample of the syrphid fauna of a target site In most circumstances the optimal timing of these two sample periods is probably June and August. At the end of each sampling period the traps should be removed and material taken for analysis.

Breeding bird survey

Should be carried over the whole site using standard methodologies The point count method to be followed is based on the RSPB bird reserves woodland survey methodology which itself was derived from Bird Monitoring Methods: a manual of techniques for Key UK species (1998) Gilbert, Gibbons and Evans and requires three visits to a series of randomly selected points with the birds counted for five minutes at each point. The only difference is that the points in each site are the monitoring plots. This will enable replication of points that are regularly spaced across sample areas to give population estimates.

The number of point counts is dependent on the size of the wood to be surveyed. It is recommended in the RSPB methodology that one point count per 5ha of woodland should be undertaken, with a maximum of 30 points per site. It is envisaged that 10-point counts per morning is feasible starting within one hour of dawn and completed by 11am (midday latest). Larger sites will be need sampled over several consecutive days or require several surveyors on the one-day. For the bird counts, three visits are required:

1st visit: 20th Mar – 5th Apr

2nd visit: 10th Apr – 3rd May
3rd visit: 10th May – 30th May

On visit 2 reverse the order in which the points are visited.

Counts should not be made in heavy rain or in strong or cold winds. Preferably conditions should be dry and mild with only light wind. Give a score for cloud, rain, wind and visibility on a scale 1 to 3, being good/clear, not so good and worse.

The birds should be allowed to settle for two to three minutes on arrival at the point. This time should be used for the surveyor to familiarize the immediate area and use a rangefinder to check the distance to prominent trees in advance of the count.

All birds that are seen or heard over a period of five minutes should be counted and entered on the standard recording form. Birds should be recorded in four distance classes: within 10 m, between 10 and 25 m, between 25 and 50 m and beyond 50 m. This distance is for the time at which the bird was first detected. It is extremely important that the distance estimation is accurate (the rangefinder should be used for checking). If birds arrive into the 10 m counting area during the 5 minutes, their numbers should be recorded in brackets so they can be distinguished during analysis. Birds flying over in the points should not be counted (but the species and numbers noted if of interest). Mark as present, in the far left column, all species detected in the wood (including those recorded during the point counts).

Vegetation monitoring programme

The objective of this vegetation monitoring programme is to compare species composition and species richness on ground and the new native woodland on the SFA sites develops, the change from open habitat vegetation to a woodland ground flora. The method described here is known as the Mini-quadrat method. A larger number of smaller quadrats are placed randomly throughout the site and the presence of each species within each quadrat is recorded. This method allows comparison of the frequency of occurrence of each species and the number of species per quadrat from one monitoring visit to the next.

The advantages of this method are that:

- There are no problems with subjectivity; there is no need to estimate plant cover values so different field workers are likely to achieve very similar results.
- There is no need to mark and relocate permanent quadrats.
- The data from randomly placed quadrats can be analysed statistically.

The disadvantages of this method are that:

- The measurement of shoot frequency can create bias in over-representation of larger species.

Monitoring methodology

The methodology below is for vegetation at each element within the site. Separate elements should be monitored separately.

1. The quadrats are not permanent but quadrat positions must be mapped, firstly so that they can be positioned truly randomly, and, secondly, so that variation between different parts of a site can be identified.
2. The locations for the sample points are ten random placed quadrats within a 12.5m radius of the plot location as supplied in arcview.
3. At each sample point, place a 100x100cm quadrat on the ground immediately in front of the right foot. The quadrat should be carefully lowered into the vegetation, avoiding pushing vegetation from outside into the quadrat area. (This can be difficult with small quadrats in tall vegetation.
4. Estimate the % coverage of litter and bare ground and measure the height of the vegetation before the vegetation is disturbed by searching for species (subjective assessments are unavoidable in the case of litter and bare ground). Measure the vegetation height in the centre of the plot using a ruler and estimate the coverage of litter (defined as a mat or thatch of dead material at the base of the sward) and bare ground. Litter and bare ground should be assessed as amounts visible from directly overhead.
5. Record all vascular plant species whose shoots are present within the quadrat area.

Data Storage

The data should be recorded in Excel spreadsheets, one for each site, with species names in the rows and quadrat numbers in the columns.

Timescale

Quadrats must be recorded at roughly the same time each year. Once the first visit has been made, subsequent visits should be made within two weeks of this date. The first monitoring visit should be made before the new grazing regime starts.

Data analysis

For each site, the frequency of occurrence of each species recorded during monitoring should be compared with that recorded during the first monitoring visit, using the Chi-square test to assess whether there has been any significant change. The number of vascular plant species per quadrat and the % cover of bare ground and of litter should be compared using the t-test.

Appendix 1d: SRF species trial

FOREST RESEARCH

[Name of Division] EXPERIMENT PLAN

Experiment Title: **ENERGY FORESTRY (SCOTLAND) - SRF SPECIES TRIAL**

Key Words: SRF, species, biomass

Background:

Renewable energy is a topic that is high on the political agenda and forestry is increasingly being seen as an important potential source of biomass for burning in heating and power installations. Much of conventional forestry is committed to producing timber on a long rotation for existing markets, so has limited availability as biomass. There is a need for a fast growing, dedicated, woody crop that can sustainably meet the biomass demand. Short rotation forestry (SRF) i.e. growing trees on a short rotation specifically to produce biomass, has the potential to make a useful contribution to renewable fuels. However, there is little current knowledge of SRF n the UK. This knowledge gap is recognised in the *Scottish Forestry Strategy* (2007), the *Scottish Government Woodfuel Taskforce Report* (2008) and the FCS *Climate Change Action Plan* (2008 -2010). All three publications indicate the need for SRF research.

Species choice for SRF is driven by the need for fast early growth of high-density timber. This tends to suggest that broadleaf species should be preferred to conifers. A suite of species has been chosen for comparison in this experiment that all show potential for matching these criteria.

To capture site growth potential over a short rotation closer spacing than would be advised for a full rotation timber crop will be used, equivalent to 5000 trees/ha. The optimum rotation length, balancing productive and economic yield, under such a system is not known, but will vary between species.

Objectives:

1. To compare the growth and biomass yield of a selection fast growing tree species.

2. To assess the optimum rotation length of each species within an SRF system.

Location: Various FCS-owned farmland sites.

Species:

Sycamore	*Acer pseudoplatanus* L.
Italian alder	*Alnus cordata* Desf.
Red alder	*Alnus rubra* Bong.
Silver birch	*Betula pendula* Roth.
Sweet chestnut	*Castanea sativa* Mill.
Ash	*Fraxinus excelsior* L.
Hybrid larch	*Larix x marschlinsii* Coaz.
Rauli	*Nothofagus procera* Oerst.
Hybrid aspen	*Populus tremula* L. *x tremuloides* Michx.
Sitka spruce	*Picea sitchensis* (Bong.) Carr.

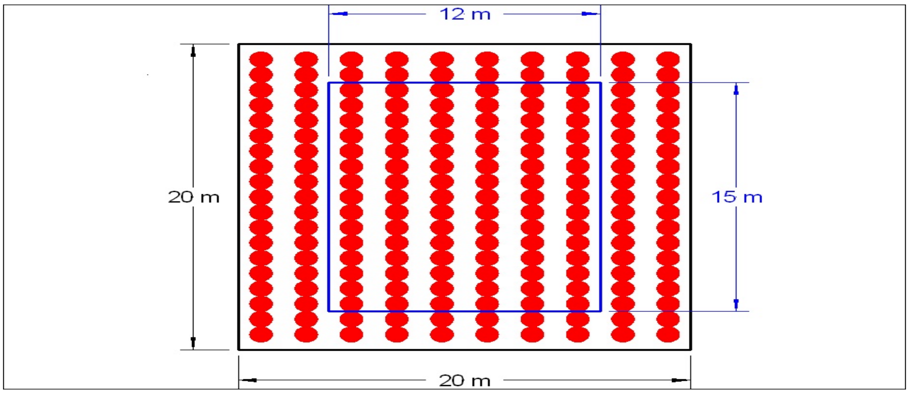
Products & Active Ingredients: No proprietary treatments used in this experiment.

Experimental Treatments:

6.	SY	Sycamore	12.	AH	Ash
7.	IAR	Italian alder	13.	HL	Hybrid larch
8.	RAR	Red alder	14.	PRN	Rauli
9.	SBI	Silver birch	15.	ASP	Hybrid aspen
10.	SC	Sweet chestnut	16.	SS	Sitka

Design: 10 species x 4 blocks = 40 plots

Plot size - each plot will be 20m x 20m in extent and be planted at 1m spacing along the rows and 2m spacing between rows, giving 200 trees per plot. The assessment plot will be the central 12m x 15m area containing 96 trees, leaving a 2 tree buffer.



Methods:

1. The site will be ploughed, harrowed and then sown with a low-productivity, dwarf rye-grass mix and managed as detailed in Ian Willoughby's recommendations

2. The 850 plants, out of a batch of at least 1200 plants for each species, will be graded within a height range of 30 - 40 cm. They will have a corresponding root collar diameter as defined in OGB29 '*Handling Plants for Successful Planting*'. The surplus plants will be retained for one year as potential beat ups.

3. Immediately prior to planting, 50 of the graded plants of each species will be retained for plant characterisation assessment. This will include height, root collar diameter, root:shoot ratio, woody:fine root ratio, REL and SEL.

4. Each plot will be planted by hand (SOP092) and consist of 10 rows of 20 plants at 1.0 m spacing along the row and 2.0 m spacing between rows. The rows will be orientated so as to run in a N - S direction to reduce intra-row shading effects. Planting will be done in February/March.

5. A 4.0 m unplanted gap will be left between blocks to aid access.

6. Immediately following planting, the 96 trees in each central assessment plot will be measured for:

   a. Stem diameter at 10 cm above ground level to the nearest 1.0 mm.

   b. Height in cm above ground level to the nearest 1.0 cm.

   This will be done as a map-form assessment, starting in the SE corner of the plot and working systematically up and down the rows to end in the top NW corner.

7. A similar assessment to '4' will be done after full tree dormancy in November/December of the planting year.

The assessment will be repeated at the same time and in the same format in subsequent years, until the minimum height of >90% of the living trees within a particular species (over all blocks) exceeds 2.5 metres. On the first assessment after this condition has been met, both stem diameter at 10cm and at breast height (1.3 m) will be measured. DBH only will be measured annually thereafter.

8. Tree damage will be recorded at the same time as height and dbh measurement, and will include shoot/branch death, development of multiple leaders, browsing animal damage and physical damage.

9. Badly damaged or dead trees will be beaten up in the spring following the first year assessment, using the surplus plants from the initial grading exercise. Beating up will only occur once; plants remaining after this will be discarded.

10. Detailed tree form assessments will be done on a sub-sample of each species every 5 years up to and including felling age. Assessments will include stem form and branching habit and will measure incremental stem diameter every 1.0 metre, straightness, branch size, angle and number.

11. Phenology (bud burst and dormancy onset to be assessed during the second and third growing seasons on the same sub-sample of trees from each species.

12. Cold damage to be assessed in two ways:

    a. Reactively, during the spring flushing period from March 15 to May 30, the sites will be visually assessed for leaf and shoot within 5 days following a forecast air frost event of -3°C or less. Actual frost level to be checked with the on-site weather station.

    b. Scale and intensity of visible leading shoot damage at the end-of-May.

13. Pest and disease monitoring - most likely to show visible symptoms of attack during mid - late summer. Therefore, conduct an annual visual check in August of each year. If any species shows significant signs of infection or infestation, then conduct a more systematic crop survey within that species to identify the level and cause of the problem.

14. Thinning 50% of plots will be considered as an future option for some or all of the species, depending upon growth rates and observed competition.

Requirements:

Area: Gross = 2.0 ha (180m x 110m)
Net = 1.6 ha.

Plants: 800 of each species listed above in '*Species*'.

Fencing: Plots within a deer/rabbit-fenced exclosure.

Statistical analysis:

	df
Blocks	3
Species	9
Residual	27
Total	39

Duration & Responsibilities: 20 years, then review.

Bibliography: See Appendix I

Drafted by: Alan Harrison

Date: 05.01.09

List of Appendices: Appendix I: Bibliography

Appendix I

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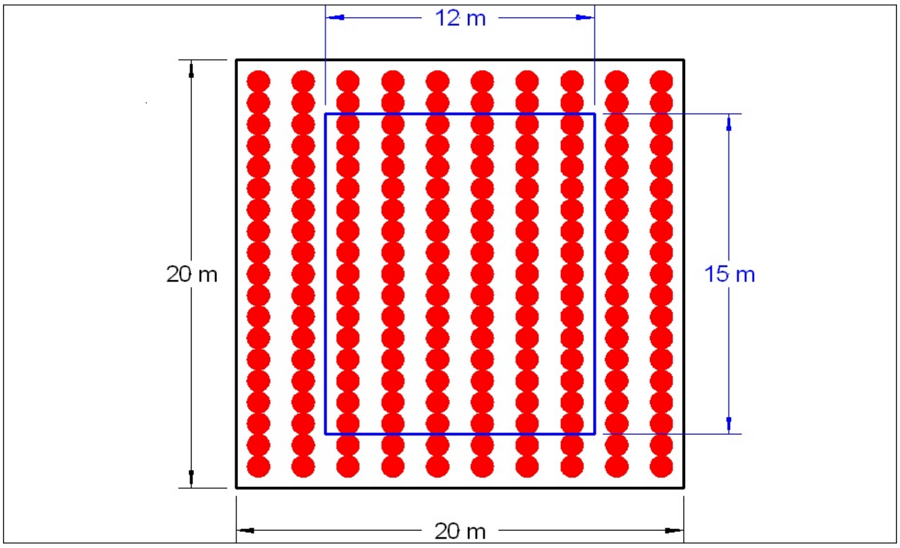
Appendix 1e: *Eucalyptus* species trial

FOREST RESEARCH

[Name of Division] EXPERIMENT PLAN

Experiment Title:	**ENERGY FORESTRY (SCOTLAND) – *EUCALYPTUS* SPECIES TRIAL**
Key Words:	SRF, species, *Eucalyptus*, biomass
Background:	Renewable energy is a topic that is high on the political agenda and forestry is increasingly being seen as an important potential source of biomass for burning in heating and power installations. Much of conventional forestry is committed to producing timber on a long rotation for existing markets, so has limited availability as biomass. There is a need for a fast growing, dedicated, woody crop that can sustainably meet the biomass demand. Short rotation forestry (SRF) i.e. growing trees on a short rotation specifically to produce biomass, has the potential to make a useful contribution to renewable fuels. However, there is little current knowledge of SRF n the UK. This knowledge gap is recognised in the *Scottish Forestry Strategy* (2007), the *Scottish Government Woodfuel Taskforce Report* (2008) and the FCS *Climate Change Action Plan* (2008 -2010*).* All three publications indicate the need for SRF research. Species choice for SRF is driven by the need for fast early growth of high-density timber. Many temperate climate *Eucalyptus* species have higher growth rates (>1.5m per year) than most, if not all, native or other non-indigenous tree species in the UK. Allied to this is an above average wood density (>450 kg/DT), making the genus a very worthwhile biomass crop. However, yield performance and survival are closely linked to climatic factors, which may be less than favourable in some more inland and elevated parts of the UK. To capture site growth potential over a short rotation closer spacing than would be advised for a full rotation timber crop will be used, equivalent to 5000 trees/ha. The optimum rotation length, balancing productive and economic yield,

	under such a system is not fully known, but existing trials suggest a period of not more than 15 years, and probably significantly less. Three species will be tested for growth and yield in this experiment. These have been chosen as being potentially among the hardiest and most productive in UK climatic conditions.
Location:	Various FCS-owned farmland sites.
Specific test conditions	N/A
Species:	Tingiringi gum — *Eucalyptus glaucescens* Maiden & Blakely. - origin: Victoria Cider gum — *Eucalyptus gunnii* Hook.f. - provenance: Glenbranter, origin: W. Mountains of Tasmania Shining gum — *Eucalyptus nitens* (H.Deane & Maiden) Maiden -two origins: 1000m Victoria 1200m NSW
Products & Active Ingredients:	No proprietary treatments used in this experiment.
Experimental Treatments:	11. GLA *E. gluacescens* 12. GUN *E. gunnii* 13. NIN *E. nitens* (NSW) 14. NIV *E. nitens* (Vic)
Design:	4 species x 4 blocks = 16 plots Plot size - each plot will be 20m x 20m in extent and be planted at 1m spacing along the rows and 2m spacing between rows, giving 200 trees per plot. The assessment plot will be the central 12m x 15m area containing 96 trees, leaving a 2 tree buffer.



Methods:

1. The site will be ploughed, harrowed and then sown with a low-productivity, dwarf rye-grass mix and managed as detailed in Ian Willoughby's recommendations (Appendix II)

2. The 850 plants, out of a batch of at least 1200 plants for each species, will be graded within a height range of 30 - 40 cm. They will have a corresponding root collar diameter as defined in OGB29 '*Handling Plants for Successful Planting*'. The surplus plants will be retained for one year as potential beat ups.

3. Immediately prior to planting, 50 of the graded plants of each species will be retained for plant characterisation assessment. This will include height, root collar diameter, root:shoot ratio, woody:fine root ratio, REL and SEL.

4. Each plot will be planted by hand (SOP092) and consist of 10 rows of 20 plants at 1.0 m spacing along the row and 2.0 m spacing between rows. The rows will be orientated so as to run in a N - S direction to reduce intra-row shading effects. Planting will be done in February/March.

5. A 4.0 m unplanted gap will be left between blocks to aid access. (see layout plan, Appendix I)

6. Immediately following planting, the 96 trees in each central assessment plot will be measured for:

   a. Stem diameter at 10 cm above ground level to the nearest 1.0 mm.

   b. Height in cm above ground level to the nearest 1.0 cm.

7. This will be done as a map-form assessment, starting in the SE corner of the plot and working systematically up and down the rows to end in the top NW corner.

8. A similar assessment to '4' will be done after full tree dormancy in November/December of the planting year. The assessment will be repeated at the same time and in the same format in subsequent years, until the minimum height of >90% of the living trees within a particular species (over all blocks) exceeds 2.5 metres. On the first assessment after this condition has been met, both stem diameter at 10cm and at breast height (1.3 m) will be measured. DBH only will be measured annually thereafter

9. Tree damage will be recorded at the same time as height and dbh measurement, and will include shoot/branch death, development of multiple leaders, browsing animal damage and physical damage. (SOP required)

10. Badly damaged or dead trees will be beaten up in the spring following the first year assessment, using the surplus plants from the initial grading exercise. Beating up will only occur once; plants remaining after this will be discarded.

11. Detailed tree form assessments will be done on a sub-sample of each species every 3 years up to and including felling age. Assessments will include stem form and branching habit and will measure incremental stem

diameter (every 1.0 metre) and straightness, branch size, angle and number.

12. Cold damage to be determined by assessing the scale and intensity of upper crown shoot damage at the end-of-May.

13. Pest and disease monitoring - most likely to show visible symptoms of attack during mid - late summer. Therefore, conduct an annual visual check in August of each year. If any species shows significant signs of infection or infestation, then conduct a more systematic crop survey within that species to identify the level and cause of the problem.

14. Thinning 50% of plots will be considered as a future option for some or all of the species, depending upon growth rates and observed competition.

Requirements:	Area:	Gross = 0.84 ha (92m x 92m), Net = 0.64 ha.
	Plants:	800 of each species listed above in '*Species*'.
	Fencing:	Plots within a deer/rabbit-fenced exclosure.

Duration & Responsibilities:	15 years, then review.
Drafted by:	Alan Harrison
Date:	06.01.09
List of Appendices:	Appendix I: Bibliography

Appendix I

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Appendix 1f: SRF spacing trial

FOREST RESEARCH

[Name of Division] EXPERIMENT PLAN

Experiment Title:	**ENERGY FORESTRY (SCOTLAND) – SRF SPACING TRIAL**
Key Words:	SRF, Nelder, ash, birch, biomass
Background:	Renewable energy is a topic that is high on the political agenda and forestry is increasingly being seen as an important potential source of biomass for burning in heating and power installations. Much of conventional forestry is committed to producing timber on a long rotation for existing markets, so has limited availability as biomass. There is a need for a fast growing, dedicated, woody crop that can sustainably meet the biomass demand. Short rotation forestry (SRF) i.e. growing trees on a short rotation specifically to produce biomass, has the potential to make a useful contribution to renewable fuels. However, there is little current knowledge of SRF n the UK. This knowledge gap is recognised in the *Scottish Forestry Strategy* (2007), the *Scottish Government Woodfuel Taskforce Report* (2008) and the FCS *Climate Change Action Plan* (2008 -2010*).* All three publications indicate the need for SRF research. Initial tree spacing has a significant effect upon the subsequent growth and form of a tree crop. With SRF, to capture site growth potential over a short rotation, closer spacing than would conventionally be used for full rotation timber crop has been assumed, equivalent to 5000 trees/ha. The optimum rotation length, balancing productive and economic yield, under such a system is not fully known, but is expected to be no more than 20 years. In this experiment, in order to test the effects on growth and yield over a wide range of spacings in a limited area, a series of 'Nelder' plots will be established (See Appendix I for a summary of the method). Two species of trees, ash and silver birch, will be tested in this way, as these species are considered to be among the most likely candidates for

	SRF in Scotland.
Objectives:	3. To examine the effect of initial tree spacing upon the growth and biomass yield of ash and silver birch. 4. To assess the effect of spacing on the optimum rotation length of each species within an SRF system.
Specific test conditions:	N/A
Species:	Ash *Fraxinus excelsior* L. Silver birch *Betula pendula* Roth.
Products & Active Ingredients:	No proprietary treatments used in this experiment.
Experimental Treatments:	Each species considered independently at variable spacing
Design:	4 replicates of Nelder quadrant design per species. <u>Plot layout</u> - see Appendix I The progressive spoke spacing design will be used as shown in Diagram 2. <u>Plot size</u> - each plot will fit within a 25m x 25m square.
Methods:	1. The site will be ploughed, harrowed and then sown with a low-productivity, dwarf rye-grass mix and managed as detailed in Ian Willoughby's recommendations. 2. The 500 plants required for each species will be graded within a height range of 30 - 40 cm out of a batch of at least 800 plants. They will have a root collar diameter of >5.0 mm (John Purse, Prima Bio, pers. com.) 3. Each plot will be planted by hand (SOP092), accurately laid out according to the approved Nelder design (Appendix I). Each Nelder fan quadrant will be positioned so that its focus is located in the NE corner of

a plot square whose sides are orientated N - S, E - W, thus with the fan opening to the SW.

4. A 4.0 m unplanted gap will be left between plots to aid access and avoid between plot interaction.

5. At planting, the trees will be measured for:

   a. Stem diameter at 10 cm above ground level to the nearest 1.0 mm.

   b. Height in cm above ground level to the nearest 1.0 cm.

6. This will be done as a map-form assessment, starting at the NE focus point of the plot and working systematically along each Nelder spoke working from N to S.

7. A similar assessment to '4' will be done after full tree dormancy in November/December of the planting year. The assessment will be repeated at the same time and in the same format in subsequent years, until the minimum height of >90% of the living trees within a particular species (over all blocks) exceeds 2.5 metres. Once this condition has been met, stem diameters will be measured at breast height (1.3 m) annually thereafter.

8. Tree damage will be recorded at the same time as height and dbh measurement, and will include shoot/branch death, development of multiple leaders, browsing animal damage and physical damage.

9. Non-destructive, detailed tree form assessments will be done on a sub-sample of each species every 5 years up to and including felling age. Assessments will include stem form and branching habit and will measure incremental stem diameter (every 1.0 metre) and straightness, branch size, angle and number.

10. Phenology will be visually examined in spring of the second year to see if there is any indication of a shelter interaction with spacing that is giving rise to differential

	flushing. If this is apparent, a more detailed assessment will be devised.
Requirements:	Area: Gross = 0.54 ha (92m x 92m), Net = 0.32 ha. Plants: 500 of each species listed above in '*Species*'. Fencing: Plots within the intensive area, deer/rabbit-fenced exclosure.
Records & Assessments:	As per relevant SOP's.
Statistical analysis:	As per Nelder (1962)
Duration & Responsibilities:	15 years, then review.
Bibliography:	See Appendix II
Drafted by:	Alan Harrison
Date:	07.01.09
List of Appendices:	Appendix I: Nelder plot design Appendix II: Bibliography

APPENDIX I: NELDER PLOT DESIGN

Nelder plots are named after their originator, J. A. Nelder (1962), who developed the system to test the spacing of vegetable crops at Rothampstead. They provide a systematic way of testing the effects of wide range of plant spacing in a confined area. Various designs of Nelder plots exist, but they basically fall into two categories:

1. Where the spacing along the radiating spokes of the plot is fixed, and therefore the only variation in spacing is achieved through the divergence of the spokes out from the centre (Diagram 1).

2. Where the spacing along the radiating spokes varies progressively, either arithmetically or geometrically, so that spacing variation depends upon both spoke divergence form the centre and the distance out from the centre along each spoke (Diagram 2).

By complex statistical analysis, the interaction between spacing and assessed factors can be determined.

Considerations

- A small number of tree deaths in this type of design can cause major analytical problems, therefore, Nelders must be planted, protected and maintained to a high standard.

- When using Nelder fans, as in Diagrams 1 & 2, in order to avoid differential shading effects between plots, all fans should be orientated in the same direction.

- The outermost spokes and those trees on the edge of the inner and outer arcs are effectively a buffer zone. Assessment needs to be confined to the trees within these boundaries.

- To maximise their usefulness, the spacing range of greatest interest should be decided before designing the plot. This should form the central portion of the layout and should also display the highest degree of 'rectangularity', i.e. distances between trees along and between the spokes should be close to that in a preferred square layout.

  E.g. In Diagram 2, it has been assumed that the range of interest is between 1.0 and 2.0 metres. Therefore the region of greatest rectangularity has been designed to be between these spacings along the spokes.

The actual type and layout of the design that will be utilised requires further discussion with statisticians. Both have merit; the fixed design would test variations in within row spacing relative to rows spaced 2.0 metres apart, and the progressive design would test variations in square plant spacing from 1.0m x 1.0 metre to 2.0 x 2.0. Diagram 1:

Fixed spoke spacing design - 2.0m

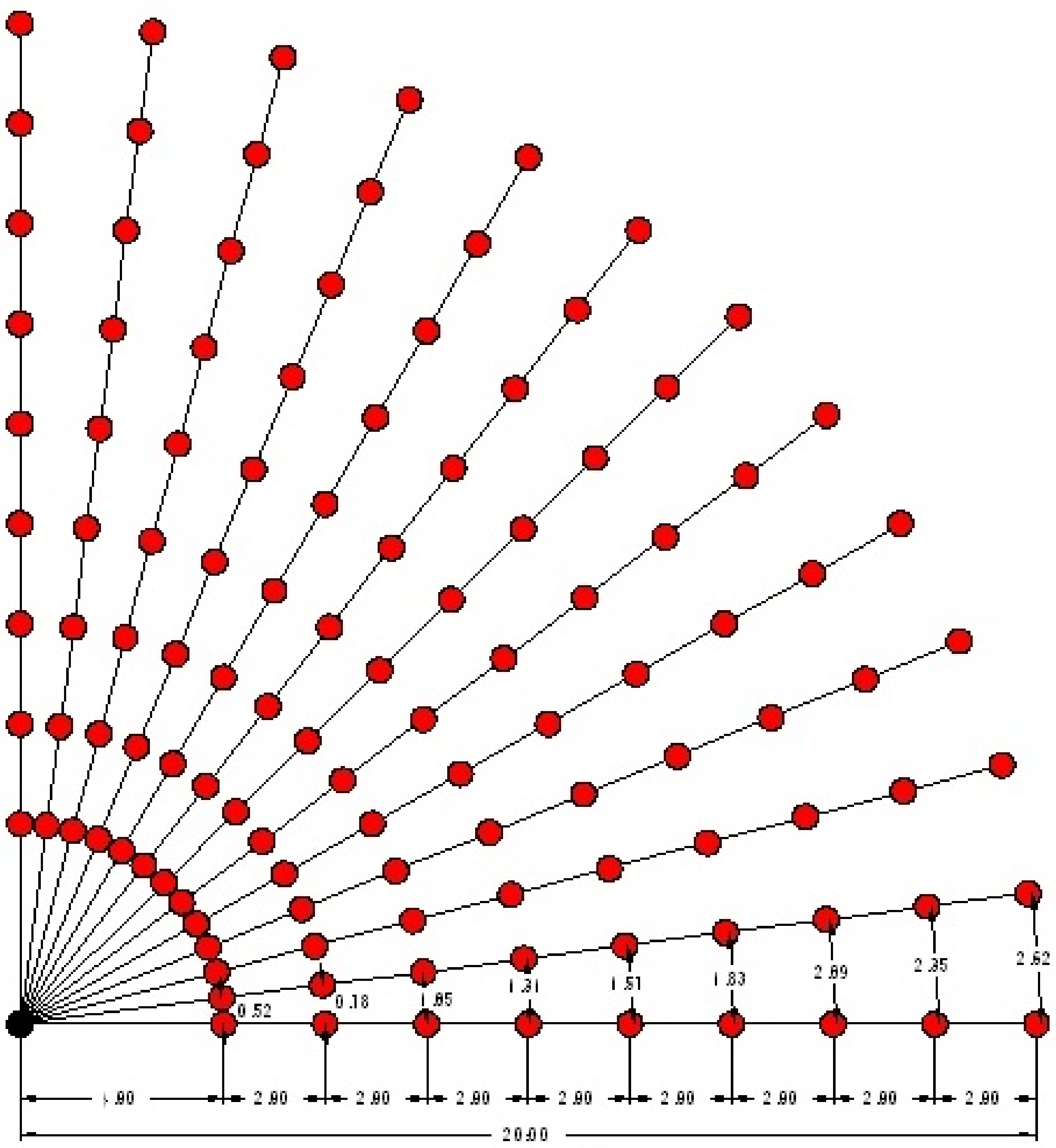
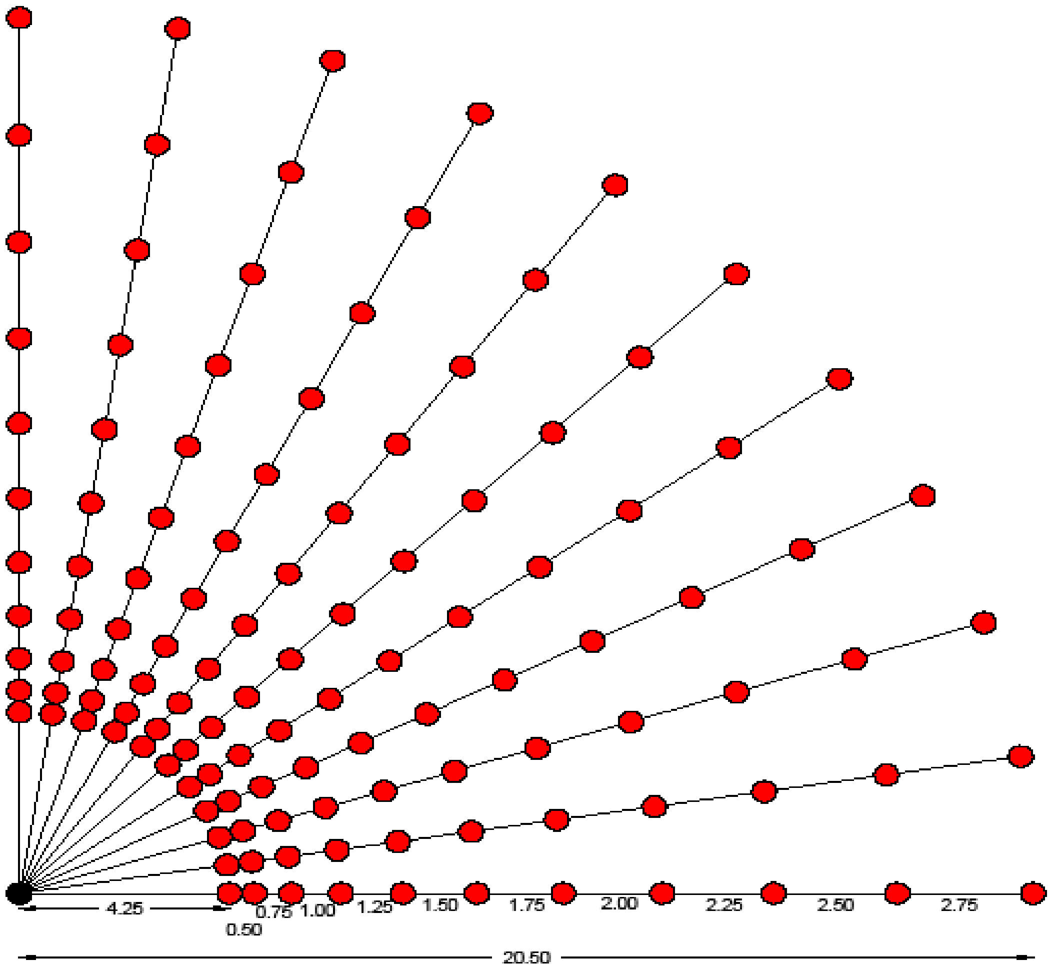
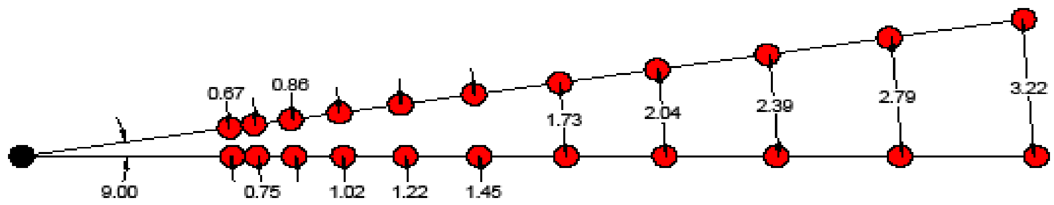


Diagram 2: Progressive spoke spacing design - increment 0.25m, start 0.5m, finish 2.75m.





Appendix II

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Appendix 1g: Establishment and Maintenance Studies

FOREST RESEARCH
TECHNICAL DEVELOPMENT WORK PLAN

Work Title: Energy Forestry (Scortland) – Establishment and Maintenance Studies

Key Words: Energy Forestry, Short Rotation Forestry, Output, Cost, Establishment, Maintenance.

TD Resource Control Number: 1200A/30/08.

Background: Short rotation forestry (SRF) i.e. growing trees on a short rotation specifically to produce biomass, has the potential to make a useful contribution to renewable fuels. However, there is little current knowledge of SRF in Britain. This knowledge gap is recognised in the *Scottish Forestry Strategy* (2007), the *Scottish Government Woodfuel Taskforce Report* (2008) and the FCS *Climate Change Action Plan* (2008 -2010*).* All three publications indicate the need for SRF research.

Forestry Commission Scotland (FCS) are establishing large scale trials of SRF to inform knowledge of methods, yields, and operations. As part of this research Technical Development will carry out time study on operations to determine output and cost information, as well as recording information on energy balance for producing fuel from SRF (covered by a separate plan: Work Plan Number *TD SRF 2*).

Two distinct site strata are present where establishment will take place at the FCS East Grange SRF site: i.) Former grazing pasture and ii.) Former agriculturally cultivated land, previously cropped with Barley. Separate studies will be carried out on these two areas.

If there is a need for pesticide application and/or mechanised weeding independently of the planting operation these will be studied as separate operations.

Time study will be carried out on the *Keen Planter* planting machine provided by contractor (Brian Keen) as appointed by Scottish Woodlands.

Objectives:

1. Complete formal time study for Short Rotation Forestry establishment within FCS EF site East Grange for planting and weeding operations.
2. Complete a hardwood planting study and a conifer planting study on each site type, with similar species composition if possible.
3. Comment on operational efficiency of establishment systems studied and, where appropriate suggest method improvements in the interests of efficiency, efficacy and health and safety.
4. Record stocking density of planting (using OGB 4 assessment procedure), plant spacing within and between rows and angle of plant placement in the rip.

Location: East Grange, Scottish Lowlands FD.

Specific test conditions

Trial site where time study will be carried out will be homogenous in terms of ground conditions and slope, these site characteristics will be recorded as part of the study.

Species: Mixed – made up of 7 species depending on site applicability as defined by ESC. Species choice composed of: Ash (*Fraxinus exccelsior*), Aspen (*Populus tremula*), Japanese/hybrid larch (*Larix kaemferi/x marschlinsii*), Silver birch (*Betula pendula*), Sitka spruce (*Picea sitchensis*) and Scots pine (*Pinus sylvestris).*

Products & Active Ingredients: Standard forestry pesticides, to be specifically identified during operational trials.

Work Treatments: Two distinct site strata are present where establishment will take place at East Grange: i.) Former grazing pasture and ii.) Former agriculturally cultivated land, previously cropped with Barley. Separate studies will be carried out on these two areas.

Design: This time study will not use statistical design to validate results. Conclusions will be based on Work Study observations and a description of planting density.

Methods: The trial will be conducted in the following chronological order:

SITE CRITERIA

The site will be viewed prior to the study to select a study area with the most uniform conditions (that can reasonably be expected on a large-scale trial site). The study site will have uniform site conditions (slope, ground conditions), good access for machinery, no specific obstacles, hazards or constraints that will affect the study.

Ground Conditions, Roughness, Slope using Forestry Commission Terrain Classification procedure as defined in Forestry Commission Forest Record 114: Terrain Classification will be measured.

Soil type using FC Field Guide The Identification of Soils for Forest Management will be recorded.

Due to the division of land use type at East Grange of previously cultivated agricultural land (sown with Barley) and land previously established as pasture, separate studies will be carried out on these different areas to compare effects of former land use on establishment outputs.

Species planted and size of trees used will be recorded for each study.

PLANTING

The SRF planting stock will be mechanically planted in single rows to a predefined spacing (to be confirmed by FCS, as specified in the establishment contract with Scottish Woodlands).

Time study of the mechanised planting will be carried out to standard work study principles. The following elemental breakdown will be used in the time study:

Cyclic Elements	Other Work Elements
Planting row	General Preparation
Turning	On/Off Protective Clothing
Load up with trees	Avoidable Delay
Clear build up of mud from machine	Unavoidable Delay

*	Rest and Personal
	Wait/Talk to TD
	Inspect
	Maintenance
	Refuel

* Additional Cyclic work elements to be added to study by the studyman as they occur as part of the work cycle.

Operator competency will be assessed through the planting density and uniformity achieved and observations made during the time study by the studyman.

MEASUREMENTS

After planting the following measurements will be made:
Total area established, calculated by site plan measurements taken by measuring wheel and compass bearings.
Plant density per hectare (using OGB 4 assessment sampling protocol) including a record of species.
Plant spacing within rows.
Plant spacing between rows.
Angle of plants in the planting rip in relation to the ground surface of trees sampled within the OGB 4 plots.
Size of planted trees by species.

Basal Treatments: No basal treatment. Study is complete when the studyman has assessed the planting.

Requirements:

- Area required for experiment (gross and net): NA – studies based on output per day.
- Plants (or seeds) – FSC.
- Treatment products – FSC.
- Basal treatments – FSC.
- Specific equipment / machinery needed – Data logger , stopwatch, backup stopwatch, clipboard, study recording sheets, compass, loggers tape, measuring callipers, measuring wheel, spray marker paint, waterproof notebook.
- Other materials/chemicals, N/A.

Records & Assessments: The following variables will be measured:

- Mechanised planting outputs using recognised Time Study

methodology with elemental breakdown.
- Plant stocking density using 0.01 ha plots as per OGB 4 methodology.
- Species.
- Ground Conditions, Roughness, Slope using Forestry Commission Terrain Classification procedure as defined in Forestry Commission Forest Record 114: Terrain Classification.
- Soil type using FC Field Guide The Identification of Soils for Forest Management.

Statistical analysis: No statistical analysis to be carried out. Time Study results will be indicative only – representative of the case study information gathered.

Duration & Responsibilities: Project to commence April 2008. Initial project planning and organisation managed by Duncan Ireland. Work plans completed by mid November 2008.

Time study and field measurements to be assessed by Bill Jones during November/December 2008.
Time study findings to be written up as a TD Internal Project Information Note by end FY 2009.

TD to provide support to the energy forestry trials through formal time study of operations commencing with establishment operations, through to harvesting.

This plan period covers the establishment phase of the operations. Future TD time study of management operations associated with the EF trials will be covered by separate work plans.

Relevant approvals: PPE must have relevant EN standard approval.
Equipment requires appropriate CE marking.

Health and Safety: The TD Study Safety and Contract Procedure will be used.
Lone working will be managed through TD 'CRISIS' system.
Outline Risk Assessment to be obtained from FCS and specific contractors.
Time study to be covered by a Job Risk Assessment completed in advance of study being carried out.

Drafted by: Duncan Ireland.

Date: 17/11/08

Appendix 1h: Energy Balance Assessment

FOREST RESEARCH

TECHNICAL DEVELOPMENT WORK PLAN

Work Title: Energy Forestry Trials – Energy Balance Assessment

Key Words: Energy Forestry, Short Rotation Forestry, Output, Cost, Establishment, Maintenance.

TD Resource Control Number: 1200A/30/08.

Background: Short rotation forestry (SRF) i.e. growing trees on a short rotation specifically to produce biomass, has the potential to make a useful contribution to renewable fuels. However, there is little current knowledge of SRF in Britain. One aspect of SRF where there is currently a lack of information is in the overall energy balance of the operation in terms of fuel use and Greenhouse Gas emissions.

Forestry Commission Scotland are establishing large scale trials of SRF to inform knowledge of methods, yields, and operations. FC Technical Development will gather information on fuel and pesticide use in order to increase understanding of the energy inputs required to establish a SRF crop.

As part of this research Technical Development will carry out separate time study measurements on operations to determine operational outputs and costs (covered by a separate plan: Work Plan Number *TD SRF 1*).

Objectives:

1. Collect figures of fuel use for SRF establishment, as measured by computerised management system on tractor or by manual tank dipping and refilling to a known level or full tank for each study carried out. Ensure start and finish values are known for each study area.
2. Fuel use to be measured against outputs during time study and area established.
3. Record type and volume of pesticide used during each establishment study.

   Data on fuel use for SRF establishment to be presented in raw format in litres used per time studied per area covered.

Location: East Grange, Scottish Lowlands FD.

Specific test conditions: Trial site where time study will be carried out will be homogenous in terms of ground conditions and slope. Site characteristics and working methods will be recorded as part of the study, as well as constraints on working methods such as one-way working due to slope conditions.

Species: Mixed – made up of 7 species depending on site applicability as defined by ESC. Species choice composed of: Ash (*Fraxinus exccelsior*), Aspen (*Populus tremula*), Japanese/hybrid larch (*Larix kaemferi/x marschlinsii*), Silver birch (*Betula pendula*), Sitka spruce (*Picea sitchensis*) and Scots pine (*Pinus sylvestris).*

Products & Active Ingredients: Standard forestry pesticides, to be specifically identified during operational trials and quantities of concentrate and diluted pesticide applied will be recorded.

Work Treatments: Operation: Establishment of SRF crop for energy forestry using tractor trailed planting machine.
During establishment fuel use of the tractor will be measured.

Design: This time study will not use statistical design to validate results. Conclusions will be based on Work Study observations and a measured quantity of fuel and pesticide used during the establishment operation.
Figures of fuel use will be presented as raw data giving amount of fuel & pesticide used over a given time and area studied.

Methods: The trial will be conducted in the following chronological order:

SITE CRITERIA

The site will be viewed prior to the study to select a study area with the most uniform conditions (that can reasonably be expected on a large-scale trial site). The study site will have uniform site conditions (slope, ground conditions), good access for machinery, no specific obstacles, hazards or constraints that will affect the study.

Site criteria will be recorded as described in Work Plan *TD SRF 1*.

FUEL CONSUMPTION

At the end of the study period fuel consumption will be assessed either by assessing the flow rate recorded by the tractor's computer or by refilling the tractor tank to a known level e.g. to full capacity or to a known level established at the start of the study period by tank dipping.

The measured area planted and study duration will show fuel and use for a given area and time.

PESTICIDE APPLICATION

The type and volume of pesticide applied at establishment will be recorded as product application rate and volume sprayed (figure to be taken from the tractor volume management spray box).

Basal Treatments: No basal treatment. Study is complete when the studyman has assessed the fuel use of the operation.

Requirements:

- Area required for experiment (gross and net): NA – studies based on output per day.
- Plants (or seeds) – FSC.
- Treatment products – FSC.
- Basal treatments – FSC.
- Specific equipment / machinery needed – Data logger ,clipboard, study recording sheets, waterproof notebook, dip stick for tank dipping (if required should tractor not measure fuel use independently).
- Other materials/chemicals, N/A.

Records & Assessments: The following variables will be measured:

- Fuel use in litres for area established over a day of treatment.
- Quantity of pesticide used for establishment of known area; as undiluted concentrate and diluted solution.

Statistical analysis: No statistical analysis to be carried out. Fuel and pesticide use to be presented as raw data in study report.

Duration & Responsibilities: Project to commence April 2008. Initial project planning and organisation managed by Duncan Ireland. Work plans completed by mid November 2008.

Time study and field measurements to be assessed by Bill Jones during November/December 2008.
Time study findings to be written up as a TD Internal Project Information Note by end FY 2009. Fuel use and pesticide quantity data to be included in study IPIN from work plan *TD SRF 1*.
TD to provide support to the energy forestry trials through formal time study of operations commencing with establishment operations, through to harvesting.
This plan period covers the establishment phase of the operations. Future TD time study of management operations associated with the EF trials will be covered by separate work plans.

Relevant approvals: PPE must have relevant EN standard approval.
Equipment requires appropriate CE marking.

Health and Safety: The TD Study Safety and Contract Procedure will be used.
Lone working will be managed through TD 'CRISIS' system.
Outline Risk Assessment to be obtained from FCS and specific contractors.
Time study to be covered by a Job Risk Assessment completed in advance of study being carried out.

SOPs: No relevant SOPs. Time study to be carried out in accordance with formal TD study procedure.

Location of records:

- Paper folder kept at Ae, Library, fireproof cabinet, plan folder FR08XXX
- Electronic folder stored at Ae, PCRUG09: C:\MyDocuments\PROJECTS\Projects 2008-2009\SRF Evaluation Trials.

Drafted by: Duncan Ireland.

Date: 17/11/08

Appendix 2: TIMING OF RESEARCH INPUT

SRF RESEARCH TIMING	Baseline	Establishment	Growth	Harvest & Utilisation
	Yr 0	Yr 1 - 3	Yr 4 - (10) 15 (20)	Yr (10) 15 (20)
ENVIRONMENT:				
Basic site data				
Soil survey + sampling				
Hydrology				
Biodiversity				
SILVICULTURE:				
Specialist plant supply				
Growth rate				
Spacing				
Phenology				
Nutrition				
Health monitoring				
Yield				
CARBON BALANCE (linked to all the abve)				
TD operational studies, including fuel usage.				
ECONOMICS				
TD studies, including operational cost, product type, quality and value.				

SRC RESEARCH TIMING	Baseline	Establishment	Growth	Harvest & Utilisation
	Yr 0	Yr 1	Yr 2 - 4	Yr 4
ENVIRONMENT:				
Basic site data				
Soil survey + sampling				
Hydrology				
Biodiversity				
SILVICULTURE:				
Growth rate				
Nutrition				
Health monitoring				
Yield				
Regeneration				
CARBON BALANCE (linked to all the abve)				
TD operational studies, including fuel usage.				
ECONOMICS				
TD studies, including operational cost, product type, quality and value.				

Appendix 3:

OUTLINE BASAL VEGETATION MANAGEMENT RECOMMENDATIONS FOR THE FOREST RESEARCH SCOTTISH SRF PLOTS ON FERTILE, LOWLAND SITES:

Spring 2009 – spray off existing vegetation, prepare seedbed,

Sow low productivity grass sward (use dwarf rye grass). Cut 1-2 times through growing season to encourage establishment.

Alternatively, sow low cost grass / wildflower sward (see Emorsgate seeds http://www.wildseed.co.uk/ for options, go for low cost mix heavy on species such as ox eye daisy that will persist in unmanaged swards). Hay cut (+ ideally remove) in September.

All of the above operations should be sub contracted to an agricultural specialist, e.g. local farmer.

September 2009 – spray out 1.2m wide planting lines using glyphosate.

Winter 2009 – plant

January 2010 – if planting is complete by mid January, if application of herbicide can be made **before the end of January**, apply a tank mix of 3.75 l/ha Kerb Flowable or equivalent (propyzamide) + 2.0 l/ha Flexidor (isoxaben) along 1.2m wide clean planting lines (if overwintering herbaceous species persist, add glyphosate to mix and ensure spray is directed).

If planting is not completed by mid January, apply a tank mix of 2.5 l/ha Butisan (metazachlor) + 3.75 l/ha Stomp (pendimethalin) in early March along 1.2m wide clean planting lines (if overwintering herbaceous or grass species persist, add glyphosate to mix and ensure spray is directed).

Spring / summer 2010 – monitor site AT LEAST every 4 weeks, and react promptly if seedling weeds start to reinvade. Options for selective control include cycloxydim, clopyralid, asulam and metazachlor – I am happy to advise as necessary.

Winter 2011 – if site is dominated by grass, apply propyzamide and isoxaben as before. If herbaceous species are present, apply add glyphosate to the mix and ensure sprays are carefully directed.

Spring / summer 2011 – as 2010

2012 – 2013, consider if further weeding is necessary following the same general prescription as above.

All the above may need to be modified depending upon what mother nature throws up.

Tree guards – as a minimum, all trees should be fitted with vole guards after planting.

Pendimethalin and isoxaben are on the FSC so called 'highly hazardous' list, and the status of propyzamide is being reviewed. The herbicides are still perfectly safe, and legal to use in the UK, and my understanding is that they can be used on research plots without affecting FC certification.

Ian Willoughby
Forest Research

24.12.08
