Forestry Commission Scotland

Energy Forestry Exemplar Trials

Annual Update Report

March 2010

Energy Forestry Exemplar Trials

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SUMMARY OF ACTIVITIES

Forestry Commission Scotland (FCS) and Forest Research (FR) initiated the network of Energy Forestry (EF) exemplar sites in September 2007. We have developed a programme of work to address the important information gaps on the growth and development of Short Rotation Coppice (SRC) and Short Rotation Forestry (SRF) in Scotland. The sites are also a practical, operational, demonstration of the potential for SRF and SRC. We will be use these exemplar sites to highlight the opportunities for these new crops to foresters and farmers.

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.

FR worked closely with FCS district staff to develop broad proposals for both research and operational practice, which were published in spring 2008. During 2009, FR then developed detailed proposals to look at the key research areas: environment, silviculture, carbon balance and economics. Six trial sites, spread throughout Scotland, were originally envisaged; five are now agreed and a sixth is close to selection. Over the last year FCS has planted 3 of the sites and FR have started work on gathering data from all the sites. The research plots will be planted by TSU this spring.

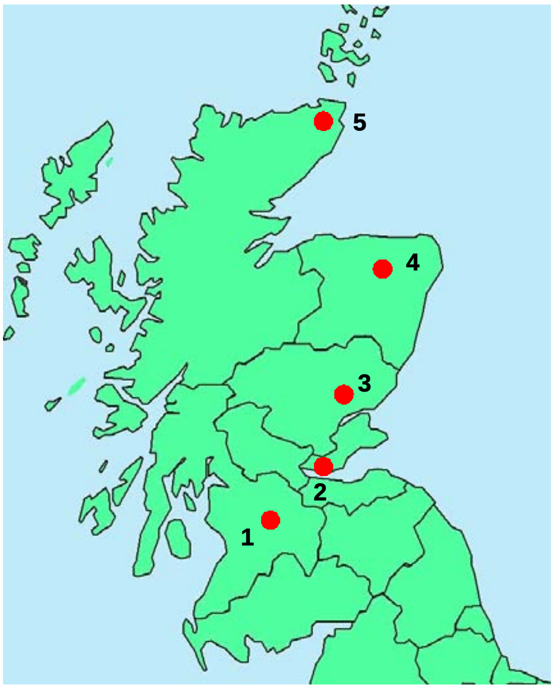
We have already begun to disseminate the information from the sites with the first seminar on the Energy Forestry network in Stirling in 2009. This unique network of research sites offers great opportunities for collaboration and SNH have funded additional research to complement and extend FR's biodiversity monitoring.

Over the last year, we have already gathered useful data and have taken advantage of new opportunities to enhance the work programme. The severe winter has had the upside of providing an extreme test of the resilience of different varieties of eucalytpus – including a fortuitous new hybrid. We have also had the opportunity to source some seed stock from similar trials in Lativa, bringing an international angle to the work. The work study data, which we have collected over the last years, already gives us realistic and practical information on the economics of these new crops.

This report summarises the progress made during 2009 and up to the end-of-March 2010, and gives an indication of the programme for the coming year, 2010/11.

2. ESTABLISHING THE TRIAL SITES

The five confirmed sites are listed below, all on former agricultural sites acquired by FCS for new woodland planting FCS is in the process of establishing the whole of these sites and this should be completed in spring 2011. The map shows that the sites to date have an easterly bias, so we have been looking at options to address the gap. Mull is actively being considered as the location for a sixth and final site. However, because of the lack of new planting ground in this region, the site will be on restock and will be confined to planting just the research plots element of the trials. As much of the available SRF land is likely to be restock, the trial on Mull will be a very useful addition to the network and an interesting comparison with the other new-planting locations.



1. Auchlochan, Scottish Lowlands FD
2. East Grange, Scottish Lowlands FD
3. Alyth, Tay FD
4. S. Balnoon, Moray & Aberdeenshire FD
5. Sibster, North Highland FD

On most sites, research on the operational areas is combined with a research plot to carry out detailed monitoring. FR will be planting the research plots this spring, with Auchlochan and the site on Mull to follow in spring 2011. However, The severe weather this winter has pushed the establishment operations until April.

Individual site details follow:

- **Sibster**

FCS put this site to barley in spring 2009, undersown with dwarf rye-grass, the intention being to crop the ground while leaving an emergent, low-maintenance grass sward after harvesting. This has been successful and has provided a potentially easily maintained site. The research area has been fenced and laid out ready for band herbicide treatment of the planting rows and subsequent direct planting.

Barley and undersown rye-grass.

- **South Balnoon**

During 2009 the deer-fenced broadleaf area at S. Balnoon, planted in spring 2008, suffered greatly from weed (primarily grass) competition. Allied to this, a rapid rise in the field vole population caused significant stem damage to most planted species, but in particular the ash and sycamore. The recent hard winter and snow cover has dramatically increased the level of vole damage such that >50% of the planting seems likely to fail. This makes the area of little value as an SRF trial, but is a salutary lesson in the weed control and protection needed for broadleaf planting on ex-agricultural land.

Most interestingly, the small area (~0.2 ha) of eucalypts within the broadleaf area, has not suffered any vole damage. This finding is backed up from other sites and sources. However, deer and rabbits are not so fussy, so other protection issues remain.

Initially, two eucalypt species were planted in 2008: *E. gunnii* and *E. dalrympleana*. Also present, by 'chance', were a small number of what we now believe to be *E. gunnii x nitens* hybrids. During their first winter, 2008/09, all the *E. dalrympleana* were killed by temperatures that were between -10°C and -15°C. The *E. gunnii* and the hybrids survived. The recent winter, 2009/10, saw temperatures plummet to at least -15°C. Despite this, >90% of the remaining eucalypts have survived, again including the hybrids. Survival, no doubt, was helped by the deep snow cover, but is nevertheless encouraging. The productive and economic potential of a hybrid that combines that hardiness of *E. gunnii* with the vigour and form of *E. nitens* is clearly worth further consideration.

It was not initially possible to include research plots at S. Balnoon. Purchase of an extension to S. Balnoon has now provided the opportunity to put the plots in, so we can get comparable data across all the sites. This area has been fenced, but due to its late acquisition and thus an inability to prepare the site as the others have been, the area will be cultivated by shallow agricultural plough, with trees planted into the plough ridges. This will give us an initial benefit against the anticipated rapid grass growth.

New intensive trial area at Balnoon.

- **Alyth (Westfield)**

The whole SRF/quality broadleaf area was completely ploughed and harrowed in spring 2009, and then sown with low productivity grass. This will be band-sprayed with herbicide and the trees planted direct, by machine in the operational areas and by hand in the research plots, this spring. The species in the operational area include ash, sycamore and silver birch. Landscaping concerns forced a move of the research plots from the first choice field to a slightly smaller, but still adequate, one.

Ploughed and harrowed site at Alyth

➢ **East Grange**

FCS planted the operational areas of East Grange, including SRC, in spring 2009 by machine. This has proven very effective and current survival is >90%. The range of species includes pine, larch, silver birch, ash, oak and aspen, with the broadleaves planted at ~4,500 plants per hectare, therefore potential for both SRF and quality broadleaf production.

The SRC was planted relatively late in May, but established well, and weed control has been good. By the end of the year, many stems were approaching two metres high. The maiden cut was done at the end of February 2010 and appeared to go smoothly.

The research area was ploughed, harrowed and sown with low-productivity grass, as at Alyth, in early summer 2009. The area has been deer-fenced, is laid out and ready for planting.

➢ **Auchlochan**

This site is still in the process of final planning, however, FR have agreed an area for the research trial with FCS. This will be deer fenced and the ground prepared similarly to the other sites, in preparation for planting in 2011.

3. PLANT SUPPLY

Plants for the research plots have been specifically grown and sourced by FR's Technical Support Unit during 2009 to ensure uniformity across the trial sites.

No source has been found for either seed or plants of *Nothofagus* this year. However, we are pursuing this through Kew Millenium Seedbank and their contacts in Chile, to see if this winter (their summer) has been a good seed year. If seed can be obtained, the species will be added to all the trials next year.

We were able to obtain the hybrid aspen from Latvian Forest Research, comprising equal numbers of 10 clones. These will be planted on all sites as replicated species blocks. The same clones are also planted as trials in Latvia, enabling a potentially useful future comparison with Scotland in growing what the Latvians consider to be some of their most productive clones. This will show how transferable productivity is between climatic zones and hence the species adaptability.

The table below shows the species, source and plant type:

Species	Common Name	Source	Plant Type
Acer pseudoplatantus	Sycamore	Delamere	Container
Alnus incana	Italian alder	Delamere	Container
Alnus rubra	Red alder	Delamere	Container
Betula pendula	Silver Birch	Delamere	Container
Castanea sativa	Sweet chestnut	Greenhills	Bare-root
Eucalyptus glaucescens	Tingiringi Gum	Silvigen	Container
Eucalyptus gunnii	Cider Gum	Delamere	Container
Eucalyptus nitens	Shining Gum (Vic)	Silvigen	Container
Eucalyptus nitens	Shining Gum (NSW)	Bush	Container
Fraxinus excelsior	Ash	Delamere	Container
Larix kaemferi	Japanese larch	Wykeham	Bare-root
Picea sitchensis	Sitka spruce	Delamere	Bare-root
Populus tremula x tremuloides	Hybrid aspen	Latvia	Bare-root

TSU and FE will grow the same range of species and origins again during 2010 to be used on the two new sites and as beat-ups for the four sites planted this spring.

Willow cuttings for the SRC blocks from 10 recommended clones have been ordered from Murray Carter Horticulture in Yorkshire.

4. RESEARCH SUMMARY

A more detailed summary of the research work done and proposed for the coming year can be found appended to this report. This is a brief résumé of the main points.

➢ **Hyrdrology** (Appendix 1)

- We will be assessing the water quantity at Alyth and water quality at Sibster.
- Monitoring equipment has been made ready and will be installed into the ash and sycamore operational areas and into a grass field control at Alyth.
- We will monitor Alyth monthly until the end of the SRF rotation.
- We will monitor two burns for quality at Sibster; one fed from the SRF area and the other unaffected by SRF planting for comparison.
- We will take fortnightly samples to test for water quality, and annual invertebrate samples.

- From initial samples, we have identified high numbers of coliform bacteria consistent with the previous agricultural land use.
- We will produce comprehensive site reports on initial findings in year three.

➢ **Soils** (Appendix 2)

- We are taking soil samples from all sites to establish a baseline for nutritional and soil carbon status.
- Samples are taken from various depths down the soil profile.
- So far, we have carried out sampling and analysis for East Grange and Alyth.
- Preliminary results have shown the top soil at East Grange to be more acidic than Aylth and have lower carbon and nitrogen contents.
- The initial site sampling has shown that the number of samples required on future sites can be reduced without unduly affecting the quality of data.
- We will produce progressive annual reports as more site data is analysed.

➢ **Technical Development** (Appendix 3)

- In addition to the mechanical planting studies done at East Grange in February 2009, over the last year TD have studied mechanised herbicide application in SRF, inter-row flail mowing, maiden cut of SRC, and 'gapping-up' of SRC.
- Initial planting studies formed the basis of a report produced by TD in September 2009.
- TD will report on the results of this year's work by the end of June, 2010.
- TD are planning further work comparing establishment methods on other trial sites for the coming months.

➢ **Biodiversity** (Appendix 4)

- We have decided upon the protocols (as appended) for monitoring the sites which will be put into action during the coming year.
- We have commissioned The British Trust for Ornithology to do a breeding birds survey on all 4 sites being planted this spring. They have already made preliminary visits to the sites.
- Outside finance has been obtained from SNH to fund the BTO in an additional winter bird survey on the sites.
- A survey report will be produced by the BTO for the end-of-March 2011.

➢ **Silviculture**

- Designs and plans have been agreed and are being acted upon.

- Assessments will commence with initial height measurements immediately following planting.
- Ongoing establishment will be checked regularly through the growing season.
- Comprehensive growth measurements will be done in October/November 2010, and annually thereafter.
- State of the art, automatic weather stations have been purchased and will go out onto sites shortly after planting.

5. CONCLUSION

The Energy Forestry Exemplar Trials are major programme of work, which will be a significant contribution to improving our knowledge of SRF and SRC in Scotland. 2009/10 has been very much a preparatory year, choosing sites, planning and raising planting stock. We have initiated the research programme and begun to gather useful data from the operational activities on some of the sites. Although the abnormally severe winter has delayed site establishment, all is now ready to actively begin the trials on the ground. Once they have this physical presence, the trials will become a demonstrable entity. The network of sites will be very important to demonstrate to practitioners, researchers and policy makers throughout Scotland what we think is possible and the best ways of achieving this. This is a long-term programme following the development of the sites over the rotation. We will also progressively gain information on the effects that the crop has on the environment it sits in and its surroundings, giving us the information we need to produce and disseminate best practice.

The planting of the two remaining sites, at Auchlochan and on Mull, in 2011, will complete this comprehensive series of trials, giving Scotland a unique resource, and leading the way on research into woody biomass production.

Appendix 1:

Report on Studies to Assess the Hydrological Impacts of Energy Forestry

Background

Concern has been raised that the establishment of energy forest crops could have an adverse impact on water resources. This arises from the potential high water use of SRF, which could reduce water supplies and ecological flows. Another issue is the impact on water quality, with energy crops expected to benefit water quality compared to the previous agricultural land use due to reduced soil disturbance and chemical and pathogenic inputs. 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

- To quantify the effects of different SRF species on water resources.
- To evaluate the impact of SRF on water quality.

The field experiment on water use is being conducted at Alyth, Tayside (funded by CFS via the Forest Hydrology Programme), and on water quality at Sibster Farm, Caithness (funded by FC(S)). Separate reports will be prepared at the end of year three, evaluating the impacts of the initial planting on water quantity and quality at the respective sites.

Status report

Water Resources – Alyth

Suitable sites have been identified for the water use experiments following field visits and assessments. Cultivation of the sites is planned for March 2010, after which monitoring equipment will be installed to measure soil moisture content (Theta probes), soil hydraulic potential (tensiometers) and interception (rainguages and automatic weather station). These measurements will allow estimates to be made of water use via transpiration and interception processes. All equipment has been prepared and is ready to install. Experimental plots will be established within operational trial areas of Ash (*Fraxinus excelsior L.*) and Sycamore (*Acer pseudoplatanus*), with an adjacent area of grass used as the control (where the automatic weather station will also be sited).

Monthly visits will be made to the site to download data and maintain equipment. The intention is to continue measurements throughout a complete SRF rotation.

Water quality - Sibster

Two water sampling points were selected, one in a stream draining the experimental area (dominated by the proposed SRF trial) on Sibster Farm and the other in the Achingills Burn, a stream unaffected by the SRF planting and therefore suitable as a control (Figure 1). A sampling programme was initiated in September 2009 to provide baseline data prior to SRF planting; fortnightly water samples are being taken for water quality analysis at our laboratory in Alice Holt and same day microbiological analysis at Scottish Water's laboratory in Inverness. Early results from the microbiological data indicate relatively high numbers of coliforms, *Escherichia coli* and *Enterococci* reflecting the current/recent land use, namely mixed beef and cereal farming**.**

The Sibster farm site is due to be planted with a range of woodland types, including a central area of SRF, in 2010/11. A site visit is planned at the end of March 10 to install water level recorders, which will enable us to estimate the volume of runoff and allow chemical concentrations (mg/l) to be converted to fluxes (kg/ha).

The benthic macroinvertebrate population will be sampled once a year using the 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, a key component of the EU Water Framework Directive. It is intended to repeat this survey at annual intervals.

Water sampling will continue at fortnightly intervals for a period of three years to assess the initial impact of the land use change on water quality. Thereafter, the intention is to reduce the frequency of sampling to monthly until the SRF crop reaches harvesting age.

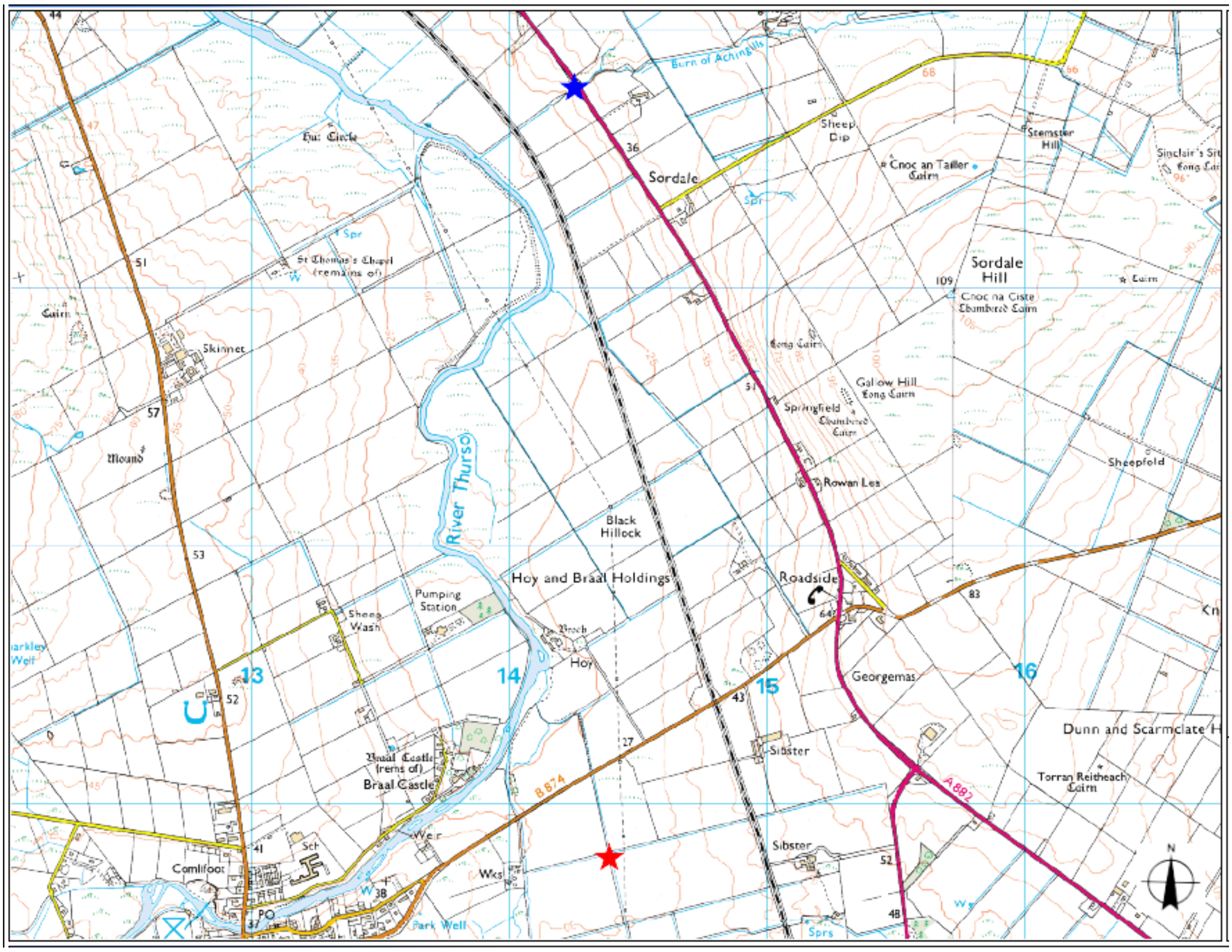


Figure 1 Water sampling locations: Stream draining operational area on Sibster Farm (★) and control catchment unaffected by SRF planting (★)

Appendix 2:

Soil baseline assessments at the Short Rotation Forestry sites in Scotland

Forest Research Report, March 2010
Elena Vanguelova, Centre for Forestry and Climate Change

Scientific Rationale

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.

Some studies and preliminary modelling provide estimates of C sequestration rates for SRF and SRC and suggested that short rotation plantations have significant potential to sequester carbon in the soils at comparable or greater levels than for naturally regenerating woodland. 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. The long-term impacts on soil carbon and nutrient status remain largely unknown, especially for SRF. Another key need is to consider carbon-offset through production of bioenergy crops. 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?

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

Research 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.

Soil baseline at Alyth and East Grange in 2009/2010.

The purpose of the soil assessment in the Short Rotation Trials in Scotland was 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 soil baseline for two plots was established: East Grange and Alyth early in 2009. The assessment plot for establishing the soil baseline was the central 12m x 15m area containing 96 trees, leaving a 2 tree buffer. GPS was used to map the plots and locate the sample points. The soil sampling and assessments took place in all plots of different tree species and also the SRC plots in each site.

A rigorous assessment of the impact of the proposed SRF/SRC planting on soil conditions requires that the baseline assessment captures very well the within-site spatial variability in soil C and nutrients because 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. So, these first two plots were sampled as detailed as possible to obtain information on the spatial variability of agricultural sites in order to estimate a minimum statistical number of soil sampling points for the rest of the SRF plots in Scotland. Within the 12 x 15 m central plot area, 12 soil sampling points were selected on a 4 x 5 grid system. Samples were taken from the topsoil layer at 0-20 cm depth, 20-40 and 40-80 cm soil depth, overall 3 sample per sampling point. On total there were about 50 plots per site where 12 points and three depths made up to nearly 1900 soil samples per site.

Samples were processed in Forest Research Alice Holt laboratory following the standard chemical procedures for the soil processing, determination of soil moisture, soil pH, soil total carbon and nitrogen, exchangeable cations and acidity, available phosphorous. The depth of soil horizons and samples for soil dry bulk density determination were taken from 4 soil pits, located in the four cardinal direction of the sites within the buffer zone.

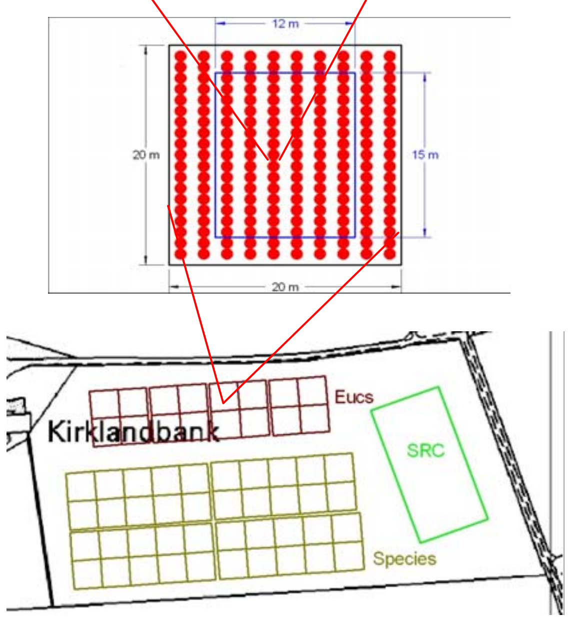
Preliminary results

The preliminary soil analysis of soil pH, soil C and N concentrations, soil bulk density and soil C and N stocks are shown in Figures 1 to 3 below. The results suggest that tops soil (0-20 cm) at Alyth is more acidic that East Grange but this is reverse at lower depth (20-40cm) (Figure 1). The soils at Alyth are shallower than East Grange and data is only available down to 40 cm of the soil profile. There are clear relationships between soil C and N concentrations in the topsoil of 0-20 cm at both sites (r2 = 0.72 East Grange and r2 = 0.91 at Alyth), with much more scattered relationship at East Grange suggesting higher soil variability (Figure 2). Soil C and N concentrations are higher at Alyth compared with East Grange. Soil dry bulk density is much higher at East Grange compared with Alyth (Figure 3) and this is due to the higher stone content at Alyth. Carbon stocks calculated for the top 20-cm soil at both sites are on averaged 43 t C ha^{-1} at East Grange compared with 69 t C ha^{-1} at Alyth.

Soil sampling intensity was reduced from 12 soil sampling points to 3 sampling points per single plot of 12 x 15 m for establishing soil baselines in the rest of the SRF sites in Scotland. Figure 4 shows the standard error of the mean at different number of sampling points for the data on soil C concentration in top 20 cm soil from two plots (each 12 x 15 m plot), data from the more variable site at East Grange.

Further analysis of the data will provide estimates of the soil C and N stocks with depth, exchangeable soil base cations and acidity content and phosphorous. Geostatistical analysis could also be applied to the datasets to investigate in details the spatial variability of the soils at these two sites in order to provide the baseline necessary for future assessments.

12 soil sampling points in a grid system of 4 x 3 m



Soil analysis

pH

Soil bulk density/soil moisture content

Total organic/inorganic C

Total N

Exchangeable base cations and acidity

- **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*

Soil pit - East Grange

Soil pit - Alyth

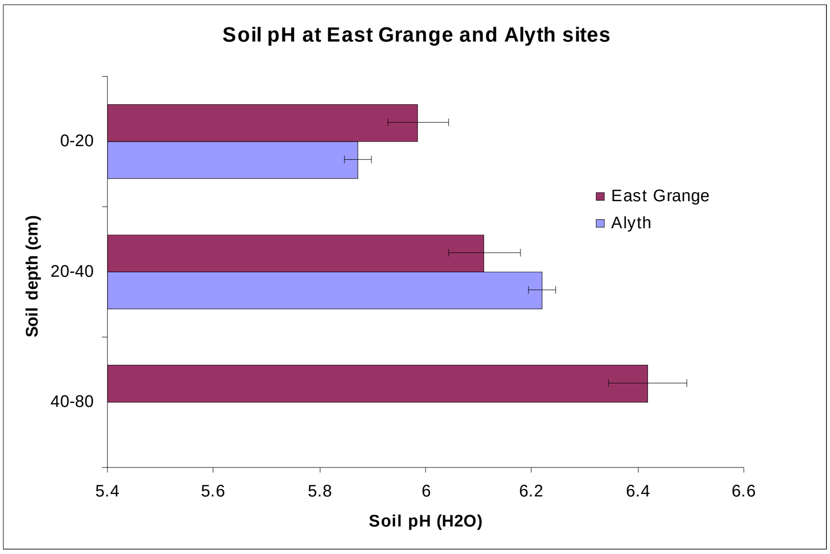


Figure 1. Soil pH at East Grange and Alyth Scottish SRF sites. Bars are mean values and vertical lines represents the standard errors of the mean.

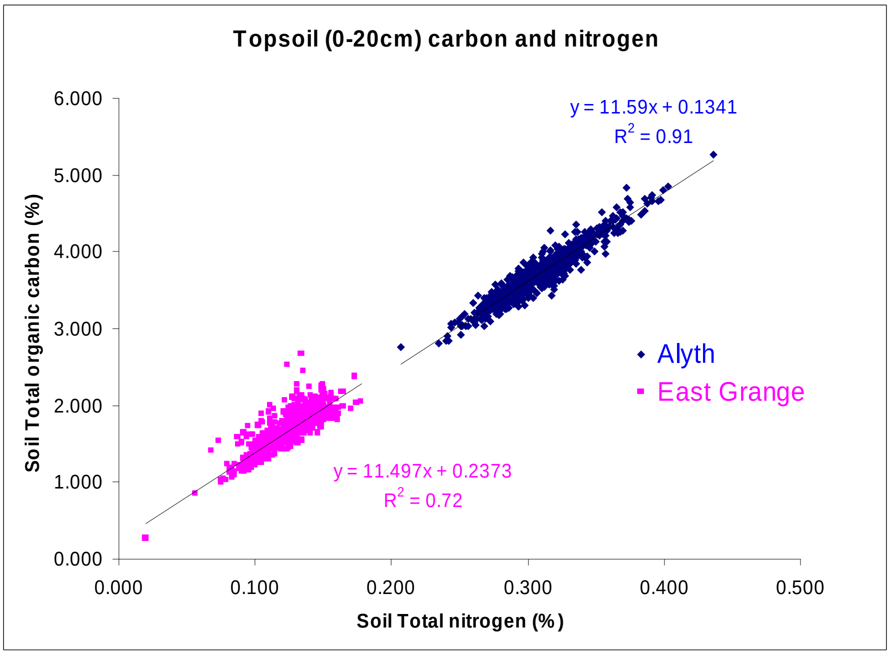


Figure 2. Relationships between topsoil (0-20 cm) C and N concentrations at East Grange and Alyth Scottish SRF sites.

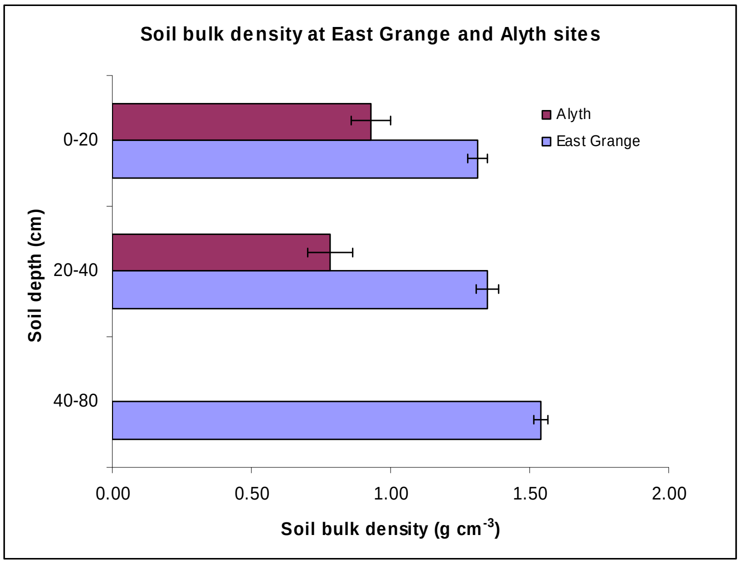


Figure 3. Soil dry bulk density from the East Grange and Alyth Scottish SRF sites. Bars are mean values and vertical lines represent standard errors of the mean.

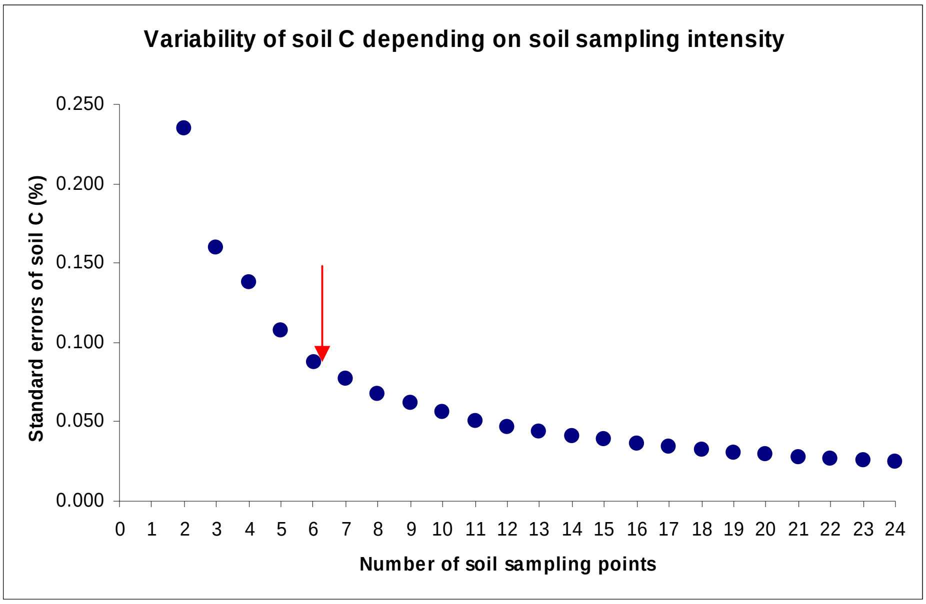


Figure 4. Estimated standard error in relation to number of sampling points for two SRF plots of 12 x 15 m at East Grange. The vertical arrow indicates the estimated minimum sampling number for two plots (each 12 x 15m).

Appendix 3:

TD SRF Project Update

Summary

This report summarises work carried out by Technical Development during 2009-2010 into Short Rotation Forestry (SRF) and Short Rotation Coppice (SRC) management operations. During 2008-2009 Technical Development undertook time study of establishment operations in SRF and SRC at the Forestry Commission trial site at East Grange.

This year, time studies have been carried out into the ongoing management operations for SRF and SRC during the first growing season. Time studies on a variety of operations have gathered operational experience, outputs and costs and fuel use information.

During 2009-10 TD have carried out time studies on:

- Mechanised herbicide application in SRF.
- Mechanised inter-row flail mowing in SRF.
- Mechanised SRC first—year cutting.
- Manual 'gapping-up' of SRC.

These operational studies include assessment of the methods used, and suggested method improvements, where appropriate as well as fuel use assessments of mechanised operations.

Manual gapping up of Short Rotation Coppice at East Grange.

Introduction

Knowledge of Energy Forestry (EF) establishment and management (particularly SRF) in Britain is limited. With increasing interest and markets for Energy Forestry there is a need for greater understanding of SRF operations.

Forestry Commission EF trial sites throughout Scotland include large scale operational areas and intensive research trial areas. All TD's research has been concentrated in the operational areas; gathering information which is representative of operational best practice.

Current Energy Forestry research by TD aims to :

- Gather operational experience of SRF and SRC management in Scotland.
- Determine output information for SRF and SRC management in Scotland.
- Determine operational costs for SRF and SRC management in Scotland.
- Gather fuel use information for operations to allow Life Cycle Assessment (LCA) of EF systems.
- Comment on operational efficiency of systems studied.
- Suggest method improvements (where appropriate) in the interest of efficiency, efficacy and health and safety.

Additionally TD have also made an active contribution to the ongoing project management of the EF trials in Scotland, attending regular meetings between FR and FCS. TD have also helped to disseminate research to date through written findings, and field presentation during the FCS EF Seminar at Stirling University.

Work method

Work methods are described in Work Plan FR09026, and follow FR standard operating procedures for operational time studies.

Results

Work carried out in 2009-10:

- Produced project report: FCPR009.

Project report detailing findings of 2008-2009 research on SRF and SRC establishment at East Grange.

- Mechanised herbicide spraying study.

Time study of mechanised herbicide application using Kubota RTV900 ATV mounted Logic shrouded sprayer, (Figure 1). Output and cost information was collected and operational observations of the work were recorded. Fuel use for the ATV was also assessed for future LCA calculations.

Figure 1 Kubota RTV900 ATV mounted Logic sprayer

Figure 2 Results of mechanised herbicide spray at East Grange (c. 1 month after herbicide application)

- **Mechanised flail weed control study.**

Time study of mechanised inter-row failing with Avant Frame Steered base machine and front-loader mounted Kilworth Flail (Figure 3). Output and cost information was collected and operational observations of the work were recorded.

Figure 3 Avant Frame Steered base machine and front-loader mounted

Figure 4 tractor-mounted agricultural side knife cutter bar

Figure 5 SRC site following cut back

- **SRC 'Cut back' study – (February 2010).**

Time study of first 'cut back' of willow growth at the end of the first year (Figure 5). In the UK it is standard practice to cut willow growth from SRC at the end of the first growing season to encourage coppicing and development of multi-stemmed stools. Cutting was carried out with a tractor-mounted agricultural side knife cutter bar (Allen Scythe) (Figure 4). Output and cost information was collected and operational observations of the work were recorded. Fuel use for the tractor and cutter bar were also assessed, to provide information for future LCA calculations.

- **SRC 'gapping up' study and method improvement.**

Manual 'gapping up' (akin to beating up in a forestry context) was studied following SRC 'cut back'. Manual operators gather cut SRC stems following first year cut back and cut them to length to provide planting material for missed plant positions during mechanised SRC establishment. Output and cost information was collected and operational observations of the work were recorded. TD gave method development advice to operators allowing an improved tool for gapping up to be developed, improving efficiency and ergonomics.

- **Support to 'Energy Forestry in Scotland' seminar event in Stirling.**

Attended the seminar and gave a field presentation at the East Grange operational area, describing establishment studies carried out to date.

- **Contribution to regular project meetings**

Regular attendance of EF project meetings, reporting project progress and contributing to the management of the FCS EF trials.

Future TD research (2010-2011):

- Complete write up findings of 2009-2010 study work.
- Comparison study of mechanised and motor manual planting at FC site at Alyth.
- Ongoing monitoring of management operations at East Grange, with time study for additional operations, not yet studied as opportunities arise.
- Opportunities for comparison studies at other FC SRF sites including Alyth.
- Continue attendance at project meetings, and support future information dissemination events.

Future 2010-2011 work to be defined in project plans for the forthcoming year.

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Appendix 4:

A Process Based Approach to Monitoring Biodiversity in Energy Forestry Projects

1.1 Background

An overarching question that biodiversity monitoring needs to answer is how to measure impacts of the drivers of biodiversity change in a meaningful way. There is a danger that biodiversity monitoring is undertaken for monitoring sake. This can often provide an incoherent raft of information on a wide range of topics, which does not answer specific questions. Here it is proposed that a monitoring strategy is developed that will address specific issues such as 'assessing progress towards an objective'. The objective here is when a site or forest unit acquires a range of recognisable woodland features that can be used to indicate ecosystem function. This introduces the concept of 'condition' and whether or not this is favourable. This is essentially an objective assessment of the range of chosen woodland features.

The review focuses on identifying cost-effective methods to assess biodiversity impacts of energy forestry projects at the site (forest stand), forest unit (Angelstam et al. 2001) and landscape scales (Watts et al. 2005).

This section of the report reviews the theoretical background for the design of a biodiversity monitoring framework for energy forestryprojects. This will inform a practical methodology that will be presented in a separate report. Methods vary according to requirements, and range from measures which function as 'barometers' of change to those which provide indicators for specific aspects of biodiversity, or the impact of changes in forest management on ecosystem services. The indicator concept uses characteristics of an easily measured feature such as an organism or aspect of forest structure as an index of certain attributes of the system that are otherwise too difficult or expensive to measure directly.

1.2 Developing Biodiversity Indicators

1.2.1 Policy Drivers

There has been a wealth of policy initiatives, backed by research, into biodiversity assessments. Currently the monitoring of forest biodiversity within the EU arises from four key policy processes: the Convention on Biological Diversity (CBD), the Ministerial Conferences on the Protection of Forests in Europe (MCPFE), the Pan-European Biological and Landscape Diversity Strategy (PEBLDS), and the implementation of the Natura 2000 Network. These policies have been developed to address a range of priorities:

1. CBD - EU 2010 Target to halt loss of biodiversity
   - Monitoring compliance through Streamlining European Biodiversity Indicators (SEBI2010)

2. Extending Natura 2000 to the whole of EU-25 (IUCN 2005)
   - Identifying habitats and species of conservation concern in new states currently not covered by Habitats and Species Directives
   - Monitoring habitat extent and condition
   - Funding restoration/improvements

3. Developing/implementing Pan-European Ecological Network (PEEN) to:
   - Buffer/protect Natura sites
   - Allow migration of species in response to climate change

4. Integrating biodiversity considerations into all sectors
   - Monitoring compliance (e.g. sustainable forestry indicators - MCPFE)

The maximisation of the biodiversity benefits of energy forestry through the Kyoto protocol is now also firmly on the policy agenda. The first step in selecting indicators should be the assessment of appropriate existing indicators developed through these policy agendas and then selecting suitable cost-effective methodologies for assessing them. Below is a summary of the major policy initiatives that relate to forest biodiversity and how the are to be monitored.

Streamlining European 2010 Biodiversity Indicators (SEBI2010)

In response to the CBD, EU member states agreed to halt the loss of biodiversity in the EU by 2010. This led to a review of the effectiveness of the EC Biodiversity Strategy (launched in 1998), and culminated with representatives of member states meeting at Malahide in 2004 to develop an implementation plan for the strategy. Objective 15 captures the key message for biodiversity monitoring:

> *"To implement an agreed set of biodiversity indicators to monitor and evaluate progress towards the 2010 targets, with the potential to communicate biodiversity problems effectively to the general public and to decision-makers and provoke appropriate policy responses."* (Message From Malahide 2004, p37)

The European Environment Agency (EEA) have developed a set of core indicators for biodiversity to harmonise practice across Europe (EEA 2007). Expert groups have been formed to operationalise the different indicator groups through a process called Streamlining European 2010 Biodiversity Indicators (SEBI2010). This includes a report detailing a more descriptive categorization based on the different European forest types. Table 1.1 describes the indicators that are being developed.

The species indicator focuses on selected groups such as woodland/wild birds and threatened species. The invasive species indicator is still under development and is likely to include understory/ground vegetation species as well as tree species.

There are several initiatives already operating using various indicators. The MCPFE uses mainly structural and economic indicators to monitor the protection and sustainable management of European forests. This only divides forest into three categories: deciduous, conifer and mixed forests. The number of tree species and 'Red List' species are also recorded, but the species not named.

Table 1.1: Overview and suitability of SEBI 2010 indicators for assessing biodiversity changes in energy forestryprojects

Indicator group	Description	Suitability as a forest based climate mitigation biodiversity indicator
Species	Trends in abundance and distribution of selected species Change in status of protected/threatened species	Yes
Ecosystems	Trends in extent of selected biomes, ecosystems and habitats (Natura2000) Connectivity/fragmentation of ecosystems Coverage of protected areas	Yes Yes No
Genetic resources	Trends in genetic diversity of domesticated animals, cultivated plants, fish etc.	No
Nitrogen	Nitrogen deposition	Environmental indicator
Invasive species	Number and costs of invasive alien species; identifying the 100 "worst offenders"	Possible
Sustainable management	Area of forest under sustainable management	Yes

Monitoring Conservation Status of the Natura 2000 Network

As part of the commitment to the EU meeting their CBD 2010 target, there is also a requirement to undertake monitoring of the conservation status of the Natura 2000 network. The Natura 2000 network is the main delivery mechanism for the Habitats and Species Directive and the Wild Birds Directive. The focus of monitoring is to assess changes in the conservation status of designated habitats and species. Currently there is no harmonised approach to defining conservation status and member states are at liberty to develop their own system of assessments. A central concern of EU policy is to implement the Natura2000 network in the new member states (IUCN 2005).

Pan-European Ecological Network

One of the main mechanisms for the implementation of the PEBLDS is the Pan-European Ecological Network (PEEN). The PEEN is currently being implemented across European States with a focus on strengthening and extending the Natura 2000 network and improving ecological connectivity and resilience in response to climate change. Landscape metrics are being developed as indicators of improvement in connectivity. These range from simple assessments of changes in landscape structure, to more complex measure of landscape functioning (Opdam and Wascher 2004).The landscape diversity indicator within the MCPFE group of biodiversity indicators potentially links with the PEEN. The contribution to connectivity that forest based climate mitigation projects make should be assessed within any monitoring programme.

MCPFE Indicators

Another important aspect of EU biodiversity policy is to encourage the integration of biodiversity into sustainable forest management (this would include energy forestryprojects). The MCPFE process provides the mechanism for achieving this through the Helsinki guidelines (MCPFE 1993) and monitoring takes place through the set of Pan-European Indicators. Within this schema, nine biodiversity indicators are included under Criterion 4 (Biodiversity). These are described in Table 1.2.

Table 1.2: MCPFE Biodiversity Indicators

Indicator	Description	Suitability as a energy forestrybiodiversity indicator
Tree species composition	Area of forest and other wooded land by species and forest type	Yes
Regeneration	Area within stands	Yes
Naturalness	Area classified as undisturbed; semi-natural; plantation	Yes
Introduced tree species	Area dominated by introduced species	Yes
Deadwood	Volumes by forest type	Yes
Genetic resources	Area managed for conservation of genetic resources	No
Landscape pattern	Spatial pattern of forest cover	Yes
Threatened forest species	IUCN red list species	Yes
Protected forests	Area protected for biodiversity	Yes

The review; ‘Monitoring forest biodiversity – from the policy level to the management unit’ (Angelstam et al. 2001) sets out a scientifically based rational for biodiversity monitoring. These policy-based indicators provide a framework for national and regional reporting and are backed up by significant research. They can provide a background and reference points for the development of more specific biodiversity indicators. The development of a suitable monitoring framework is required in order to develop methodology for assessing the impacts of climate change mitigation projects on biodiversity

1.2.2 Monitoring Frameworks

As highlighted in section 1.2.1, there is widespread interest in the use of biodiversity indicators to represent and monitor complex phenomena and processes such as ecosystem and biodiversity responses to environmental change. Changes in climate and land use impose new challenges for the effective monitoring of ecosystems and biodiversity. To date, there has been a focus on modelling species specific responses. However, for forest ecosystems there is a need to develop ways of assessing changes in the structure and composition of communities and to evaluate how ecosystem development will affect biodiversity through climatic range shifts, changing existing communities and potentially triggering the development of novel assemblages.

To maximise the biodiversity benefits of energy forestry projects they should contribute to the development of ecological processes and function. This is applicable across the range of representative habitats, communities and species at a range of scales. This functionality should also allow for the development of increased connectivity across the landscape to reverse the effects of habitat fragmentation. To assess if these ecological processes are functioning will require monitoring of the habitats, communities and species at the tree stand, forest unit and landscape scale. This, in turn, will require cost-effective methodologies that are easily implemented by forest managers. While it is impractical to monitor all aspects of biodiversity a careful selection of methodologies is required to adequately reflect the state and changes in forest ecosystems and diversity.

It has been widely recognised (Angelstam and Donz-Breuss 2004; Noss 1999; Spanos and Feest 2007) that biodiversity indicators can be grouped into 3 categories (though these are not mutually exclusive).

(1) Structural indicators which are usually easily quantifiable through forest inventories and can be described as:

- Physical pattern
- Spatial pattern
- Temporal pattern

(2) Compositional biodiversity indicators are usually developed through gathering data in the field relating to:

- Species diversity
- Genetic diversity
- Biotype diversity

(3) Functional biodiversity indicators that inform our understanding of ecosystem function of forest biotypes in terms of:

- Ecological processes
- Natural disturbance
- Nutrient cycling

To be widely applied and effective, indicators of functional biodiversity should be simple rather than expert-based systems. To enable monitoring of complex ecological phenomena and processes, the indicators should:

- combine the structural and compositional elements of forest biotypes and the ecological processes that drive them
- work effectively in the different management alternatives applied to them.

The three indicator categories are then related to the different scales at which they operate.

(1) Tree
Trees are the building blocks of woodland ecosystems. Their growth and development is crucial in assessing woodland development. As trees mature they create a range of different niches that can be colonised and used by a suite of different species and become habitats that have their own dependent food chain.

(2) Stand: The ways trees interact with each other across a site and over time will determine aspects of woodland development. As with trees, as a stand matures a range of different niches develop and these are related to the structure of the stand.

(3) Forest Unit: How the different wooded stands and open space that make up the forest unit interact with each other in terms of their ecological function

(4) Landscape: The context and distribution of the forest units within the matrix of other habitats and landcover. Landscapes are determined by the prevailing land uses and management practices.

1.2.3 Criteria

The primary objective of monitoring within FBCM is to assess progress or changes in woodland ecosystem development. A secondary objective to is to assess changes in the condition of existing woodland or open ground, which may occur as a result of changes in management (e.g. selective thinning or reduced grazing pressure) and any alterations in the local microclimate. The terms ‘old growth’ and ‘ancient woodland’ are often used to indicate value or quality in a stand. The premise being that because it is late successional woodland or has been woodland for long period of time that it has developed certain structures and functional ecological processes. For new woodlands it is the establishment of aspects of structural development, the colonisation by woodland specialist species and ecological process that will give an indication of a site becoming woodland.

Ecosystem Development

The effects on ecosystem development and functionality as a result of FBCM projects will have a direct impact on a forest unit or a site's biodiversity. 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 (Schulze and Mooney 1993). These can be split into the physical structures that are present and develop as a result of ecological processes and the species that use them. The compositional element of biodiversity is 'variability of living organisms from all sources' (CBD 1992) and these develop as a result of structural and functional development.

(a) Structural development

The spatial arrangement of the various components of a forest ecosystem can give a good indication of woodland development and influences the species that will be present on a site and as such are a key component of any monitoring strategy. Table 1.5 outlines a range of structural biodiversity indicators.

(b) Functional development

Functional development is based on the principle that species can be used as indicators of ecosystem function. There is continuing discussion about the effectiveness of such indicators and the most appropriate method of assessment of ecosystem function but there is wide support for the use of what are termed 'functional species groups' (Davic 2003; Patchley 2002).

There is no single way of defining what comprises a functional species group. It has been proposed that there should be an evolutionary basis to the groupings (Chapin et al. 1992) so that these have a natural basis rather than a pragmatic one (Baker et al. 2003). Here, attributes such as phenology, physiology and life form would be selected to define the groups, but behavioural environmental responses or trophic criteria have also been used (Cohen and Briand 1984). For example, ground beetle species (Coleoptera: Carabidae) in Scottish farmland have been allocated into functional groups by the use of multivariate analysis of their ecological traits (Cole et al. 2002).

Fox and Brown (1993) suggested that intraspecific competition could be the basis for groupings so that species that have evolved to exploit a similar niche are aggregated to form a functional group. This allows for species of different taxonomic groupings with similar ecological niche requirements to be allocated to the same functional group as they have evolved to fulfil similar functional roles within an ecosystem. Key woodland niches that represent a range of microhabitats within an ecosystem are identified with species groups representing their functionality. The assumption is that the key woodland niches are functioning if the representative species of that niche are present. These species should have similar evolutionary and ecological traits (i.e. are in intraspecific competition with each other) which can then be used to form a functional species group.

Identification of Functional Species Groups

The identification of possible functional species groups was investigated (Smith and Humphrey 2005) and two possible methods of sampling are proposed:

Directly measuring the species themselves
Evidence of activity – 'the smoking gun'.

The basic characteristics of these methods are outlined below.

The monitoring of the energy forestry 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 forest ecosystem.

The challenge is to find practical and cost-effective field methodologies that are able to measure this functionality without having to assess the biodiversity resource as a whole within an ecosystem.

Directly Measuring the Species Themselves

The selection of possible functional species groups have been based on the following conditions (Speight and Castella 2001):

1. The information available about the species that would form a functional group should be sufficient to characterise their macrohabitat and microhabitat associations (KWH)

2. Less than 5% of the genera should pose significant identification problems and the taxonomic literature should be readily accessible, even if scattered

3. Reliable on-site sampling techniques should be available and open to standardisation

4. Sampling should be effective within short periods, using generally available equipment that does not require daily site visits or direct involvement of experts in sample collection

5. Processing of samples should be undemanding in terms of labour and facilities

6. The regional distribution of species must reflect selected sites.

Based on these conditions, the following species groups were identified as possible functional species groups and have been assessed on their suitability for use in the energy forestry monitoring programme: spiders, hoverflies, ground beetles, soil micro organisms, snails, butterflies and moths, and breeding bird s The aim was to select groups that could be related to forest ecosystem function. Each group is briefly discussed and recommendations made for their possible use in relation to the above criteria.

Maleque et al. (2009) have undertaken a review in which they highlight the potential for different arthropod groups to act as indicators of biodiversity with a focus on plantation forests. An extract of this along with possible methodologies for assessing these as indicators for selected arthropod groups are given below.

(a) Spiders (Arachinida)
Spiders can be split into niches by the vertical strata that they inhabit (Oxbrough et al. 2005). However, to do this several trapping methodologies would need to be used; pitfall trapping for ground dwelling species, sweep netting for lower vegetation, vegetation beating and canopy fogging. Timed hand searches on tree bark could also be undertaken. Comparisons of presence-absence of species across these different methods would then be made.

The species could then be split into guilds relating to their particular hunting strategy, i.e. orb web weavers, ambush predators or active hunters. This is aided by the fact that guild classifications usually follow family groups. The presence of the functional species groups based on hunting strategy and the different vertical strata they inhabit will then give an indication of functionality of the different key woodland niches within the woodland.

Spiders are a potential group for selection since they can be put into functional groups and as predators are of a higher trophic level than other possible groups. A drawback to their use is the range and complexity of sampling techniques needed to sample a plot which makes this approach costly based on the time required in the field and laboratory.

(b) Hoverflies (Syrphidae)
This group fulfils all six conditions outlined above and there is an established field-tested methodology for assessing key woodland niche functionality. This is based on work carried out in the development of Syrph, the Net database (see below).

(c) Ground beetles (Coleoptera: Carabidae)

After investigation (Smith and Humphrey 2005) found that there was not yet enough information readily available about this diverse group to be able to identify functional groups in sufficient detail to characterise their macro and microhabitat associations (key woodland habitats). Although this has been undertaken for the ground beetles of open farmland habitats (Cole et al. 2002) it would require further research of those of woodland habitats. Therefore, while this group would in principle be suitable it requires more research, which is beyond the remit of this project.

(d) Soil micro-organisms
As with the beetles the information available about the species that would form a functional group is not sufficient to characterise their macro and microhabitat associations. It is acknowledged, however, that soil biology plays an important aspect of ecosystem development in new native woods.

(e) Snails (Shelled Gastropods)
This group fulfils the six conditions outlined above. There is also a database of shelled gastropods of Western Europe (Falkner et al. 2001) available which could be used in the same way as that for the Syrphidae. There are, however, questions about the geographical range of species and whether there is sufficient species with a suitable distribution for the purposes of this project. This should be investigated further as this group would be useful to include as their dispersal rates are thought to be slow compared to the Syrphidae and so colonisation of new habitats will take longer.

(f) Butterflies and Moths (Lepidoptera)
Butterflies are suitable as functional indicators because they are commonly known and relatively easy to observe. However, their presence is season and weather dependent which makes them unreliable for the purposes of this methodology. Moths are easily caught with the use of light traps, they are a very diverse group with a large number of species which can be difficult to identify and therefore were not selected. They are also ‘charismatic’ species whose conservation generates public interest and support. It may therefore be politically expedient to monitor the presence of certain iconic species within the overall monitoring strategy.

(g) Breeding Birds
Breeding birds could be monitored using standard methodologies and it may be possible to allocate functional groups at some point in the future. Standard bird monitoring methodologies for breeding birds and resident birds require a degree of specialism, such as being able to identify bird calls and are quite labour intensive. This approach may therefore not be cost effective.

Grouse (Tetraonidae) and woodpecker (Picidae) species have and are used as bioindicators (Angelstam et al. 2004). Indeed, woodpeckers - as primary cavity nesters - are seen as keystone species as they also provide nesting sites for other species. This was observed at the QUEST JIFor Russia case study site where the evidence of woodpeckers could be noted both directly and indirectly. Also swifts (*Apus apus*) were observed in the primary forest using secondary cavities as nest sites.

Birds again can be seen as 'charismatic' species whose conservation generates public interest and support. It may therefore be politically expedient to monitor the presence of certain iconic species. Their selection should also reflect ecosystem function of the structural types within their forest biotype. These would need be to be regionally representative and should also be able to act as focal species for landscape analysis (see section 1.2.4).

Evidence of Activity

This element uses the evidence of invertebrate activity on micro-habitats within a woodland as a rapid assessment of faunal biodiversity and therefore ecosystem function. It is proposed (Smith and Humphrey 2005) that by measuring the evidence of activity of individual invertebrates or populations of invertebrates on a known unit of habitat (e.g. 1 metre of canopy branch) it will be possible to calculate an index of diversity for that unit. Changes in this index over time will reflect ecosystem development within a new native woodland.

Indirect signs of insects are more easily identified than the species themselves. Oliver and Beattie (1993) have shown that estimates of species richness, based on recognisable taxonomic groups, can be made by non-experts as readily as by taxonomic experts. This principle of biodiversity assessment has been put forward by Angelstam and Donz-Breuss (2004) for dead wood species. While they recognise that the measure is coarse, it does allow for rapid assessment of elements of diversity. Some background research has been undertaken by Forest Research to test methods, justify them scientifically and validate them as a methodology for long-term monitoring. The further development of Rapid Assessments of Biodiversity is ongoing.

1.2.4 Landscape Indicators for Connectivity and Fragmentation

The habitats and landscapes across the UK have undergone considerable loss and fragmentation through a long history of human activity (Kirby and Thomas 1994; Riitters et al. 2000; Wade et al. 2003). Further habitat loss and fragmentation is regarded as a serious threat to biodiversity conservation, even though some habitat fragments have been protected by site-scale conservation measures (Saunders et al. 1991; Andren 1994, 1997; Fahrig 2003). Fragmentation may further impact on biodiversity by inhibiting species range adjustment in response to climate change (Berry et al. 2002; Honnay et al. 2002; Opdam and Wascher 2004; Thomas et al.

2004). In general terms, fragmentation causes a decrease in the area of available habitat and an increase in ecological isolation between patches. Scientific theories (MacArthur and Wilson 1967; Hanski 1998) predict that the reduction in area (and population size) may lead to an increased risk of local extinction, while the increase in ecological isolation may cause a reduction in the exchange of individuals between isolated patches. The movement of individuals among small, isolated fragmented populations is an important ecological process in fragmented landscapes (Tischendorf and Fahrig 2000). These movements may maintain genetic diversity, rescue declining populations, re-establish populations, and maintain networks of populations through metapopulation dynamics (Hanski 1998). The characteristics of the surrounding matrix are increasingly recognised as having a strong influence on the impacts of fragmentation (Zuidema et al. 1996; Lindenmayer and Franklin 2002; Kupfer et al. 2006) that is additional to the direct effects of area and isolation. The landscape matrix may exacerbate fragmentation by reducing the area of habitat through detrimental edge impacts based on the degree of matrix hostility (Murcia 1995). The matrix may also increase ecological isolation, by reducing the probability of species movement between patches, based on the degree of matrix permeability (Ricketts 2001).

There is now a general consensus in the literature that connectivity is best defined by the interaction between particular species and the landscape in which they occur (Crooks and Sanjayan 2006; Taylor et al. 2006). A functional approach recognises that connectivity is essentially a species-based attribute, with a single landscape having many possible connectivity measures based on the habitat requirements and dispersal ability of particular species. Functional approaches also address the influence of the landscape matrix in promoting or hindering species movement, through the assessment of the degree to which a landscape structure facilitates or impedes the movement of individuals among habitat patches (Taylor et al. 1993; With et al. 1997).

The proposed methodology to assess changes in functional connectivity as a result of FBCM projects incorporates area, isolation, edge and permeability impacts from habitat fragmentation. The approach utilises an incidence function model (IFM) (Hanski 1994; Moilanen and Hanski 2001; Vos et al. 2001; Moilanen and Nieminen 2002) as a spatially explicit method to assess potential species-level connectivity (Eq. (1)) (Calabrese and Fagan 2004; Moilanen and Hanski 2006). The standard IFM connectivity measure is modified to account for the influence of the surrounding landscape matrix on edge impacts (through a weighted internal edge buffer) and ecological isolation (through an assessment of least-cost distance to account for landscape permeability). It has been recognised that such patch-based connectivity measures can provide misleading results when used to examine change, as they only focus on between patch movements. As a result, a modified hybrid IFM, based on a

combination of patch and cell-based approaches, is developed to account for both within (intra) and between (inter) patch connectivity.
It is also important not to asses and monitor biodiversity associated with energy forestry in isolation. The monitoring strategy should also include the monitoring of sites adjacent to energy forestry projects. This will ensure that any changes in biodiversity can be evaluated in context of the landscape that it sits in and related to regional and national trends.

1.3 Conclusions

There has been much work recently in the development of biodiversity indicators (e.g. Angelstam and Donz-Breuss 2004; Noss 1999; Spanos and Feest 2007). In order to operationalise these indicators they need to be non-specialist based and cost-effective. This has to be balanced with the requirement to be meaningful and based on our best understanding of ecological process through research. By drawing on the breadth of research and past practical applications, a range of indicators have been identified and are shown in Table 1.5. This separates them by the scale at which they operate and whether they are structural, compositional or functional. This is not intended to be an exhaustive list but summarises the most important and relevant indicators that could be used to identify ecosystem function over time. The aim is to develop a set of protocols that can be used to assess the impacts of forest-based climate change projects on biodiversity. The methodology should be able to assist in making comparisons between sites or projects, and track changes over time so that adaptive management can be put in place to maximise the biodiversity value and other ecosystem services that such projects provide.

Table 1.5 : Biodiversity monitoring indicators

	Structural Indicators: *The spatial arrangement of the various components of a forest ecosystem can give a good indication of woodland development and influences the species that will be present on a site.*	Compositional Indicators: *Ecosystem components, as characterised by species richness and abundance reflects genetic, species and biotype diversity and can be used to generate an index of biodiversity.*	Functional Indicators: *The range of forest ecological processes and the timeframe over which they occur allow us a measure of ecosystem function of forest biotypes.*
Tree: *Trees are the building blocks of woodland ecosystems and how they grow and their development is crucial in assessing woodland development. As trees mature they create a range of different niches that can be colonised and used by a suite of different species and become habitats that have their own dependent*	Volume/biomass Canopy Height Girth Form Flowering Seed/fruit bearing Deadwood (standing) Rot holes Hollowing Water pockets Bark fluxes Rot sites	Species Lichen Bryophytes Epiphytes Canopy species Saproxylic species	Evidence of animal activity Woodpecker holes Hoverflies(*Syrphidae*) Size and shape of exit holes on rot sites or bracket fungi Tree Management – pollards coppice etc.

food chain.			
Stand: *How the trees interact with each other across a site and over time will determine aspects of woodland development. As with trees, as a stand matures a range of different niches develop and these are related to the structure of the stand.*	Area Site type Area (%) of different habitats Edge: Area ratio Ecotone type Surrounding habitat Gap occurrence Tree clustering Canopy closure Number of canopy layers Veteran trees Shrub trees	Habitat type Basal area of living trees Basal area dead Ground flora diversity Red listed species –status, population, trends Non-native species - population, trends Species with specific requirements	Dead wood – type, species, decay and amount Humus- type/quantity, amount/depth (cm) Flammable litter – amount/depth Animal damage
Forest unit: *How the different wooded stands and open space that make up the forest unit interact with each other*	Area of different ecological successional phases Area of recent forest Area of plantation Key woodland habitats Non-wooded structural development Vertical layer Horizontal structure	National forest type Indicator species Red listed species- status, population & trends Problem species area/trend Top predator Bird monitoring Game population trends	Fire Yearly area regeneration (planted or natural) Wind & snow - % affected Biological disturbance Silvicultural management Agriculture & grazing pressure Visitor pressure Rubbish Pollution Water
Landscape: *The context and distribution of the forest units within the matrix of other habitats and land-covers they are found. These are determined by the prevailing land uses.*	Age structure and diameter distribution of forest units Area of different ecological successional phases Landscape matrix	Focal species distribution Bird monitoring	Forest area Landscape pattern Protected forests Land use pressures Abandonment

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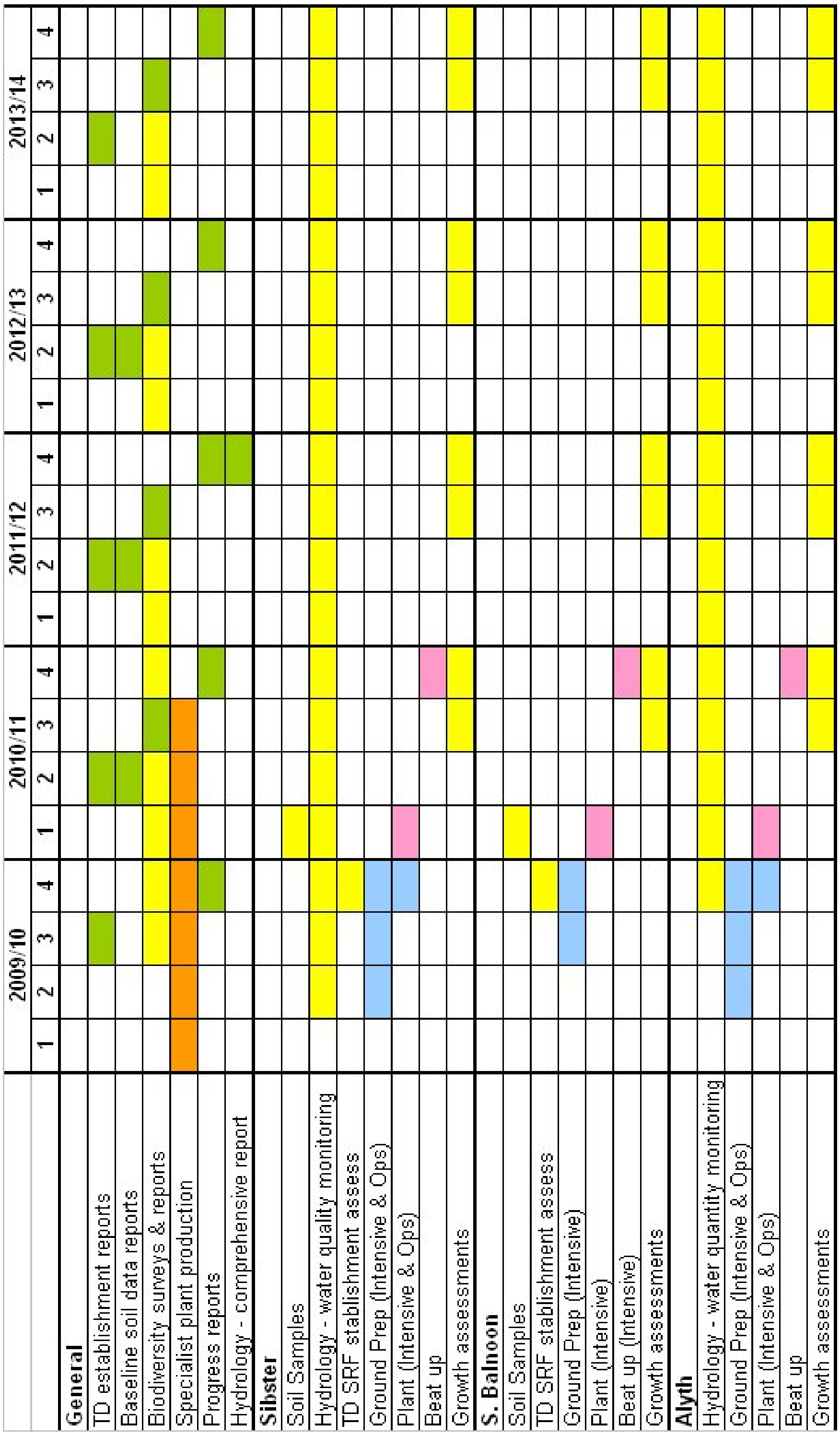
Appendix 5: **Major operational and research milestones in the establishment of the energy forestry exemplar trials.**



	2009/10				2010/11				2011/12				2012/13				2013/14			
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
East Grange																				
SRC stablishment - TD assess	Yellow																			
SRC maiden cut - TD assess				Yellow																
SRC harvest - TD assess																Yellow				
Ground Prep (Intensive)			Blue	Blue																
Plant (Intensive)				Blue	Pink															
Beat up (Intensive)								Pink												
Growth assessments							Yellow	Yellow			Yellow	Yellow			Yellow	Yellow			Yellow	Yellow
Auchlochan																				
Soil Samples								Yellow												
TD SRF stablishment assess								Yellow												
Ground Prep (Intensive & Ops)						Blue	Blue	Blue												
Plant (Intensive & Ops)								Blue	Pink											
Beat up												Pink								
Growth assessments											Yellow	Yellow			Yellow	Yellow			Yellow	Yellow
Mull																				
Soil Samples								Yellow												
TD SRF stablishment assess								Yellow												
Ground Prep (Intensive)							Blue	Blue												
Plant (Intensive)								Blue	Pink											
Beat up												Pink								
Growth assessments											Yellow	Yellow			Yellow	Yellow			Yellow	Yellow

- Yellow: Research work
- Orange: Plant production
- Green: Reporting
- Blue: Establishmnet operations (FES)
- Pink: Establishmnet operations (TSU)

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