Forest Research

Impacts of energy forestry on soil sustainability in the UK

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Woodfuel and the environment

World-wide goal - to develop renewable energy supplies and reduce GHG emissions

EU target for renewable to provide 12 % by 2010. New target agreed of 20 % by 2020

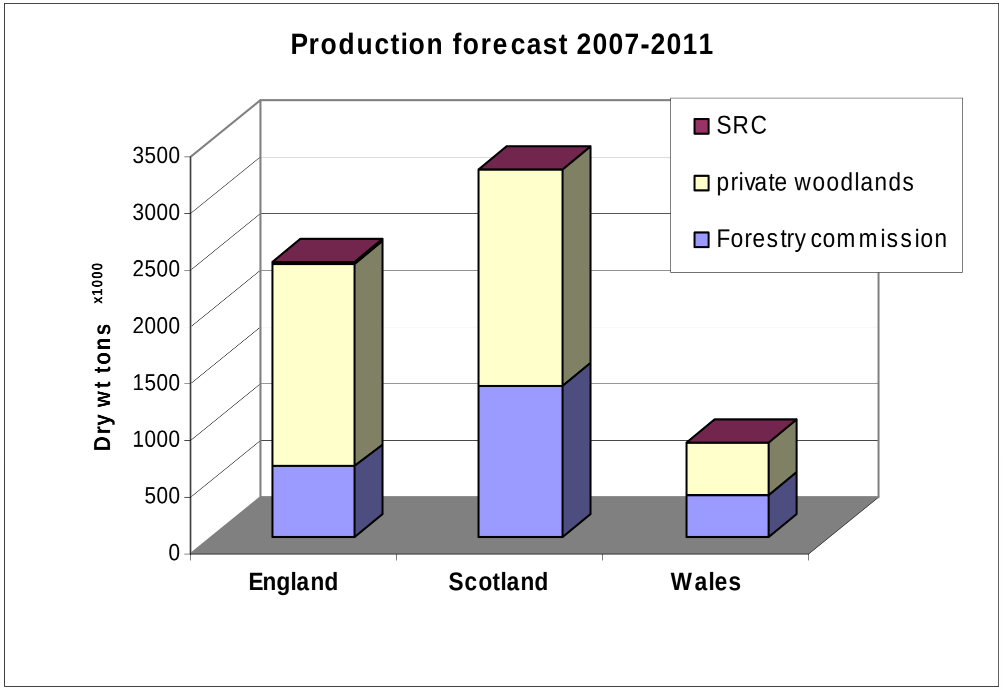
UK target for renewables (July 2009) of 15% by 2020 -

using biomass to provide 30% electricity generation and 12% heat generation

Pressure growing to exploit woody biomass from both forest residues (brash and stumps) and specific energy plantations.

Limits on expansion of energy forestry in the UK

- Afforested area currently only 12% in UK- 17% in Scotland



- Competition with food production from highly efficient agriculture
- Conservation issues in protected zones - National parks, SSSI sites, archaeology, peatlands, heathland, etc.

'The woodfuel market is in its infancy and the supply chain is dominated by small and medium-sized enterprises'

The UK Renewable Energy Strategy, July 2009

- Will demand for biomass fuels exceed the rate of production in the existing forest and residue resource?
- Is it appropriate to use agricultural land for biomass production?

If this is required, dedicated farm energy tree crops become an attractive option as high yields of biomass can be produced in a short time.

Government response to Energy crop demand

- Establishment Short Rotation Plantations in Scotland and England
- Widening the scheme to include ash, alder, hazel, silver birch, sycamore, sweet chestnut and lime - as well as willow and poplar (& eucalyptus)
- Research to examine the feasibility of **Short Rotation Forestry** and its effects on hydrology, carbon balance, local economy - to include investigation of possible environmental risks
- Defra's commissioned review of environmental impacts of SRF (2010)

DEFRA’s commissioned review on environmental impacts of SRF

- Review of SRF impacts on soil functions, including soil organic matter, nutrient capital, compaction, erosion and soil biodiversity.
- Focused on tree species that are best suited for UK energy forestry

Tree species litter quality and decomposition

Species	Rate of decomposition
Ash	Rapid
Alder	Rapid
Sycamore	Rapid
Hazel	Rapid
Hornbeam	Intermediate-rapid
Birch	Intermediate
Chestnut	Intermediate
S.beech ~ N obliqua	Intermediate
Willow (S. alba, S. gragilis)	Intermediate
Poplar (P. trichocarpa), P. tremula/P.nigra	Intermediate
Oak	Intermediate -slow
Eucalyptus (E nitens)	Slow
Eucalyptus (E gunnii)	Slow

DEFRA's commissioned review on environmental impacts of SRF

Review of SRF impacts on soil functions

Changes of soil C under SRC and SRF plantations

SRC/SRF/ species planted	Previous land use	Soil C	Time span (years)
SRC Poplar (USA)	Agriculture	increase	12-18
Mixed coppice of (Germany)	Agriculture	increase	7-9
Plantation	Arable	increase	not reported
Secondary forest	Arable	increase	not reported
Eucalyptus nitens (Tasmania, Australia)	Pasture	increase	10-40
Eucalyptus globulus (Victoria, Australia)	Pasture	increase	10-40
Eucalyptus globulus (SW Australia)	Pasture	increase	10-40
SRC Poplar (USA)	Agriculture	no change	6-15
SRC Willow (USA)	Grass/schrub land	no change	4
Poplar, Aspen and Willow	Agriculture	loss	7-9
Oak plantation (Denmark)	pasture	loss	not reported
Oak plantation (Denmark)	pasture	loss	not reported
Plantation	Pasture	loss	not reported
Plantation	Native forest	loss	not reported
Eucalyptus nitens (Tasmania, Australia)	Pasture	loss	0-10
Eucalyptus globulus (Victoria, Australia)	Pasture	loss	0-10
Eucalyptus globulus (SW Australia)	Pasture	loss	0-10

DEFRA's commissioned review on environmental impacts of SRF

Review of SRF impacts on soil functions

Rates of soil C sequestration after re-establishment of deciduous forest on ex agricultural land

Forest Ecosystem	Previous land use	Years since land use change	Soil C rate (kg C ha^{-1} y^{-1})
Old field succession to hard woods (US)	Arable	10	151
Old field sucession to mixed oak (US)	Arable	>250	94
Oldfield sucession to hardwoods (US)	Arable	>100	116
Abandoned field to mixed forest (US)	Arable	66	22
Natural oak forest sucession, Broadbalk (UK)	Arable	100	561
Natural oak forest sucession, Geescroft (UK)	Arable	102	426
Planted hardwood, West tofts (UK)	Heathland	21	~47.6
Planted hardwood, Bedgebury (UK)	Hazel coppice/standards	20	(v.high >700)
Planted hardwoo, Abbot wood (UK)	Mixed ok wood	45	~666
Planted oak, Alice Holt (UK)	Pasture woodland	80	116

The benefits of Short Rotation Forestry (SRF) for soil functions

- Increase in soil C stocks and sequestration in the soil through litterfall inputs, less cultivation, soil disturbance and fertilisation
- Reduced nitrogen and phosphorous leaching due to higher water use, deeper rooting and less fertilisation
- Soil physical stability due to reduced cultivation
- Reduced physical soil erosion due to soil stabilization
- Increased soil biodiversity particularly ectomycorrhizas and earthworms

Potential risks of Short Rotation Forestry (SRF) for soil functions

- Removal of essential nutrients in biomass, leading to lower soil fertility and potential loss of tree growth in later rotations
- Machine trafficking causing soil physical damage such as compaction and rutting
- Increased crop water use resulting in reduced groundwater recharge and ecological flows

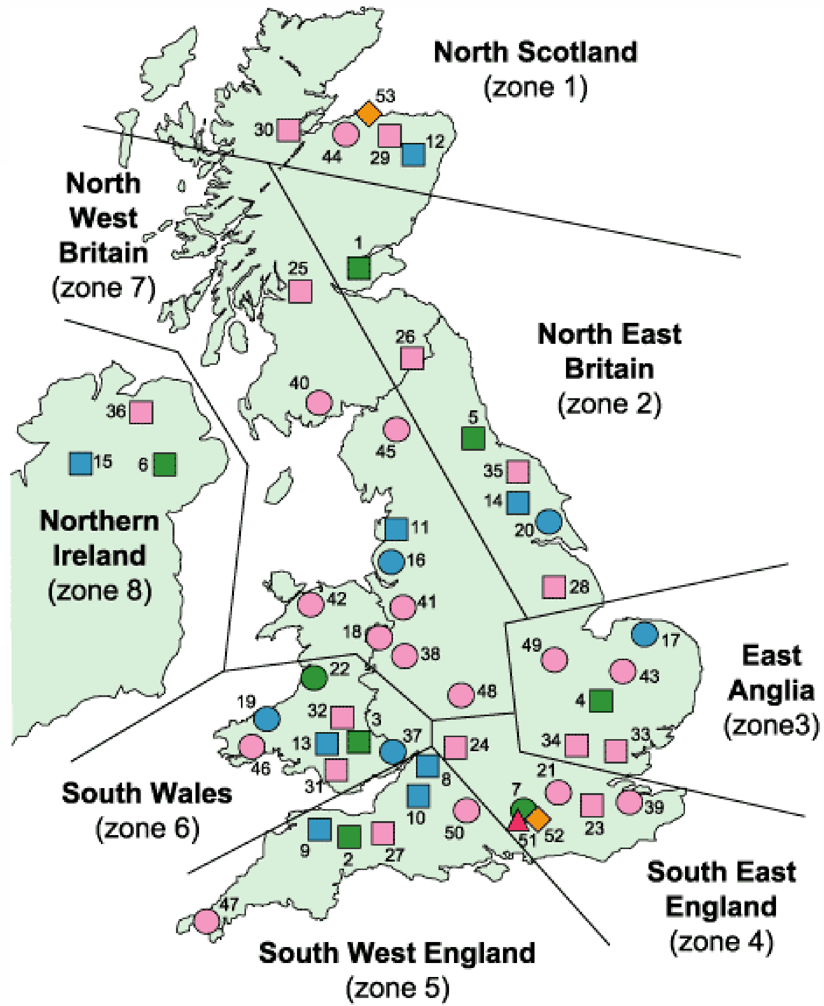
Uncertainties and Needs

- Uncertainties remains of the soil C sequestration rates in the long term.
- Urgent need for validating C models.
- Uncertainties as to what will be the impacts of Eucalyptus and Nothofagus litter on soil C, acidity and nutrients.
- 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. Soils play an important part in all.

Short Rotation Coppice - previous research

SRC Biomass yield of willow and poplar clones 1998-2003

Monitoring of water use **but not** soil baseline and change.



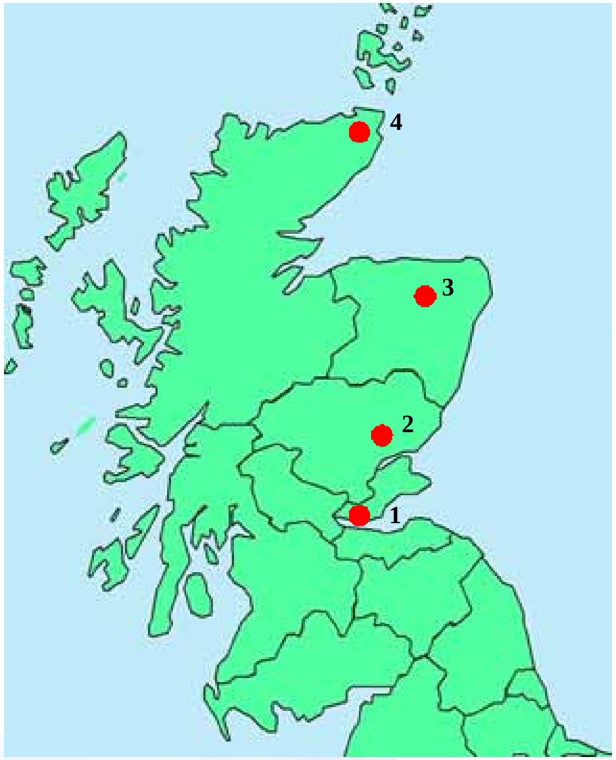
Short Rotation Forestry (SRF) in Scotland

Baseline Soil Survey 2009-2010

4 sites on ex-agricultural land

East Grange

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



Alyth

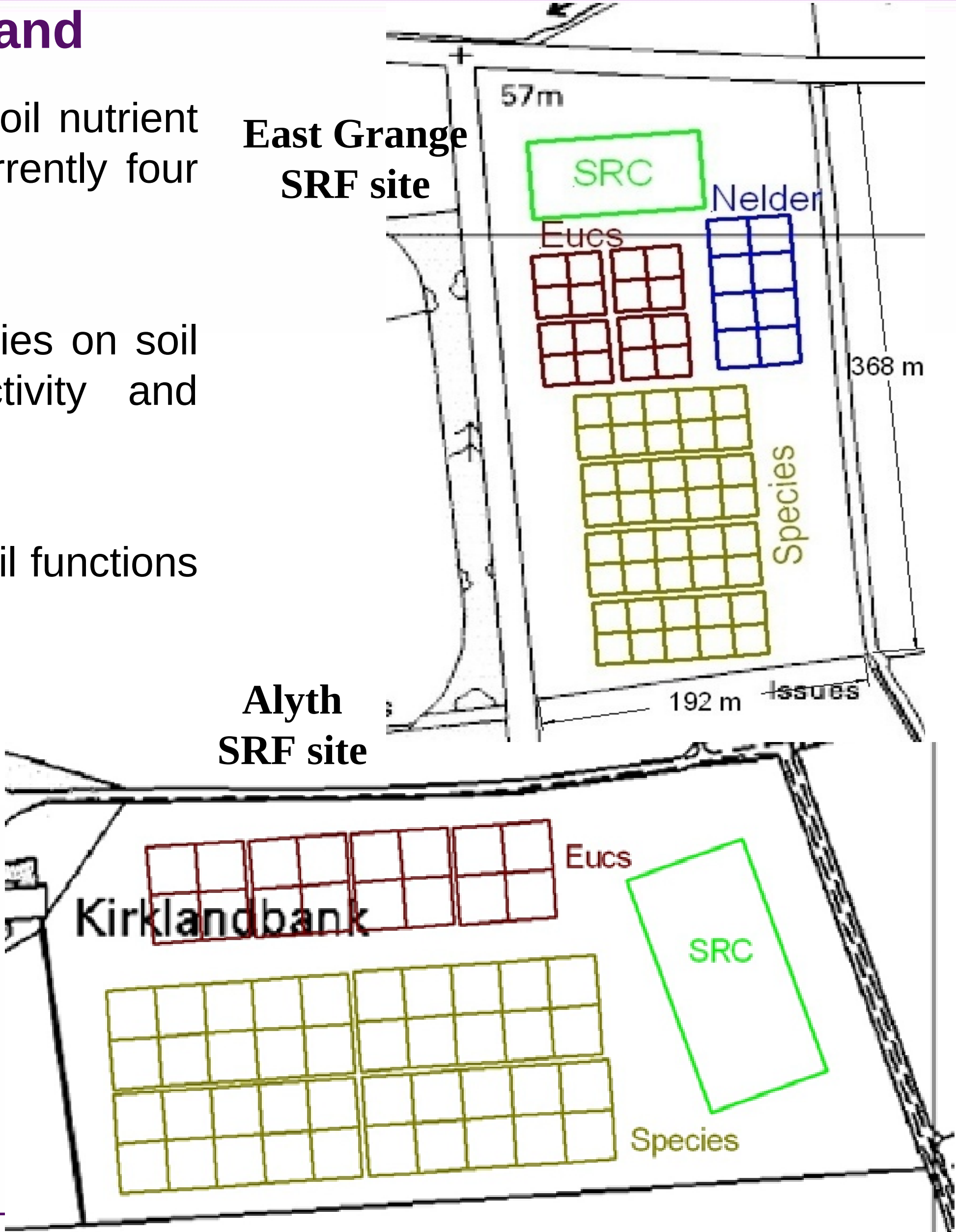
South Balnoon

Objectives in the SRF in Scotland

- To establish a baseline of soil carbon and soil nutrient and biological status, prior to planting in currently four SRF and SRC trials in Scotland.
- To evaluate the effect of different SRF species on soil carbon, nutrient dynamics, biological activity and diversity.
- To evaluate the overall impacts of SRF on soil functions compared with SRC.

East Grange SRF site

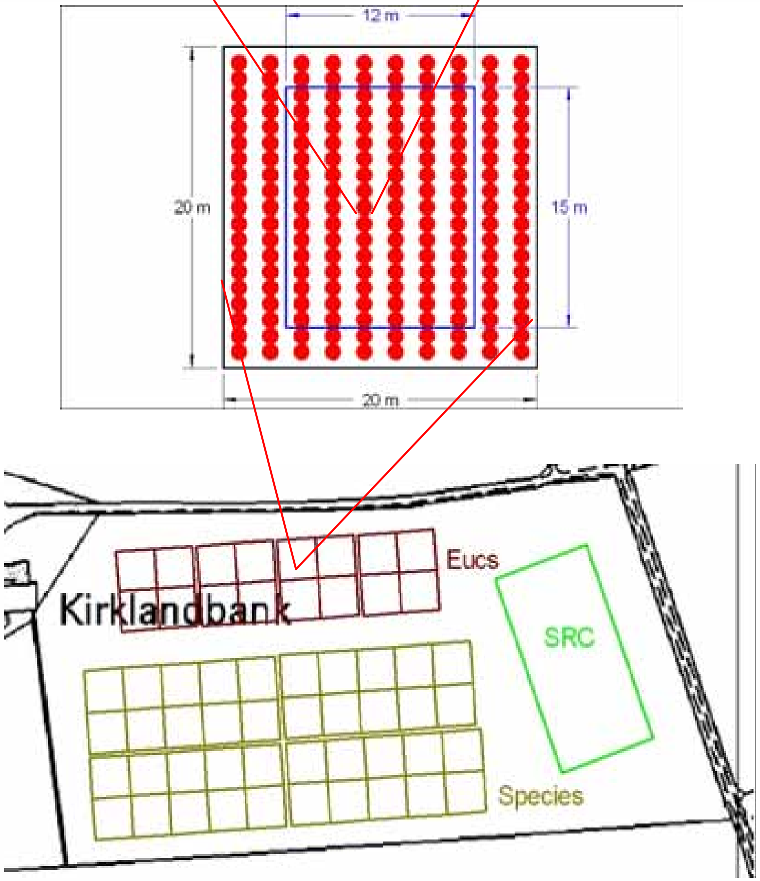
Alyth SRF site



- **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.)
- **Unplanted control**
- **Eucalyptus**

Soil survey - Methods and Analysis

12 soil sampling points in a grid system of 4 x 3 m in the centre plot; 0-20, 20-40 and 40-80 cm soil depth



Soil analysis

pH
Soil bulk density/soil moisture content
Total organic/inorganic C
Total N
Exchangeable base cations and acidity
Available Phosphorous
Microbial activity

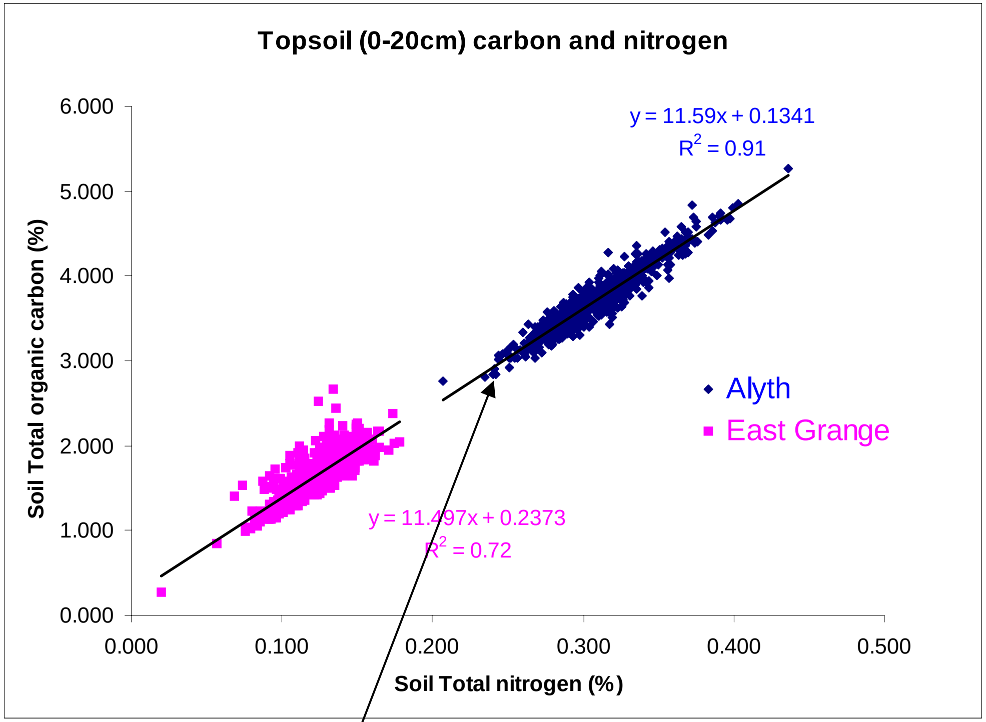
Short Rotation Forestry (SRF)

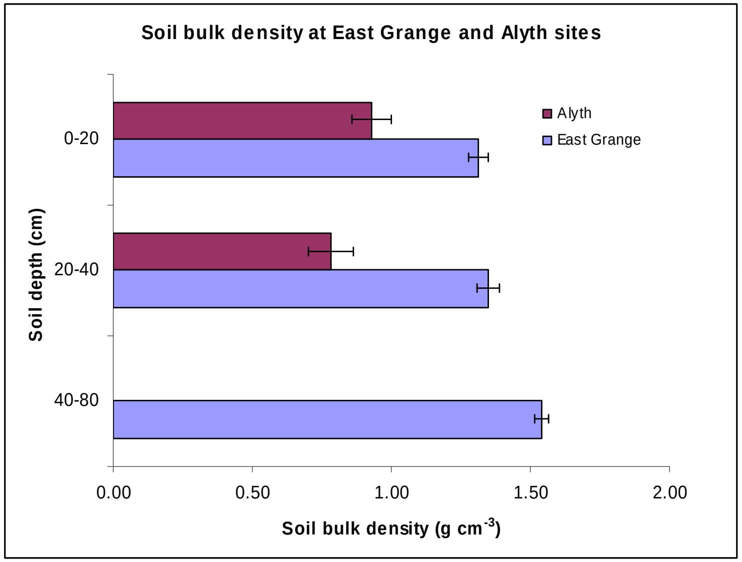
Baseline Soil Survey 2009-2010 in Scotland at East Grange and Alyth

East Grange

Alyth

Preliminary soil results at Scottish SRF sites





Different soil variability - Alyth less variable

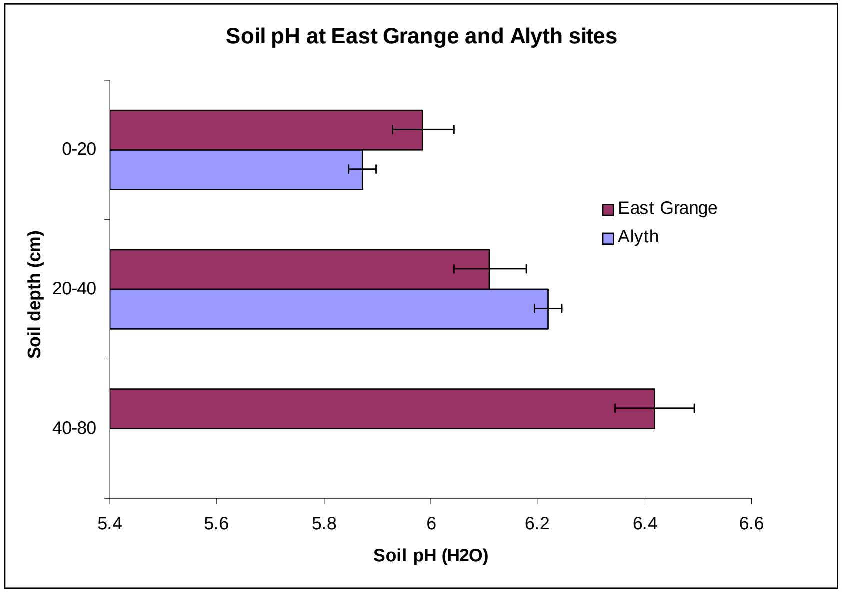
Soil C stocks in topsoil (0-20 cm)

43 t C ha^{-1} 69 t C ha^{-1}

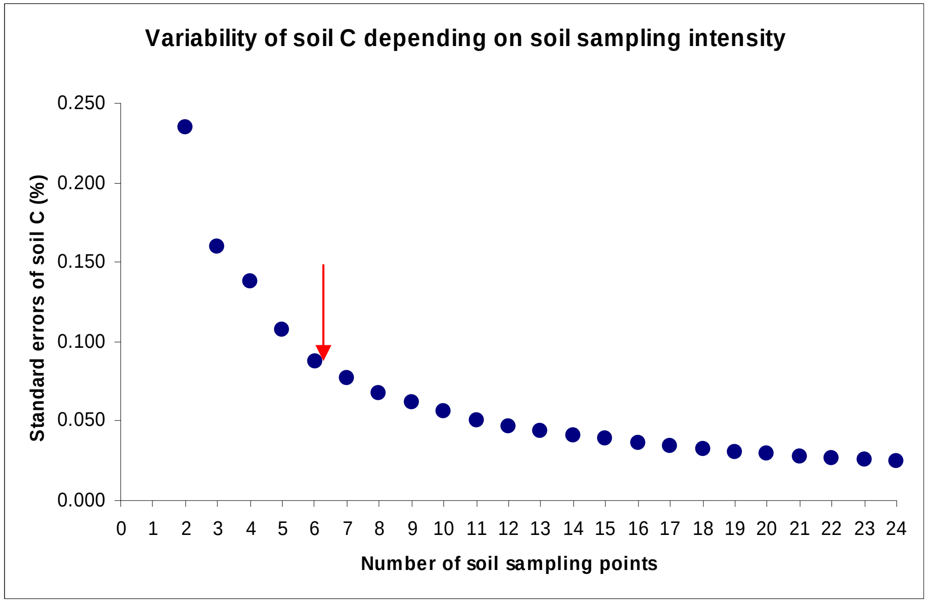
- Different soil C, N concentrations and stocks
- e.g. Alyth higher in soil C, N and their stocks, despite lower bulk density

Preliminary soil results at Scottish SRF sites

Different soil pH at top soil, e.g. higher at East Grange



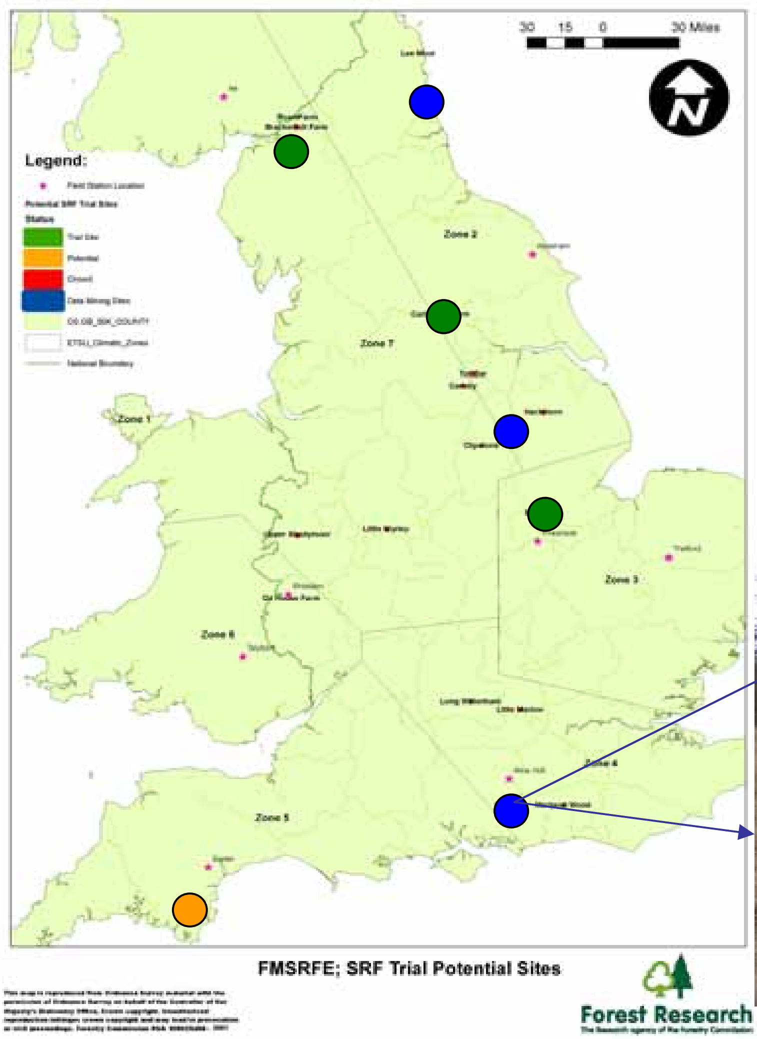
Minimum sampling points for soil baseline assessments for other SRF sites



SRF and data scavenging sites in England

- 4 sites for SRF establishment on ex-agricultural land and grassland (1 potential) soil baseline will be established in 2010

- 3 data mining sites (Eucalyptus plantations of different ages) - current evaluation on soil carbon, acidity and nutrient status and soil biodiversity



High Forest

The Woodfuel Strategies from the Forestry Commission

- **England** (2007) aims to bring an additional 2 million tonnes of woodfuel to market by encouraging owners into improved woodland management - improved grants for resource planning and establishment with Regional Development Agencies
- **Wales** (2009) in a Rural Development Plan is funding grant schemes for woodland owners to increase low quality biomass material, and scoping an increase of 80,000 t.p.annum. from the public estate
- **Scotland**(FCS): currently funding the Scottish Biomass Support Scheme (£7 million) and the Scottish heat Scheme to increase the supply of wood for renewable energy-including stump harvesting

- Creation of the **Woodfuel Research Centre** (2005) - to interface between woodland owners and researchers answering technical and practical questions arising from any step along the wood supply chain

Ways of extracting Biomass from forestry for energy

- Extraction of residues (brash)
- Extraction of tree stumps

Stump lift

Stump splitting

Stump shake

Potential risks to soils by forest residue extraction

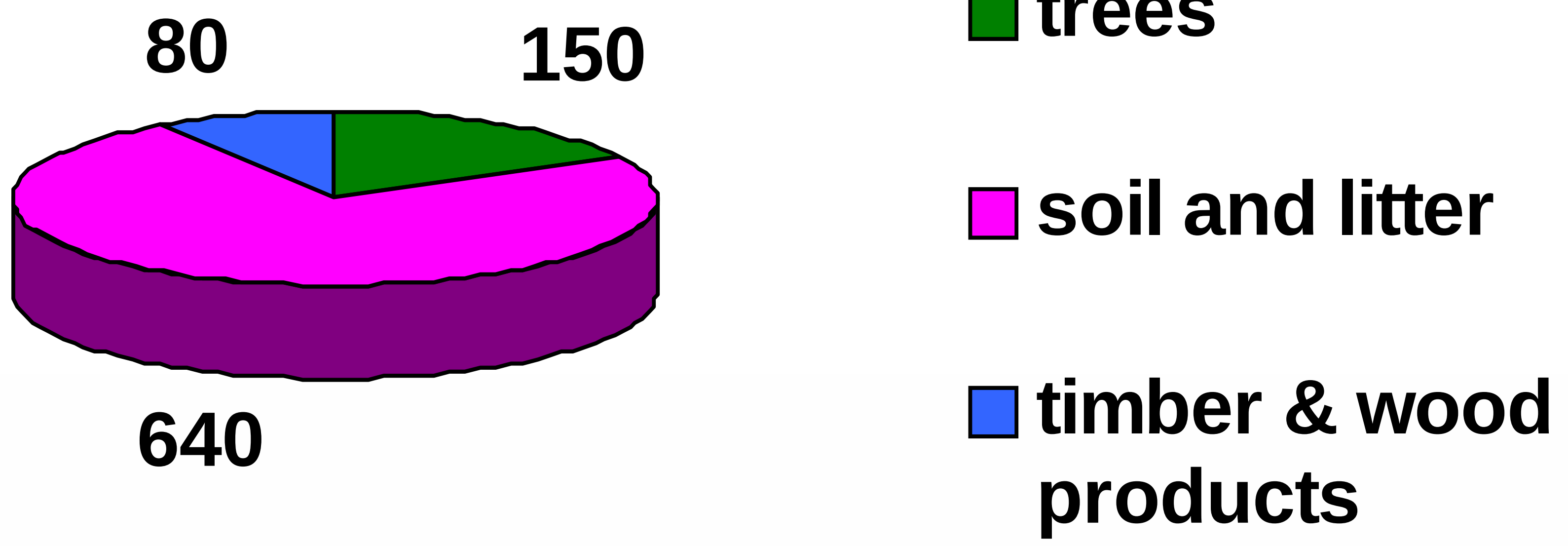
- 1) Ground damage,
- 2) Soil infertility,
- 3) Soil acidification
- 4) Soil carbon loss

1.Machine trafficking causing soil physical damage such as compaction, rutting and erosion, leading to increased turbidity and siltation of local watercourses.

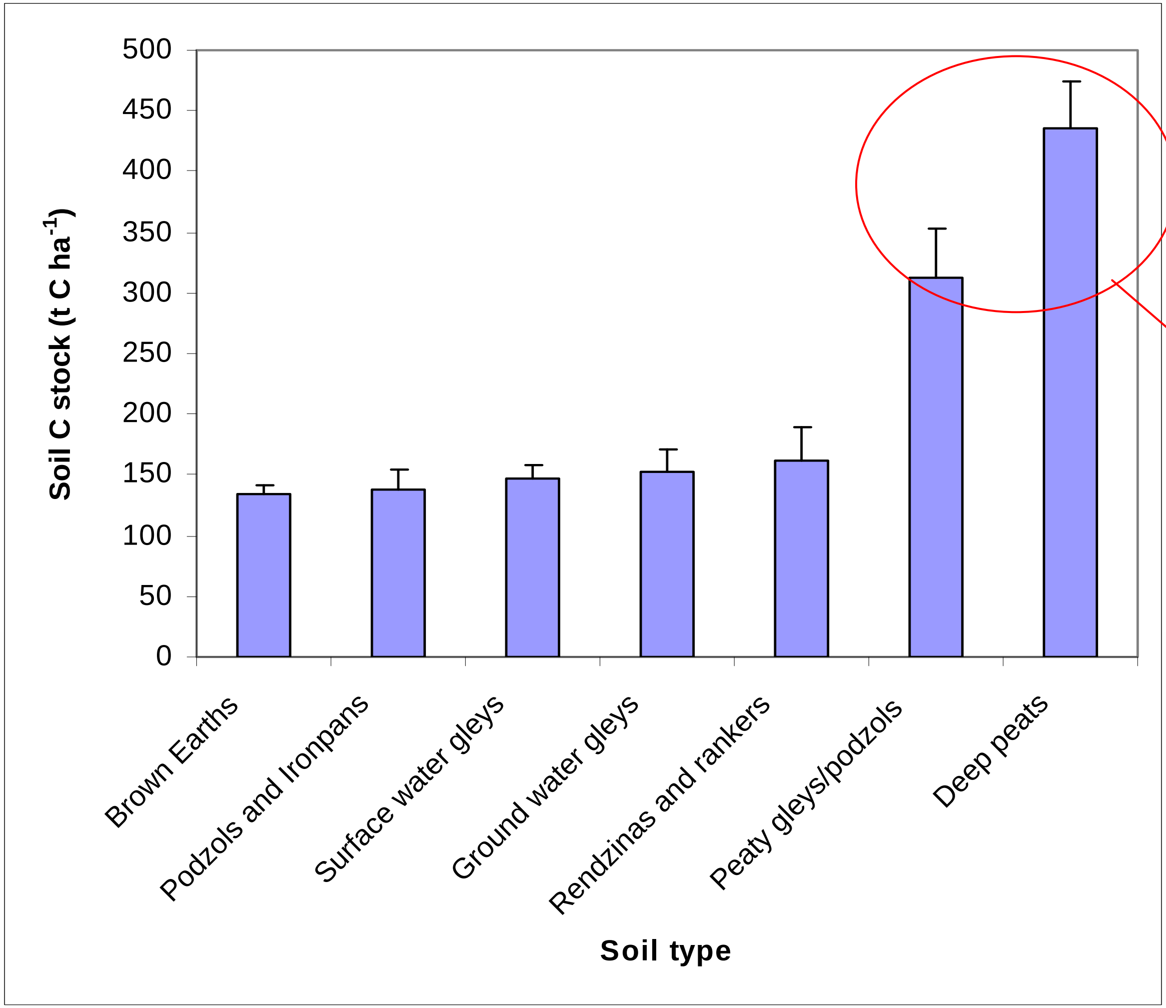
2.Removal of essential nutrients (nitrogen, phosphorus and potassium) and carbon in residues, leading to lower soil fertility, potential loss of tree growth in subsequent rotations, and reduced soil carbon storage.

3.Removal of base cations (calcium, magnesium, sodium and potassium) reducing soil buffering capacity and leading to increased soil and stream water acidification.

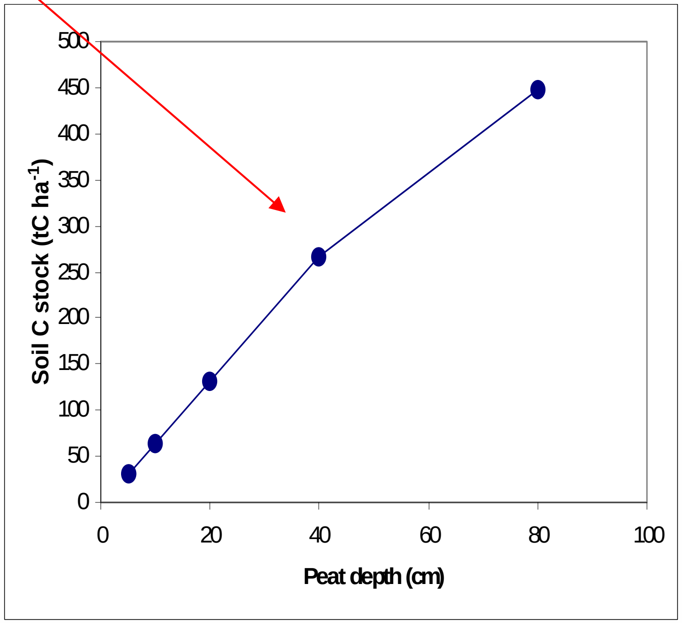
Carbon Pools in UK Forests (Million Tonnes)



CARBON STOCKS: Variability of soil C stock in each soil group

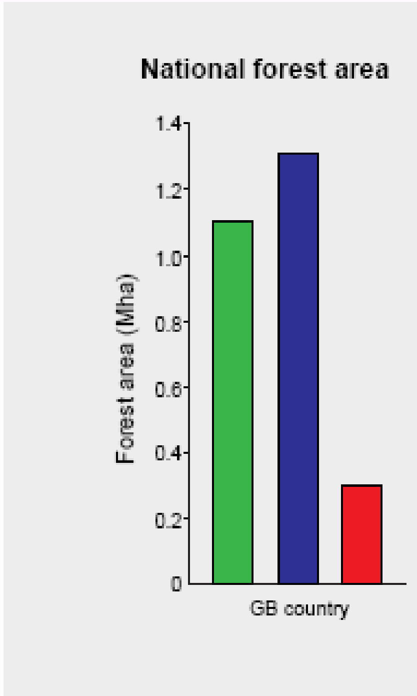


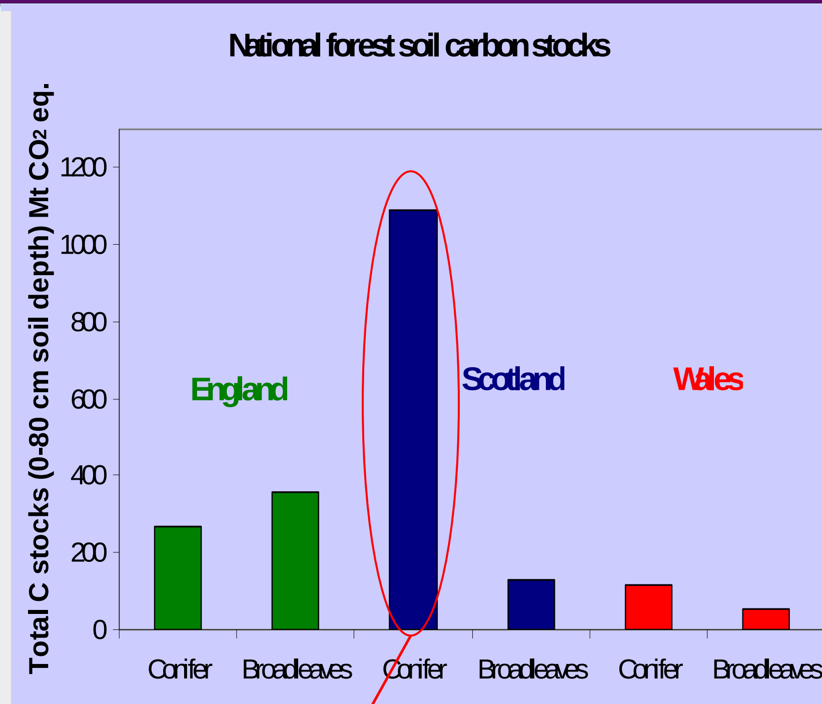
Forest soil C stocks related to peat layer depth



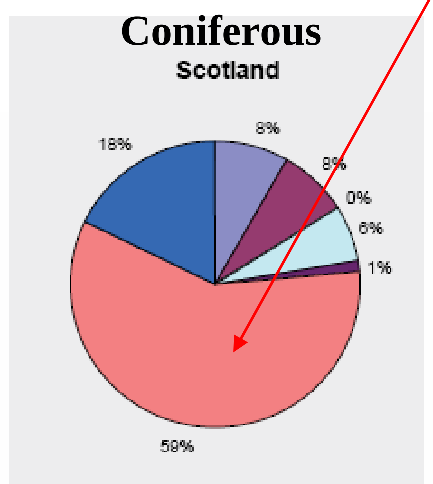
Vanguelova et al, 2009

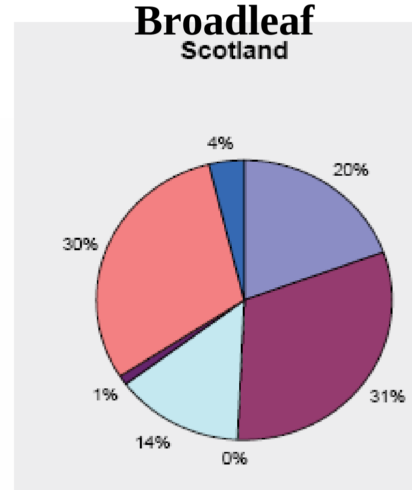
BioSoil plots in UK





Peaty Gleysoil





Stump harvesting for Biomass in the UK

- Field Demonstrations in Wales and Scotland with
- alternative harvesters

- Forest Research Review on destumping impacts
- (Pitman, 2009)

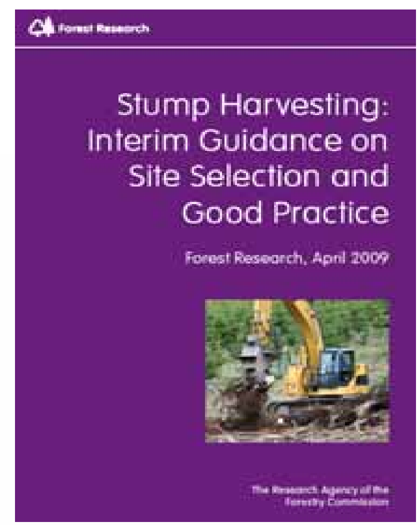
- Environmental impacts of destumping (Walmsely, 2009)

- Forest Research Information note in preparation (Moffat, 2010)

- Published Interim Guidance on site selection and good practice compiled to enable assessment of likely soil damage, soil carbon loss, and acidification by Soil groups

- Site investigation at Bala, Wales on private site with both conventional and destump harvesting

- Potential large scale experiment in Scotland



Soil survey and tree growth assessment 2009 - Bala, Wales

Soil catena from podsolic brown earth (up-slope) to peaty gley soil (lower slope)

Typical soil disturbance on the upper slope un-colonised after three years of destumping

Grateful thanks for site access to Tilhill Forestry and UPM

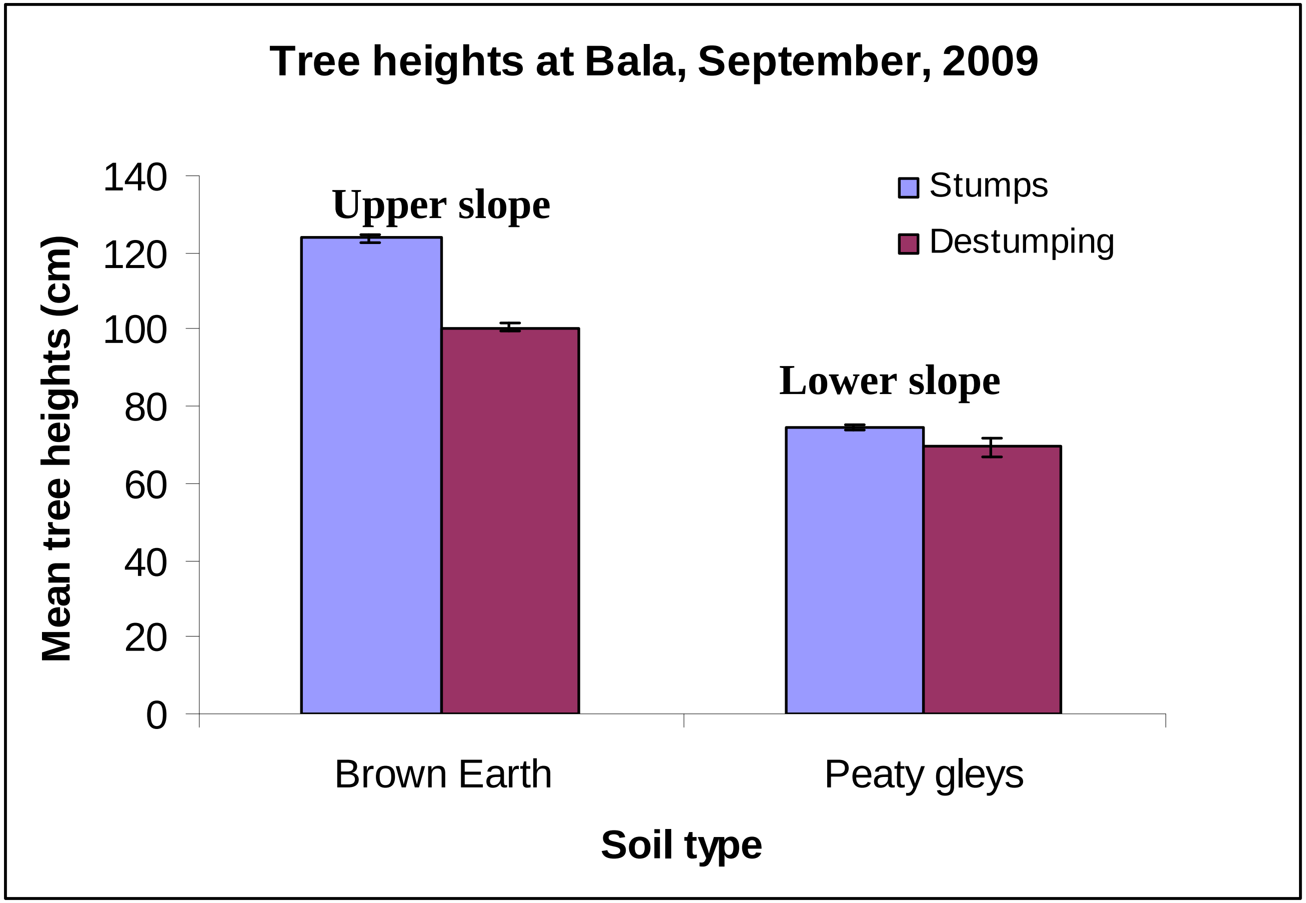
Soil survey and tree growth assessment 2009 - Bala, Wales

Sitka saplings in competition with *Juncus* rush on the peaty gley destumped soils

Naturally regenerating Sitka on peaty gley with stumps retained

Grateful thanks for site access to Tilhill Forestry and UPM

Tree heights assessments at Bala, September 2009



Soil currently being analysed!

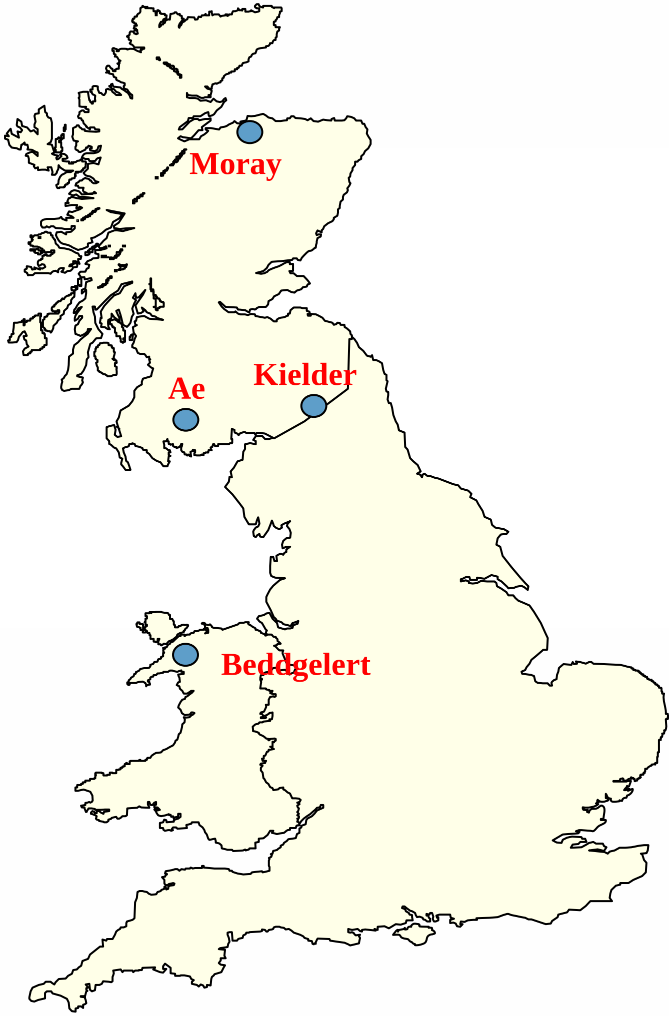
Existing long term WTH experiments in UK

Long term WTH experiments in UK:

Kielder 28 years (Titus & Malcolm, 1991; Proe and Dutch 1994);

Beddgelert site 23 years (Stevens & Hornung 1988; Walmsley et al, 2009);

Kielder 14, Ae 10 and Moray 6 years (McKay, 1995)



WTH - Kielder forest

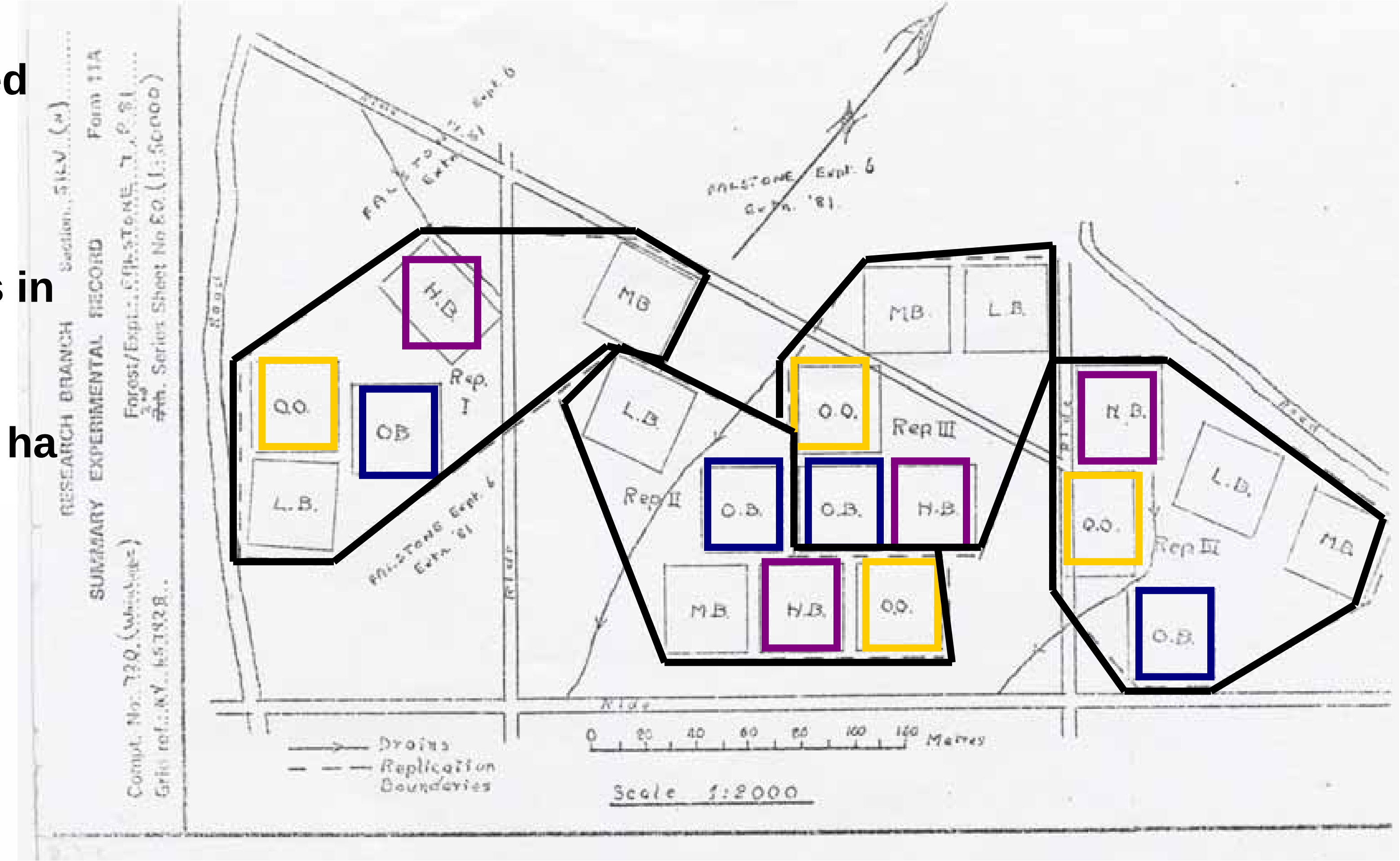
- WTH long term experiment in Kielder 1981
- 28 years of second rotation Sitka spruce
- Elevation 300m
- Precipitation 1300mm
- Peaty gley soil (16 cm peat depth)
- Carboniferous sandstones
- First rotation Sitka spruce 1939-1979

- **Treatments:**
- OB - Brash left undisturbed. No fertilisation
- OO - All brash removed at the time of felling. No fertilisation.
- HB - Brash undisturbed. Application of 150 kg/ha N, 50 kg/ha P and 100 kg/ha K at planting and every 3 years after

WTH experimental set up in Kielder Forest, UK

OB - conventional harvesting; OO - Whole Tree Harvesting; OB - Fertilisation (N,P,K)

- **4 randomised blocks, all facing SW**
- **3 treatments in each block**
- **Plot size 0.1 ha**



Kielder 1981 WTH experiment-measurements

- <u>**Soil sampling and analysis**</u>

  a) (soil horizon, litter, F, H, A, E)

  b) bulk density, July 2008

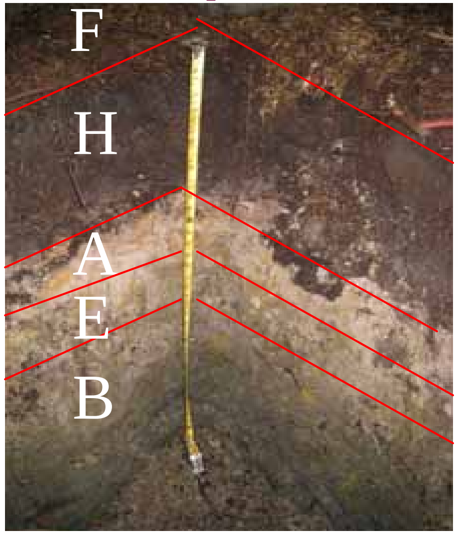
  c) 12 samples per horizon and per plot = 540 soil samples

- **Soil analysis - pH, exchangeable cations and acidity, available NO_3-N,NH_4-N, elemental analysis by acid digestions**

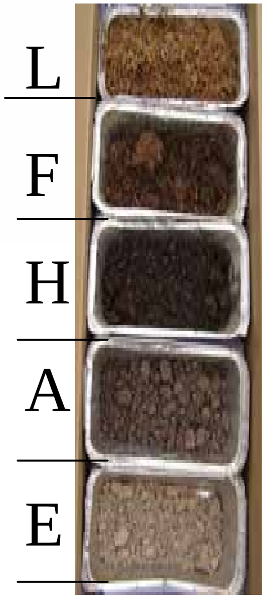
- **Dendrochronological sampling and analysis (10 trees per plot).**

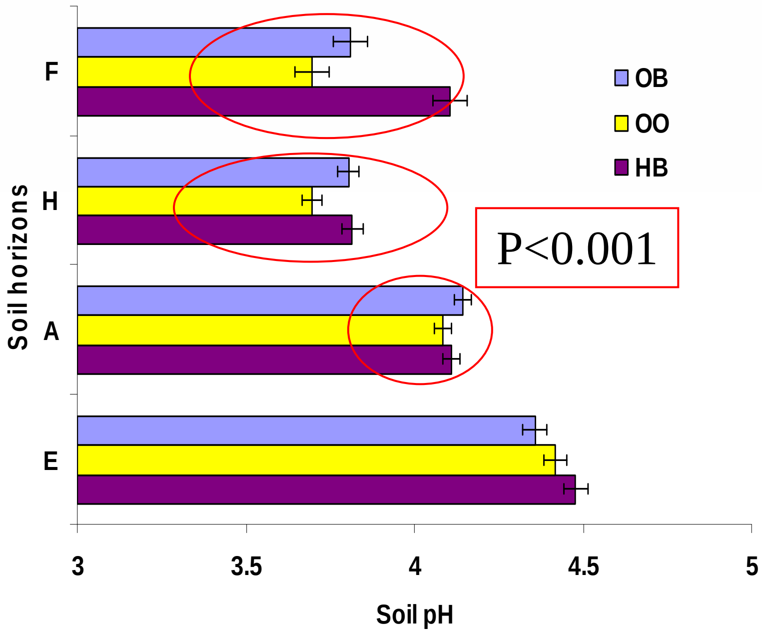
- **Tree DBH, height and density measurements.**

- **Foliar sampling (needle 0, needle 1, branches) November 2008, chemical analysis.**

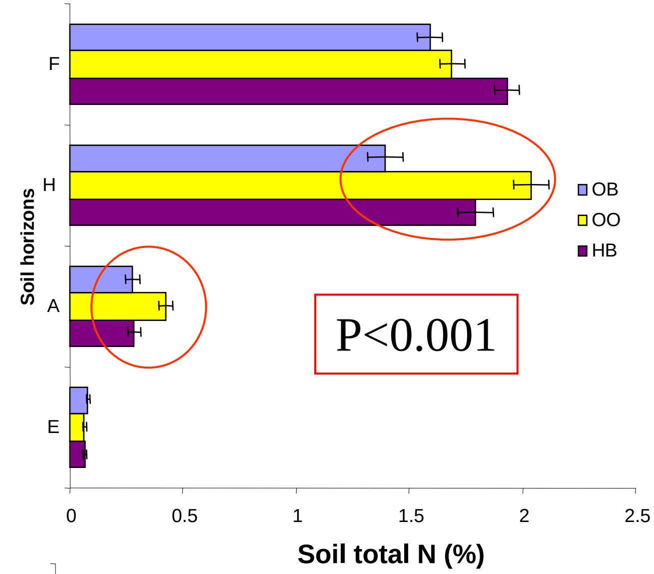


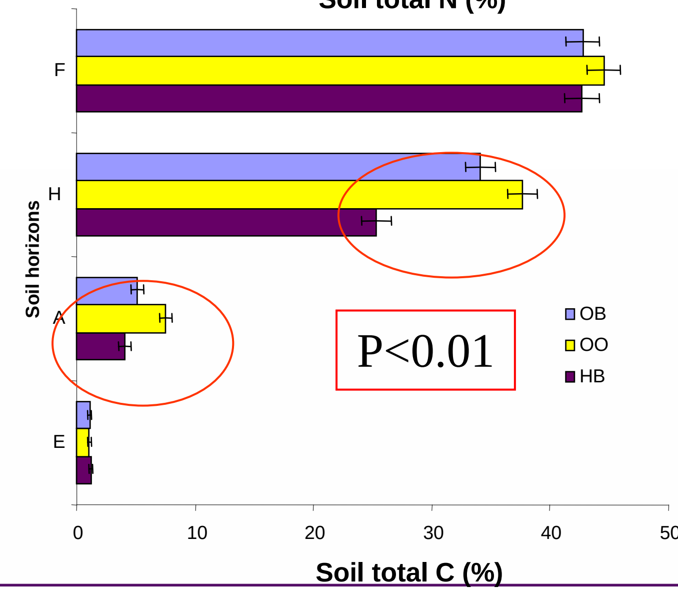
Soil acidity





Soil organic C and total N



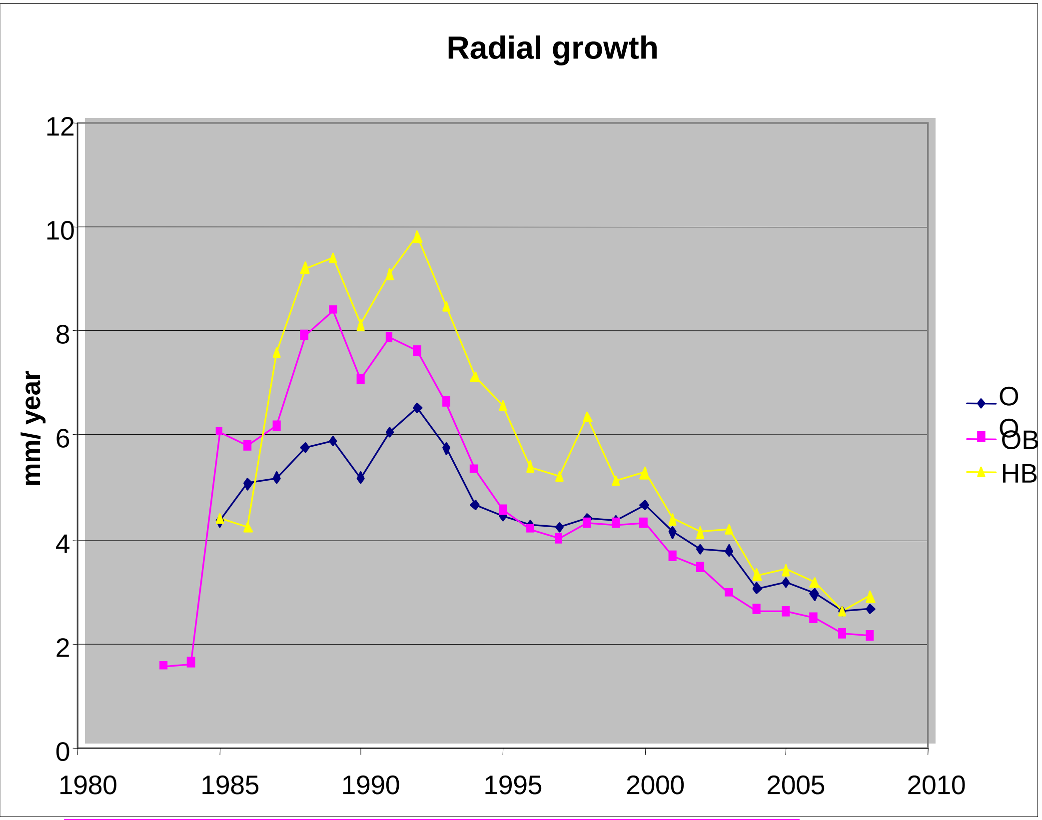


OB Conventional harvesting with brash

OO Brash removed

HB brash retained and added fertilisation

Long term tree growth dynamics



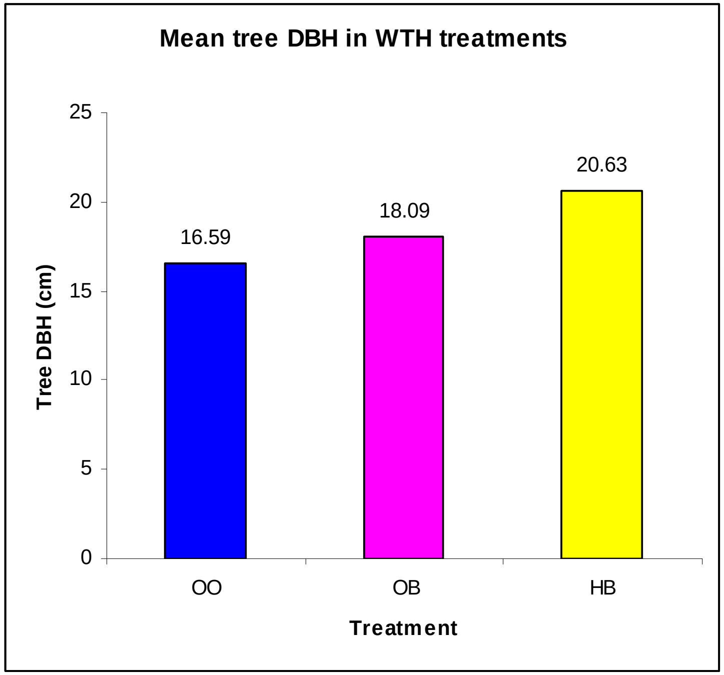
OB Conventional harvesting with brash

OO Brash removed

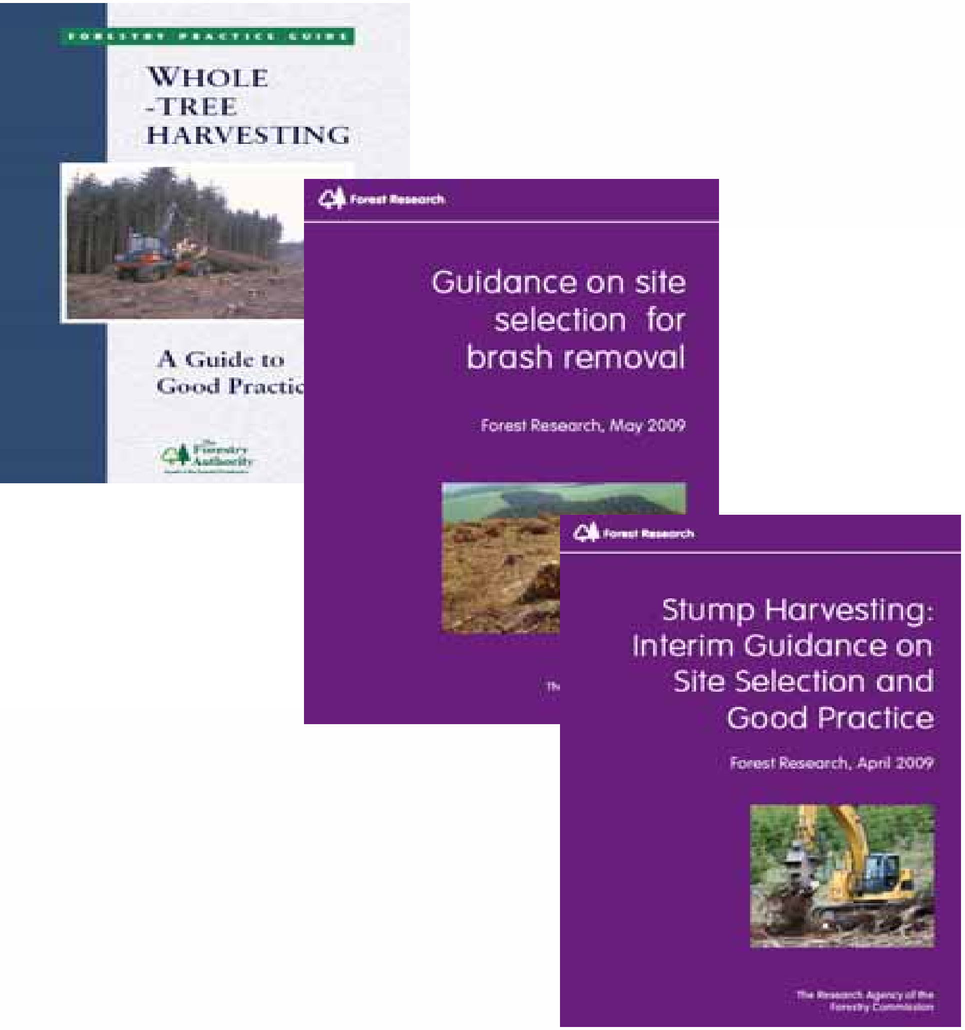
HB brash retained and added fertilisation

Soil effects

1. Acidification of WTH soil
2. Higher soil C and N in WTH
3. Greater retention of base cations& P, K in WTH soils
4. WTH on highly organic soils may offset the lower aboveground biomass
5. Carbon balance is needed



Current guidelines for best practices in the UK



Soil group	Soil type	Ground damage	Soil carbon	Soil infertility	Soil acidification	*Combined Risk*
Brown earths	1, 1d, u	L	L	L	L	L
	1z	L	L	M	M	M
Podzols	3, 3m	L	L	H	H	H
	3p	M**	M	H	H	H
Ironpan soils	4, 4p	M**	M	M	M	M**
	4b	M	L	M	M	M
	4z, 4e	M	L	H	H	H
Calcareous soils	12b, t	L	L	L	L	L
	12a	L	L	H*	L	H*
Ground-water	5	M	L	L	L	M
	5p	M**	M	L	L	M**
Peaty gleys	6	M	M	M	M	M
	6z	M	M	H	H	H
	6p	H	M	M	M	H
Surface-water	7, 7b	M	L	L	M	M
	7z	M	L	M	M	M
Juncus bogs	8a, b,	H	H	L	L	H
Molinia bogs	9a, b	H	H	M	M	H
	9c, d, e	H	H	H	H	H
Unflushed	11a, b,	H	H	H	H	H
Rankers	13b, z	L	L	H	H	H
	13g	M	L	H	H	H
	13p	M	M	H	H	H
Skeletal soils	13s	L	L	H	H	H
Littoral soils	15s, d,	L	L	H	H	H
	15g, w	H	L	H	H	H

L: low risk; M: medium risk; H: high risk. *Only for conifer stands, otherwise low risk. **3p, 4p and 5p are high risk where the depth of the peaty surface layer is >25 cm.

<u>Future directions and needs:</u>

1) Comprehensive scientific underpinning
2) Site specific soil nutrient balances
3) National mapping of forest nutrient balances

Summary

- Drive to develop renewable energy from forestry
- Potential, constrains and impacts on soils by energy forestry
- Need for detailed scientific information on the impacts of SRF/SRC on soil C, nutrients and biology
- UK forest soils protected by developed guidelines for best practices.
- Soil baseline, long term monitoring and research is ongoing in SRF/SRC trials in Scotland and England to scientific underpin the carbon models and the efficiency of SRF for climate change mitigation.
- Research is ongoing to scientifically underpin FR guidelines for sustainable forest management

Acknowledgement

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Tilhill Forestry

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