Effect of afforestation on soil carbon stocks

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CARB*i*FOR II: Carbon Sequestration in Irish Forest Ecosystems

Introduction

- General perception that forest soils would store more carbon than grassland soils.
- Coupled with the large amount of carbon in forest biomass – high sequestration potential
- Reflected in Kyoto protocol and IPCC measures

Rational – Litter quality

- Litter inputs from tree less degradable than grassland litter.
- Many SOM models suggest that high C:N and high lignin:N contribute to this slow rate of decomposition

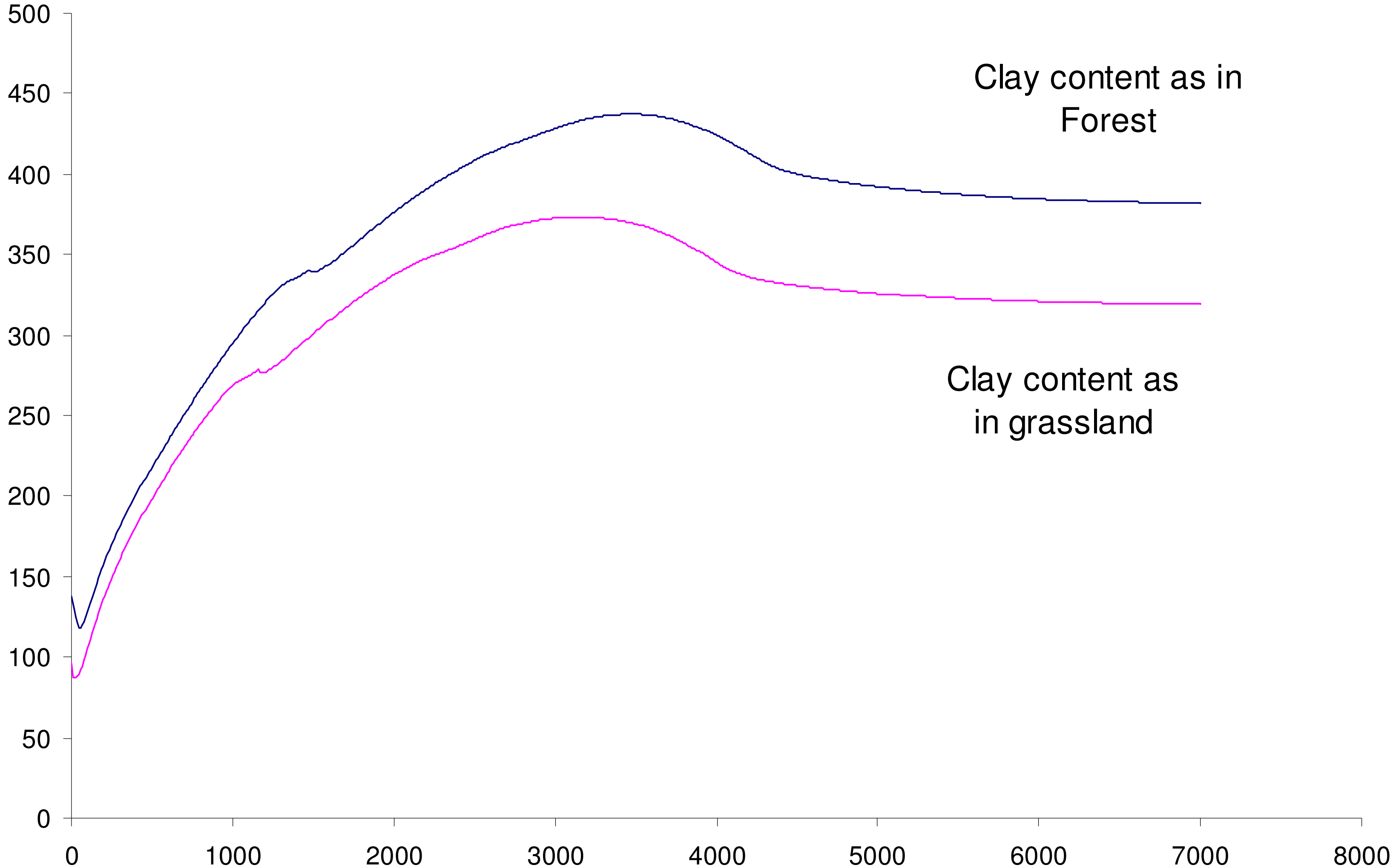
Sitka spruce litter in a 15 year-old stand

Date	C	N	C/N	% lignin	lignin/N
July-02	48.14	1.3	37.03	39.06	28.51
August-02	47.8	1.58	30.25	42.08	28.63
September-02	47.57	1.32	36.04	44.20	30.57

Rationale – Soil Texture

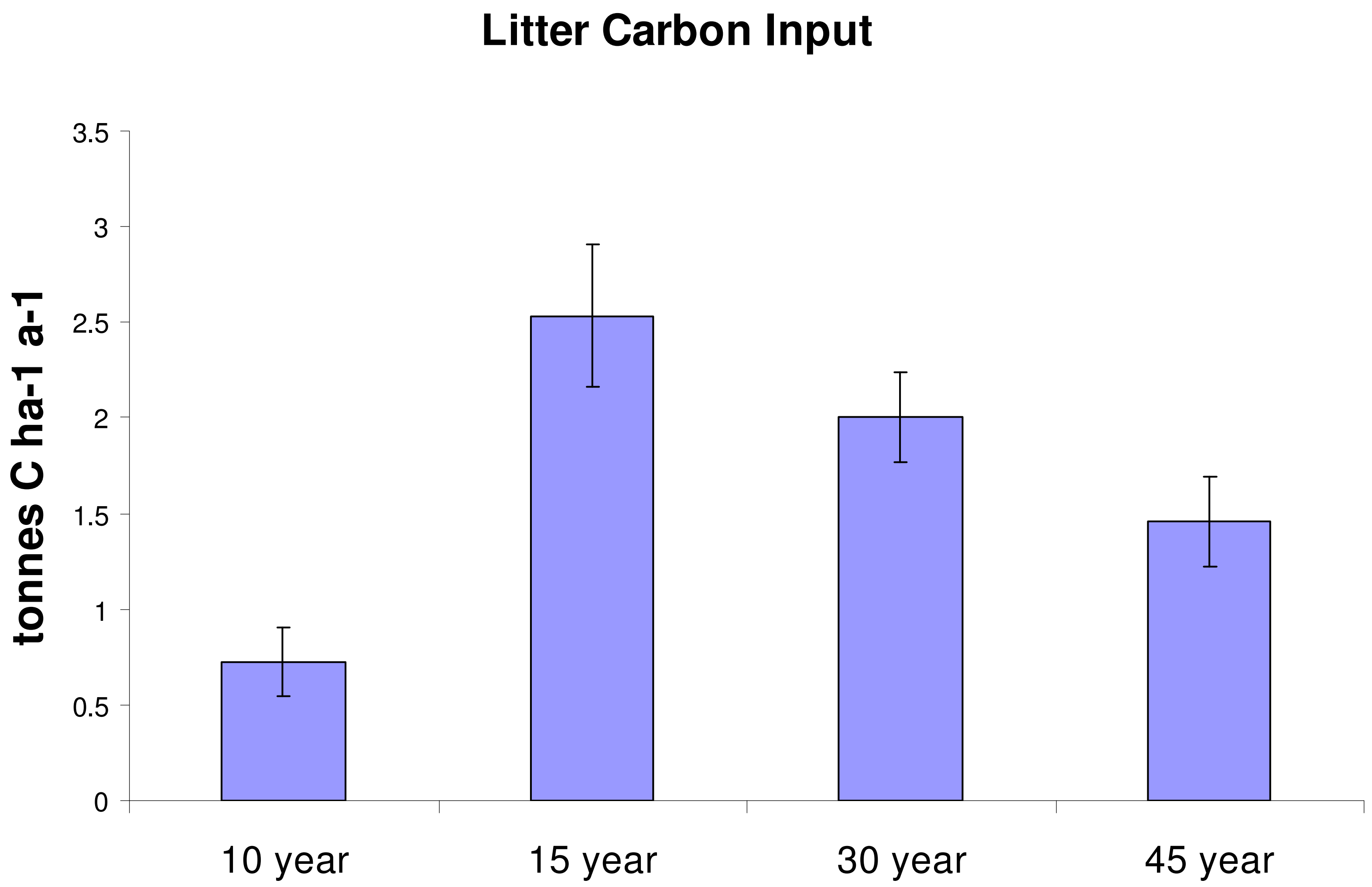
- Large proportion of Irish forests on gley soils, with high clay content which leads to increased physical protection of organic matter
- “Kyoto forests” more likely to be on gley soil rather than peat

Soil Texture

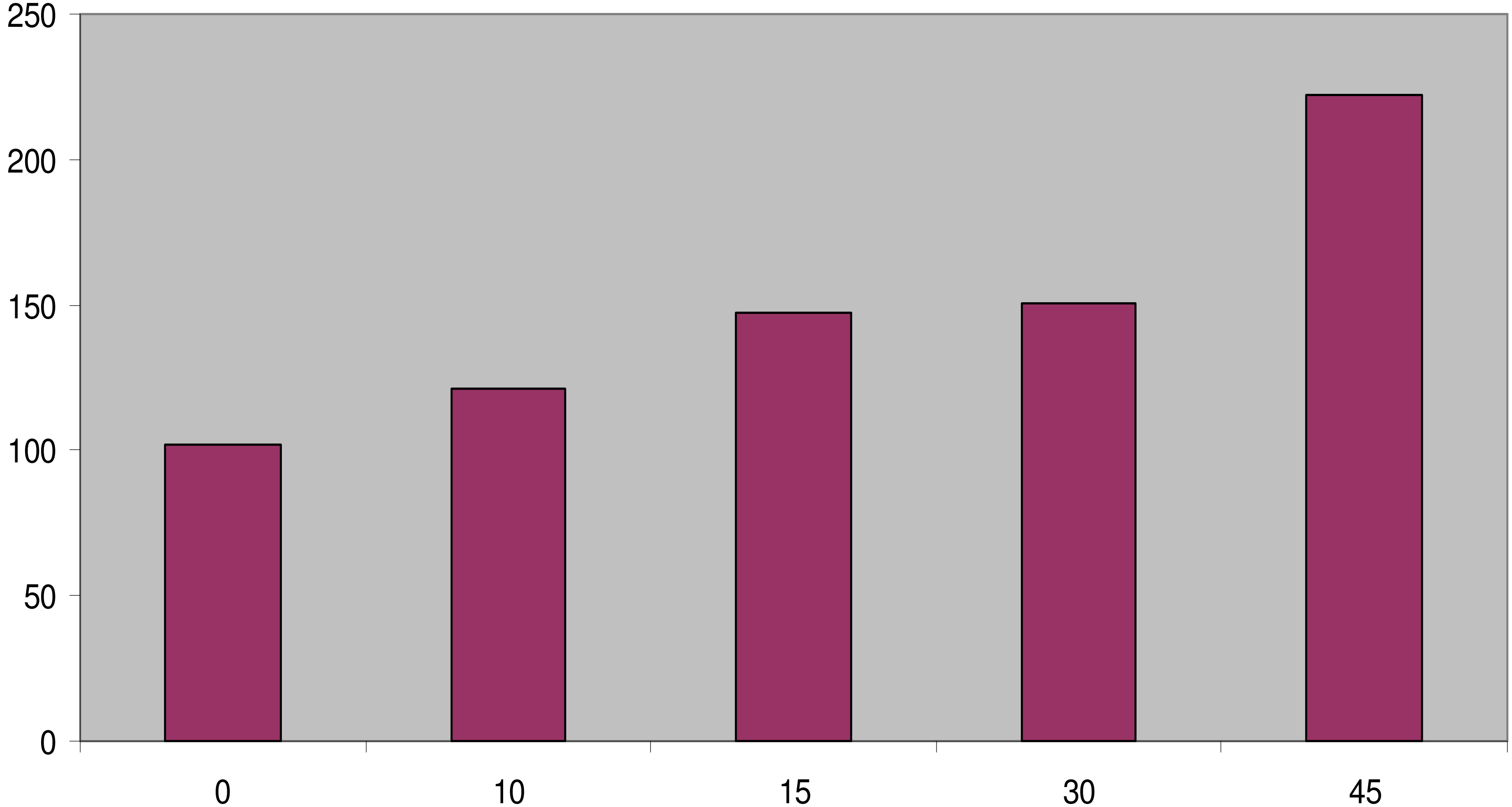


CARB*i*FOR I

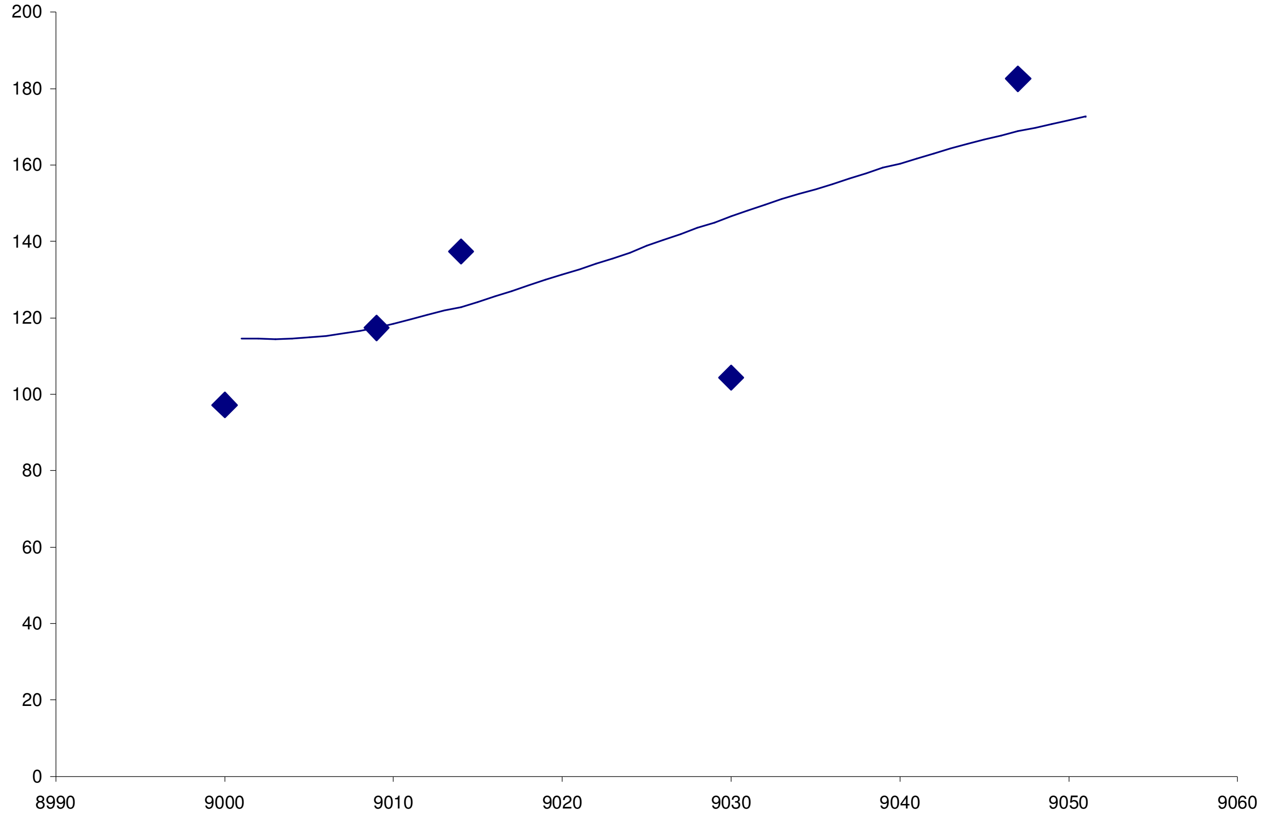
- Use a chronosequence of Sitka spruce as a space for time substitute to indicate effects of afforestation on soil C content
- Soil C increased following afforestation


Litter Carbon Input
tonnes C ha-1 a-1
3.5
3
2.5
2
1.5
1
0.5
0
10 year
15 year
30 year
45 year

Total soil C (t ha^{-1})



Model + sites



200
180
160
140
120
100
80
60
40
20
0
8990
9000
9010
9020
9030
9040
9050
9060

CARB*i*FOR II

- Joint project with UCC (Forest C) to cover the country
- Objective to determine whether forest soils sequester more C than traditional land uses.
- Paired site approach
- Representation of various soil and forest types.

Site Selection Process from NFI Sites

Soil Type	# of Mixed	# of Broadleaf	# of Conifer	Total # of Sites	% Soil Type
Brown Earth	17	17	30	64	4.6%
Brown Podzolic	5	4	25	34	2.4%
Gley	31	17	129	181	13.0%
Podzol	4	1	22	28	2.0%
Peaty Gley	9	0	72	82	5.9%
Peaty Podzol	2	1	43	46	3.3%
Basin Peat	24	6	81	112	8.0%
Blanket Peat	28	6	370	415	29.7%
Total number of sites:				1397	

- **These groups were chosen in order to capture the whole country. Lithosols and rendzinas were excluded because they made up less than 2% of the total forest soil types.**

- **Future plantings.**

*Coniferous and broadleaf are forests that are composed of at least 81% conifer or broadleaf trees (by canopy). A mixed forest is a forest composed of broadleaved and conifer species, the minor category making up at least 20% of the canopy (MHF).

Methods

- Adaptation of NZ - Carbon Monitoring System & Soil Data Collection Manual (Davis et al, 2004)
- By comparing forest and non-forest sites on mineral soils the difference in soil C sequestration due to afforestation was assessed.
- Sites with peat or peaty mineral soils were surveyed to determine peat depth.

Selection of the Site Pairs

- The success of the paired plot methodology depends on the selection of appropriate pairs.
- All characteristics of the non-forest site should be the same as the forest site except for the land-use.
- The land-use of the non-forest pair site must represent the land-use of the forest site pre-afforestation.
- The land-use of the non-forest pair must not have changed since the forest site was forested.

Other considerations for the pair site

- Soil type (Referenced definitions in Gardner & Radford, 1980).
- Physical characteristics (i.e. aspect, slope elevation etc.).
- Ownership and permission for access.

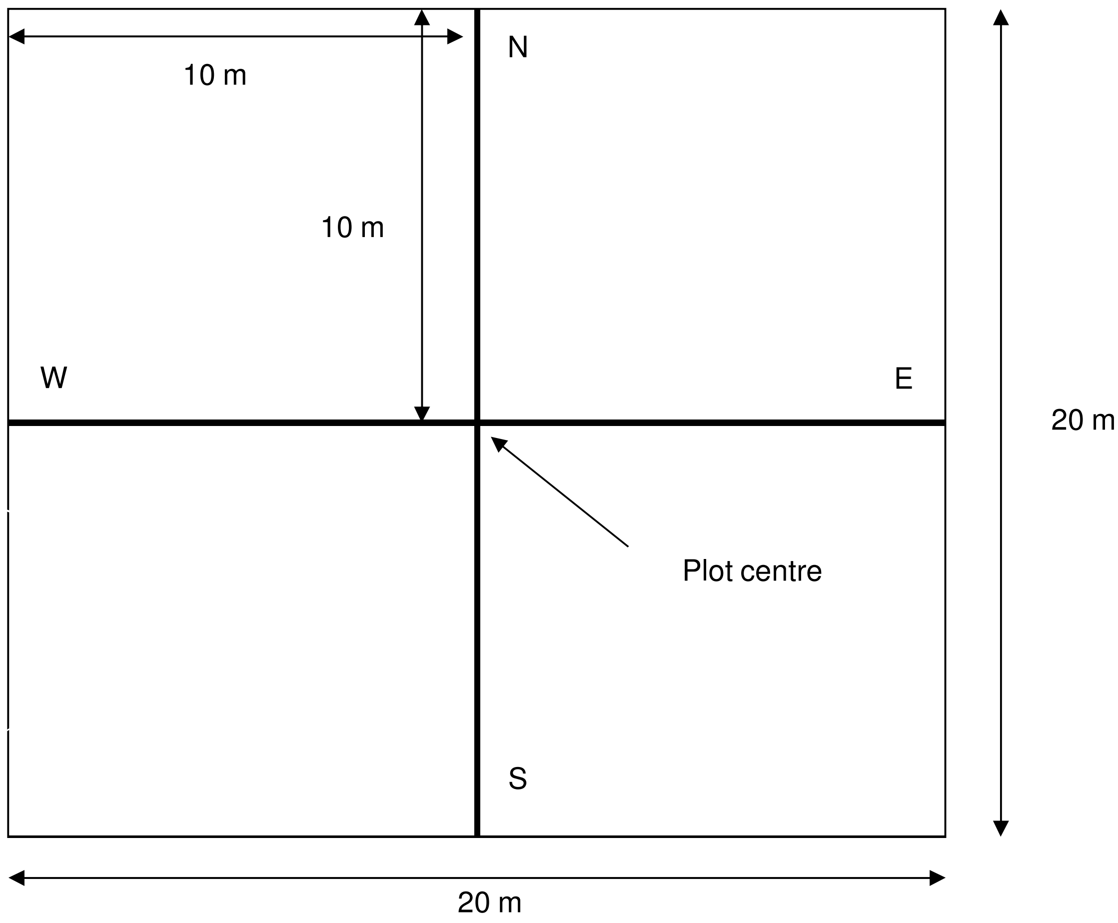
Soil Sampling Methodology

- The NFI plot within the forest was located by GPS, the centre of the plot to be sampled was positioned 50 m south east of the NFI plot going around clockwise until a suitable site was found.

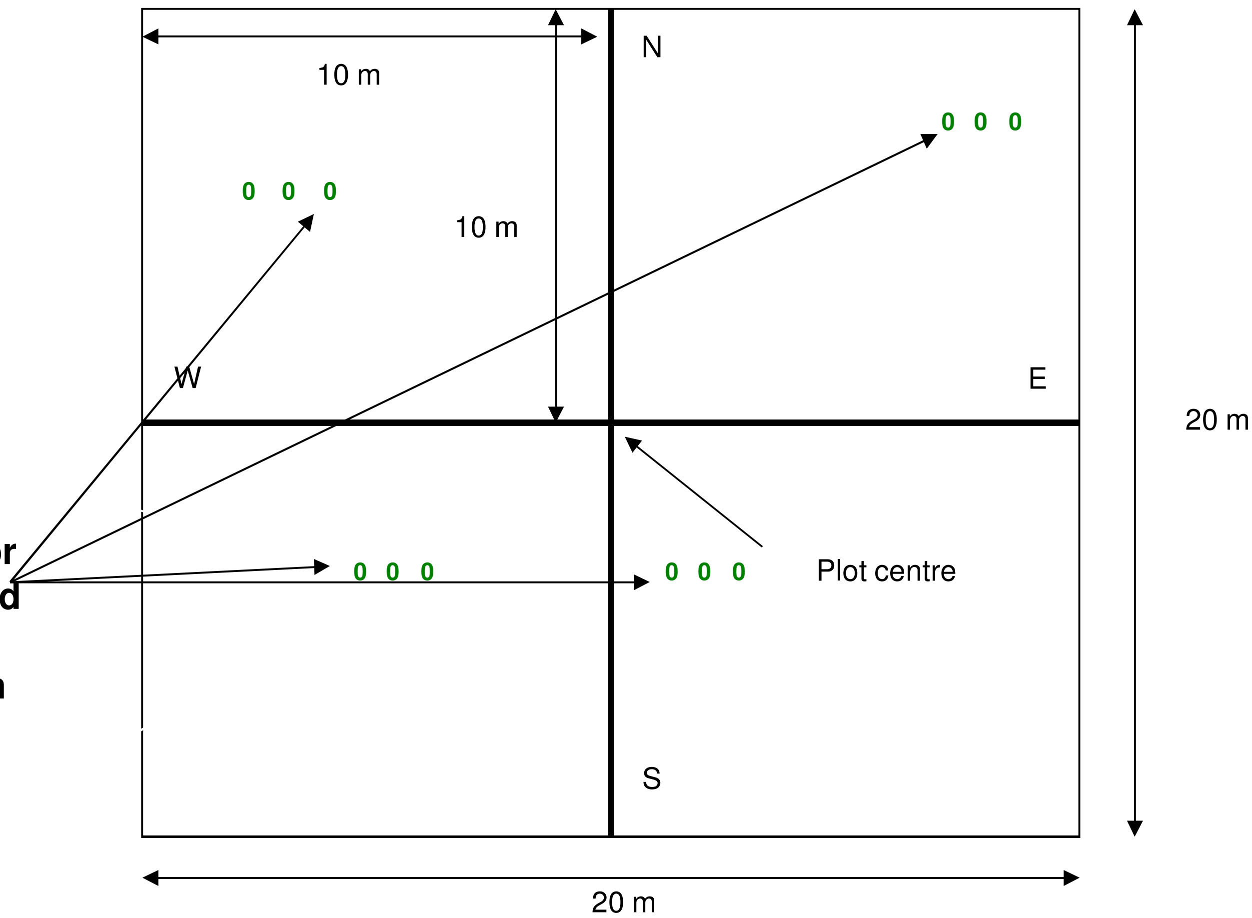
- A 20 m by 20 m square was laid out consisting of four 10 m by 10 m squares.

- Within each 10 m by 10 m square an area was chosen at random within the square.

Soil Sampling Plot Layout



Soil Sampling Layout Forest Floor

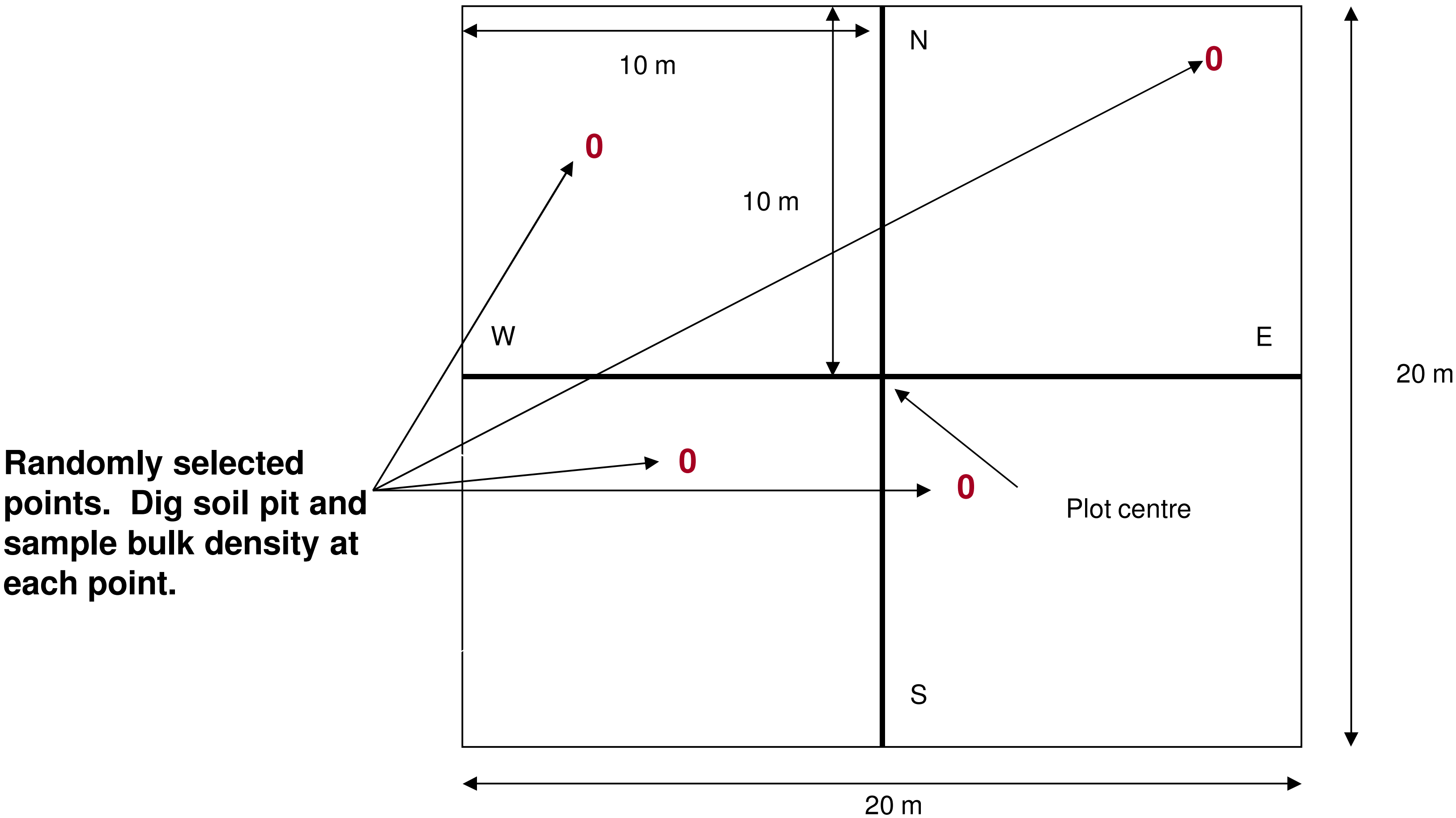


Sample the forest floor at each point displayed in green. 1 meter spacing between each point.

Forest Floor Sampling

- In each of the four 10 m by 10 m square, three 0.1 m^2 squares were sampled for:
  - Fine Woody Debris (dead material with diameter between 2.5 and 7 cm),
  - Litter (dead material with diameter less than 2.5 cm) and
  - F/H layer (decomposing material that is not mixed with soil).
  - These are collected separately.

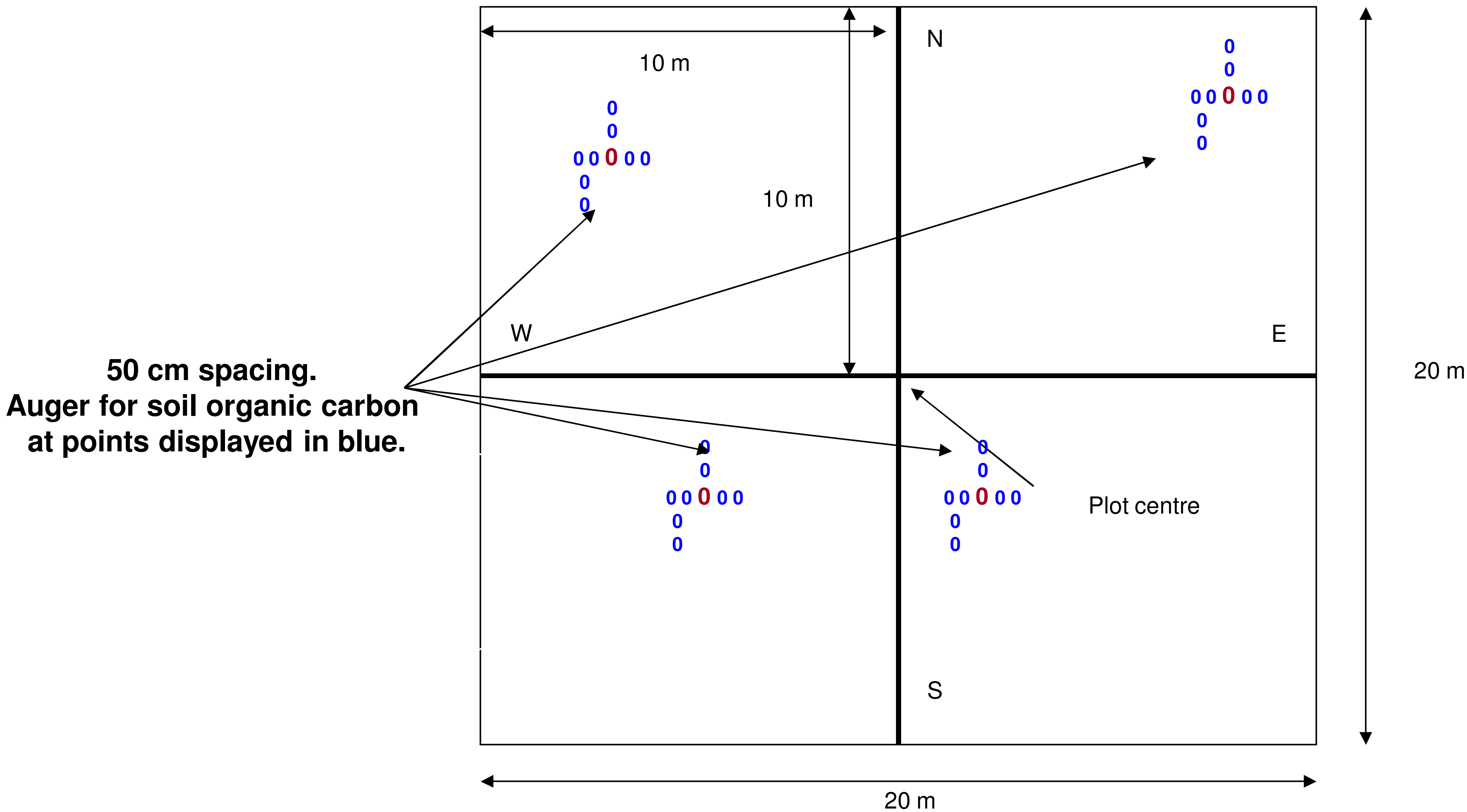
Soil Sampling Layout Bulk Density



Bulk Density Sampling

- At the randomly chosen site a soil pit was dug to around 30 cm + depending on the depth of the organic layer.
- Bulk density samples were taken at the depths of 0-5, 5-10, 15-20 and 25-30 cm in the mineral layer and to the same increments in the organic layer.

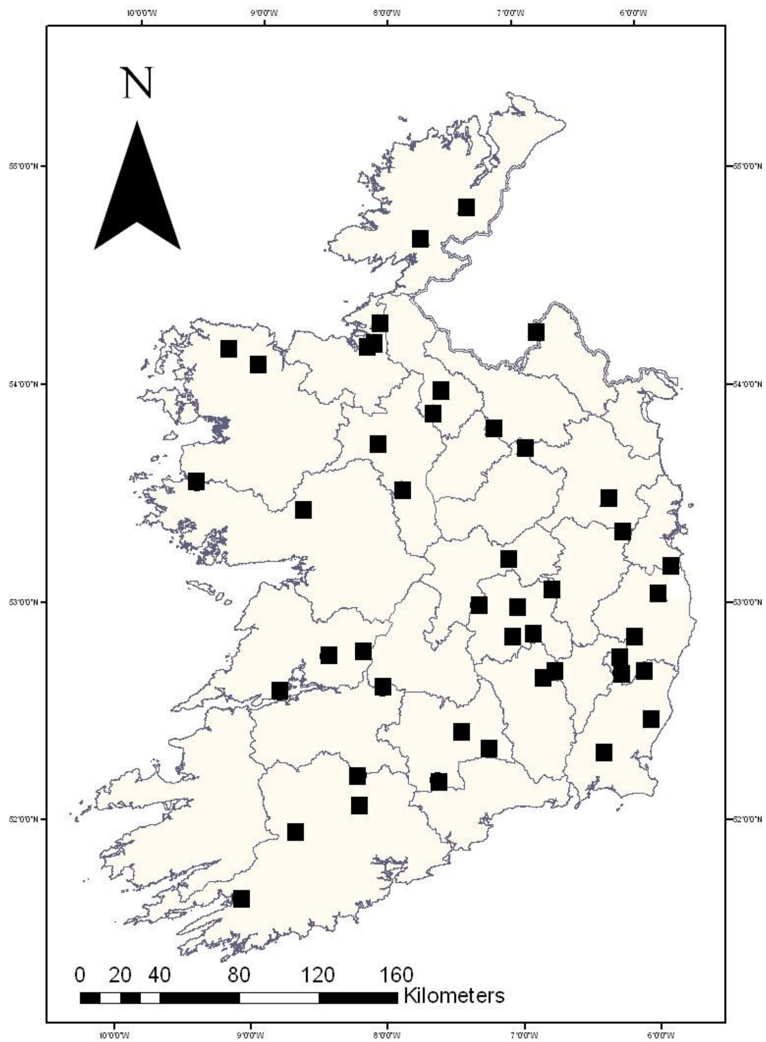
Soil Sampling Layout SOC



SOC Sampling

- Around the soil pit, 8 points were augured to depths of 0-10, 10-20 and 20-30 cm for the mineral layer and similar for the organic layer with the true organic depth recorded at each point.
- The sampling of BD and SOC was done at each of the four 10 m by 10 m squares at both the forest site and the pair site.

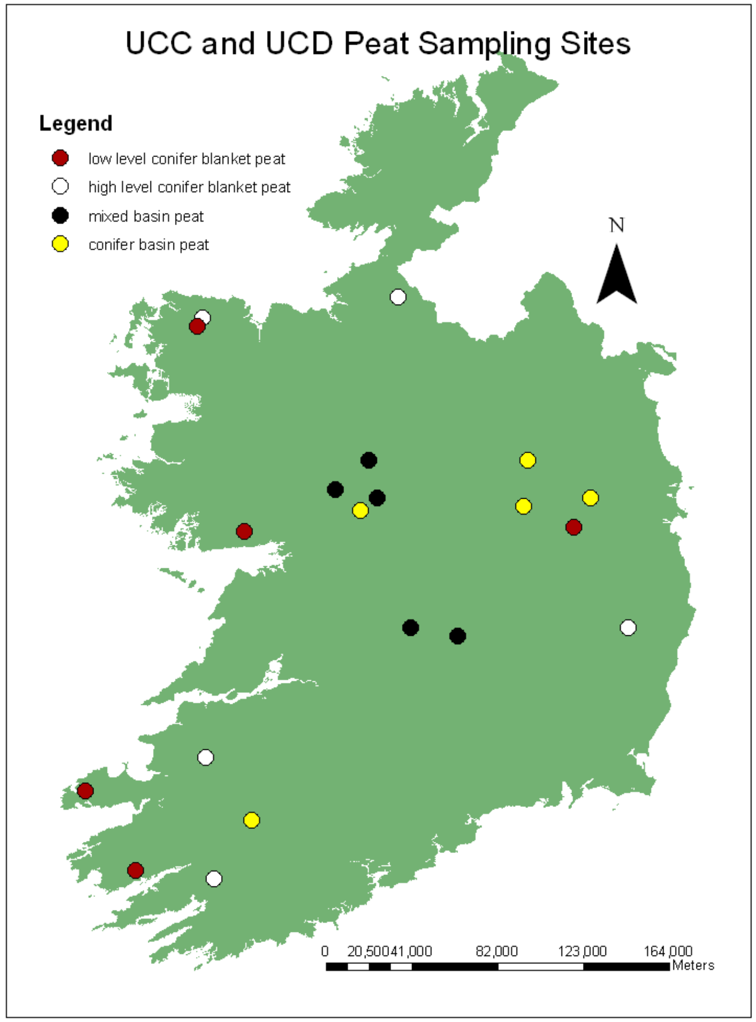
Location of Mineral sites



Peatland Sampling Methodology

- Use Russian auger
- Use 1m poles to determine the depth of the peat at the location it is collected.
- Sections of the peat core were cut in the lab. for BD and SOC determination.
- Forest floor samples were collected.

Location of peat sites



SOC

- The SOC samples are analysed for carbonates with HCl. If there was a presence of carbonates then they are acid treated before C analysis.

- Once treated the SOC samples were analysed for TOC using an elemental analyser.

Bulk Density

- The bulk density samples were sieved to 2 mm to remove the coarse content with the volume of the coarse content being determined.

- Bulk Density=<2mm dry weight/(ring volume->2mm coarse fraction volume)

Forest Floor

- The forest floor samples were dried at 55^{o}C within paper bags for 7-8 days.

- The dried samples were then ground to 2 mm using a Wiley Mill before sampling for carbon content using an Elemental Analyser.

Results

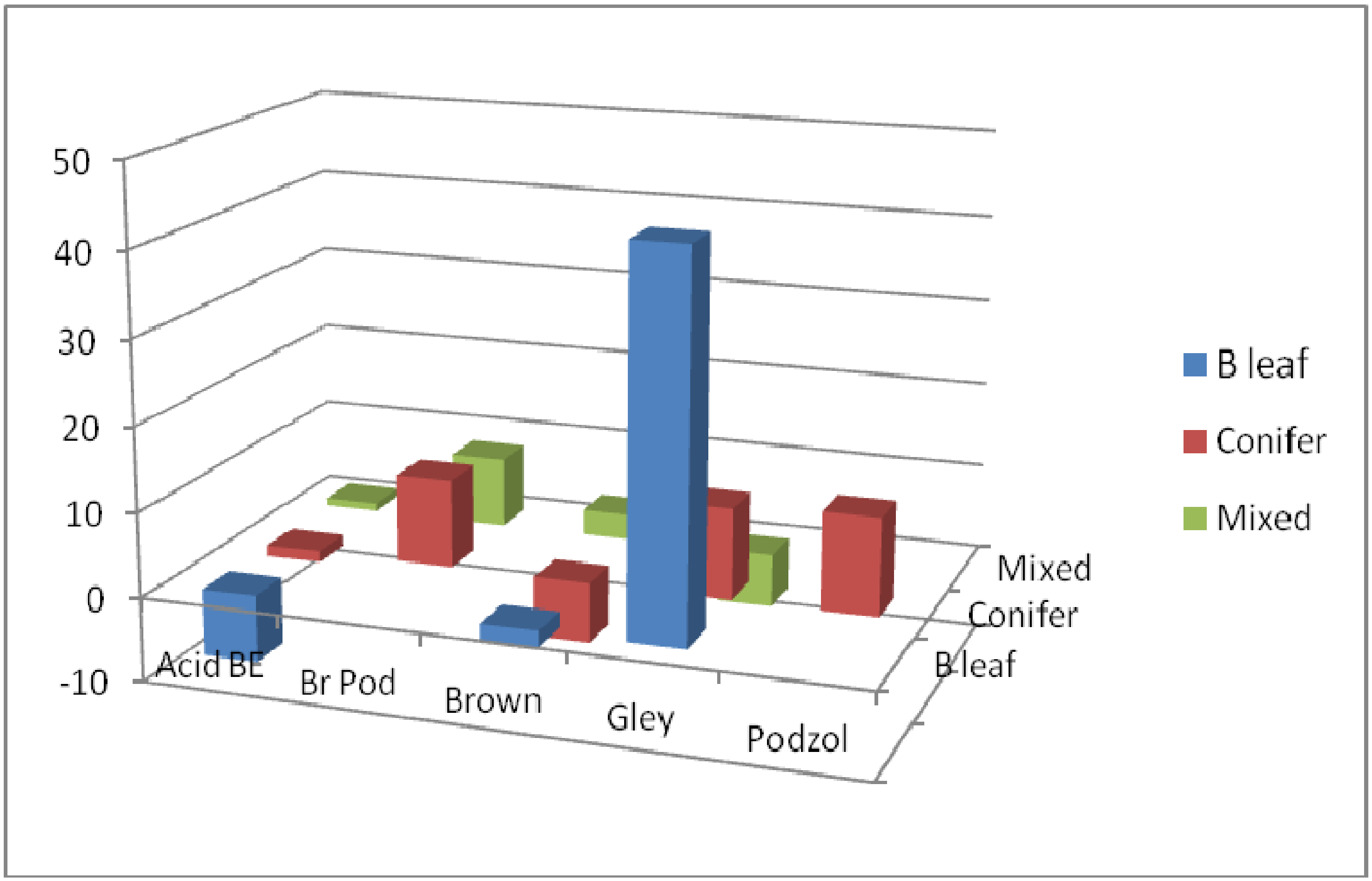
Mineral Soils

- C stocks range from 30 – 225 t C ha^{-1}
- Differences Forest vs pair 0 – 170 t C ha^{-1}
- However, for most sites less than 50 t C ha^{-1}
- The mean difference was 4.245 t ha^{-1} ($t=1.28$, $p=.20$) - therefore no significant difference

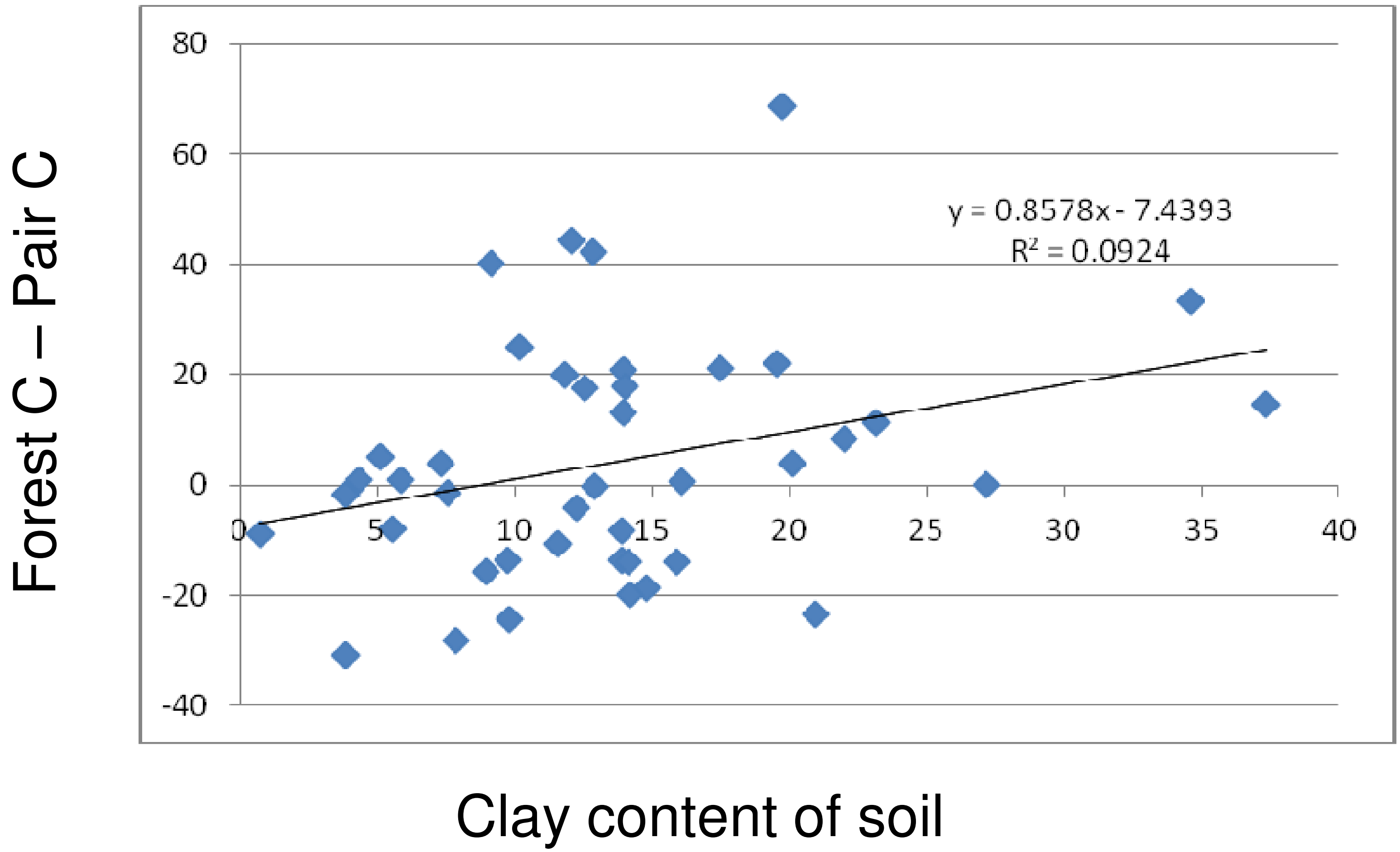
Table 1. Modelled minimum residual mean squares using GLM in SAS, indicating that several environmental factors affect the difference between the carbon in the forest and the open site.

Source	DF	Type III SS	Mean Square	F Value	Pr > F
Soil type * type of forest	11	10260.34633	932.75876	4.34	0.0022
Easting	1	1585.67792	1585.67792	7.37	0.0133
Northing	1	896.41566	896.41566	4.17	0.0546
Belowground biomass	1	2095.30206	2095.30206	9.74	0.0054
Age of forest stand	1	3013.08027	3013.08027	14.00	0.0013
Growth increment	1	1518.27363	1518.27363	7.06	0.0152
% Sand in forest soil	1	738.59842	738.59842	3.43	0.0787
% Silt in forest soil	1	740.74599	740.74599	3.44	0.0783
% Clay in forest soil	1	849.61131	849.61131	3.95	0.0608
Acumulated temperature above 5˚C	1	3628.53221	3628.53221	16.87	0.0005
Moisture Deficit	1	4026.14900	4026.14900	18.71	0.0003

Soil type versus forest type

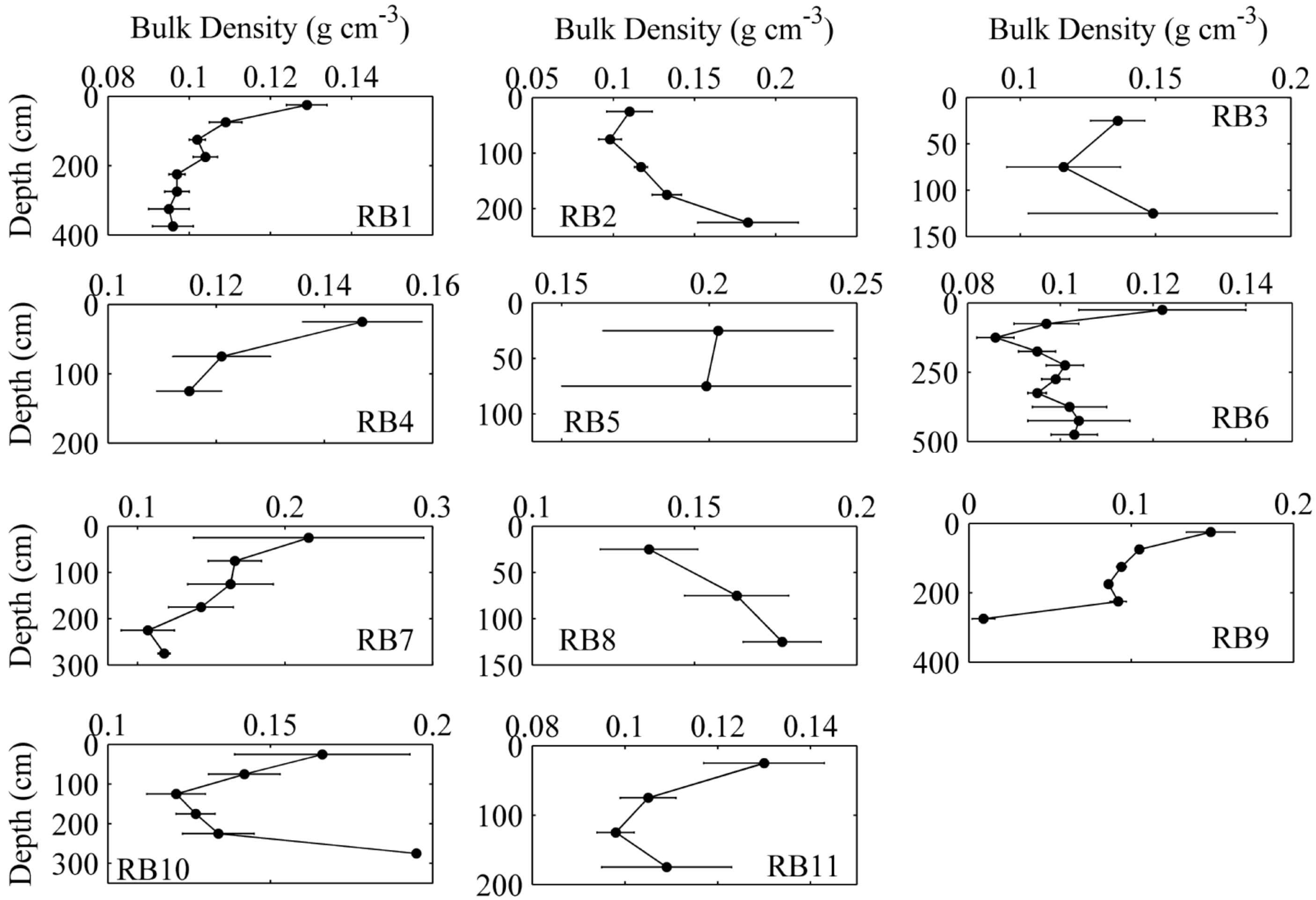


Clay content effect



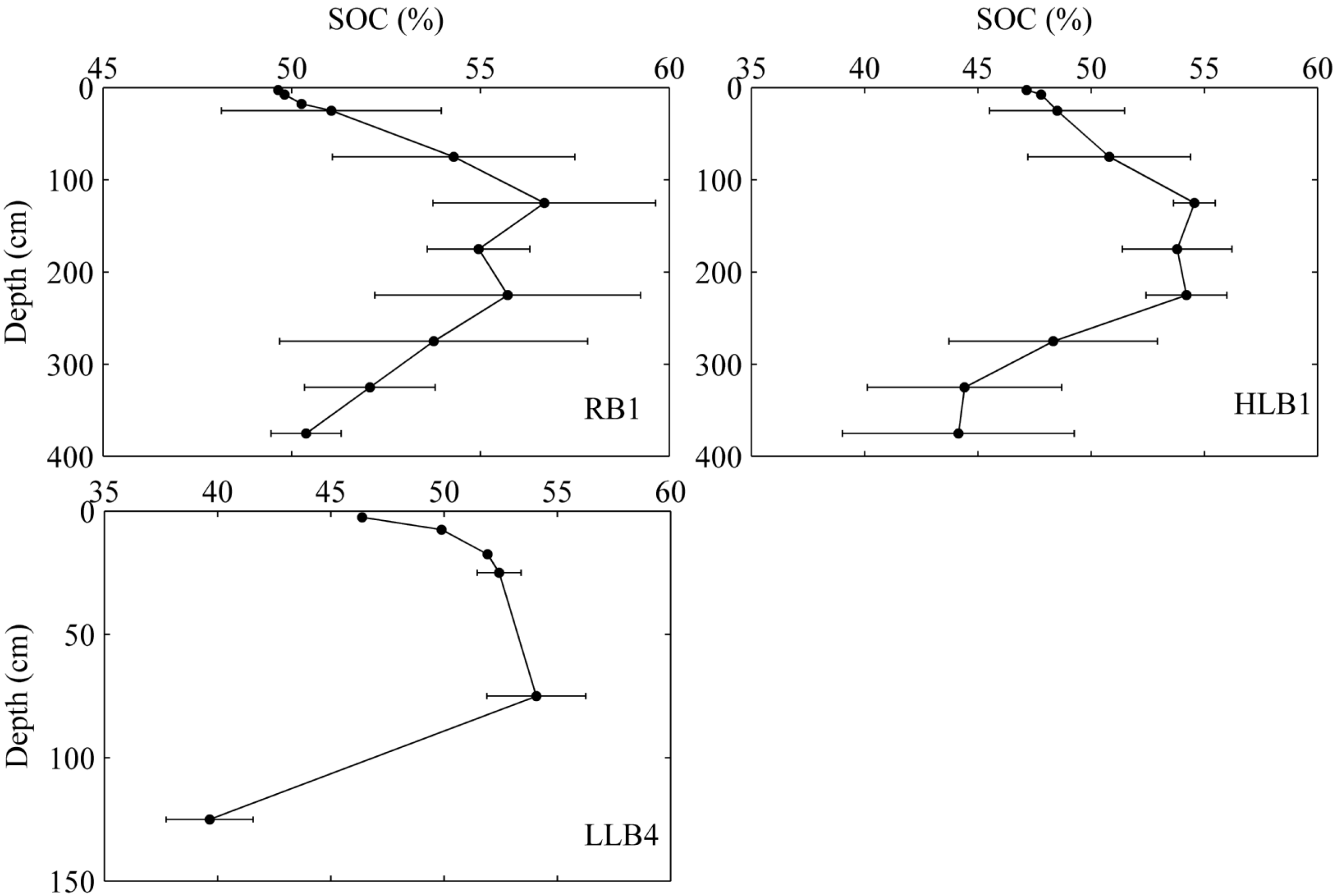
Results - Peat

- Now have an estimate of soil C content to actual depths
- Far larger C stock than previous 1m estimates
- Regression equation whereby depth can be used to estimate soil carbon content
- Raised and blanket peats depth crucial

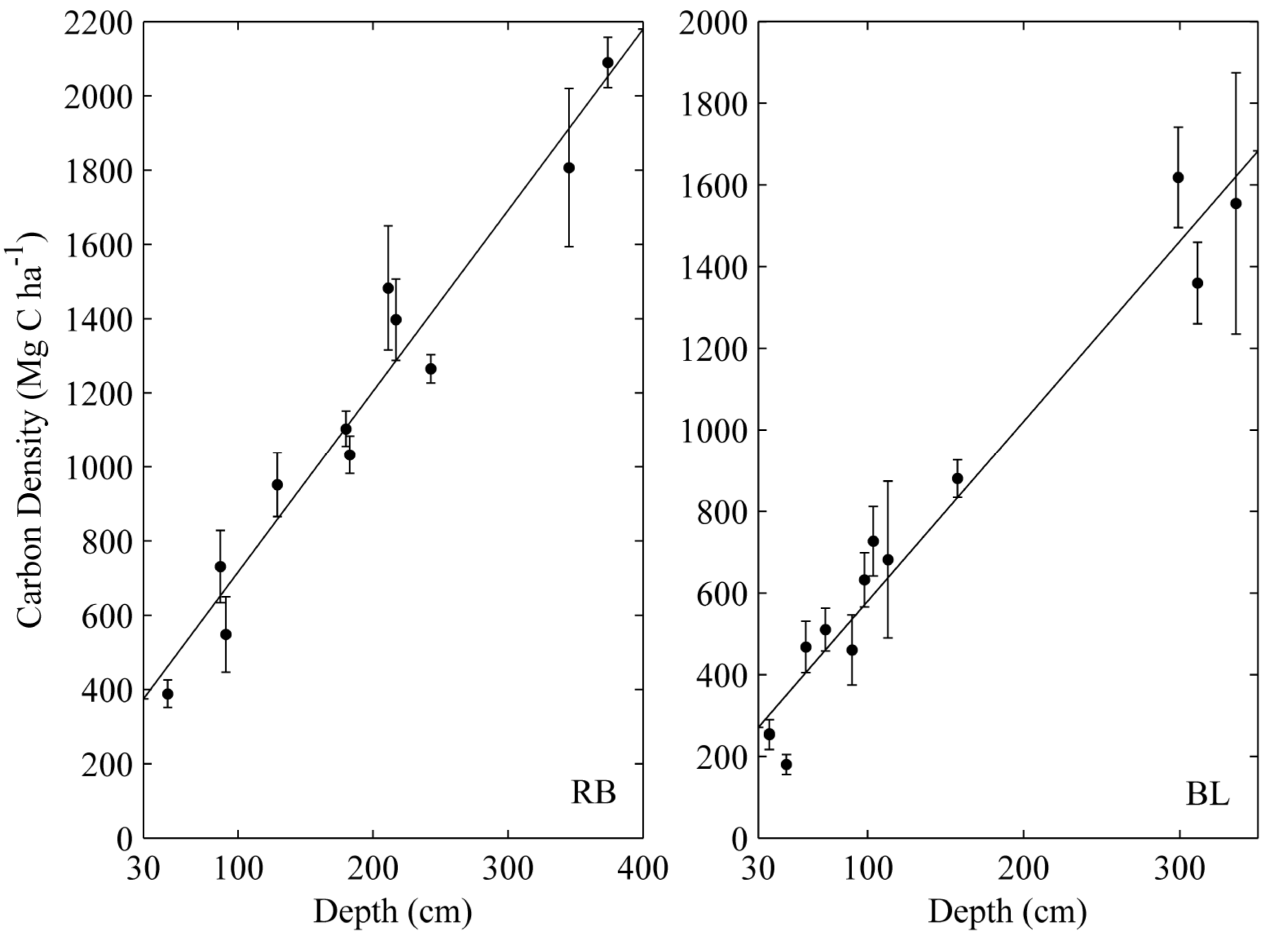


Wellock *et al*. 2011

SOC% vs depth


SOC (%)
SOC (%)
45
50
55
60
35
40
45
50
55
60
0
100
200
300
400
Depth (cm)
RB1
HLB1
35
40
45
50
55
60
0
50
100
150
Depth (cm)
LLB4

180-2000 t C ha-1



Discussion

- Why is there no forestry effect?
- C stocks and soils are not affected significantly by litter resource quality (Schmidt *et al*. 2011)
- Biological and environmental controls predominate in the main and molecular structure alone does not determine SOM stability

Discussion 2

- Corine 640,000 ha under forestry
- 130 t C ha^{-1} at 30cm depth and 250 t C ha^{-1} to 1 metre (Eaton *et al*. 2008)
- 83,200,000 t C national forest soils
- Our data would provide an estimate 60,800,000 t C for mineral sites in the top 30cm of mineral soil
- But since 42% of Irish forests are on peat the total likely to be greater than previously believed

Acknowledgements

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Thank you