National Trust

Land management for soil carbon at Wallington

Summary

The farming sector is working on many fronts to limit its impact on climate change. Whilst emissions from fossil fuels, livestock and fertilisers are of critical importance, senior IPCC scientists warn that the role of soil carbon has been underestimated and that 89% of agriculture's global potential to cut greenhouse gas emissions lies in enhanced soil carbon stores.* As a major private landowner with a charitable purpose to protect the environment, the National Trust is uniquely placed to contribute to knowledge and practice for soil carbon stewardship.

The National Trust owns 1.5% of the land in England, Wales and Northern Ireland. At Wallington alone (5500 hectares), the land-based carbon store is estimated to be 1,265,000 tonnes – equivalent to the annual CO_2 emissions from the populations of Newcastle and Gateshead. The preservation of this vast and fragile resource rests on good land management.

We sponsored a PhD at Durham University to contribute to our understanding of this issue, with Wallington in Northumberland as the study site. Based on over 700 soil samples, the study was able to build statistical models that could predict soil carbon with 67% accuracy, compared with only 48% using National Soil Research Institute soil series data. Using this statistical approach the project has been able to assess the best strategies for estimating soil carbon on other landholdings where extensive fieldwork is not possible.

The field observations highlighted a significant role for individual farmers in preserving and enhancing soil carbon, which means there is much we can do to enhance carbon storage. Variation within grazing land was found to be of particular interest. Improved pasture had significantly lower soil carbon than rough pasture and there was wide variation within rough pasture.† It was estimated that if all rough pasture on the estate could achieve optimum soil carbon, an annual sink equivalent of up to 21,500 tonnes CO_2 would be achieved over a period of 20 years. At Wallington, the gains from good grassland management have the potential to outweigh soil carbon losses from limited conversion to arable.

Land use questionnaires with individual farmers attempted to highlight land management differences between the farms. The results of the questionnaires helped us to identify some previously under-researched individual interventions to investigate further, these included:

- The suitability of locating plantation forestry on peat soils
- The role of short rotation coppice to enhance soil carbon and provide biofuels
- Whether the addition of biochar to pasture might create a carbon sink and assist in nutrient control
- The impact of certain fertilisers on soil carbon fluxes.

Previous studies have identified measures that will enhance soil carbon. Our data agrees with many of these, including the creation of permanent pasture, limiting conversion of grassland to arable and incorporation of crop residues into soil on arable land. Other interventions recommended by previous studies that are applicable to Wallington include woodland creation, hedgerow planting, field margins, the use of farmyard manures, minimum tillage and wildflower mixtures. Our findings confirm that there is great potential to create carbon sinks on grassland, and that further research is needed to identify the optimum methods by which to achieve this.

The next stage of our soil carbon work at Wallington, starting in September 2010, will be a 'Land Carbon Management Plan' in partnership with Natural England. Drawing on the Wallington study and other sources, it will identify specific practical actions for each of the farms at Wallington to enhance soil carbon and identify how to quantify and monitor them. These actions will then be incorporated into Higher Level Stewardship agreements as a national pilot for soil carbon stewardship.

* Smith, P. *et al*, 'Greenhouse gas mitigation in agriculture', *Philosophical Transactions of the Royal Society of London Series B* (2008), 363 789-813

† Land use classifications were based on the National Trust's biological survey for Wallington, field observations and interviews with farmers

Terrestrial carbon and the National Trust

This report summarises research carried out by Durham University into land-based carbon at the National Trust's Wallington estate in Northumberland.

"Carbon is the building block of life, we must value and steward it with care"

Rob Jarman, National Trust Head of Sustainability

The National Trust owns 250,000 hectares of land in England, Wales and Northern Ireland. This is 1.5% of the total land area and every field, woodland, park and garden is a store of precious carbon. Prosperous farms, healthy food, clean air and abundant wildlife are all dependent on conserving the carbon in soils and plants.

Soils and plants absorb and release greenhouse gases including carbon dioxide (CO_2) and methane. This is a natural cycle, but its balance is affected by the ways we use land. We want to manage land so it has a net benefit for climate change while supporting farms and protecting the natural environment.

Soil carbon at Wallington

At Wallington in Northumberland, the National Trust and Durham University have carried out research to further our understanding of soil carbon and land management. The Trust sponsored Madeleine Bell to complete a PhD in the Department of Earth Sciences at Durham University, under the supervision of Reader in Earth Sciences, Dr Fred Worrall.

The research set out to investigate the following:

- How much carbon is stored in soils and biomass at Wallington?
- How does soil carbon vary across the estate?
- Which factors influence soil carbon distribution?
- How does land management affect soil carbon?
- Is Wallington a net carbon sink or source?
- To use the data to develop a land management tool for other estates aimed at optimising carbon storage in soils.

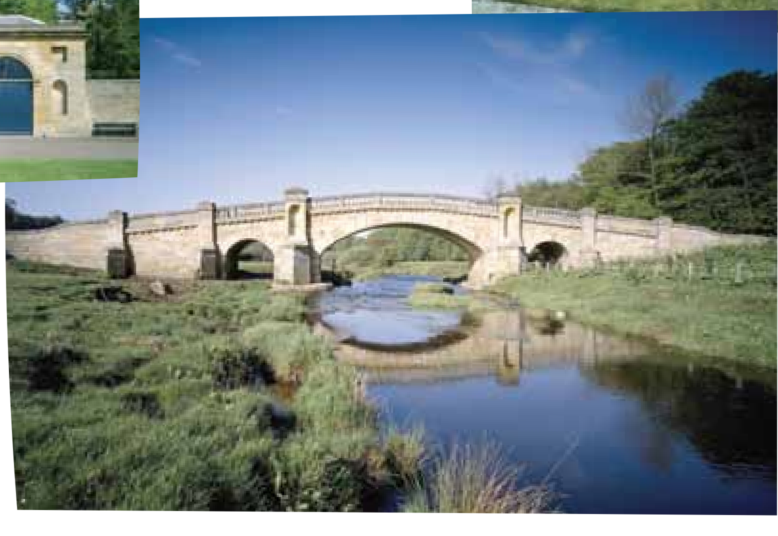
The research is part of the Wallington Carbon Footprint Project, which has taken action to cut emissions from across the estate; by linking land-based carbon to reducing greenhouse gas emissions, we aim to take a whole-estate approach to carbon management.

The next step is to translate science into practice. In September 2010 work will commence on a 'Land Carbon Management Plan' for Wallington in partnership with Natural England. This will link soil carbon actions to farm payments under the Environmental Stewardship scheme.

Why Wallington?

Wallington is 25 miles north-west of Newcastle in rural Northumberland. Its mansion and gardens are a major visitor attraction and its estate covers 5500 hectares, making it the Trust's largest complete agricultural estate. The land is managed by 15 tenant farmers raising sheep, cattle and arable crops. The National Trust manages 330 hectares of woodland in hand, with a further 1200 hectares of conifer plantation on land leased to the Forestry Commission. Soil type, altitude, land use and landscape vary across the estate, making it a good place to study the range of factors which influence soil carbon. The National Trust has invested in research here so that Wallington can act as a pilot for other estates.

Wallington covers approximately five miles from north to south with the River Wansbeck forming the southern boundary, where the altitude is 100 m above sea level. Land use here is a mixture of parkland, improved pasture and arable. As the estate extends north, altitude rises to 350 m and the landscape takes on an upland character. Areas of moor and unimproved grazing dominate and the northernmost block of land is taken up by the Forestry Commission's Harwood plantation.



How much carbon is stored at Wallington?

Extensive fieldwork is the foundation of the PhD study at Wallington. Over 700 soil samples were taken from across the estate. The majority were taken from a depth of 20 cm, the depth to which land management is likely to influence soil carbon. A total of 37 soil profiles were taken to a depth of 100 cm, and a further 65 depth measurements taken on peat.

Samples were bagged, geo-referenced and analysed at the lab in Durham using two tests:

- 'Loss on ignition', where the dried sample is burnt at 500°C. All organic matter is removed by burning, hence the change in weight indicates the amount of organic carbon that was present in the sample.
- Addition of Potassium Dichromate to the sample, oxidising organic carbon and causing its release as CO_2. Potassium Dichromate left in solution allows the amount of carbon released to be calculated. This is known as the Walkley-Black method.

Measurements of soil density were carried out to translate the soil carbon concentration values into mass of soil carbon. For biomass, the carbon store was calculated using carbon values for land uses quoted in scientific literarture.

- **1,205,184 tonnes** of carbon is estimated to be stored in soils to a depth of 100 cm
- **60,290 tonnes** of carbon is estimated to be stored in biomass
- The combined carbon estimated to be stored on the estate is **1,265,474 tonnes**.

This total is equivalent to the annual CO_2 emissions from the populations of Newcastle and Gateshead.*

*Based on per capita CO_2 emissions: www.berr.gov.uk/files/file32554.pdf and 2001 census

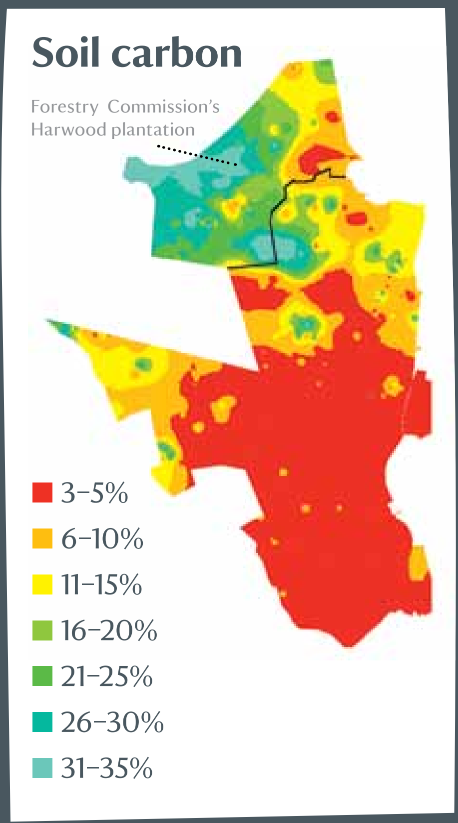
For a detailed account of this work, refer to: Bell, MJ and Worrall, F, *Estimating a region's soil organic carbon baseline: The undervalued role of land-management*, Geoderma (2009)

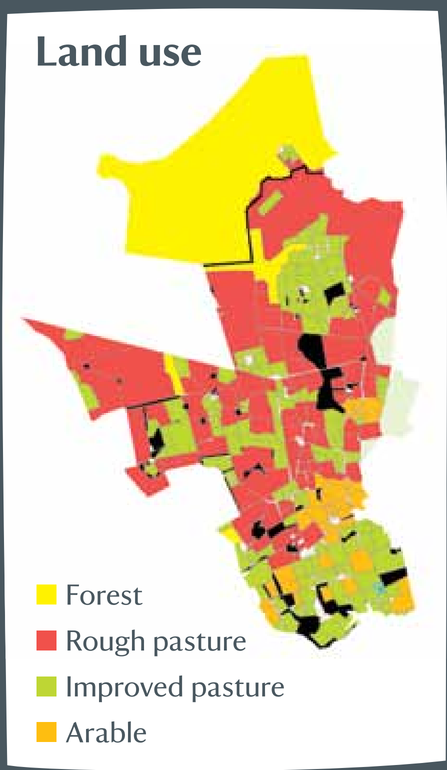
How is soil carbon distributed across the estate?

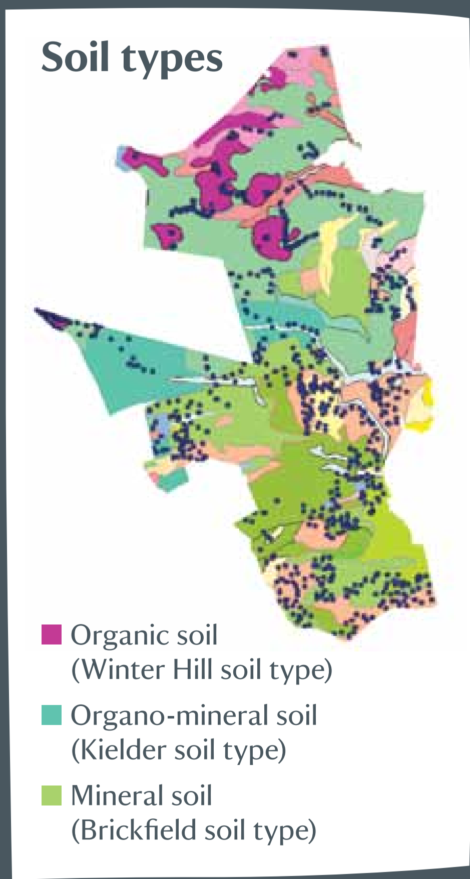
Previous studies have used soil type as an important predictor for soil carbon. While soil classification is complex, the broad distinction between organic, mineral and organo-mineral soil composition is particularly relevant and all of these soil types are found at Wallington. Deep peats with a surface layer of greater than 40 cm of organic matter are classed as organic, 15–40 cm of organic matter lying above other soil components constitutes organo-mineral soil while all other soil types are classed as mineral (these include sandy soils, clay and loam). Soil carbon is generally high in organic soils, and lower in mineral soils. Peat has the highest organic content of any soil type and is an especially valuable carbon store.

Mapping the soil samples begins to uncover the links between soil type, soil carbon and land use at Wallington.

At Wallington, organic soils are found in the northern part of the estate, where altitude is higher and the landscape has an upland character. The figures below show that these organic soils are linked to high soil carbon. The link between soil type, topography and land use is also clear; the northern part of the estate being less suited to arable farming and predominantly farmed as permanent pasture. The greatest area of peat soil at Wallington was planted as conifer plantation (Harwood Forest) in the 1950s and ’60s, a land use decision linked to its low productivity as agricultural land.







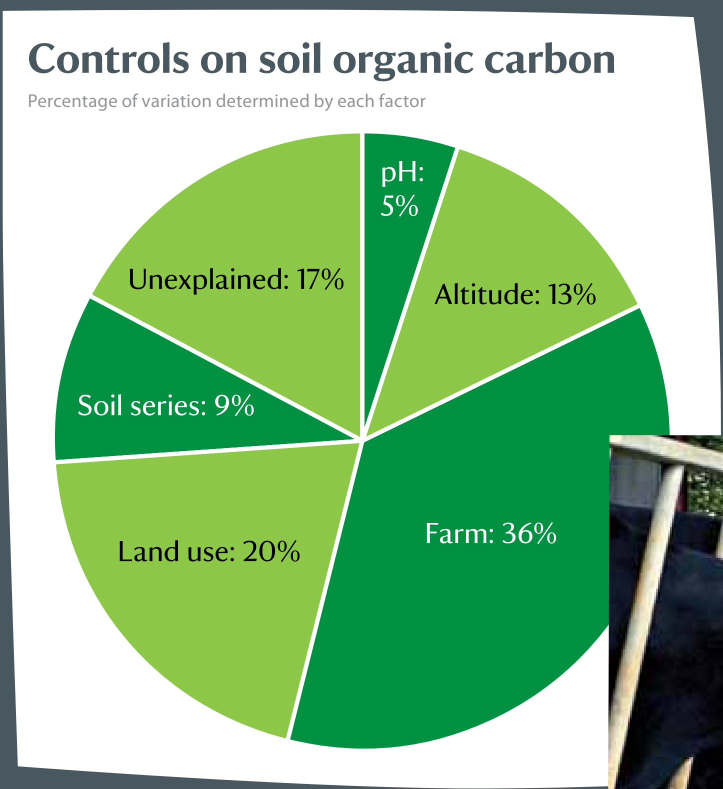
Which factors influence soil carbon distribution?

The figures on page 7 illustrate soil carbon distribution at a broad level. The Wallington research aimed to understand in much more detail how soil carbon varies from field to field and how a range of factors in addition to soil type govern this variation (Bell and Worrall 2009). A statistical analysis was undertaken to establish whether variation in the following could explain any of the variation in soil carbon concentration: soil series, land use, farm, altitude, pH, clay content, slope angle and years in current land use. The 'farm' variable indicated which farm unit a sample had been taken from, and hence which individual farmer the land was managed by.

The analysis was applied only to mineral and organo-mineral soils, as organic soils behave differently and may not be controlled by the same variables. The analysis found that soil carbon is influenced by multiple variables, and its distribution cannot be accurately predicted by any single factor.

Variation in a combination of the factors analysed was able to explain 67% of the variation of soil carbon at Wallington, with 33% remaining unexplained. The following variables were found to be insignificant: clay content, slope angle and years in current land use (the latter finding is influenced by the fact that little land use change has occurred at Wallington over the last 30 years).

Of the 67% of variation in soil carbon that could be explained a key finding is that 'farm' carries greater weight than the other variables, including soil type. This suggests that management by the individual farmer is a key factor in determining soil carbon, and supports the National Trust's ambition to increase carbon stores through optimising land management. This finding also suggests that further analysis breaking land use into a greater number of categories might further explain the variation by accounting for differing land management practices.



Soil carbon, land use and land management

When considering how soil carbon might be managed to mitigate climate change, the use and management of land are of prime importance as they might be changed, whereas other significant variables (soil type, altitude etc.) cannot. For the analysis of soil carbon, the land use at each sample point was classified as: arable, improved temporary pasture, improved permanent pasture, unimproved pasture, lowland woodland or forestry plantation. The classification was based on the National Trust's biological survey for Wallington, supported by field observations and interviews with the farmers.

The average soil carbon content as kg/m^2 was calculated for each land use:

Table 1

Land use	*Soil carbon (kg/m^2)*
Forestry plantation	28
Unimproved pasture	13
Woodland (not forestry plantation)	11
Improved pasture	10
Arable	8

While comparison between land uses is of interest, the limitations in looking at any variable in isolation have already been discussed. For example, the high carbon content of soils under forestry plantation at Wallington is due to the peat soils on which conifers were planted (see page 7), rather than to the land use.

Of particular interest is the variation within land uses, especially where variation occurs within the same soil type. Analysis of soil samples revealed the most significant variation in soil carbon between farms, with all other variables held constant, to be on rough pasture. This suggests scope to improve the carbon storing capacity of soil in this land use. On improved pasture there was less variation, suggesting less capacity in the soils under this land use to increase carbon storage. A land use questionnaire was conducted with tenant farmers with the aim of identifying links between soil carbon and land management, both current and historic. The questionnaire investigated: livestock species and variety, stock density, grazing regimes, fertiliser and manure application, crop varieties, rotations and tillage. Key conclusions were:

- Using the land use questionnaire it was not possible to link variation in soil carbon to specific land management practices.
- Despite the statistical importance of the variation between farms, no link was identified between pasture management regimes and soil carbon, with the exception of a possible link between high soil carbon and the application of phosphate as basic slag. This reflects the review of literature, which reports conflicting findings.
- The comparison of arable regimes included only two farms, between which there was a significant difference in soil carbon, although the small sample number means that that the findings must be interpreted with caution. The farm with higher soil carbon did not remove crop residues whereas the other farm did, and this finding agrees with the literature.
- The influence of land management on soil carbon is likely to be the result several interacting variables: more controlled studies are required before firm conclusions can be drawn.

Land management trials

A series of trials and experiments were conducted in years two and three of the PhD study to investigate the effect on soil carbon of specific land management interventions. Previous research has identified a range of measures likely to benefit land carbon including; creation of permanent pasture, limiting conversion to arable, retention of crop residues on arable land, woodland creation, hedgerow planting, field margins, the use of farmyard manures and minimum tillage. This study elected to add to current knowledge on other, previously under-researched interventions. The selection and design of the trials was also guided by the aim of producing results within the study period.

Areas of interest which were not investigated beyond year one were; the effect of manure application and grazing regimes – the literature and year one analysis did not indicate an experiment would yield useful results within the PhD study period.

Peat soils and forest plantation

This trial was carried out at Greenleighton Mire in the Northern part of the Wallington estate. Greenleighton is one of only two lowland raised peat bogs on National Trust land and is rich in species including bog rosemary, cranberry, bog asphodel, round-leaved sundew and the large heath butterfly. The bog covers approximately 25 hectares, and 14 hectares were planted with sitka spruce by the Forestry Commission in the 1980s. While the non-plantation part of the bog is in good condition, the plantation has caused severe habitat degradation through disturbance, drainage and uptake of water by the trees.

The soil at Greenleighton contains up to 45% organic carbon and carbon loss will have occurred through the planting and growth of the forest. Peat bogs in poor condition are potentially large sources of CO_2 emissions as organic carbon is exposed to air. The study conducted here measured: the difference between the forested and non-forested parts of the bog for soil respiration (loss of CO_2), flux of dissolved organic carbon and water chemistry. Readings were taken fortnightly over a 52 week period using six sites in the forested area and six in the non-forested area. The study did not monitor methane flux. The key findings were:

- There is significantly greater loss of CO_2 from the soil and surface vegetation and roots beneath the forested part of the bog
- There is significantly greater loss of dissolved organic carbon from the forested part of the bog
- More research is required to determine whether carbon sequestered in above and below ground tree biomass growth are sufficient to offset the greater emissions from soil.

The National Trust was awarded funding in 2009 from the SITA Trust to restore Greenleighton Mire by removing sitka spruce from eight hectares of the mire and blocking the drains. This will restore an important wildlife habitat and create more favourable conditions for the long term accumulation of organic carbon in the peat soils, although it should be noted that this study has not calculated the overall net carbon balance of deforestation.

Short rotation coppice

Short rotation coppice (SRC) willow plantations capture atmospheric carbon in their biomass during growth, which can then be used as a fuel. It is relevant to National Trust land holdings as a potential fuel source; it might also be a source of biochar production (see below). Few studies have examined the effect of SRC on soil carbon. This trial investigated how converting arable land to SRC affects soil carbon, with the aim of helping to understand its overall impact on land carbon (soil and biomass).

As there is currently no SRC at Wallington, the fieldwork was conducted at Newcastle University's Cockle Park farm. The site is 10 miles from Wallington and has comparable soil type and climate.

Soil respiration was measured fortnightly over one year using an infra-red gas analyser at six points on three sites: three year-old SRC plantation, 1½ year-old plantation, and an arable field as control. Leaf litter was collected on each field visit. Ten soil samples from each site were analysed for soil organic carbon at the beginning and end of the fieldwork. Key findings were:

- Carbon losses from the soil, roots and surface vegetation were greater from the SRC willow plantations than from arable control site
- Carbon loss from the soil, roots and surface vegetation increased with plantation age.

This study indicates that where land managers are considering the conversion of arable land to SRC, the potential depletion of soil carbon should be taken into account, although further studies would be needed to confirm the finding. The net impact of SRC remains uncertain, with further investigation needed of below ground biomass. The end use of the crop and its potential to be used to offset fossil fuels would also be an important factor in making land use change decisions.

Biochar

Biochar is a stable form of carbon, formed during the pyrolysis (heating in the absence of oxygen) of organic material. Biochar production is a method of preserving the organic carbon from plants so that it is not emitted to the atmosphere as CO_2. There is currently considerable interest in biochar, since it is claimed to have the potential to create new carbon sinks, and to give benefits for agriculture in terms of potential increased crop productivity and reduced fertiliser use. Few studies have tested the use of biochar in UK agricultural soils.

The term 'biochar' is generic and can refer to material derived from a wide variety of sources. The experiments at Wallington used lump-wood charcoal as substitute for biochar. It should be noted that the results here apply to the effects of lump-wood charcoal – further study would be needed to determine the effects of other forms of biochar. If application to land were to proceed in the future, it would be preferable to use agricultural and forestry wastes as the source of biochar.

Two experiments were carried out over two successive years and sought to test; the value of charcoal as a carbon sink, its effect on plant growth, respiration of CO_2 from soil, soil nutrients and water chemistry.

Biochar lysimeter trial
This trial was conducted using soil taken from two sites at Wallington; one arable with mineral soil and one forestry with organic soil. Its aim was to determine the impacts of incorporating a biochar-like material (lump-wood charcoal) into soils in arable and forestry land-use. The soil was placed in 24 lysimeters kept outside at Durham University. A lysimeter is a cylindrical container allowing the accurate measurement of gaseous emissions and water from the soil.

Quantities of charcoal in four concentrations from zero to the equivalent of 87,500 kg/hectare were incorporated into the soils and the surface seeded with grass. The following measurements were made from the soils; soil respiration (CO_2) using an infra-red gas analyser (to assess the stability of biochar and its effect on native soil organic matter decomposition), leachate properties (pH, conductivity, volume, nutrient concentrations, dissolved organic carbon), plant productivity. The trial ran for 26 weeks. Key findings were:

- Slight, non-significant increases in net ecosystem respiration (loss of CO_2) with increasing application
- Significant increases in dissolved organic carbon loss with increasing application
- Neither of the above were sufficiently large to alter the carbon sink created with charcoal application
- Application of charcoal resulted in a carbon sink equivalent of up to 70,000 kg C/ha/year. For the zero charcoal addition control, carbon loss to the atmosphere of 2638 kg C/ha/yr would occur
- There was a significant decline in nitrate flux in the soil leachate, and a significant increase in soil pH, from 6.98 to 7.22 on bare arable soils when 70,000 kg C/ha was applied.

The findings of this trial make an important contribution to the biochar debate and indicate that further investigation would be of interest. Further field-based studies would be required before land management prescriptions might be made for biochar on arable land. Given the extent of pasture at Wallington, and as no previous research has been undertaken relating to the application of biochar to pasture, a charcoal plot trial was carried out at Rothley West Shield farm at Wallington in year three of the PhD study.

Biochar plot trial
Charcoal (used as a substitute for biochar) was applied to 5m x 5m plots of pasture on mineral soil at four levels of concentration based on the findings of the lysimeter trial. Each application was replicated and data was collected fortnightly for a year. Respiration and grass productivity measurements were made from six sites on each treatment using an infra-red gas analyser. Run-off was collected and water chemistry analysed for a range of water quality parameters including nitrate. The site was grazed by sheep whilst the experiment was running. The key findings were:

- Charcoal application created a significant carbon sink in the soil
- CO_2 respiration from the soils increased, but this increase was small in comparison to the carbon sink, with emissions originating from decomposition of the charcoal rather than the native soil organic matter
- As the field was not fertilised, the effects of charcoal application on fertiliser leaching or retention could not be assessed
- There was a significant increase in soil pH, suggesting a reduced need for lime application
- There was significantly lower grass productivity under the plots treated with large amounts of charcoal, although this is thought to be a short term effect.

The trial makes a valuable contribution to knowledge of the effects of biochar on UK soil and indicates potential benefits. As with the previous trial, we cannot make firm recommendations at this stage and longer running trials would be required before application to pasture can be encouraged.

Fertiliser

Analysis of results from soil sampling and the land management questionnaire conducted with estate farmers suggested a possible link between soil organic carbon and the application of phosphate based fertilisers on pasture. The treatments chosen for this trial were based on a hypothesis that the greatest soil carbon stocks under pasture were on fields fertilised with basic slag (a phosphate rich by-product of the steel industry). This trial was conducted at the same site as the biochar plot trial, which was grazed by sheep. The experimental design was the same as for the biochar trial and the same monitoring regime was undertaken.

The following treatments were applied to the plots:

- NPK: in the ratio 20: 10: 10 at an application rate of 92 kg/hectare (0.23 kg/plot)
- Nitrogen fertiliser: 20% N content at an application rate of 62 kg/hectare (0.16 kg/plot)
- Basic slag at an application rate of 2470 kg/hectare (6.18 kg/plot)
- Basic slag and nitrogen fertiliser (20% N content) at an application rate of 2470 kg/hectare basic slag + 62 kg/hectare Nitrogen (6.18 kg basic slag + 0.16 kg/plot)
- Zero fertiliser to act as a control.

Key findings were:

- No significant difference was found between the fertilisers in their effects on soil carbon, soil respiration, grass productivity or run-off water chemistry
- No significant effect on soil carbon was identified for any of the fertiliser treatments
- A significantly greater net ecosystem exchange was measured on plots treated with nitrogen fertiliser than the un-treated plots
- Dissolved organic carbon loss was not affected by fertiliser application
- The concentration of nitrate and phosphate in soil and run-off water did not vary with fertiliser application
- A significantly lower soil water pH was found beneath plots fertilised with nitrogen and NPK than below un-treated and basic slag fertilised plots.

The hypothesis that basic slag is beneficial for soil carbon was not confirmed, but the results do suggest a liming effect which may result in benefits over a longer period. Further studies would be needed to confirm this. After a one-year study the use of fertiliser did not demonstrate any benefit for soil carbon. It should be noted that this is a relatively short study period and grazing during the trial may have influenced the findings.

Wallington: carbon sink or carbon source

There are 1,265,474 tonnes of carbon estimated to be stored in Wallington's soils and biomass. Computer modelling can estimate how much of this carbon is exchanged between land-based stores and the atmosphere each year. Whether there is a net absorption into the stores, or a net emission into the atmosphere, determines whether the estate is a carbon 'sink' or 'source'.

The area of Wallington managed by the National Trust and its farm tenants (i.e. excluding the Forestry Commission lease at Harwood Forest) is currently estimated to be a small source of carbon emissions, at around 136 tonnes per year. The absence of any large land-use change on the estate over recent years is responsible for the small magnitude of this source, as the majority of soil carbon within soils is currently near to equilibrium. Harwood Forest is currently a net biomass carbon sink of around 1000 tonnes per year. This is due principally to the annual increment of carbon in trees and their roots exceeding losses of carbon from peat oxidation.

How might land use change affect the carbon sinks and sources?

Computer modelling is useful in showing how different land use scenarios might damage or enhance soil carbon stores. For example, if all improved pasture at Wallington (a total of 2000 hectares) were to be converted to arable, the soils of the Estate would go from a small source of 136 tonnes carbon per year to a source of 4000 tonnes per year and would stay a net source for over 20 years.

The wide variation found in soil carbon on land classified as rough pasture at Wallington suggests scope for the creation of carbon sinks. If all rough pasture (a total of 1200 hectares) could achieve equilibrium at the highest soil carbon concentration found for this land use, an annual sink equivalent of up to 21,500 tonnes CO_2 might be achieved over a period of 20 years. This example is hypothetical, but it indicates that even relatively small increases in soil carbon for this land use could make a significant impact on the estate's carbon balance.

These two examples demonstrate that achieving optimum grassland management for soil carbon is the priority for Wallington. Within a balanced, estate-wide approach, some conversion to arable might be accommodated whilst still achieving net soil carbon gains.

Transferring the findings

Estimating soil carbon stocks using the Wallington analysis

The research carried out by Durham University will help land managers at other sites to understand and protect soil carbon. The analysis of soil carbon stores generated a valuable dataset of 700 soil carbon concentration values. Existing databases of soil carbon concentrations for specific soil groups, soil series and land-uses were used to predict the soil carbon stock of the sampled locations at Wallington, and the predictions then compared to the actual values measured in this study. We can thus give a guide for how accurate an estimate can be derived from nationally available databases (Bell and Worrall 2009). In summary:

Table 2

Data available	*Predictive value for estimating soil carbon*
NSRI* major soil group only	17%
NSRI soil series only†	48%
NSRI soil series plus land use observed in the field	59%
Countryside Survey major soil group plus land use	51%

*National Soil Research Institute | †Data does not cover the whole of the UK

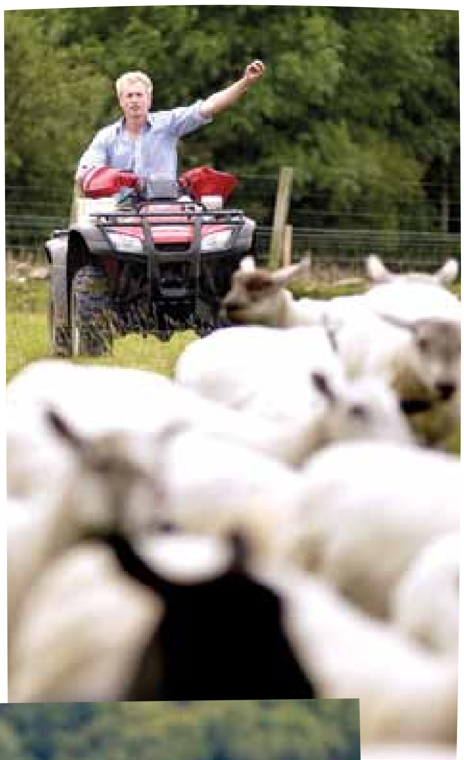
All the variables included in the Wallington analysis were able to explain 67% of soil carbon variation. Table 2 shows that if NSRI soil series data is available and the soil series soil carbon values from the NSRI database are adjusted accordingly for the land use observed at each site then 59% of soil carbon variation could be predicted. Where fieldwork cannot be carried out, this suggests that the right combinations of secondary data can offer a useable alternative.

There is the possibility however that the mean soil carbon values found at Wallington for major soil group, soil series, land-use and their combinations may produce more accurate estimates for other locations across the UK than secondary data. The study investigated whether accurate estimates could be produced if the statistical models used to explain variability at Wallington are used to predict the soil carbon at other locations. This hypothesis was tested at the National Trust's 1000 hectare estate at Wimpole in Cambridgeshire using 400 soil samples.

The Wimpole study concluded that in the absence of fieldwork and NSRI soil series data, the most accurate soil organic carbon stock predictions for other National Trust estates will be achieved knowing the land-use distribution on the estate and applying the mean soil carbon values from the Wallington database to each respective land-use.

Further information and resources

At the time of writing (August 2010), the Wallington PhD thesis remains unpublished. In addition to the published paper referenced here (Bell and Worrall 2009), several journal articles based upon the work are in review and details of these will be added to the Wallington page of the National Trust website **www.nationaltrust.org.uk** as they become available. For any questions relating to the study, please contact Dr Fred Worrall (fred.worrall@durham.ac.uk).



Next steps: science into practice

This study makes a significant contribution to several previously under-researched questions in relation to land management for soil carbon and confirms previously identified interventions to be of benefit at Wallington. The quality of the data has enabled us to establish Wallington as a national pilot for developing soil carbon practice.

We are pleased to announce that this study will form the basis of an innovative project under Natural England's Higher Level Stewardship (HLS) scheme due to start in September 2010. The development of a 'Land Carbon Management Plan' will enable further consideration of questions raised by the PhD. The rich data now available on soil carbon at Wallington will enable interventions to be targeted where the greatest gains might be made, or the greatest losses avoided. It will seek innovation as well as the use of more established methods such as the creation of permanent pasture, limiting conversion of grassland to arable, woodland creation, hedgerow planting, field margins, the use of farmyard manures and minimum tillage.

Land Carbon Management Plan actions will be identified for each farm at Wallington, and included in HLS agreements as they are developed for each tenancy. The soil carbon benefits of proposed actions will be quantified, monitoring regimes designed and suitable incentives proposed.

The current report has not attempted to be a 'how to' guide to manage land for soil carbon. Clear advice aimed at farmers is obviously a priority and this will result from our work with Natural England and synthesis of other initiatives taking place across the National Trust.

Acknowledgements

The work summarised in this report was completed by Madeleine Bell of Durham University Department of Earth Sciences supervised by Dr Fred Worrall. The National Trust and the researchers are grateful to Wallington's tenant farmers in facilitating the fieldwork and to Newcastle University for hosting part of the fieldwork.

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