SOIL CHEMISTRY CHANGE IN A LOWLAND ENGLISH DECIDUOUS WOODLAND 1974-1991

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Abstract. This study outlines the results of analysis of soil samples collected from fixed quadrats located in a regular pattern across Wytham Wood, Oxfordshire, England. The site contains plots of mixed deciduous ancient woodland and more recent plantations. A previous soil study was undertaken in 1974 and samples archived. Soils were resampled in 1991 and some re-analysis of the 1974 samples was undertaken. Soils were of a wide range in types from sands to gravels with a pH range of 3.0-7.0. Results showed some decline in pH in lower horizons, but most striking was a large increase in soil nitrogen for all horizons and soil types.

Key Words: soils, acidification, ancient woodland, nitrogen, environmental change

1. Introduction

The chemistry of soils is not constant. The release of elements by weathering, leaching by rainwater and changes caused by inputs from vegetation all result in a natural evolution of the soil. However, other changes do take place due to the influence of man. One of these is the changes caused by the deposition of pollutants, both directly as dry deposition and also in rainfall. Sulphur and nitrogen pollutants can lead to acidification of soils and the nitrogen input can cause eutrophication. It is possible to estimate the degree of pollutant input that would be necessary to initiate changes in different soil types, e.g. where the acid inputs cannot be buffered by cation release from mineral weathering. This is the "critical load" approach and can be used to predict soils at risk around Britain. However, it is also important that changes in soil chemistry can be documented over different time periods, describing the changes that take place.

This paper reports a study of soil chemistry changes between 1974 and 1991 at Wytham Wood, Oxfordshire, England. It gives results from the examination of soils from permanently marked locations throughout the site taken in each of the two years and describes and discusses the changes that have occurred.

2. Study Site and Methods

Wytham Wood is an important forest research site in Oxfordshire, containing some blocks of ancient woodland, together with more recent plantations and open grassland areas. It is also a Site of Special Scientific Interest (SSSI). The site also covers a wide range of soil types including coral rag, clays and acidic sands. The site is owned by the University of Oxford who have undertaken research there for many decades and is now a site within the NERC UK Environmental Change Network.

Dawkins and Field (1978) set up a series of permanent quadrats covering the whole of Wytham Wood in 1973-4. A 100 x 100 m grid (following the national grid) was marked out using wooden posts. At every other post a permanent quadrat was located and marked by underground metal posts which can be located using a metal detector. 164

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were located throughout the site. Each quadrat was a 10 m^2 square, with the metal posts forming two diagonal corners. Soil samples were taken, using an auger, along the south and west sides of the square. Four samples were taken for each quadrat, at 40 cm and 90 cm along each of the two sides. Each sample was divided into 0-10 cm, 10-20 cm and 20-30 cm depth profiles. The four samples were bulked for each depth profile, producing three overall samples per quadrat. These were taken to be representative of the quadrat.

Samples were first taken by Dawkins and Field (1978) in the winters of 1974 and 1975, when 150 quadrats were sampled, analysed and the dry soils archived. In November/December 1990 50 quadrats were resampled in three areas of the site including all major soil types. Some of the quadrats cover rides and small areas of open grassland. However, many cover ancient and more recent deciduous woodland. This study reports on results from 18 plots in ancient woodland and 16 in recent woodland. These quadrats were taken from three parts of the wood and represent all of the important soil types present in the site. Sample points were relocated exactly according to the methods of Dawkins and Field (1978). Drying and analysis of the samples in 1990 followed the same procedures as in 1974/5. For all analyses except pH the results from Dawkins and Field (1978) are used.

The methods described by Dawkins and Field (1978) do not allow an exact replication of the determination of pH. It is also known that results for pH analysis can vary between workers. For these reasons, pH change was not assessed by analysis of fresh soil pH and comparison with the 1974/5 data, but by analysis of dry soil pH on the 1990 and archived soil samples from 1974/5. Soils were dried at 40°C in an oven and broken into fine particles. Dry soil samples from the 1974/5 survey and dry samples from the 1990 survey were analysed for calcium chloride pH. 5 g of dry soil was incubated for 12 hours in 10 ml of 0.01 M calcium chloride solution and pH determined on the resulting suspension. All samples were analysed in pairs, i.e. pHs were determined on samples from the same quadrat and depth for the two time periods together. This minimised any non-chemical variation.

Analysis for loss on ignition, acetic acid exchangeable potassium, calcium, magnesium phosphate and total nitrogen was contracted out in 1974/5 to the Institute of Terrestrial Ecology at Merlewood. In order to reduce variation the 1990 samples were also sent to ITE for the repeat analysis. Rather than simply follow present day analytical procedures, the methods used in 1974/5 were studied and used whenever possible. This was done in order to reduce the errors that may have occurred due to different laboratory procedures. Methods for analysis followed Allen (1989). Once soils were analyzed, the remaining dried material was placed in secure bags and archived at the ECN site at Wytham, where the archived samples from 1974/5 are now stored.

3. Results

Table 1 presents the mean and ranges for the soil chemistry results for the two woodland plot types. Statistical analysis was undertaken to examine changes and relationships between chemical parameters for the two woodland types and for different depth profiles. Table 2 presents the results for changes in chemistry for the two woodland types. It can be seen that there is a significant increase in the loss-on-ignition in the ancient woodland plots and a significant increase in nitrogen in both woodland types. No significant correlations were found between changes in one chemical parameter and another. Changes in cations and loss-on-ignition were not significant when examined by depth profile. However, Table 3 shows that the 20-30 cm samples show a significant decline in pH and all depths show the significant increase in nitrogen. The 20-30 cm depth profile also showed a significant correlation between change in pH and increase in nitrogen and change in pH and change in calcium. For full details, all of the raw data are presented in Farmer (1994).

Table I

Soil chemistry data for the two woodland types for 1974 and 1991, giving the means and ranges (in parentheses) of the analyses, all soil depths combined.

Soil Chemical Character	Ancient Woodland 1974	Ancient Woodland 1991	Recent Woodland 1974	Recent Woodland 1991
Dry soil pH ($CaCl_2$)	4.79 (3.00-6.64)	4.64 (3.01-6.69)	5.63 (3.72-6.89)	5.51 (3.46-7.01)
Loss-on-Ignition (%)	8.6 (3.1-17.0)	10.8 (3.1-20.0)	9.7 (3.7-22.0)	11.3 (2.7-25.0)
Potassium (mg/100g)	17.9 (8.6-38.0)	18.2 (6.5-37.0)	18.6 (5.2-42.0)	18.2 (5.6-51.0)
Calcium (mg/100g)	564 (56-5700)	514 (41-3700)	4913 (89-23000)	2781 (62-14000)
Magnesium (mg/100g)	19.4 (7.2-34)	17.0 (6.5-34)	42.9 (7.7-140)	27.6 (5.3-89)
Phosphate (mg/100g)	0.77 (0.003-6.5)	0.95 (0.10-5.0)	0.90 (0.05-4.10)	1.22 (0.15-5.70)
Nitrogen (%)	0.24 (0.09-0.56)	0.36 (0.14-0.66)	0.28 (0.09-0.63)	0.42 (0.10-0.86)

4. Discussion

This study shows that significant changes have taken place to the soil chemistry of the woodland plots at Wytham between 1974 and 1991. There has been a tendency for a decline in pH. The mean pH change when analysed by woodland type or soil depth is always negative, although it is only significant for the deepest soil collected. The mean change is -0.155 for ancient woodland and -0.17 for recent woodland. This decline is less than that found for the nearest comparable study that has been undertaken. This has been the long-term monitoring of soils at Rothamsted, Hertfordshire (Johnston *et al.*, 1986). Here soils in the upper horizon of a small woodland has declined in pH by nearly 3 units over a 100 year period. This is a greater rate of acidification than noted at Wytham. However, many of the Wytham soils are already acidic and could not exhibit such a pH decline. Johnston *et al.* (1986) also analyzed various potential causative agents of such acidification and concluded that 30% of the decline was attributable to dry and wet deposited acidity from the atmosphere. The Rothamsted woodland plot was a secondary woodland growing on old fields. Some natural acidification is to be expected, therefore, as the woodland develops. This may also be true of the recent woodland plots at Wytham.

Table II

Results of paired t-test analysis for significant differences between the 1974 and 1991 Wytham soil chemistry data for two woodland type, all soil depths combined.

Soil Chemical Character	Ancient Woodland Quadrats Significance Level	Recent Woodland Quadrats Significance Level
Dry soil pH ($CaCl_2$)	n.s.	n.s.
Loss-on-Ignition	increase (1%)	n.s
Potassium	n.s	n.s
Calcium	n.s	n.s
Magnesium	n.s	n.s
Phosphate	n.s	n.s
Nitrogen	increase (5%)	increase (1%)

Table III

Results of paired t-test analysis for significant differences between the 1974 and 1991 Wytham soil chemistry data for different soil depths for both woodland types combined.

Soil Chemical Character	0-10 cm Depth	10-20 cm Depth	20-30 cm Depth
Dry soil pH	n.s	n.s.	0.1%
Nitrogen	0.1%	0.1%	0.1%
Calcium	n.s.	n.s.	n.s.
Change in pH vs Change in Nitrogen	n.s.	5%	n.s.
Change in pH vs Change in Calcium	n.s.	5%	n.s.

Declines in soil pH have been identified in a number of locations in Britain and north west Europe. Kuylenstierna and Chadwick (1991) found that soils in north west Wales had declined in pH by up to 1.7 pH units between 1957 and 1990. They also noted that soils with higher original pH values had shown the greatest degree of acidification. This was not found for the Wytham samples. In contrast, the higher pH soils from Wytham tended to show a greater variation in pH changes and the lower pH soils showed a more consistent decline. This may reflect the wider variation in soil type at Wytham than at many previous studies.

Changes in forest soil chemistry have also been found in north east Scotland (Billett *et al.*, 1988), with a decline of up to 1.3 pH units over 40 years. Peat soils in Scotland have shown a decline in pH related to levels of atmospheric acid deposition (Skiba *et al.*, 1989). In south Norway (Bjornstad, 1991) mildly acidic (pH 5.2) forest soils were found to show a decline of up to 1.2 pH units over a 20 year period, but the most acidic soils (pH 3.6) had shown a slight increase. The decline in soil pH has been confirmed elsewhere in Norway and Sweden (Falkengren-Grerup, 1987; Dahl, 1988; Tamm and Hallbacken, 1988). Even calcareous soils are predicted to acidify using model analysis with ambient deposition in The Netherlands (De Vries *et al.*, 1994)

A decline in pH of the soils would also be predicted from the fact that the national critical loads maps for acidity (UKCLAG, 1991) indicate that at least the acidic soils at Wytham receive deposition in exceedence of their critical loads. Forward projections of exceedence, however, indicate that acidification would not continue to take place at Wytham, due to sulphur deposition, after implementation of the EC Large Combustion Plant Directive in 2003 (Bisset and Farmer, 1994).

The greatest change in the Wytham soils has been the increase in nitrogen. The soils at Wytham Woods receive considerable inputs of wet and dry deposited acidity (UKRGAR, 1990). The deposition of acidifying species may lead to soil acidification and the deposition of high levels of nitrogen may explain the increase in soil nitrogen at Wytham. However, our understanding of nitrogen deposition processes is still growing and recent work by Ineson *et al.* (1993) has shown that woodlands in rural areas are very efficient as surfaces for deposition of ammonia from agricultural emissions (throughfall in commercial plots being over 100 kg N/ha/y). Wytham occurs in a typical rural lowland environment and the woodland soils may have experienced higher nitrogen loading than would be predicted by a simple estimation from national deposition models.

Nitrogen deposition, both of oxidised and reduced species, is increasing, however. Estimates for critical loads for nitrogen for productive forests are around 20kg $N.ha^{-1}.y^{-1}$ (Nilsson and Grennfelt, 1988). The levels deposited at Wytham are in excess of this. The deposited nitrogen may also lead to acidification even though the sulphur critical loads may no longer be exceeded.

Changes in soil chemistry in woodland do lead to changes in the associated ground flora. Small scale variations in soil acidity, e.g. around the trunks of trees, are significant determinands of plant distribution (e.g. Wittig and Neite, 1985). Changes in soil acidification in Sweden also resulted in changes in ground flora (Falkengren-Grerup, 1986; 1990), with a decline in acid-intolerant species and an increase in nitrophilous species. Experimental studies of nitrogen addition also leads to an increase in nitrophilous herbaceous species and a decrease in the macrofungal community (e.g. Ruhling and Tyler, 1991). In lowland England, Ling & Ashmore (1989) suggest that changes in the ground flora of some beech woodlands on the Chiltern hills may be due to the effects of nitrogen deposition.

At present a full analysis of the floristic data for 1974/5 and 1990 at Wytham has not been undertaken nor related to soil chemistry changes. Preliminary analysis by Thomas and Kirby (1992) suggest that some ground flora and shrub species have shown significant changes, but that alterations in woodland structure through management and changes in deer numbers may explain these. A full analysis will, however, be undertaken.

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