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ROTHAMSTED
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Guide to the Classical and Other Long-term Experiments, Datasets and Sample Archive



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Long-term Experiments As a Resource

Rothamsted Research

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incorporated; 6. Continuous spring barley with straw removed. In treatments with rotations only one phase was present each year. Crop yields were taken each year and soils were collected in 1997, 2008 and 2015. Maize and spring barley were chosen as crops with contrasting $\delta^{13}\text{C}$ enrichment in their residues to provide an opportunity to follow the fate of the C incorporated in the maize crop residues. The experiments were discontinued in 2015.

METEOROLOGICAL DATA

Because of climate change it is important when interpreting data from long-term experiments that changes in temperature, rainfall (amount and distribution), chemical inputs (in rainfall and as dry deposition) *etc.*, are all taken into account. Total rainfall has been measured at Rothamsted since 1853 and temperatures since 1873; other meteorological data have been collected subsequently. Annual rainfall averages 704mm (mean 1971-2000) but ranges



Rothamsted Meteorological Station, 2017

widely from 380mm in 1921 to 973mm in 2000. Increases in temperature in many parts of the world are well documented (Hansen & Sato, 2016) and Rothamsted data (Figure 14) show that the average (1989-2018) annual mean air temperature was approximately 1.1°C warmer than the long-term mean of 9.04°C (1878 to 1988). There has been a similar rise in average annual temperature at Woburn. Much of that rise is accounted for by increases during the autumn and winter months. Average soil temperatures have also risen.

Since the 1850s, chemical inputs in rain have changed considerably. Inputs of acidity (H^+ ions) are small; less than 0.1 kg $\text{ha}^{-1}\text{yr}^{-1}$ up to the 1950s. They reached a maximum of 0.4 kg $\text{ha}^{-1}\text{yr}^{-1}$ in the 1970s and are now about 0.2 kg $\text{ha}^{-1}\text{yr}^{-1}$. Inputs of sulphate-S were about 5 kg $\text{ha}^{-1}\text{yr}^{-1}$ in the 1850s and reached a maximum of 65 kg $\text{ha}^{-1}\text{yr}^{-1}$ by 1980. After a dramatic decline, associated with decreasing emissions from power stations and a decline in heavy industry they are now about 5 kg $\text{ha}^{-1}\text{yr}^{-1}$. Inputs of nitrate- and ammonium-N in rainfall were 1 and 3 kg $\text{ha}^{-1}\text{yr}^{-1}$, respectively, in 1855, and increased to 8 and 10 kg $\text{ha}^{-1}\text{yr}^{-1}$ in 1980. In 1996, N in dry deposition amounted to 34 kg N $\text{ha}^{-1}\text{yr}^{-1}$; about three times that in rainfall. The total N input for wet and dry deposition at that time was about of 43 kg $\text{ha}^{-1}\text{yr}^{-1}$. Since then, atmospheric inputs have declined to about 21 kg N $\text{ha}^{-1}\text{yr}^{-1}$ (Storkey *et al.*, 2015) compared with about 10 kg N $\text{ha}^{-1}\text{yr}^{-1}$ in the mid-1850s.

LONG-TERM EXPERIMENTS AS A RESOURCE

Changes in agricultural practices or other factors influencing soil quality and soil processes can take decades to have any measurable effects. Effects of agriculture on

the wider environment may also take many years to become apparent. In this context long-term experiments are an invaluable resource that can be used to quantify changes that are impossible to detect in short term experiments.

Thus, Broadbalk, Hoosfield and Park Grass have been used for detailed work on N cycling using the stable isotope, ^{15}N , applied to microplots within the experiments. Results show that, in our temperate climate, recoveries, by cereals, of fertiliser N greater than 60% can be achieved (Powelson *et al.*, 1986; Glendining *et al.*, 1997) and that most of the nitrate present in the soil profile in the autumn, and therefore at risk of loss by leaching, is derived from SOM, not from unused fertiliser N. Exceptions are where excessive amounts of N are applied, in relation to potential crop yield, or where a crop fails. On Park Grass labelled N, as either $^{15}\text{NH}_4$ or $^{15}\text{NO}_3$, was applied in 1980 and 1981. After 18/19 years, 67% of the $^{15}\text{NH}_4$ -N had been removed in successive grass harvests (mostly in the first year) but a further 17% still remained, in organic forms, in the soil. Less of the $^{15}\text{NO}_3$ -N was recovered; 60% in the herbage plus 14% in the soil (Jenkinson *et al.*, 2004). Labelled N has also been used to assess losses of N by denitrification and leaching, and to measure gross N mineralisation.

Other work has focussed on the soil's ability to act as a sink for methane (CH_4), an important greenhouse gas. For example, on the arable plots on Broadbalk, less CH_4 is oxidised in the soil where fertiliser N has been applied, compared with soil receiving FYM or soil receiving neither fertiliser nor manure (Hutsch *et al.*, 1993). In the adjacent woodland (Broadbalk Wilderness) the rate at which CH_4 was taken up was 6 times faster than on the FYM soil. However, in the acid soil of the Geescroft Wilderness there was no CH_4 uptake. Similarly, on Park Grass, CH_4 oxidation was

inhibited on soils with a pH of c.5 or less.

Recent work on Park Grass has examined how the differing nutritional statuses of the plots has affected the intrinsic water-use efficiency of the different swards. By measuring the $\delta^{13}\text{C}$ enrichment of archived herbage samples from selected plots on Park Grass from 1915 to 2009 Köhler *et al.* (2012) were able to examine the effects of different fertilisers and manures on changes in the intrinsic water-use efficiency of the plant communities over a period of nearly 100 years, under conditions of increasing atmospheric CO_2 . The CO_2 -responsiveness of the plant communities was found to be related to their grass content. This may have been due to the greater CO_2 responsiveness of stomatal conductance in grasses relative to forbs and the greater CO_2 response found in the fertilised swards may be related to the effects of N supply on botanical composition.

Broadbalk has been used to investigate the influence of both amount and form of N on gene expression in wheat grain (Lu *et al.*, 2005). Clustering of gene expression profiles separated high and low N treatments. In addition, where the crop was accessing N derived from an organic source (FYM) there was a unique gene expression pattern and separate clustering. Analysis of this profile indicated the presence of genes encoding N assimilation components, seed storage proteins and several unknowns. These patterns were confirmed in successive years on Broadbalk and on the Woburn Ley-arable experiment where gene expression differed between wheat receiving fertiliser N and that receiving N derived from the mineralisation of grass ley residues. The most recent studies are combining both transcriptome and metabolome profiling to gain insights into processes relating to nitrogen use efficiency in wheat. In addition, Broadbalk and Hoosfield have been used to test and develop

remote sensing techniques using drones fitted with multispectral cameras for mapping soil C.

Data from 16 long-term experiments was evaluated to see whether the “4 per 1000 initiative: Soils for Food Security and Climate”, launched at the Paris Climate Conference in 2015 and aimed at increasing soil organic matter, thus mitigating global warming is achievable (Poulton *et al.*, 2018). Whilst the target of 4‰ per year for 20 years can often be reached by increasing inputs of manure or by changes in management, for example the introduction of grass or legume leys into arable cropping, such options are not always available to the farmer or desirable. The reasons for this include lack of resources or possible impacts on food security. However, any initiative which seeks to increase soil organic matter, and thus soil quality and functioning, should be welcomed.



New sample archive

THE ROTHAMSTED SAMPLE ARCHIVE

The unique Rothamsted Sample Archive was established by Lawes and Gilbert in 1843 and its scientific value has been, and continues to be, immense. The Archive comprises, predominantly, soil and plant samples from the long-term field experiments at Rothamsted, Woburn and Saxmundham described in this guide. Plant samples consist of oven-dried, unground wheat and barley grain and straw and herbage from Park Grass, as well as finely ground material from many other crops. Soils (air-dried) have been taken from top-soils/plough layer (generally 0-23 cm) and occasionally from sub-soils, some to > 200 cm. They are usually stored as either 6.35mm, 2mm or more finely ground samples. There are also dried samples of organic manures and fertilisers that have been applied to the experiments, and several thousand soils from different locations in the UK and from other countries. Samples are stored in sealed glass bottles or jars, airtight tins, glass vials or card boxes. The samples were re-located in 2009.

The Sample Archive has been used extensively by Rothamsted staff and by scientists from other research institutes and universities in



Archived soil samples