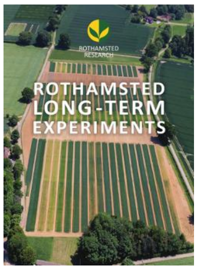
ROTHAMSTED RESEARCH

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



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The Rothamsted Sample Archive

Rothamsted Research

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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

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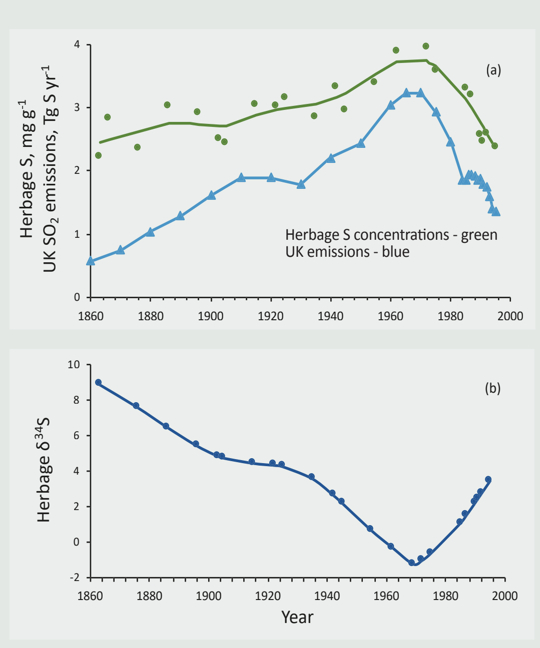

Fig. 15 Park Grass; the effect of changes in emissions of SO_2 in the UK on herbage S (a) and herbage $\delta^{34}S$ (b).

the UK and abroad. The retrospective analysis of archived material allows us to look back more than 175 years at, for example, many aspects of plant nutrition and soil fertility, and pollution that could not have been anticipated when the samples were taken. This is particularly true with respect to organic pollutants and environmental issues. Thus, archived samples have been analysed for their heavy metal content following the application of sewage sludge, for cadmium following applications of phosphate fertilisers and for poly-aromatic hydrocarbons and dioxins, which have increased in the atmosphere since the early 1900s.

Sulphur dioxide (SO_2) was an important atmospheric pollutant in the UK for much of the 20th century, but one that supplied much of agriculture's sulphur needs. Inputs have declined markedly since the 1970s (see section on Meteorological Data). Soil and herbage samples from Park Grass were used to assess the impact of the changing inputs of SO_2 on S cycling in the plant:soil system. While concentrations of S in herbage were positively correlated with annual SO_2 emissions (Figure 15), the trend in the stable S isotope ratio, $\delta^{34}S$, was negatively correlated with SO_2 emissions, reflecting the more negative $\delta^{34}S$ values associated with anthropogenic S sources (Zhao *et al*., 1998). Calculations suggest that up to 50% of the herbage S uptake came from anthropogenic sources at the peak of SO_2 emissions in 1970.

The plant material in the Rothamsted Sample Archive also contains fungal pathogens and it is possible to isolate and analyse the pathogen DNA. Pyrosequencing of this DNA was used to examine the development of resistance to triazole fungicides in the barley pathogen *Rhynchosporium commune* (leaf blotch fungus) conferred by the presence of CYP51A, a paralogue of the target site encoding gene CYP51 (Hawkins *et al.,* 2014). Spring barley has been grown since 1852 on Hoosfield, and *R. commune* DNA was successfully amplified from the archived barley samples collected in 33 separate years between 1892 and 2012. The pyrosequencing assay revealed that, for most of the 20th century, the majority of the *R. commune* population on Hoosfield lacked the azole fungicide resistance conferring gene, but in 1985, following the introduction of azole fungicides in the UK, levels rapidly increased and subsequently the majority of the *R. commune* population possessed the resistance gene.

Data from the analyses of soils for their organic carbon and ^{14}C content was used to develop and validate RothC, a computer model that simulates the turnover of soil organic matter, a key component of soil quality (Jenkinson, 1990). RothC is widely used by researchers worldwide and is now linked to the global climate model developed by the Hadley Centre.

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Scientists at Southampton Oceanography Centre analysed samples of herbage from the Park Grass experiment over a 50-year period to measure concentrations of plutonium and uranium. They were able to detect the effects of, and distinguish between, nuclear bomb tests carried out by the US, USSR, UK and France, and show that plutonium contamination from weapons testing in the Nevada Desert in 1952/3 reached Northern Europe (Warneke *et al*., 2002). Such measurements have only become possible in recent years with the development of more sophisticated analytical techniques.

There are written and electronic records of samples that have been archived and, increasingly, information on the samples is being stored electronically in the Electronic Rothamsted Archive (see below).

ELECTRONIC ROTHAMSTED ARCHIVE (e-RA)

Data from the most important Classical experiments are accessible from the electronic Rothamsted Archive (e-RA), which is a permanent managed database for secure storage and dissemination of data, plus accompanying meteorological records and associated documentation. Users can query the password-protected database, via an internet application, http://www.era.rothamsted.ac.uk/.

e-RA currently holds records of yields, species composition, weeds, diseases, crop nutrient contents, grain quality and soil properties for four 'Classical' experiments: Broadbalk (both wheat and other crops in the rotations); Hoosfield Spring Barley; Park Grass; Hoosfield Alternate Wheat and Fallow, and also the two Wilderness Sites (Broadbalk and Geescroft). Daily meteorological data are held for Rothamsted (since 1853), Woburn (since 1928) and Broom's Barn (since 1982). Importantly, e-RA also contains a wealth of background information about the experiments, including plans, soil maps, details of fertiliser and manure treatments, management, photos, methods of analysis, site details and case studies. These metadata are vital to fully understanding the experiments, and ensuring that the results are correctly interpreted. The e-RA curators assist users by providing support in data selection, and ensuring they have all necessary background information.

Commonly requested data, published with a Creative Commons Licence and citable with DOIs, are available from the e-RA website as Open Access summary charts and tables; no password is required. These include mean long-term crop yields (Figures 1 and 7), long-term changes in soil organic carbon (Figure 4) and Park Grass species numbers (Figure 6). There is also a dedicated section for schools, with simple sub-sets of meteorological data.

A comprehensive searchable bibliography is included, containing over 1500 references relating to the long-term experiments, including details of over 500 publications by Lawes and Gilbert. Many of Rothamsted's historical documents are being made available through eRAdoc, an online repository for documents relating to the LTEs http://www.era.rothamsted.ac.uk/eradoc. These include Annual Reports, Yield Books, Guides and plans containing important information about the LTEs. These are being given DOIs so that they can be readily accessed and cited and many are available as searchable pdfs, with manually curated Tables of Contents.

Requests for e-RA data from the scientific community have been increasing steadily,

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