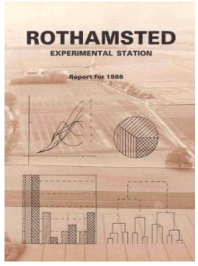
ROTHAMSTED RESEARCH

Rothamsted Experimental Station Report for 1986

Full Table of Content



Soil Survey of England and Wales

P. Bullock

P. Bullock (1987) *Soil Survey of England and Wales ;* Rothamsted Experimental Station Report For 1986, pp 193 - 216 **- DOI: https://doi.org/10.23637/ERADOC-1-27**

SOIL SURVEY OF ENGLAND AND WALES

STAFF

Head of Survey P. Bullock Ph.D.

Headquarters
J. M. Hodgson, B.Sc.
J. M. Hollis, B.Sc.
P. J. Loveland, Ph.D.
A. J. Thomasson, M.Sc.

Information systems
Mary E. Proctor, B.Sc.
S. R. Clarke, B.Sc.
P. L. Thorne

Cartographers
E. M. Thomson
M. J. Williamson
M. S. Skeggs

Assistant Staff
I. Patricia Bond
N. A. Dayton
Christine M. Lapwood
Alison E. Saxby
Janet Y. Shuttleworth
Anne E. Williams

Northern England
R. I. Bradley, M.Sc.
S. J. King, B.A.
R. W. Payton, B.Sc.

East Anglia
R. G. O. Burton, M.Sc.
P. S. Wright, M.Sc.

Midlands
J. M. Ragg, B.Sc.
G. R. Beard, B.Sc.
Andrée D. Carter, Ph.D.
R. J. A. Jones, Ph.D.
R. C. Palmer, B.Sc.
M. J. Reeve, B Sc.
J. D. Robson, B.Sc.
W. A. D. Whitfield, M.Sc.

Christine Bembridge
Hilda Roberts

South-east England
M. G. Jarvis, B.A.
J. Hazelden, M.A.
R. G. Sturdy, M.Sc.

South-west England
D. W. Cope, B.Sc.
T. R. Harrod, Ph.D.
Carole M. Scott

Wales
R. Hartnup, B.Sc.
T. R. E. Thompson, B.Sc.

Students
J. K. Atherton, B.Sc.
Maureen McHugh, B.Sc.

Introduction

The year has been one of mixed fortunes. The abrupt reduction in funding by the Ministry of Agriculture, Fisheries and Food (MAFF) led to the loss of seventeen staff, including highly trained, able scientists of many years experience. At a time when there is so much concern over changing land use, alternative cropping possibilities and soil pollution and degradation, the country can ill afford such losses.

The cuts in funding have meant that the detailed national mapping programme, which in 1983 was rated as Priority A by the Joint Consultative Organisation for Research and Development in Agriculture and Food, has been suspended. Only five of the 1:50 000 sheets in the programme will be completed until additional funds become available. A quarter of England and Wales is now covered by detailed soil maps at a scale of 1:63 000 or larger. This forms a sound background for planning land use, creative management of land and for assessing the environmental implications of a particular change in land use. Until the programme can be resumed some 75% of the two countries will lack this important database.

The Ministry of Agriculture, Fisheries and Food continues to fund the development of the Land Information System (LandIS), developments in land evaluation, soil hydrology and soil erosion, and some *ad hoc* soil mapping. This support allows the Survey to retain an important research base for which it has a strong national and international reputation, and to provide a sound background for improvement of methodology, necessary to apply the soil information for a wide variety of purposes.

https://doi.org/10.23637/ERADOC-1-27

This year, for the first time in its 46 year history, the Soil Survey is seeking major funding other than that provided by government. With the reduction in funding from MAFF came the clear message that the many individual users and groups that previously had free access to the Survey's information and expertise would now be expected to pay. The year ends on a high note, for not only has the Survey's staff risen magnificently to the challenge but there has been substantial demand for our services and information both here and overseas by government and private bodies.

1:50 000 Scale mapping

Sheet 81 (Alnwick and Rothbury). A further 321 km^2 have been mapped mainly around Alnwick, around Longframlington and Cambo, and in the Cheviot Hills. This leaves about 310 km^2 still to survey. All the soils likely to occur on the sheet have been established and several new soil series have been defined. The latter occur mainly on the Fell Sandstone, over rocks of the Cementstone Group and over Cheviot andesites.

Large areas of the till-covered lowlands are dominated by seasonally waterlogged stagnogley soils of the Dunkeswick, Hallsworth and Pinder series; better drained soils being restricted to localized glaciofluvial deposits, areas of thin drift over sandstone, and steep slopes. Clayey surface-water gleys of the Hallsworth and Foggathorpe series are dominant in the south-east on the Northumberland coastal plain where relief is subdued and the till is derived mainly from Coal Measures shales. Here there are contrasting sandy or coarse loamy soils on patches of glaciofluvial deposits, giving brown sands and brown earths of the Wick, Arrow, Wighill, Newport and Ollerton series.

The more undulating terrain north and east of Alnwick is covered by varied drifts which give a contrasting soil pattern with a greater proportion of well drained loamy soils which are mainly under intensive cereal production. Here the till tends to be medium-textured and thinner on ridge flanks and hillsides. It is often absent on hilltops, and elsewhere is replaced laterally by glaciofluvial deposits. Dunkeswick and Pinder series are both common on low-lying ground but ridge flanks and hillsides carry stagnogleyic argillic brown earths belonging to Bishampton and Wighill series, with freely drained East Keswick or Ludford series on steeper slopes. The hilltops often have brown earths over sandstone (Rivington and Neath series), or dolerite (Trusham series). North-west of Alnwick there are shallow stony podzolic soils over sandstone belonging to Batch and Lazonby series. Mounded glaciofluvial deposits and river terraces carry coarse loamy brown earths of the Wick, Arrow and Hall series. The brown earths on till have proved to be argillic in thin sections, but those on glaciofluvial deposits often fail to show a significant clay increase within the soil profile.

In the wetter west on high ground where the till contains more sandstone there are stagnohumic gley soils (Kielder and Wilcocks series), and cambic stagnogley soils with a thin humic surface horizon (Brickfield series). Associated ironpan stagnopodzols occur on steeper ground (Harwood series) or over sandstone (Belmont series). In the extreme south west on the repeated cuestas formed by Carboniferous rocks, the till varies in thickness and this modifies the soil pattern to give brown rankers (Crwbin series) and brown earths (Waltham or Barkston series) over limestone on upper dipslopes and stagnogleyic brown earths (Nercwys series) over thin till on middle dipslopes. On lower ground where the drift thickens, Brickfield and Wilcocks series are found.

In the north-west, complex soil patterns occur in three main landscapes: the elevated Fell Sandstone cuestas, the undulating Cementstone Lowlands and the Cheviot Hills. The pattern of podzolic soils found on the Fell Sandstone (*Rothamsted Report for 1983*,195) has been confirmed. New soil series have been defined for sandy humus-ironpan stagnopodzols (Callaly, Cartington and Simonside series), stagnogley podzols (Rothbury

https://doi.org/10.23637/ERADOC-1-27

and Thrunton series) and sandy stagnohumic gley soils (Debdon series). The differentiation of these soils is significant for forestry as they have different capacities to support tree growth and require contrasting management.

The nature and distribution of soils in the Cheviot Hills are closely related to the granitic and andesitic parent materials and to a climatically controlled altitudinal sequence. Further mapping of the soil pattern on the Cheviot andesites has shown that shallow stony humic brown podzolic soils belonging to Bowden series and ferri-humic cryptopodzols (Cheviot series) occurring under *Nardus* on convex summits and north facing slopes are more common than previously thought. Stagnohumic gley soils over reddish lithoskeletal andestic drift (Alnham series) and cambic stagnogley soils on similar materials (Ingram series) are common in the valleys and on the flanks of the Cheviot massif. Ingram soils respond well to reclamation and drainage, and with the deeper brown podzolic soils (Davidstow series) they form the most useful agricultural land in the Cheviots. The Cheviot granite, which forms the highest ground on the map, is dominated by deep raw peat soils (Winter Hill series) on summits and by ironpan stagnopodzols (Hexworthy series) on upper slopes. Humic rankers and humic brown podzolic soils occur on the steepest slopes. Well-developed fragipans are widespread in all the deeper soils of the Cheviots particularly in the brown podzolic soils and stagnopodzols, forming horizons which are impenetrable by roots and only slowly permeable to water at a depth of about 50 cm.

The soils of the Cementstone lowlands are diverse and were briefly described last year (*Rothamsted Report for 1985*). Convex low ridges of Cementstone Group rocks are drift free or only thinly covered. The varied lithology of soft weathered siltstones, limestones, shales and hard sandstones gives abrupt changes in parent materials along ridge crests and flanks with soils ranging from argillic brown earths to stagnogley soils. Isolated paleoargillic brown earths have been confirmed by thin sections. Several of the soils have been named as new soil series but brown earths over sandstone (Neath and Plowden series) are also common on ridge crests. Low lying ground between the ridges is underlain by till to the north-west of Rothbury where Pinder or Dunkeswick series are usual. However, around Whittingham and Powburn, there are level tracts of reddish glaciolacustrine clays above the level of the river alluvium which carry stoneless calcareous pelosols or pelo-stagnogley soils. These merge laterally with sandy or coarse loamy glaciofluvial deposits that form terraces or mounded terrain and give brown sands of the Newport and Ollerton series, or gravelly brown soils with andesite stones (Netherby and Roddam series), or typical brown earths belonging to Wick, Hall, Arrow, Hopsford and Rockland series. North of Powburn there are extensive mounds of glaciofluvial sands and gravels giving Netherby, Newport and Penrith soils. These suffer from droughtiness, giving low yields of cereals. (Payton, King and Bradley)

Sheet 106 (Market Weighton). Fieldwork was completed with the re-assessment of the remaining 80 km^2 of published and earlier reconnaissance surveys which were incorporated into the final map. Work was concentrated in the Stamford Bridge area west of the escarpment of the Wolds where the pattern of soils is similar to that described earlier (*Rothamsted Annual Report for 1984*). East of Stamford Bridge, however, outcrops of Mercia Mudstone form gentle or moderately sloping ground on knolls and on the flanks of river terraces. These outcrops impart a reddish colour to soils on both solid and drift deposits. The clayey Worcester and Spetchley series are developed directly in mudstone whilst Brockhurst and Whimple soils are found where there is thin drift overlying the mudstone.

A draft of the map at the final 1:50 000 scale was compiled from the sixteen 1:25 000 field sheets. The final map is being prepared for publication using digitized computer techniques.

https://doi.org/10.23637/ERADOC-1-27

The draft of the memoir describing the physical background, the soils and the agriculture was written and edited. It includes assessments of the suitability of common soil series for selected aspects of land management including workability, the risk of nitrate leaching, arable cropping, land drainage and straw incorporation. (King and Bradley)

Sheet 108 (Liverpool). Field mapping was completed with the survey of 120 km^2 in various parts of the sheet. The previous surveys of the Formby, Southport and Preston sheets have been re-evaluated, and the final draft soil map drawn up.

The original area of raised mire, mapped 30 years ago as Turbary Moor series, has shrunk. Sections of Halsall Moss and large parts of Tarleton and Hesketh Mosses are now wasted down to the underlying reed peat and are now mapped as Altcar and Ridley series. Some of the smaller raised mires in the south have retained their upper layers of *Sphagnum* peat. Of these the best remaining example is Knowsley Hall Moss which has been taken into agriculture only recently. Areas of lowland heath and bog vegetation are now rare.

The 32 map units represent seven of the ten major soil groups. One new soil series is recognized and has been named Ormskirk series. This is a stagnogley-podzol in sandy over fine loamy stoneless drift and is extensively mapped in association with Sollom soils on the low ridges around Ormskirk. The two series are significantly different in terms of their management for arable and horticultural crops.

Much of the Memoir has been written. Cropping practice is diverse with a strong horticultural industry, and arable and grassland enterprises which tend to be located on the soil types that best suit them. Following discussions with local ADAS staff, the report will contain information on the suitability of soils for a range of horticultural and other crops. Brassica, carrot and other roots are the most common horticultural crops but the Memoir will include information on lettuce and onions which are present on a limited range of soils. Information on the suitability for slurry acceptance and other properties of soils will also be included. (Thompson and Beard)

Sheet 131 (Boston and Spalding). About 180 km^2 were mapped mainly in the central part of the Sheet on 1:25 000 Sheets TF32, 33, 42, and 43. Detailed mapping identified the disposition of Romney soils which are on the higher ground where the main settlements occur. This higher ground forms long 'islands' which are usually fringed by coarse silty Wisbech soils on both landward and seaward sides. Locally, narrow creeks once breached the islands and their former courses can often be traced as sinuous strips of Wisbech soils extending far inland towards the mainly clayey fens. Calcareous silty over clayey Stockwith soils or non-calcareous fine silty over clayey Pepperthorpe soils form transitional zones between the silty Wisbech and clayey Wallasea or Newchurch soils. Non-calcareous coarse silty Snargate and Rockcliffe soils are fairly extensive near Fleet, south east of Holbeach. Although these soils often have calcarous subsoil layers below 60 cm depth, patchy topsoil acidity has been reported.

The detailed mapping, especially near Holbeach, has enabled the separation of strips of Wisbech, Rockcliffe, Stockwith, Snargate and Pepperthorpe series which were mapped together with Wallasea series as Wallasea 2 association on the National Soil Map at 1:250 000 scale. Elsewhere the pattern of Wallasea and Wisbech soils is so intricate that subdivision is impracticable and a composite map unit will be used. In these areas the patchy distribution of contrasting soils is likely to cause difficulty both in the timing of field operations and in the best use of fertilizers and herbicides.

Large patches of salterns, the sites of a former salt-making industry, occur at 5 m OD at Holbeach Hurn and near Saracen's Head. They have deep unmottled calcareous coarse silty soils which in places contain charcoal. The surface of the mounds is often undulating

https://doi.org/10.23637/ERADOC-1-27

and this causes some difficulties in precision drilling or planting of horticultural crops especially on slopes.

Marsh reclamations near the coast are dominated by Wisbech soils but they vary somewhat in topsoil and subsoil texture. Usually, the topsoil and subsoil texture is sandy silt loam but the subsoil is often fine sandy loam. Where the topsoil is also fine sandy loam, the soils are considered hungry by farmers. Wisbech soils on the immediate seaward side of old banks where depositional conditions were quietest, usually have heavier, silty clay loam topsoils than elsewhere. These soils are less suitable for onion production than other Wisbech soils. Patches of fine sandy soils occur locally as near Fosdyke Bridge where an unnamed calcareous sandy gley soil occupies a narrow strip of land bordering the River Welland. Here the topsoil texture is in places loamy fine sand and there is a risk of wind erosion. Locally, coarse silty ditch clearings are applied to these soils in an attempt to improve topsoil structure and retained water capacity and to reduce the risk of blowing. (Cope and Robson)

1:25 000 Scale mapping

Sheet TG40 (Great Yarmouth). In recent years about 12 km^2 of the Halvergate marshes west of Great Yarmouth have been converted to arable land from traditional summer grazings. Water levels in the ditches have been lowered and pipe drains installed. Some of the drainage schemes have failed within three or four years resulting in surface ponding and subsequent crop failure in parts of the fields. Initial investigations by the Soil Survey and MAFF suggest that there are salt-affected soils similar to those on the North Kent Marshes (Hazelden *et al.*, 1986) and that drainage failure is due to movement and redeposition of deflocculated clay which blocks both the drain pipes and the fissures and pores in the overlying soil or fill. The current survey aims to map the soils of the marshland and identify areas of particularly unstable or saline land.

There are 65 km^2 of marshland on the sheet of which 35 km^2 have been mapped. The alluvial sediments of the marsh are mainly clayey. Silty deposits are found where the major creeks and other channels crossed the saltmarsh before the sea wall was built. Peat occurs at depth beneath the marsh. Near the landward edge, particularly along the western side, there is peat at the surface.

Wallasea series is the most extensive soil developed in the clayey alluvium. It is characterized by dominantly grey horizons and is non-calcareous in the uppermost 40 cm. Locally it tends to be less clayey than similar soils in north Kent with a clay content about 50%. The subsoil is commonly silty clay loam and is often calcareous within 70 or 80 cm depth. Similar but calcareous Newchurch soils occur sporadically and small areas have been mapped separately. Within the areas mapped as Wallasea series, Dymchurch soils are found on small levées flanking former creeks but they are too narrow to map. Near the the edge of the marsh at Limpenhoe and Wickhampton, and in small patches elsewhere as on Haddiscoe Island, clayey Normoor soils (Hodge *et al.*, 1984) with sulphuric horizons and jarosite in the subsoil are found.

The old saltmarsh creek systems are apparent on air photographs and the associated microrelief can be seen on the ground. The major channels, which often serve today as main drainage ditches, are flanked by silty soils. Calcareous Agney and Stockwith soils are most common but non-calcareous Tanvats (Hodge *et al.*, 1984) and Pepperthorpe series are also found. As the old creeks narrow upstream the adjacent soils become more clayey and the features too small to delineate.

In a few places, mainly along the western edge of the marsh, there are patches of peat soils. These are mainly Adventurers' series but Mendham and Prickwillow soils with sulphuric horizons also occur.

https://doi.org/10.23637/ERADOC-1-27

Sampling of the mineral soils of the marsh to measure dispersion ratio, the exchangeable sodium percentage and salinity has started. The sampling points are on a square, 333 m, grid giving nine observations per km^2. At each point samples are taken at three depths, 0–15 cm, 35–50 cm and 70–85 cm, as in north Kent (Hazelden *et al.*, 1986). Preliminary results on Wallasea soils suggest that, in problem areas, salinity and sodium levels are similar to those in north Kent but that the soils are more stable at depth. Samples for pH measurements are being taken in areas of both mineral and peat soils where acid sulphate conditions are known or suspected.

There are 35 km^2 of upland on the sheet of which about 5 km^2 have been mapped. Wick and Newport series developed in coarse loamy and sandy drift are the most common soils mapped so far. Hanworth and Sustead soils occur in the bottoms of small valleys. (Hazelden)

National Peat Inventory

The few remaining peatland soils in the Witham Fens and Cam valley, East Anglia, in South Wales, in Anglesey, in Northumberland and in Lancashire have been sampled during the year to complete the field survey. Many sites smaller than the 100 ha minimum shown on the National Soil Map have been visited but time and resources have not permitted the assessment of the smallest sites some of which are valued for conservation. Data obtained from the Inventory have been assembled and analysed at the regional survey centres where detailed site records are filed. Summaries provided by regional staff are being compiled into a monograph which also reviews the formation, use, classification and physical and chemical characteristics of peat and peat soils. Special emphasis is being placed on the acid sulphate peats of the Fenland and the Norfolk and Suffolk valleys.

The rate of peat wastage is of interest to conservationists, agriculturalists and planners alike. Preliminary figures for the Fenland from this, the first systematic field survey of its kind, show that of 147 630 ha of peat soils in the early 17th century only 24 000 ha remain. Of the remaining peat 56% is less than a metre thick. At 12% of the sites examined the peat is between 40 and 49 cm thick, the modal thickness class. Only a small further wastage of the peat is needed for this class to be removed from the peat soils to the humic gleys (skirt soils). Of the 10 500 ha with peat thicker than one metre, 22% is in nature reserves or under grass in flood relief washes. These are largely protected from oxidation and wastage by high water-tables. By applying an average rate for peat wastage of 1.37 cm a^{-1} (Richardson and Smith, 1977) to arable land it is predicted that by 2050 AD the peat will be reduced to one-third of its present extent.

MAFF recommend that for most arable rotations the topsoil pH of peat soils should be maintained at 5.8. Data for the Fenland shows that 22% of all peat soils are below this value. A third of these are acid sulphate soils (Prickwillow and Mendham series). In these, topsoils with low pH values tend to overlie strongly acid upper subsoils. The low topsoil pH results from the gradual incorporation on wastage of subsoil material into the plough layer without adequate neutralization by liming. Though topsoils are sampled regularly as a routine for optimum crop performance, subsoil samples are rarely taken, so farmers may be unaware of acidity at depth. Over-liming to a pH greater than 5.8 should be avoided as it induces trace element deficiencies. Almost a third of the peat soils sampled have a pH of 7.0 or above. This could, however, be natural rather than a result of over-liming.

All the Suffolk and Norfolk coastal valleys between the Gipping and the Broads contain actual or potential acid sulphate soils but they are very erratically distributed. In the lower parts of the valleys the pyrite giving rise to these soils is known to have formed in brackish water. Further inland, brackish tidal surges may have been the basic cause of pyrite

https://doi.org/10.23637/ERADOC-1-27

accumulation but groundwater percolating through chalky till is the probable source of the necessary sulphate. Because of the unpredictable occurrence of these soils, soil surveys to identify potential problem areas should precede any attempts at reclamation. Only in this way can environmental damage be avoided.

In the Somerset Moors, strongly acid soils (Mendham series) developed in detrital woody peat were noted in a few places in Queens' Sedge Moor, the upper Axe valley and North Moor. In Baggy Moor and at other sites in Shropshire and Cheshire, total sulphur contents in the range 0.2 to 4.6% were measured from Mendham soils with subsoil pH values less than 4.0. As routine analysis does not distinguish organic from pyritic sulphur, the definition of a sulphuric horizon may need to be reviewed.

In Lancashire the peat deposits east of Southport and around Rainford were sampled. Most of the soils on Tarleton and Hesketh Mosses are Altcar series and there is now little evidence for extensive Turbary Moor soils as shown by the original soil survey (Crompton 1966). The average thickness of peat is 194 cm ranging from 42 cm to almost 7 m. On Rainford and Knowsley Park Mosses, the peat averaged 210 cm in thickness with Ridley and Turbary Moor soils most common depending on the thickness of *Sphagnum* moss cut from the surface. Shirdley Hill sands underlie most of the peat deposits. The pH values of over 7000 samples were measured in the laboratory before and after slow moist oxidation. This has enabled the identification of areas of potential acid sulphate soils. (Burton and others)

Special projects for MAFF

Survey of Efford Experimental Horticulture Station. A soil survey was made for MAFF of Efford Experimental Horticulture Station. Areas of difficult land were shown to be related to seasonally waterlogged soils. (Cope)

Rabbit survey. Fifty-two further sites mainly in the Midlands and southern England, each covering a square kilometre, have been surveyed as a contribution to the study of rabbit populations by the Worplesdon Laboratory of MAFF. At these sites, which are randomly distributed within counties, soil series were mapped at 1:10 000 scale. Particular note was made of soil conditions in woodland and on waste ground and of evidence of the presence of rabbits. (Beard, Bradley, Harrod, Hazelden, Sturdy, Whitfield)

Land restoration. Surveys were made of proposed sites for opencast coal and clay at China (200 ha), Stoke-on-Trent, Staffordshire and Newdale (100 ha) and Caughley (20 ha), Telford, Shropshire to support advice given to ADAS soil scientists on soil stripping, handling storage and restoration. (Palmer and Jones)

Other work. Detailed soil descriptions were made and soil series identified for ADAS Soil Science Department's Nitrate Leaching Project in Herfordshire, Shropshire and Cheshire. (Palmer)

Detailed information on the soils of an area near Swavesey, Cambridgeshire, were supplied to the Field Drainage Experimental Unit of MAFF for use in a joint project with the Institute of Terrestrial Ecology. (Burton)

Field work was completed for a soil map of Pwllpeiran EHF, Dyfed. The farm, which covers about 1255 ha, rises from 160 m OD to more than 600 m OD On the lowest ground the soils are well-drained brown podzolic soils of the Manod series and seasonally waterlogged Cegin and Brickfield soils. At middle altitudes Manod series is dominant on slopes, and there are peaty-topped Wilcocks and Kielder soils on slowly permeable drift on flatter land.

https://doi.org/10.23637/ERADOC-1-27

On high ground there are extensive areas of blanket peat of the Crowdy series with characteristic blanket-bog and wet-heath vegetation. On steep slopes under semi-natural Nardus grasslands and improved pastures, however, there are mainly drier shallow soils over siltstones and sandstones. These belong to Skiddaw series or are stagnopodzolic rankers, but there are some deeper podzolic soils of the Hafren and Hiraethog series. (Hartnup)

Publications programme

During the year a further 11 records and one Technical Monograph have been edited, thus clearing most of the backlog of publications incurred during the National Map programme. Sixteen records and maps have been published along with a Special Survey of Saline Soils in North Kent and a new Memoir, the first in the series to describe a map at the 1:50 000 scale. Two further Memoirs and two Records have been written and await editing. (Hodgson, Palmer, Reeve, Lapwood and others)

Land evaluation

Introduction. The term land evaluation (McRae and Burnham, 1981) includes various land classification systems developed during the past 30 years to organize information mainly for agricultural purposes. It includes schemes for forestry, the control of mineral extraction and urban development (MAFF, 1966; Bibby and Mackney, 1969; FAO, 1976; Pyatt, 1982; Bunce *et al.*, 1981). Early studies were essentially general purpose. A single integration of soil, site and climatic data was expected to summarize all aspects of a piece of land including its flexibility for cropping, expected yield levels, suitability for intensive grassland or horticulture, broad rental or sale value, the desirability of restricting urban development and its suitability for mineral extraction.

In recent years the Survey and others have used computers to examine and integrate soil, site and climatic information in different ways for each purpose separately. Computer graphics have been particularly useful. By accepting the concept of specific suitability it is then possible, using computers, to reappraise the various physical datasets. In this way a wide range of interpretations of land properties becomes possible.

The use of computers allows us to assess the suitability of land not only for individual crops, or tree species, but also its suitability for various agricultural techniques, the risks to the environment or hazards to crop production and hydrological processes. Conceptually, we change from the supply of a single product – a soil map or a land classification map that the user interprets for his own needs – to a flexible system in which the user defines his needs. A model is set up and the information system is programmed to provide the best available response.

Methodology. A soil map, though complex, can be interpreted and simplified for a wide range of practical uses. Often such interpretations require additional climatic, topographic and socio-economic information, and the construction of simple models to integrate the data in a systematic manner. In recent years the Survey has published several suitability schemes for specific crops, for example amongst several others, main crop potatoes in the Regional Bulletin for Eastern England (Hodge *et al.*, 1984).

The climatic datasets used for such practical interpretations include data for mean temperature, meteorological moisture deficit and field capacity periods, at 5 × 5 km resolution. They are now easily accessible in computer or cartographic format, to apply

https://doi.org/10.23637/ERADOC-1-27

the system (Jones and Thomasson, 1985). Soil series datasets for plant available water and workability properties are also stored. From this data and from existing soil maps the Survey has produced a range of interpretative maps for internal use.

They include:

Crop suitabilities
Winter wheat
Spring barley
Potatoes
Sugar beet
Oilseed rape
Vegetables
Intensive grassland
Forestry

Suitability for management techniques
Irrigation
Straw incorporation
Sewage injection
Subsoiling and moling
Direct drilling
Earthmoving and landscaping

Risks to the environment
Soil erosion
Nitrate leaching
Poaching of grassland
Acid sulphate soils
Acidity following afforestation
Shrink/swell (building foundations)
Soil salinity

Hydrologic processes
Winter rain acceptance potential
Soil water regime
Soil wetness class
Land drainage (design and responses)

Further developments in land evaluation are constrained to some degree by the quantity and precision of soil profile data. In most cases, soil map unit boundaries, whether of soil series or soil associations, are accepted as the basis of the new interpretations. Usually the basic map units on the soil map, often thirty or more in number, can be simplified and amalgamated to four or five classes for a crop or technique suitability.

Ideally, it would be preferable to reappraise the basic point data collected by the Survey for each new interpretation and create new boundaries. This is not currently feasible without excessive cost. Another constraint is the shortage of data on hydraulic conductivity for many soils and classes of horizons. Such data are needed to improve models of soil workability and crop-water uptake amongst others.

Selected examples of interpretive maps listed above are described below, these and others can be made available to interested bodies on enquiry. (Thomasson)

A soil suitability map for bulb onions. Sheet TF45 (Friskney), representative of high quality land in Lincolnshire, has been used to produce a map showing suitability for onions. For consistently good yields of quality onions, soils need sufficient reserves of water to maintain even growth and need to have physical properties that allow early working of the land in most years, the production of a fine seed bed and clean conditions for lifting. The best suited soils in the Friskney district are deep silty soils with less than 18% clay in the topsoil. Soils with slightly heavier topsoils do not give clean enough lifting conditions, and such soils are classified as *Moderately Suited*. With greater clay contents the necessary seedbed conditions are difficult to achieve, crop available water is less and there is increased risk of adverse ground conditions at lifting. Such soils are classified as only *Marginally Suited* for onions. In parts of the district there are contrasting silty and clayey soils in the same field and in these circumstances an intermediate *Moderate/Marginal* class is recognized because the silty soils within the individual fields are often extensive enough to grow onions, the rest of the fields being used for less demanding crops.

https://doi.org/10.23637/ERADOC-1-27

Soil suitability for straw incorporation. Sheet TF04 (Sleaford) has a wide range of soils and a three-class system of suitability for straw incorporation has been used to derive a straw incorporation map assuming ploughing to be the main method. The system is based on information on soil depth, topsoil and subsoil texture, soil porosity, nature of underlying material and the incidence and duration of soil wetness producing estimates of soil workability and likely conditions at ploughing. The three classes are:

Easy	Mainly well drained deep sandy and loamy soils with ample opportunity for land work in average years and acceptable conditions even in a wet autumn.
Intermediate	Loamy soils with clayey impermeable subsoils; well drained shallow, stony soils on limestone.
Difficult	Clayey soils with impermeable subsoil. Difficulties with incorporation in most years due to excessive wetness causing smearing and compaction or dryness giving large strong clods on cultivation.

Risk of nitrate leaching. Using the same soil information for the Sleaford Sheet it has proved possible to assess the risk of nitrate leaching and designate a risk class to each soil series. A system with four classes of risk is used: *Extreme, High, Moderate* and *Low* risk. Examples of the extreme class are shallow, loamy, very porous soils over fissured limestone and of the low risk class deep, seasonally waterlogged soils with few macropores over very slowly permeable clay. Subsequent work suggests that while the derived risk classes shown on the map are satisfactory for assessing risk of losses of nitrate to aquifers, some modification of the low risk class is necessary to allow for losses of nitrate through mole or pipe drains. (Robson)

Suitability classes for vegetables. The basic methodology used to derive crop suitability maps has been extended and adjusted to assess the suitability of the land on 1:50 000 Sheet 108 (Liverpool) for the vegetable crops commonly grown in this district. The vegetables chosen were beetroot, spring-planted lettuce, spring-sown carrots, bulb onions and Brussels sprouts. The aspects taken into account in devising the new schemes were: the need for progressive cropping; the need for quality crops for a discriminating market; the range of cultivars and their sowing dates; and the varied growing periods required by the different crops and varieties. The first assessments made were for crops grown on a field scale, sown in spring and mechanically harvested. For this the main factor was soil workability which affects access to the land early in the season. Other soil properties such as stoniness and organic matter content also modified the suitabilities. The requirement for Brussels sprouts are soils with good drainage, a pH greater than 6.5 and medium loamy textures giving a high available water capacity. Both the autumn and spring work periods are taken into account when making the assessments. The moisture deficit values are generally not critical since a large proportion of the crop matures after the return to field capacity in November. Some further fine adjustments to the suitability assessments are necessary. These will be made using information on vegetable performance at specific sites. (Beard)

Land suitability classification for forestry. A provisional scheme classifying the suitability of land for forestry was prepared. It is intended to provide a scientific background to the

https://doi.org/10.23637/ERADOC-1-27

current debate on alternative land uses and to give guidance in land management. The scheme uses soil, site and climatic factors to rank land into classes according to its flexibility for growing both hardwoods and softwoods for commerce or amenity. A coloured, interpretative draft map of the Abbeycwmhir sheet (SO07) has been prepared to illustrate the classification and show how it can be used. An overlay to accompany the map indicates the risks of acidification and the release of toxic aluminium if the land was planted with softwoods. The work continues in collaboration with the Soil Survey of Scotland with the aim of producing a joint classification for Great Britain. (Hartnup)

The Soil Survey Information System

Introduction. The Soil Survey information system now contains a wide range of topographic, environmental and geological as well as soil data, so it has been renamed LandIS (Land Information System) to reflect its broader content. At present the system contains mostly Soil Survey data but negotiations have continued this year for the inclusion of MAFF data and access by MAFF staff. With these developments in view, new hardware was installed at the AFRC Computing Centre in June 1986 comprising a VAX 11/750 with an RA81 Winchester disk and a TU80 tape drive. An RA60 demountable disk drive was added later to provide 670Mb of online storage. The following software from DEC and other sources is available on the VAX:

- VAX VMS version 4.3
- VAX FORTRAN
- Genstat
- SPITBOL
- SAGIS (a geographical information system)
- VAX Datatrieve
- VAX Common Data Dictionary
- GHOST (a graphics package)
- SURFACE II (for trend surface analysis)

The VAX, though linked to AGRENET, was not networked initially, but a full network connection was in operation by the end of the year. Since its installation, much time has been spent transferring software and data from the VAX computers at Rothamsted and the AFRC Computing Centre to the new machine. Data archived on ICL System 4 tapes have been transferred to VAX compatible tapes. Most of the systems management work, formerly done for us by the Rothamsted Computing Unit, is now our own responsibility and a new archiving procedure has been designed using the VMS command language which is being operated and maintained by our staff.

Microcomputers. Two IBM-PC microcomputers with MS-DOS and a Sigmex T6130 colour graphics workstation have been purchased. The latter, which is connected directly to the VAX, has full GKS graphics facilities and can emulate a Tektronix 4014 graphics terminal. This workstation is ideally suited to the representation of raster format spatial datasets and output from SURFACE II or a geographical information system. One of the IBM-PCs is currently being set up with programs and statistical packages to handle soil moisture data at the Shardlow laboratories and will eventually replace the Midas microcomputer that has served us for the last five years. The other PC has a colour and monochrome graphics capability and is being used for database creation, development work and dBASE III programming. It also has an inexpensive geographic information system (CRIES) mounted but this particular package has a number of limitations, including difficulty in manipulating attribute data. Evaluation of CRIES is not yet complete. Eventually, this PC will also be used for vector digitization but, until a suitable geographic information system has been selected, the type of digitizer and the software cannot be

https://doi.org/10.23637/ERADOC-1-27

chosen. Other software used on these machines includes the CP/M operating system, a VT100 terminal emulator and the Kermit file transfer protocol. When a database has been established on the microcomputer, the resulting ASCII file can be transferred to LandIS on the VAX by using Kermit. Many files of properties related to soil series are being developed and can be transferred to LandIS in this manner. They include:

Proportions of soil series within National Map associations
Depth to slowly permeable horizon
Depth to rock
Depth to calcareous material
Map unit reliability
Retained water capacity of the topsoil
Integrated air capacity
Permeability

Software. To help in the choice of a suitable system for geographical information and database management, software used by the following organizations has been appraised:

Michigan State University; US Geological Survey; US Department of Agriculture; Georgia Institute of Technology; Stichting voor Bodemkartering (STIBOKA), Wageningen; Rijksinstituut voor Onderzoek in de Bos- en Landschapsbouw 'De Dorschkamp', the Netherlands; Geografische Instituut, University of Utrecht; Bundesforschungsanstalt für Naturschutz und Landschaftsökolige, Bonn-Bad Godesberg, West Germany; British Geological Survey; Cranfield Institute of Technology.

LandIS. Menu-driven procedures have been developed to replace the Datatrieve query language so that onerous procedures are avoided when using several databases together. This also enables staff without programming skills to use the system. Using the new procedures the following databases can be used singly or in combination: purposive auger borings; the National Soil Inventory; the agroclimatic databases (annual average and summer rainfall, field capacity period, potential soil moisture deficit, crop-adjusted available soil water); and in raster format, the 1:250 000 National Map.

Datatrieve procedures have been written to calculate soil droughtiness, machinery work periods, and crop suitability. Output is available as tables, summary reports, histograms or scatter plots according to need. There is also a facility to search for data within a specified distance of a National Grid Reference. The procedures are flexible and they can be modified to meet users' requirements, particularly those of outside users such as MAFF who will have new requirements when they begin to access LandIS.

LandIS has been updated in other ways. Analytical data for the National Soil Inventory have been added to the system as they became available. Almost three-quarters of the analyses for pH, extractable P, K, and Mg, and a quarter of measurements for 19 trace elements undertaken by the Soils and Plant Nutrition Department are now available. During the year most of the large backlog of purposive auger borehole records has been entered to the system, which now holds about 100 000 records. The remainder, awaiting error correction, should be included early in 1987.

A major task this year has been the updating of all the moisture deficit, field capacity and evapotranspiration data in the system. This has involved reprocessing the 5 km grid matrices produced originally by interpolation from 970 irregularly spaced rainfall stations in the case of moisture deficits and from regular 10 km data in the case of field capacity, using the SURFACE II graphics system. Final refinement of the data involved use of

https://doi.org/10.23637/ERADOC-1-27

Genstat and the 5 km altitude and average rainfall datasets already set up within the information system.

The existing files on soil wetness class, workability assessment, and crop-adjusted available water have also been updated and average monthly rainfall and average potential transpiration have been manipulated to calculate excess winter rainfall data for eventual transfer to LandIS.

LandIS - graphics and spatial data. The Sigmex T6130 colour graphics workstation has been used to plot most of the agroclimatic datasets. High quality ink-jet plots have been produced showing: rainfall averages for the year and the summer periods; field capacity, return and end dates, and duration for normal and wet years; moisture deficits, potential month-end, maximum and crop-adjusted values; growing season data; various aspects of accumulated temperature.

Software has been developed to convert x,y coordinate points on a polygon (vector format) into change-point-coded raster format, thus enabling the extraction and manipulation of data to be carried out within any boundary, for example to determine the proportions of soil associations within an irregular boundary.

Application of LandIS. Staff have made use of LandIS for many purposes during the year. It has been used in the publication programme, in research projects, to support contract services and to produce promotional literature. It has proved invaluable in the development of a new forestry suitability classification and also in the joint project with the Institute of Hydrology, and the Soil Survey of Scotland on the hydrology of soil types.

The information system has provided a powerful tool for the rapid compilation and validation of a national climatic database. This database and the ability to manipulate it have proved invaluable as foundations for improving the MAFF Agricultural Land Classification.

Other applications include a study for the improvement of analytical methodology and the selection of sites for a study on acid rain by the British Geologiocal Survey. (Ragg, Proctor, Jones, Clarke, Thorne)

Consultancy services

Introduction. The Survey has continued to expand its range of consultancy services over the past year by vigorous marketing of its accumulated data and expertise. As well as serving the agricultural sector, it has acted as consultant on broader environmental topics for which the Survey is uniquely placed to contribute its national knowledge and understanding of soils and the processes that affect them. Over 150 consultancies of various sizes have been undertaken and some of the principal activities are briefly described below.

Agriculture. Faced with a fundamental review of farming practices and cropping patterns many farmers and land managers, often in consultation with their agronomists or agro-chemical suppliers, are seeking a better understanding of the land in their care. The Survey has provided information about the soils of over 50 farms and estates during the past year. Our service has equipped farmers with the necessary background to their soils which together with appropriate climatic information gives them a reliable and scientific basis for re-evaluating existing land use and exploring the possibilities of new systems. Knowledge of the soil types on a farm enables a farm manager to draw from the Survey's and other national information systems and allows him to make real comparisons with experimental work on similar land elsewhere.

Most farmer clients have been supplied with a black and white or coloured soil map

https://doi.org/10.23637/ERADOC-1-27

at an appropriate scale and a report describing both the soils and their management characteristics. In these reports the following practical aspects are usually evaluated: the need for drainage and subsoiling; the periods in autumn and spring during which the land can be worked or traversed safely; the risk of drought affecting crop yields, and suitable crops for the holding. For some clients land quality was assessed to support rent review cases; for others the incidence of acid conditions in peat lands was identified. Irrigation schedules have been drawn up for some farmers using Soil Survey data, in several cases in conjunction with outside irrigation specialists. In some reports advice is given about the suitability of land for organic farming systems. The Survey has also assembled background data for landholders wishing to make a case for inclusion in a Less Favoured Area.

Industry and planning. Land is used during industrial and other development activity for many purposes, for example the building of factories and domestic housing, the installation of pipelines, the extraction of minerals and the provision of parks and other recreational facilities. In each case the soil has to be either built over or removed and perhaps later restored, or soil from elsewhere has to be brought in to cover the scars. Consequently there are many projects in which a knowledge of the existing soil conditions or the properties of imported soil is required if they are to be successful. During the year the Soil Survey has investigated and given advice in a wide range of situations including the following:

Assessment of soil conditions on land restored after test drilling, after pollution incidents and along pipelines.
Assessment of soils under heathland prior to the installation of a pipeline. Advice was given on the best method of reinstatement.
Survey of land set aside for landfill operations and proposals for its reinstatement and management.
Investigation of erosion along pipeline trenches.
Comparison of land restored by different methods following sand and gravel extraction.
Assessments of agricultural land quality at proposed extraction sites.
Evaluation of the effects on surrounding land of proposed mineral working.
Quality and condition of restored land.
Consideration of the risk of groundwater pollution by a proposed industrial liquid waste disposal site.
Description of fragile soils and proposals for their handling and restoration.
Study of soil disturbance by agriculture and land use in a conservation area.

Experimental sites. New crop varieties, land management systems, innovative farm machinery and experimental examination of environmental conditions are tested on sites where the variation in soil needs to be understood if results are to be properly explained. The Survey has evaluated over 20 varied sites used for testing and developing new products and ideas by official agricultural and industrial experimental stations and laboratories as well as by commercial organizations.

Water and pollution. The Soil Survey has worked during the year with several water authorities to assess the effects of land use and soil type on water supplies and the risk of aquifer pollution by farming practices. The quality of drinking water whether gathered by extraction from streams and rivers or by pumping from aquifers is affected both by the management and use of the land on which the rain falls and the soils through which the water passes.

https://doi.org/10.23637/ERADOC-1-27

Purification of sewage is a costly process and a German method using beds in which reeds are planted is being investigated as a suitable system for villages and small groups of houses. The material used in these beds and their performance is being investigated.

The movement of water in landfill sites is difficult to predict and we are monitoring the water regime using a neutron probe and tensiometers installed deep into the landfill.

Data provision. The Land Information System (LandIS) and other unpublished material held by the Soil Survey represents an unequalled source of data about the soils and agroclimate of England and Wales. Various organizations have requested information for their own use in, for example, irrigation scheduling, education, route planning and for advisory services.

Training. The Survey has organized a number of short courses for land managers, estate agents, agrochemical suppliers and official valuers to meet their need to understand the role of soil in land development and management. The courses have shown how soil maps can be interpreted and how soil data can be related to land potential and use. (Jarvis, Wright and others)

Archaeological investigations. A report was prepared on the soils of a Mesolithic occupation site at Williamson's Moss near Eskmeals, Cumbria for Edinburgh University based on fieldwork in 1985. The studies proved useful in the identification of a palaeo-landsurface and in the identification of archaeological features below this level. The investigation also provided information on the rates of soil forming processes and the modification of archaeological features by such processes. (Payton)

Sub-tropical horticulture. The Survey provided specialist advice on the soils and suitability of land in Estepona, Spain, to Minster Agriculture Ltd who are retained by Aspect Leisure Ltd, a company integrating a commercial sub-tropical fruit farm with villa development. The suitability of the land for terracing and for sub-tropical tree and bush crops including citrus fruit, avocado pears and a range of introduced exotics was assessed. (Harrod)

Conservation. An understanding of the soils occurring on conserved land is essential for its proper management. A report on soil interpretation in the Gwent Levels was prepared for the Nature Conservancy Council (NCC). It concentrates on the characteristics of the dominant Newchurch series, with sections on soil water regime, field drainage, nitrate leaching risk, surface run-off, slurry application and crop suitabilities. The effects of soil water regimes on agricultural practice, and on semi-natural communities in drainage channels were described to help the NCC identify management techniques which will maintain the scientific interest of the area. (Hartnup and Carter)

A report on the soils of the Martin Down National Nature Reserve in Hampshire was supplied to the Nature Conservancy Council. (Hodgson and Hollis)

Basic, methodological and applied research

Soil water regimes. The eighth and final site at Skipwith Common, North Yorks was described and sampled. The profile is classified as a humo-ferric gley podzol in fine sandy stoneless drift and is similar to the Lakenheath series. Information was also compiled on the profile morphology; duration of waterlogging; particle-size distribution; organic carbon

https://doi.org/10.23637/ERADOC-1-27

and calcium carbonate content; bulk density; packing density; total pore space and air capacity of the other seven sites. Saturated hydraulic conductivity (K_{sat}) was measured from 200 cm^3 cores taken from two horizons of each soil for which there is no available data (Cranbrook, Curtisden and Wighill series). K_{sat} data is already available for the Denchworth, Evesham and Salop profiles and samples for such measurements from the Newchurch and Lakenheath soils will be taken next spring.

The relationship between gley morphology, soil structure and duration of waterlogging in each horizon of the eight profiles is now being evaluated. Measurements of pore size, shape and symmetry in each horizon sampled will be made next year using an image analyser. The results will be used in combination with structural data and K_{sat} data to produce tentative criteria for the estimation of horizontal K_{sat} in the field. (Hollis with Dr P. Curmi, INRA, Rennes)

SEM and EDXRA studies of soil thin sections. Techniques of chemical analysis using energy dispersive X-ray analyses on polished thin sections of soils viewed with a scanning electron microscope have been further investigated. The techniques have proved useful in studies of the composition and formation of thin ironpans, and of the degradation of clay coatings in soils. (Payton)

Argillic horizons in Northumberland. Clay translocation has not been widely recognized in the soils of Northumberland but micromorphological studies of soils on Late Devensian terraces and on locally-derived drift on the Fell Sandstone outcrop have shown that argillic horizons are well developed. A pedological study of soils hitherto classified as typical and stagnogleyic brown earths on till and glaciofluvial deposits in Northumberland has been mounted jointly with the Department of Soil Science at the University of Newcastle-upon-Tyne. All the soils investigated so far have argillic horizons except for one which was calcareous. The work suggests that argillic brown earths of the Ludford, Bishampton and Kearby series are more widespread in the lowlands of east Northumberland than previously reported. The study has also shown that stagnogleyic argillic brown earths are common on the Cementstone Lowlands west of Alnwick on weathered sandstones, siltstones, shales and limestones. One of the profiles studied, over interbedded siltstone, limestone and shale, proved to have a horizon with paleo-argillic features. (Payton)

Soil erosion. The five year study monitoring soil erosion at 17 localities in England and Wales is now complete and a report is being prepared. As there is continuing public interest in erosion in terms of both soil degradation and the effects on the environment, a new project to monitor erosion at a national sample of sites selected on a sound statistical basis is being planned. Remote-sensing techniques and ground observations will be combined to produce a national appraisal of erosion risk, taking into account soil, slope, climate and land use data. (Thomasson and Jones)

Laboratory automation. The microprocessor controlled version of the semi-automatic particle size analyser is now in routine use. Software has been written to produce reports of particle-size distribution automatically from raw data. (Loveland, with Edwards, Instruments Workshops, and Summerfield, Computing Unit)

Humber warplands. Supervision of work on the warplands and adjoining areas by NERC/CASE student J. K. Atherton, continued. The project comprises two parts which are being assessed independently. In the absence of detailed stratigraphic information for the Flandrian sediments of the Humber Estuary, their provenance has been tackled by looking at their geochemical variation over a wide area. The second part of the work,

https://doi.org/10.23637/ERADOC-1-27

pedogenic study of these sediments, has been aided by the Survey's earlier work. The location, age, mode of origin and particle-size of the soils are being studied in an attempt to shed light on the genesis of the sediments.

During the year the study has been widened to compare soils and sediments of marine and estuarine origin with those of riverine origin.

The year's fieldwork was spent sampling within the estuary, and along the main tributaries above and below the tidal limits. It involved describing soil profiles and extracting cores up to two metres in length for sub-sampling.

A large geochemical database has been compiled, consisting of two hundred and five samples individually analysed for twenty-five elements. From this a three-dimensional model of the distribution of elements within the alluvial sediments of the lower Humber is being constructed. Analysis of regression of various elements upon others will help to define the geochemical signature of individual sediments.

Sixteen soil profiles have been studied in the field and sampled. Laboratory studies are underway to establish trends in the physical and chemical development of the soils. Micromorphological techniques are being used to separate depositional and pedogenic features in the soils. (J. K. Atherton and King)

Moisture regime of upland soils. Ferric stagnopodzols, ironpan stagnopodzols and stagnohumic gley soils are being studied in duplicated unreclaimed and reclaimed sites on Exmoor by Maureen McHugh (NERC/CASE student).

Frequent site visits have been made to quantify the intensity and duration of wetness using tensiometers and piezometers and to define differences between reclaimed and unreclaimed soils, and assess the effects of reclamation on their physical and chemical properties. The work aims also to relate soil moisture regime to morphology and chemical processes using redox and temperature measurements and to identify any critical values of moisture content, air-filled porosity and redox potential. It is hoped to identify seasonal trends.

Instrumentation at the sites includes tensiometers, piezometers, thermocouples, redox probes and raingauges. The tensiometer systems comprise porous cups inserted into the soil and connected to the surface by water-filled tubes sealed by a rubber septum. A portable tensiometer is connected to each tube in turn by a hypodermic needle place through the septum. In the spring replicate tensiometers were installed.

Site visits at weekly intervals, supplemented by more frequent observations at critical times, for example when the soils return to field capacity, have produced data for preliminary statistical analysis and plotting, using computing facilities at Exeter University.

Preliminary results suggest that, on unreclaimed sites, ironpan stagnopodzols are hydrologically distinctive, with positive soil water potential in the E horizon greater than that in the O or B horizons, during much of the year. In contrast ferric stagnopodzols and stagnohumic gley soils have the largest potential in their O horizons and least in B or BC horizons. In long-reclaimed soils, moisture tension profiles become inverted and are very similar for all the subgroups. All unreclaimed soils, once wet, show a slow response to drainage and evapotranspiration, while reclaimed soils respond rapidly. Interpretations of tensiometer results in terms of absolute water content and air-filled porosity, await data on water retention and pore-size distribution of each soil horizon.

Three replicate probes to measure redox potential were placed in each major horizon at each site early in the spring, using platinum electrodes. Duplicated thermocouples were inserted to measure soil temperature.

Each of the 12 sites has been thoroughly described and sampled for particle-size distribution, for water retention and pore-size distribution, for a range of chemical analyses and for micromorphological study.

https://doi.org/10.23637/ERADOC-1-27

Measurements of water and dye infiltration have been made at a number of sites. On long-reclaimed soils water infiltration is rapid but is very slow in O and E horizons of unreclaimed soils. The use of dye shows marked contrasts between sites depending on land use history. In reclaimed profiles, water penetrates thoroughly along macropores, in particular along root and earthworm channels, and on stone surfaces. In unreclaimed peaty O horizons and E horizons some of the prismatic structure faces are picked out by the dye, the penetration being most marked in the ferric stagnopodzols and least in the stagnohumic gley soils. In the ironpan stagnopodzols water was clearly impeded by the ironpan, but where the dye reached the highly porous B horizon it diffused rapidly. (Miss Maureen McHugh, Department of Geography, Exeter University; Harrod)

Soil and badger setts. As part of a model to predict badger density from habitat parameters, a preliminary scheme of soil suitability for badger setts was devised. The model is based on an analysis of habitats and populations within a random sample of 2 × 2 km blocks of land in south-west England. Soil information from the National Map (1:250 000) was rated using the scheme. This information explained more of the variation in badger populations and distribution than any other parameter in the physical environment except hilliness of the terrain. (Dr P. S. Thornton, Department of Biological Sciences, University of Exeter and Harrod)

Supporting work

Soil water retention. Soil water retention properties were measured on approximately 750 samples from 50 profiles. These included samples taken for research projects and outside contracts. The database at Shardlow has again proved invaluable in answering queries on soil physical properties from environmental consultants, research institutes, Soil Survey staff and ADAS. (Bembridge, Carter and Jeffreys)

Soil plasticity and shrinkage. A computer database has been compiled which contains information on rheological properties of soil for approximately 1000 soil horizons. Regression analyses were performed on the dataset as a step towards improving trafficability and workability models and also to predict rheological properties from other soil data. The dataset has proved extremely useful when answering queries concerning opencast working and land restoration. (Carter, Loveland, Leverton and Jeffreys)

Soil water dataset. The soil water dataset now contains information on water retention, porosity, density and particle size data for more than 3 500 horizons from a wide range of soils. The data are organized to provide information for individual soil profiles or for soil series, including crop available water, depth to impermeable horizon and topsoil retained water. A computer program (APTAB) is now available which calculates and then tabulates profile available water for winter and spring sown cereals, potatoes, sugar beet and grass for a chosen soil profile, from the data on particle-size class, density, organic carbon and stone content of the soil. (Carter)

Hydraulic conductivity. Laboratory equipment to measure saturated and unsaturated hydraulic conductivity has been constructed. Soil cores are being collected from representative soil profiles to improve understanding of the relationship of slowly permeable soil horizons to soil wetness class. (Carter and Bembridge)

Peat analysis. During the year the various analytical and interpretive problems that arose when determining the moisture release characteristics of peats, and mineral soils

https://doi.org/10.23637/ERADOC-1-27

with peaty horizons prompted further investigation. After a wide search of the literature, analytical methods have been improved. Samples taken from the Lincolnshire fens are currently being analysed using the new techniques. (Bembridge)

Other work

AFRC Institutes. Soil and climatic data for the three sites of the AFRC Institute of Horticultural Research at Wellesbourne, East Malling and Littlehampton were examined to evaluate the suitability of their land for a wide range of horticultural crops. The factors used to assess suitability included slope, available soil water reserves, degree of waterlogging, stoniness, pH and lime content, soil stability at low organic matter contents and exposure to wind and salt spray. Trafficability in relation to soil properties and climatic conditions was also considered. In the assessment horticultural crops were grouped into four categories: vegetables, top fruit, bulbs and ornamental nursery stock. No single site holds land that is well suited to experimental work on all four groups of crops. This conclusion was not appreciably altered by further appraisal of nearby purchasable land. (Thomasson)

Hydrological classification of the soils of England and Wales. A joint project has started with the Institute of Hydrology (IOH) to classify the hydrological properties of soil associations on the National Soil Map (1:250 000) as an aid to hydrological design.

The 1:1 000 000 Winter Rain Acceptance Potential (WRAP) map is used widely in the water industry for flood estimation in ungauged catchments. Since its publication in 1978 knowledge of soil distribution and physical properties has increased sufficiently to justify a revision of the original WRAP classification. The aim is to provide a more comprehensive scheme with 9 or 10 classes instead of the original 5. As a first step significant soil factors including the air capacity integrated to 100 cm depth, the kind of substrate, the depth to a lithoskeletal substrate, the depth to an impermeable horizon, and the depth to gleying are being assessed. Subsequently the effects of climate, slope, land use and underdrainage will be evaluated and incorporated into the scheme. The IOH hold base flow and percentage run-off for 1,000 gauged catchments throughout the United Kingdom and this data is being used to calibrate and adjust the new classification. (Palmer and Hollis)

Agricultural land classification (ALC). A further five meetings of the MAFF ALC climate sub-committee were held during the year. The date for implementation of the new National Agricultural Land Classification for England and Wales has been put forward to mid-1987. Most of the effort this year has been expended on validating the 5 km datasets of average annual rainfall (AAR), average summer rainfall (ASR), accumulated temperature above 0°C for January to June (ATO) and accumulated temperature above 0°C for April to September (ATS). This was done using software written in-house and the Sigmex T6130 hardware linked to the Rothamsted VAX. The existing ATO dataset prepared for the National Soil Map and the altitudes from the National Soil Inventory have been of great value in this process.

A new database, NALC, has been set up under Datatrieve and now forms part of the information system. User-friendly procedures have been written to estimate the best possible land grade based on AAR and ATO; calculate and plot ASR as a proportion of AAR on a 5 km grid; and adjust all temperature and rainfall grid point data for altitude. To help the Resource Planning Group to appraise the new scheme, the digital datasets were plotted onto acetate sheets with the grid point values spaced to coincide with the standard 5 km intervals at 1:625 000 scale. (Jones)

https://doi.org/10.23637/ERADOC-1-27

Staff

The complement of the Survey was severely reduced because of cuts in MAFF funding. Long-serving staff who retired or were made redundant during the year include C. A. H. Hodge (38 years), C. C. Rudeforth (31), W. M. Corbett (28), Cynthia M. Gosney (26), H. George, R. R. Furness, C. P. Murphy, D. M. Carroll, R. Evans, S. J. Staines, J. W. Lea, G. J. N. Colborne, I. N. L. Kilgour, F. W. Heaven, D. V. Hogan and R. H. Allen. They contributed much to the Survey's work during their years with us and will be greatly missed. Amongst other staff whose valuable services and enthusiasm we will also lack are Susan Nicholson, Barbara Cain, D. I. Bamford, Joan Robinson and June M. Cooles.

H. Hakesley transferred to Engineering and Maintenance Services. S. R. Clarke was appointed to work on the Land Information System and Alison E. Saxby was taken on as personal secretary.

In January, M. G. Jarvis and W. A. D. Whitfield visited US Army 526 Engineering Detachment in Stuttgart, West Germany to discuss assessment of terrain for vehicle mobility.

In January, P. Bullock and M. G. Jarvis went to Brussels where they visited EC Directorates-General XII Science, Research and Development; VI Agriculture; XI Environment, Consumer Protection and Nuclear Safety; and VIII Development to discuss SSEW involvement in EC research and aid programmes. In October, M. G. Jarvis again visited Brussels for further discussion with EC Directorates-General VI, XII, and VIII.

M. G. Jarvis went to Rome in February to the FAO Soil Resources, Management and Conservation Service where he discussed the use of Soil Survey personnel in FAO funded projects.

In March and April, M. G. Jarvis visited Indonesia, Thailand and Sri Lanka to develop contacts for SSEW involvement in aid-funded projects. Organizations visited included, in Indonesia, Centre of Soil Research, Bogor, Ministry of Transmigration, Jakarta; in Thailand, Ministry of Agriculture and Co-operatives, Land Development Department as well as attending the Second International Soil Management workshop in Hatyai; in Sri Lanka, Ministry of Lands and Land Development, Land Use Division and Land Use Policy Planning Division.

R. W. Payton visited Kenya and northern Tanzania to establish links with organizations involved in soil and land appraisal and development. These included OXFAM, the Kenya Soil Survey, the International Council for Research in Agroforestry, and the Tanzania-Canada Wheat Project.

In February, R. C. Palmer attended a workshop on Water in the Unsaturated Zone organized by the Norwegian National Committee for Hydrology in As, Norway, under the auspices of UNESCO. P. Bullock, A. J. Thomasson and J. M. Hollis went to the ISSS Congress held in Hamburg in August where A. J. Thomasson read a paper. J. M. Hollis went on a post-congress tour to study the soils of the Black Forest. T. R. Harrod was British delegate in Brussels at an EC (SCAR) workshop on the Agro-ecological zoning of EEC land. He also visited the Servicio de Planiafacion de Recursos Naturales in Seville, Spain, the Department of Edaphology at Granada University and a soil survey project in the Silves-Faro district, Portugal.

In September, P. Bullock went to Spain at the invitation of the Catalonian Agricultural Society to lecture on soil survey and land resources. In October, he visited Berlin and attended an EC Symposium on soil quality for which he was rapporteur. In December he read a paper in Brussels at a Workshop organized by the Land Use and Water Management Group of EC on soil erosion assessment.

R. J. A. Jones attended the ISSS Workshop on Quantified Land Evaluation in Washington DC, USA, in April, and gave a paper describing the Soil Survey's Land Suitability Classification for temperate arable crops. Afterwards he visited the headquarters

https://doi.org/10.23637/ERADOC-1-27

of the US Department of Agriculture in Washington to appraise the EPIC erosion model and the US Geological Survey in Reston, Virginia, to assess database management software and equipment for automated cartography. He then visited Michigan State University to look at software for the digitization of soil maps at the Centre for Remote Sensing and the CRIES package at the Department of Natural Resources. During a visit to the Georgia Institute of Technology, Atlanta, software for a geographic information system was also examined. In July, Jones represented the UK at the Workshop on Computerization of Land Data–Agricultural and Environmental Aspects (DG VI) hosted by the Federal Ministry of Food, Agriculture and Forestry in Bonn, West Germany. In November, he was invited to EC Headquarters in Brussels to discuss the production of thematic maps based on the digitized version of the Soil Map of Europe (1:1 000 000).

At the invitation of the Deutsche Forschungemeinschaft, J. M. Ragg and R. J. A. Jones gave a paper to an International Colloquium on the Construction and Display of Geoscientific Maps Derived from Databases, at Dinkelsbuehl, West Germany.

J. M. Ragg and M. E. Proctor visited Stichting voor Bodemkartering (STIBOKA), Wageningen, The Netherlands, where data from LandIS was downloaded from tape onto the STIBOKA VAX and converted into Oracle files, so that Oracle could be appraised. They also visited the Geografisch Instituut, University of Utrecht, The Netherlands where they were given demonstrations of the geographic information systems, and statistical packages in current use. In January, J. M. Ragg attended an International Workshop of the ISSS in Wageningen, The Netherlands, on 'The Structure of a Digital International Soil Resources Map Annex Data Base'. In November, he gave an invited paper on hand-held dataloggers to the Netherlands Soil Science Society.

In November J. Hazelden and P. J. Loveland visited Bordeaux and La Rochelle, France, at the invitation of CEMAGREF to study salt-affected soils. In August at Wageningen, The Netherlands, P. J. Loveland took part in a Workshop organized by the International Laboratory Methods and Data Exchange Programme.

During the year the staff contributed to several scientific meetings in the UK and gave numerous lectures and promotional talks. J. Hazelden and R. G. O. Burton appeared on The Farming Programme on BBC television discussing the effects of salinity and acid sulphate on soils in Kent and East Anglia.

References Cited in Report

Bibby, J. S. & Mackney, D. (1969) *Land use capability classification*. Soil Survey Technical Monograph No.1.

Bunce, R. G. H., Barr, C. J. & Whittaker, H. A. (1981). *Land classes in Great Britain: Preliminary descriptions for users of the Merlewood method of land classification*. Merlewood Research and Development Paper No.86. Grange-over-Sands, Institute of Terrestrial Ecology.

Crompton, E. (1966) *The soils of the Preston district of Lancashire*. Memoir of the Soil Survey of Great Britain.

FAO (1976) *A framework for land evaluation*. Soils Bulletin No. 32. Rome: FAO.

Hazelden, J. & Green, R. D. (1986) *Soils in Kent IV: Sheet TQ64 (Paddock Wood)*. Soil Survey Record No.99.

Hodge, C. A. H., Burton, R. G. O., Corbett, W. M., Evans, R. and Seale, R. S. (1984). *Soils and their use in Eastern England*. Bulletin Soil Survey, Great Britain.

Jones, R. J. A. & Thomasson, A. J. (1985) *An agroclimatic databank for England and Wales*. Soil Survey Technical Monograph No.16.

MAFF (1966) *Agricultural Land Classification*. Agricultural Land Service Technical Report No.11. London: MAFF.

McRAE, S. G. and BURNHAM, C. P. (1981) *Land evaluation*. Oxford: Clarendon Press.

PYATT, D. G. (1982) *Soil classification*. Forestry Commission Research Information Note 68/82/SSN.

RICHARDSON, S. J. & SMITH, J. (1977) Peat wastage in the East Anglian Fens. *Journal of Soil Science* **28**, 485-9.

PUBLICATIONS

Books

ALLEN, R. H. & STURDY, R. G. (1986). *Soils in Essex V. Sheet TL83 (Halstead)*. Soil Survey Record No.95.

BEARD, G. R., COPE, D. W., JONES, R. J. A., PALMER, R. C. & WHITFIELD, W. A. D. (1986). *Soils of Worcester and the Malverns district*. Memoir of the Soil Survey of Great Britain.

BURTON, R. G. O. (1986). *Soils in Cambridgeshire III: Sheet TL54 (Linton)*. Soil Survey Record No.94.

COPE, D. W. (1986). *Soils in Gloucestershire IV: Sheet SO72 (Newent)*. Soil Survey Record No.93.

FINDLAY, D. C. (1986). *Soils in Wiltshire II: Sheet SU05N/06S (Devizes)*. Soil Survey Record No.91.

FORDHAM, S. J. (1986). *Soils in Surrey I: Sheet TQ05 (Woking)*. Soil Survey Record No.90.

FURNESS, R. R. (1986). *Soils in Humberside II: Sheet SE85 (Fridaythorpe)*. Soil Survey Record No.97.

GEORGE, H. (1986). *Soils in Lincolnshire V: Sheet TF39 (Covenham)*. Soil Survey Record No.100.

HAZELDEN, J. (1986). *Soils in Oxfordshire II: Sheet SP60 (Tiddington)*. Soil Survey Record No.98.

HAZELDEN, J. & GREEN, R. D. (1986). *Soils in Kent IV: Sheet TQ64 (Paddock Wood)*. Soil Survey Record No.99.

HAZELDEN, J., LOVELAND, P. J. & STURDY, R. G. (1986). *Saline soils in North Kent*. Soil Survey Special Survey No.14.

HEAVEN, F. W. (1986). *Soils in Lincolnshire VII: Sheet TF36 (Old Bolingbroke)*. Soil Survey Record No.103.

HODGE, C. A. H. & ELDRIDGE, D. J. (1986). *Soils in Norfolk VI: Sheet TL99 (Caston)*. Soil Survey Record No.104.

HOLLIS, J. M. (1985). *Soils in Staffordshire IV: Sheet SK00/10 (Lichfield)*. Soil Survey Record No.89.

KING, S. J. (1986). *Soils in North Yorkshire VIII: Sheet SE97/98 (Wykeham Abbey)*. Soil Survey Record No.96.

MACKNEY, D. (1986). *Soils in Buckinghamshire/Berkshire I: Sheet SU88 (Marlow)*. Soil Survey Record No.92.

MURPHY, C. P. (1986). *Thin section preparation of soils and sediments*. Berkhamsted: A B Academic Publishers.

SEALE, R. S. (1986). *Soils in Cambridgeshire IV: Sheet TL34 (Royston)*. Soil Survey Record No.105.

WHITFIELD, W. A. D. (1986). *Soils in Warwickshire VI: Sheet SP25/35 (Stratford-upon-Avon East)*. Soil Survey Record No.101.

Research Papers

(CLARKE, M. J.) and ALLEN, R. H. (1986) Peatland soil-plant relationships in the New Forest. *Aquatic Botany* **25**, 167–177.

(Douglas, J. T.), Jarvis, M. G., Howse, K. R. & Goss, M. J. (1986). Structure of a silty soil in relation to management. Journal of Soil Science 37, 137–151.

(Foster, I. D. L.), Carter, A. D., (Dearing, J., Simpson, A. & Appleby, P.) (1985). Lake catchment studies of erosion and denudation: estimates of contemporary and historical sediment yield on Merevale catchment, Warwickshire, U.K. *Earth Surface Processes and Landforms* **10**, 45–68.

Goulding, K. W. T. & Loveland, P. J. (1986). The classification and mapping of potassium reserves in soils of England and Wales. *Journal of Soil Science* **37**, 555–565

(Grieve, I. C., Foster, I. D. L.) & Carter, A. D. (1984). Spatial and temporal variations in concentrations of three ions in solutions extracted from a woodland soil. *Catena* **11**, 305–312.

Loveland, P. J., Hazelden, J., Sturdy, R. G., & Hodgson, J. M. (1986). Salt-affected soils in England and Wales. *Soil Use and Management* **2**, 150–156.

Moffat, A. J. (1986). Quartz signatures in Plio-Pleistocene gravels in the northern part of the London Basin. In: *Clast lithological analysis*. Ed. D. R. Bridgland. Quaternary Research Association Technical Guide **3**, Cambridge: Quaternary Research Assocation. pp. 117–128.

Moffat, A. J. & Catt, J. A. (1986). A re-examination of the evidence for a Plio-Pleistocene marine transgression on the Chiltern Hills. II. Drainage Patterns. *Earth Surface Processes and Landforms* **11**, 169–180.

Moffat, A. J. & Catt, J. A. (1986). A re-examination of the evidence for a Plio-Pleistocene marine transgression on the Chiltern Hills. III. Deposits. *Earth Surface Processes and Landforms* **11**, 233–247.

Moffat, A. J., Catt, J. A., Webster, R. & (Brown, E. H.) (1986). A re-examination of the evidence for a Plio-Pleistocene marine transgression on the Chiltern Hills. I. Structures and surfaces. *Earth Surface Processes and Landforms* **11**, 95–106.

Reeve, M. J. (1986). Water retention, porosity and composition inter-relationships of alluvial soils in mid Hawke's Bay and their relevance in irrigation planning. *New Zealand Journal of Agricultural Research* **29**, 457–468.

General Papers

(Boardman, J.) & Hazelden, J. (1986). Examples of erosion on brickearth soils in east Kent. Soil Use and Management 2, 105–108.

Bradley, R. I. (1986). Climate and Soils of Yorkshire. In: *Programme and Excursion Guide; Autumn Meeting of British Society of Soil Science, September 1986*. Eds K. Atkinson and G. M. Whiteley. Leeds: British Society of Soil Science.

Burton, R. G. O. (1985). Acid sulphate soils near Mepal. *Seesoil* **2**, 58–67.

Harrod, T. R. (1986). The effects of soil and climate on yields of common arable crops and grass. *Journal of the Science of Food and Agriculture* **37**, 677–678.

Hartnup, R. (1986). The Manod Series. *Soil and Water* **14**, 8.

Hodge, C. A. H. (1985). Acid sulphate soils in the Fens. *Seesoil* **2**, 56–57.

Jones, R. J. A. & Thomasson, A. J. (1986). Land suitability classification for temperate arable crops. *Proceedings of the International Society of Soil Science Workshop on Quantified Land Evaluation, 28 April to 2 May 1986*, Washington DC, USA.

Lea, J. W. (1986). Soils of the Shirdley Hill Sands. *Proceedings of the North of England Soils Discussion Group* **21**, 11–20.

Moffat, A. J. (1985). William Cobbett: politician and soil scientist. *Geographical Journal* **151**, 351–355.

Murphy, C. P. & Kemp, R. A. (1986). Micromorphology and the argillic horizon – a reappraisal. In: *Proceedings of the International Working Meeting on Soil Micromorphology, Paris 1985/6*.

https://doi.org/10.23637/ERADOC-1-27

PALMER, R. C. (1986). The Newport Series. *Soil and Water* **14,** (2), 8.

PALMER, R. C. (1986). Winter Rain Acceptance Potential: Soil and spatial aspects. In: *Water in the unsaturated zone*. Nordic Hydrological Programme, Report No.15. Eds S. Haldorsen and E. J. Berntsen. As, Norway: Co-ordinating Committee for Hydrology in Norden.

RAGG, J. M. (1986). Soil profile recording – an overview. In: *Proceedings of an International Workshop on the Structure of a Digital International Resources Map Annex Data Base 20–24 January 1986*, Eds M. F. Baumgardner and L. R. Oldeman. Wageningen: International Society of Soil Science, pp. 34–36.

THOMPSON, T. R. E., RUDEFORTH, C. C., HARTNUP, R., LEA, J. W. & WRIGHT, P. S. (1986). Soil and slope conditions under bracken in Wales. In: *Bracken: Ecology, land use and control technology*. Eds R. T. Smith and J. A. Taylor. Carnforth: Parthenon Publishing, pp.101–107.

WRIGHT, P. S. & (PRAG, P. A. B.) (1986). Soil survey as an aid to land management. *Country Landowner* **39,** 35–36.

Maps

ALLEN, R. H. & STURDY, R. G. (1986). Soil map 1:25 000. Sheet TL83 (Halstead). Harpenden: Rothamsted Experimental Station.

BEARD, G. R., COPE, D. W., JONES, R. J. A., PALMER, R. C., SMITH, C. A. & WHITFIELD, W. A. D. (1986). Soil map 1:50 000. Sheet 150 (Worcester and the Malverns district). Harpenden: Rothamsted Experimental Station.

BURTON, R. G. O. (1986). Soil map 1:25 000. Sheet TL58 (Linton). Harpenden: Rothamsted Experimental Station.

COPE, D. W. (1986). Soil map 1:25 000. Sheet SO72 (Newent). Southampton: Ordnance Survey.

CORBETT, W. M. & ELDRIDGE, D. J. (1986). Soil map 1:25 000. Sheet TF82 (Helhoughton). Harpenden: Rothamsted Experimental Station.

ELDRIDGE, D. J, & HODGE, C. A. H. (1986). Soil map 1:25 000. Sheet TL99 (Caston). Harpenden: Rothamsted Experimental Station.

FORDHAM, S. J. (1986). Soil map 1:25 000. Sheet TQ05 (Woking). Harpenden: Rothamsted Experimental Station.

FORDHAM, S. J. & GREEN, R. D. (1986). Soil map 1:25 000. Sheet TQ64 (Paddock Wood). Harpenden: Rothamsted Experimental Station.

FURNESS, R. R., KING, S. J., JARVIS, R. A. & GUARDIOLA SAENZ, J. L. (1986). Soil map 1:25 000. Sheet SE85 (Fridaythorpe). Harpenden: Rothamsted Experimental Station.

GEORGE, H. (1986). Soil map 1:25 000. Sheet TF39 (Covenham). Harpenden: Rothamsted Experimental Station.

HARROD, T. R. (1986). Soil map 1:25 000. Sheet SU05/06 (Devizes). Harpenden: Rothamsted Experimental Station.

HEAVEN, F. W. (1986). Soil map 1:25 000. Sheet SK99 (Kirton in Lindsey). Harpenden: Rothamsted Experimental Station.

HEAVEN, F. W. (1986). Soil map 1:25 000. Sheet TF36 (Old Bolingbroke). Harpenden: Rothamsted Experimental Station.

KING, S. J. (1986).. Soil map 1:25 000. Sheet SE97/98 (Wykeham Abbey). Harpenden: Rothamsted Experimental Station.

SEALE, R. S. (1986). Soil map 1:25 000. Sheet TL34 (Royston). Harpenden: Rothamsted Experimental Station.

WHITFIELD, W. A. D. (1986). Soil map 1:25 000. Sheet SP25/35 (Stratford-upon-Avon East). Harpenden: Rothamsted Experimental Station.

https://doi.org/10.23637/ERADOC-1-27