Soil Information and its Application in the United Kingdom: An Update

Michael G. Jarvis
Soil Survey and Land Research Centre, Cranfield University, Silsoe
Bedfordshire, MK45 4DT, UNITED KINGDOM.

Introduction

Meetings in 1989 (Hodgson, 1991) and 1994 to review the extent, availability and application of soil data across the European Union were followed by the production of a report (Le Bas and Jamagne, 1996) which included accounts of soil survey activity and application in England and Wales (Bullock and Jones, 1996), Scotland (Gauld and Paterson, 1996) and Northern Ireland (Cruickshank and Jordan, 1996). This paper constitutes an update on these accounts.

Appreciation of the significance of soil resources in the United Kingdom for sustainable land management continues to grow albeit slowly. Evidence for national interest and concern is clear in a number of official publications. For example, a code of practice for the protection of soil was published in 1993 (MAFF, 1993) and in 1996 a significant report on the sustainable use and stewardship of soil followed an enquiry by the independent Royal Commission on Environmental Pollution (RCEP, 1996). A key recommendation of this report is that a soil protection policy for the United Kingdom should be framed and implemented. This is currently under development and should be put in place shortly.

History and Development of Soil Survey

The development of soil survey in Britain has been summarised by Muir (1960) and Hollis and Avery (1997). Muir makes reference to early suggestions about the collection of information on British soils as far back as 1665. In the 18th century a series of reports entitled General Views on Agriculture were the first to incorporate soil maps and descriptions, some of which give a good indication of the range of soil types and their spatial distribution within the counties. Notable examples are the reports for Hertfordshire, Cambridgeshire, Essex, Sussex, Devon and Hampshire. In the early 20th century a number of projects looked at the nature and distribution of soils mainly in England and Wales. The basis for mapping the soils was almost always the supposed link and correlation between soils and geology and at this time none of the researchers seemed to appreciate the significance of soil morphology for this purpose. Study of the soil profile as the basic unit in making soil maps began in the 1920s and a Soil Survey conference was instituted in 1926 when a demonstration was made of this novel approach.

Further meetings established a standard system of soil description and methods for recording soil series and types on the maps, the whole being crystallised in the Soil Survey Handbook (Clarke, 1940). By 1930 surveys were being undertaken in Southeast England, Oxfordshire, around Bristol, Shropshire, South Wales, in the Lothians of Scotland and in Aberdeenshire. A Soils Correlation Committee was set up in 1930 to promote uniformity of methods classification and nomenclature.

The Soil Survey of England and Wales was formally set up in 1939. Soil survey in Scotland was based in the Macaulay Institute for Soil Research, founded in 1930, and in the early years most work was done from Aberdeen. In 1946 the Soil Survey of England and Wales was transferred to Rothamsted Experimental Station and a truly national soil survey programme began. In Scotland, the first national survey was started in 1948.

The principal products of the national systematic soil survey programmes in Scotland, England and Wales are described in Hodgson (1991) and Le Bas and Jamagne (1996). These programmes had effectively ceased to function by 1987. In summary the output comprised a range of general purpose detailed maps at scales ranging from 1:25,000 to 1:63,360 together with explanatory reports incorporating information about the soils

and their associated landscapes and environments. In many, soil data are interpreted to provide guidance about specific land use, mainly for agriculture and forestry. About 24 per cent of England and Wales is covered by such maps and in Scotland most of the arable land has similar cover. Together with other special purpose surveys, remote sensing, geological data and further limited field work, these maps formed the basis for the production of the National Soil Maps at the 1:250,000 scale which completely cover England, Wales and Scotland (Figure 1).

In Northern Ireland as reported by Cruickshank and Jordan (1996), systematic soil survey did not commence until 1987. However by 1994 a number of detailed soil maps at the 1:50,000 scale had been published. The full programme is now finished and, for the first time a complete cover of soil maps at the 1:250,000 scale exists for the whole of the United Kingdom (Figure 1).

Developments in England and Wales

Soil mapping

The coverage of detailed soil mapping is described by Bullock (1991) and Bullock and Jones (1996). To date there has been no resumption of a strategic national mapping programme.

However, some small amounts of special purpose soil mapping have been undertaken as follows:

1. A project to collect detailed information and prepare maps of soil series, pH and land use around nuclear power stations has produced some 500 km^2 of new and revised detailed soil survey.
2. A request from a commercial company requiring detailed soil (series) information for an area around Bristol, in south-west England, where there was only partial detailed map cover, was met by means of a desk study. This was undertaken by an experienced soil scientist who knew the area well and who, with the aid of aerial photographs and his detailed knowledge of local landscapes and soil patterns, prepared a soil series map. This map formed the basis of a spatial application for the company concerned. The approach demonstrated what could be achieved with little or no additional fieldwork by using the accumulated knowledge of landscapes acquired by experienced field scientists.

Soil Monitoring

National Soil Inventory.

As reported by Bullock and Jones (1996), the National Soil Invertory (NSI) was a programme of sampling and describing the soils of England and Wales on a regular 5km x 5km grid across the countries. It was undertaken during the period of construction of the National Soil Map (1979-1982). The analysis of the 5692 samples taken from the upper 0-15 cm give a national picture of soil quality in that period (McGrath and Loveland, 1992). Subsequently 900 arable and ley grass sites and 750 permanent grassland sites have been revisited (1995-1996) and samples analysed for pH, organic carbon, P, K, Mg and heavy metals to discover if changes have occurred since the first inventory of 1979-82. Preliminary results suggest that there has been a slight overall decline in soil organic carbon under all the forms of land use re-sampled. These changes are shown in Figure 2. The results for other soil properties will be published in the near future.

Environmental Change Network.

A series of terrestrial sites to monitor changes with time of a wide range of environmental parameters has been established across the United Kingdom. These sites are mainly located in places where there was already a good historic record of environmental measurements. The soils of each site have been mapped and within a target sampling area, the soil described in detail according to a standard protocol. Samples have been taken and analysed for particle-size distribution, pH, organic carbon, nutrients and heavy metals.

The intention is to monitor these sites in the long-term and five-year and twenty-year soil sampling cycles are planned. The first sampling and analysis has been completed and the second of the five-year cycle samplings is now under way.

Soil Databases

The Land Information System - LandIS.

The structure of LandIS and its key databases have been described by Bullock and Jones (1996). The re-engineering process whereby LandIS was transferred to Oracle, an 'industry-standard' relational database software system, is now complete. Some additional vector datasets have been added to the system and these include the boundaries of groundwater vulnerability and Nitrate Vulnerable Zones.

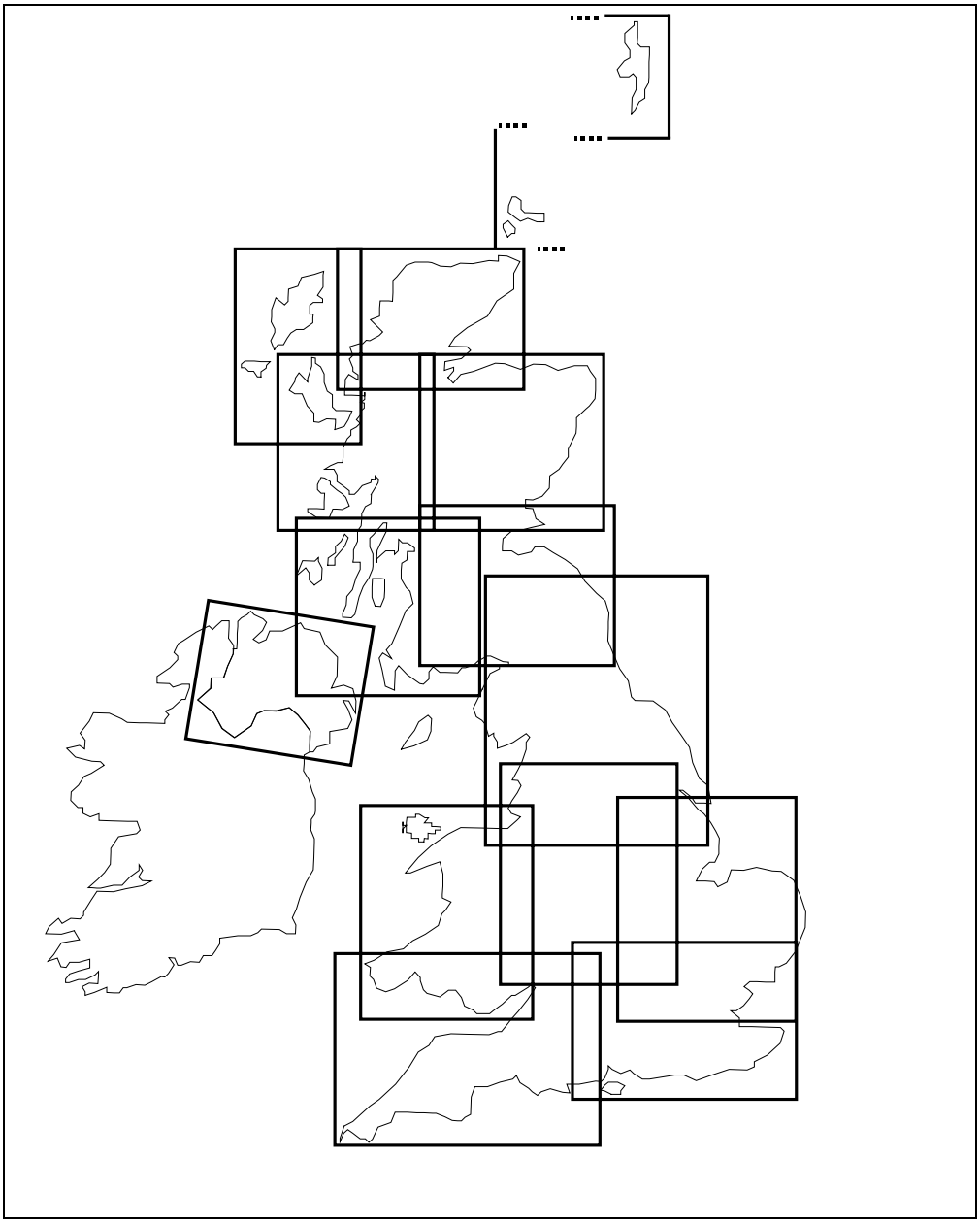


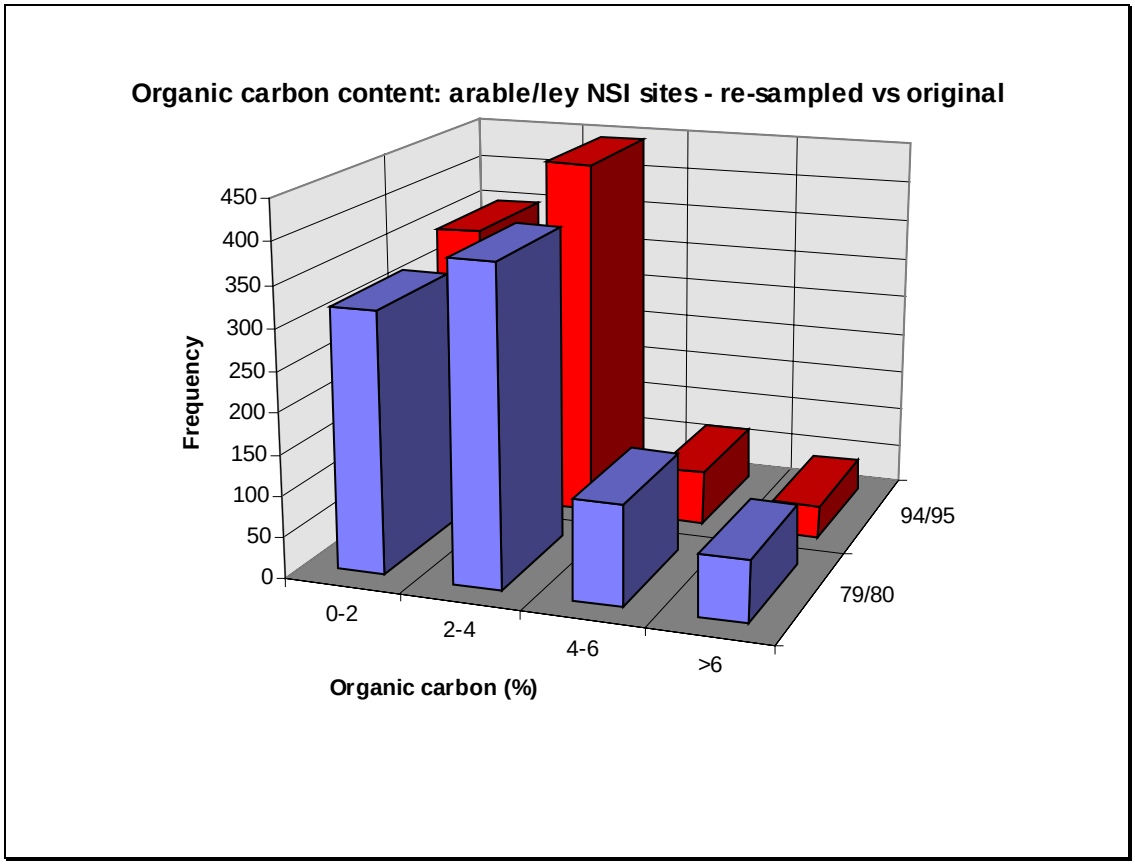
Figure 1: Soil maps published at 1:250,000 scale for the UK

Stand-alone (off-line) packages have been developed to provide querying and reporting of a number of LandIS datasets (Dufour *et al.*, 1998; Hallett *et al.*, unpub.).

Spatial representation of data held in the Oracle system and manipulation of vector data is now possible using GIS software such as ArcView. Graphical user interfaces have been developed to allow on-line data query and reporting. Remote on-line access to these interfaces is currently under investigation. A recent account of these developments is given in Proctor *et al.* (1998).

Applications and use of soil data

During the period since 1987, much of the work undertaken by the Soil Survey and Land Research Centre in England and Wales has been to use the accumulated soil information and other environmental data for the provision of solutions to specific issues of concern. Some of these applications are listed by Bullock and Jones (1996). Further information on the principal developments are given in the sections below.



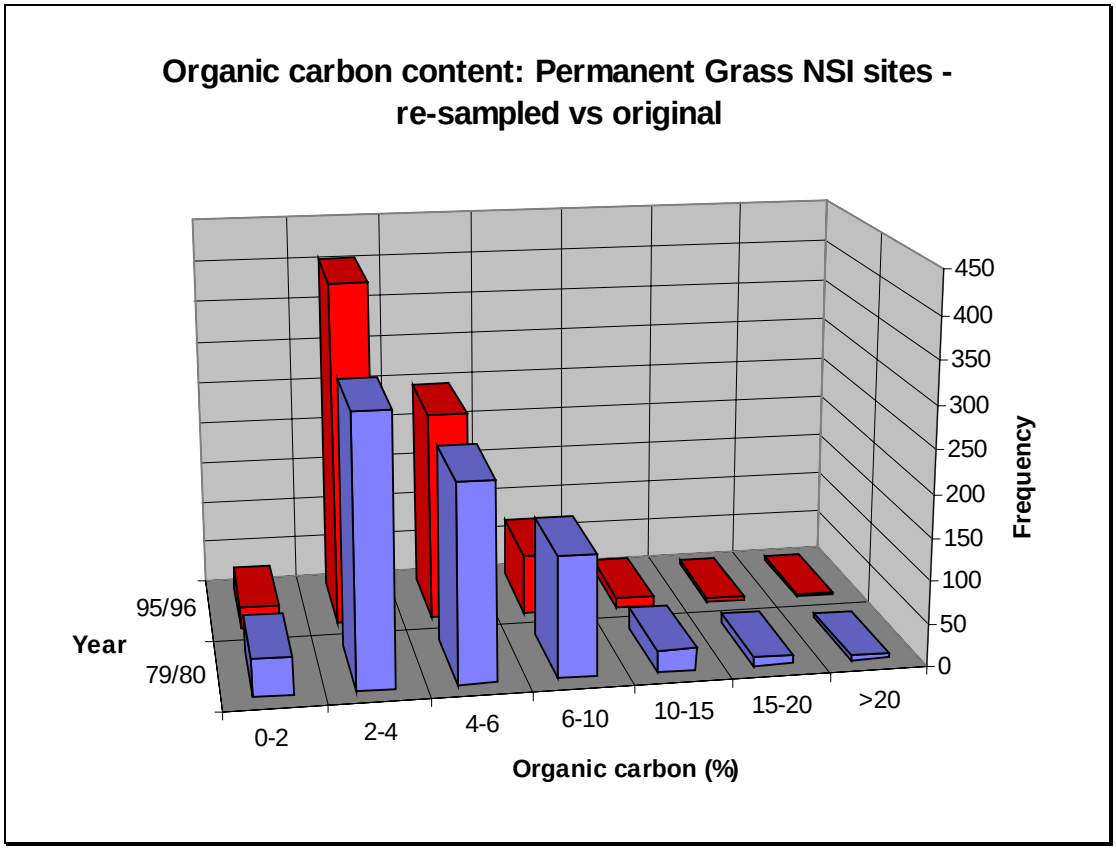


Figure 2: Monitoring Organic Carbon contents under different land uses

Table 1. Summary Statistics for NSI resampled sites and the original data for the same sites

	Arable Re-sample 1994/95 (n = 904)						Arable original 1979/80 (n = 883 - 904)					
Var.	**Min**	**25%**	**Med**	**75%**	**Max**	**Mean**	**Min**	**25%**	**Med**	**75%**	**Max**	**Mean**
pH	4.01	6.56	7.22	7.78	8.57	7.12	4.2	6.1	7	7.7	8.4	6.9
OC%	0.43	1.66	2.29	3.14	46.8	2.78	0.4	1.8	2.4	3.8	30.2	3.27
Ptot	51	451	595	783	8150	661	170	611	785	1034	3728	875
Pav	0.2	21	33	53	2329	44	1	16	25	41	274	32
Kav*	6	129	198	289	2000	236	12	105	160	249	960	199
Mgav*	1	46	81	180	1060	143	9	59	98	171	981	141
Cd	0.05	0.18	0.23	0.31	3.5	0.32	0.05	0.6	0.8	1.1	11.7	0.82
Cr	0.05	19	28	40	2340	40	2	31	42	55	285	44
Cu	0.05	12	16.7	21	223	18.5	2.6	13.3	18.1	23.1	189	20.2
Pb	0.05	22.3	28.7	40.3	1287	38.5	3	24	32	44	3461	45
Ni	0.05	14.7	22	31.7	1350	28	0.9	18	25	34	299	27
Zn	0.05	49.3	67	87	1427	70.1	10	64	83	105	1850	91
Co	0.43	7	10.3	13.7	59.3	10.9	0.2	7.5	11	14.5	4.76	11.6
Mo	0.05	0.05	0.37	0.83	33	0.71						
V	0.05	26	40.8	57	330	44.1						
As	0.05	1.92	3.2	6	110	5.4						
Hg	0.05	0.05	0.10	0.10	2.2	0.14						
Se	0.04	0.16	0.40	0.44	4.4	0.41						
Permanent Grass Re-sample 1995/96 (n = 768)							**Permanent Grass Original 1979/80 (n = 768)**					
pH	3.72	5.23	5.64	6.40	8.29	5.88	3.4	5.1	5.6	6.4	8	5.7
OC%	0.98	2.88	3.72	4.74	33.38	4.21	0.6	3.15	4.2	6.0	49.3	5.0

*n = 903

Hydrology of Soil Types (HOST).

The HOST classification is based on a number of conceptual models that describe dominant pathways of water movement through the soil and, where appropriate, the substrate (Boorman *et al.*, 1995). The most important soil properties that influence the hydrological response of a catchment are hydraulic conductivity, soil moisture retention and pathways of water movement. Such properties are both difficult and expensive to measure.

To develop the HOST classification, soil types from the whole of the United Kingdom were characterised in terms of surrogates for direct measurement of soil hydraulic properties, e.g. depth to gleying, depth to a slowly permeable layer, integrated air capacity and the presence of a peaty surface layer. HOST has been used to estimate low flow indices and standard percentage runoff from stream and river catchments.

Groundwater Vulnerability.

The risk that groundwater will be polluted by substances applied to or spilled upon the land surface, depends on the natural characteristics of a site and relates to the ease of vertical movement of pollutants. Assessments of soil leaching potential were combined with aquifer type and distribution, and the occurrence of low permeability drift, to gauge the risk of groundwater pollution (Palmer *et al.*, 1995). A series of 53 maps at the 1:100,000 scale have been produced covering England and Wales. These maps are intended for use by planners, developers and regulatory bodies to help implement the Groundwater Protection Policy. Maps at the 1:250,000 scale have also been produced for Scotland and Northern Ireland.

CatchIS

The Catchment Information System – CatchIS – is a spatial computer based system developed by the Soil Survey and Land Research Centre in collaboration with Severn Trent Water Ltd and is a decision support tool to help manage water quality in midland England. The system presents an overview of the water resources, soil and climate together with cadastral and catchment features. It combines the environmental datasets with simulation models of contaminant movement, so that the user can assess the vulnerability of water resources to diffuse pollution. Use of CatchIS is described in more detail by Hollis *et al.* (1995).

SEISMIC

The Spatial Environmental Information System to Model the Impact of Chemicals – SEISMIC – (Hallett *et al.*, 1995) brings together spatial and parameter soil data, spatial cropping data, computed agroclimatic data, daily weather data and crop suitability assessments to aid the assessment of the fate and behaviour of potential environmental contaminates. The system uses data from LandIS and processes them for use in other software packages such as simulation models.

INSURE

The Information System for Underground Risk Evaluation (INSURE) has been developed to identify areas of England, Wales and Scotland where low buildings and domestic houses are susceptible to subsidence damage because of soil shrinkage and swelling. The risk assessment model (Hallett *et al.*, 1994; Jones *et al.*, 1996) is based on soil shrink-swell potential and potential soil moisture deficit (Jones and Thomasson, 1985). A commercial version of INSURE is currently in use by the insurance industry (Hallett, unpub).

LEACS

The is a Land Evaluation for Corrosivity and Shrinkage (LEACS). Failures in the potable water pipe distribution network are a major cost to water supply companies. The chemical aggressiveness of soils and their capacity to shrink and swell as they dry and re-wet are significant natural factors leading to bursts. Soil data are used in LEACS to identify where aggressive and shrinkable soils are found and therefore where damage might occur (Jarvis and Hedges, 1994; Dufour *et al.*, 1998).

Developments in Scotland

The full extent of soil survey in Scotland is described by Bibbly (1991) and Gauld and Paterson (1996).

Soil mapping

Most arable areas are covered at the 1:63,360 scale with surveyor's field maps available in many cases at the 1:25,000 scale. There are also numerous unpublished farm, estate and other local soil maps often covering areas of high ecological value at the 1:10,000 scale. The National Soil Map at 1:250,000 covers the whole of the country (Figure 1).

Soil monitoring

National Soil Inventory

Coincident with the preparation of the National Soil Map, soils were described at 5 km intervals (3,200 profiles) in a similar way to the NSI in England and Wales, except that samples were taken and analysed only at every 10 km intervals (810 profiles). No further re-sampling has been undertaken.

Environmental Change Network.

Two of the sites in the Network are located in Scotland, one at Glensaugh near Aberdeen, the other at Sourhope in the Borders. The soils are mapped and sampled to the same protocols as elsewhere in the United Kingdom.

Soil databases

The principal datasets held in the Macaulay Land Use Research Institute (MLURI) soils database have been described by Gauld and Paterson (1996). The database now incorporates digital images of all detailed soil maps.

Application and use of soil data

The following are examples of the ways soil data are being applied:

1. soil acidification and critical load assessment;
2. assessment of environmental and experimental sites;
3. review of sites intended for opencast coal mining;
4. appraisal of land proposed for gravel extraction;
5. assessment of the agricultural potential of development land;
6. selection of suitable sites for forest nurseries, vegetables etc.;
7. predicting risk of soil related subsidence (see INSURE above);
8. estimates of the soil carbon pool.

It is officially recognised that soil data are needed for the prevention of environmental pollution from agicultural activities (SOAFD, 1992).

Soil data are also being incorporated into models being developed at MLURI that predict the behaviour of deer and the restoration of native woodland.

Developments in Northern Ireland

Soil mapping

Cruickshank and Jordan (1996) reported that detailed mapping had been completed in Northern Ireland (13,550 km^2). In total, 17 map sheets covering the whole area at 1:50,000 scale (Figure 3) and a single 1:250,000 map have now been published together with an explanatory text (Cruickshank, 1997).

Soil monitoring

Soil geochemical survey.

Coincident with the fieldwork for the soil mapping project, soils were sampled to 15 cm depth at a site in each 1km x 1km in the agricultural lowlands and analysed for total concentrations of 15 elements (calcium, cadmium, cobalt, chromium, copper, iron, lead, magnesium, manganese, molybdenum, nickel, phosphorus, potassium, sodium and zinc) to constitute a geochemical database. The results have also been published as an atlas (Jordan *et al.*, 1997). Available concentrations of these elements have also been measured.

Environmental Change Network.

One of sites in this national network is located at Hillsborough, Co. Down. It is representative of grassland in much of the north-western United Kingdom.

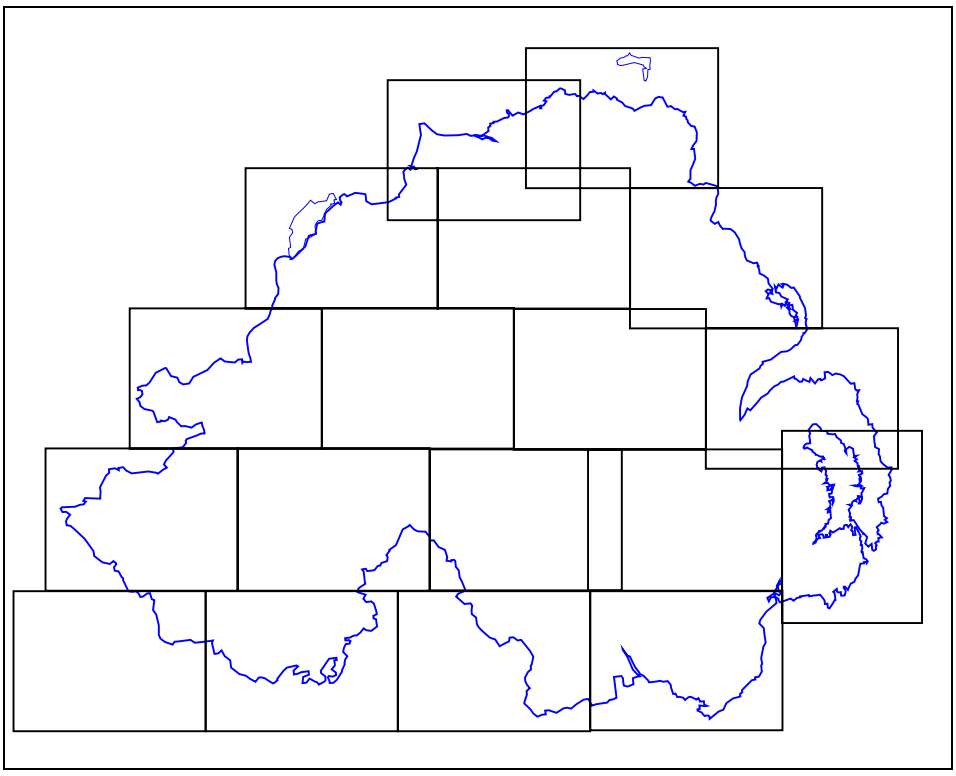


Figure 3: Soil maps at 1:50,000 for Northern Ireland

Soil databases

Soil maps.

The 17 soil maps at 1:50,000 and the 1:250,000 soil map are available also in digital form.

Soil attribute database.

This is a comprehensive compilation of information on the observed physical and chemical nature of all soil horizons at inspection pits, sampled on a 5km x 5km grid, as part of the soil survey (Cruickshank, 1997). The database is held as a number of ORACLE tables linked by the grid reference of the actual site. It is distributed on CD-ROM.

Environmental database.

This is a database storing data on dominant soil series, HOST class, solid and drift geology, and a various climate data for every 1 km^2.

Application and use of soil data

Cruickshank (1997) cites a range of applications. The following is a selected list:

1. Estimations of the soil carbon pool;
2. Soil acidification and critical load assessment;
3. Soil hydrology classification (see above);
4. Agricultural land classification;
5. Groundwater vulnerability (see above);
6. Assessment of pipeline corrosion risk (see above).

Outlook

As indicated earlier there is a slowly growing national appreciation of the role and significance of soil in sustainable land management, the need to protect and conserve soils and to give them equivalent status to that accorded to air and water. This thinking received considerable impetus following the publication of the Royal Commission's report on the sustainable use of soil (RCEP, 1996). Among its key recommendations were the following:

A soil protection policy should be implemented for the UK:

1. Planning policies should be reviewed to give greater weight to the appropriate use of soil resources;
2. A national soil quality monitoring scheme should be established;
3. Legislation governing the spread of wastes on land should be reviewed.

Despite the above there is no indication of support for the resumption of strategic soil mapping programmes. This is particularly important in England and Wales and parts of Scotland where detailed knowledge of soil patterns is still inadequate in some areas. There is an urgent need to trial methodologies for gathering soil landscape data that are less expensive than those arising from the traditional free survey approach and that use novel data sources and modern geostatistical techniques.

Within the United Kingdom, the fact that soil mapping and data have been generated by three separate autonomous groups has led to different approaches and production of incompatible data and maps. A project to prepare a single map and unified database for the whole country is planned. In addition better links between the organisations holding the soil data and the British Geological Survey are being pursued with the intention of facilitating data exchange to the ultimate benefit of all users.

The digital databases available in Northern Ireland and Scotland are reasonably comprehensive but there are still many data, particularly in England and Wales including the detailed maps, which still need to be captured in digital form. The intention is to gradually achieve this over the next five years or so.

Acknowledgements

The assistance of Dr J. H. Gauld, Macaulay Land Use Research Institute, Aberdeen, Scotland and Mr J. G. Cruickshank, Department of Agriculture for Northern Ireland in compiling this paper is gratefully acknowledged.

References

Boorman, D.B., Hollis, J.M. and Lilley, A. (1995). Hydrology of soil types: a hydrologically-based classification of the soils of the United Kingdom. Institute of Hydrology. Report No. 126.

Bibby, J. (1991). Soil mapping in Scotland. In: *Soil Survey – A Basis For European Soil Protection.* Hodgson, J.M. (ed.). Soil and Groundwater Research Report No. 1. Office of Official Publications of the European Communities.EUR 13340 EN. p.99-106.

Bullock, P. (1991). Soil mapping in England and Wales. In: *Soil Survey – A Basis For European Soil Protection.* Hodgson, J.M. (ed.). Soil and Groundwater Research Report No. 1. Office of Official Publications of the European Communities.EUR 13340 EN. p. 27-38.

Bullock, P and Jones, R.J.A. (1996). England - Wales. Databases to support sustainable soil management. In: *Soil databases to support sustainable development.* C. Le Bas & M. Jamagne (eds.). European Soil Bureau Research Report No. 2. EUR 16371, p.27-35. Office for the Official Publications of the European Communities.

Clarke, G.R. (1940). Soil Survey of England and Wales: Field Handbook. University Press, Oxford.

Cruickshank, J. G and Jordan, C. (1996). Northern Ireland. Soil Survey: progress and planning. In: *Soil databases to support sustainable development.* C. Le Bas & M. Jamagne (Eds.). European Soil Bureau Research Report No. 2. EUR 16371, p.83-87. Office for the Official Publications of the European Communities.

Cruickshank, J.G. (1997). Soil and environment: Northern Ireland. Agricultural and Environment Science Division, DANI and The Agricultural Environmental Science Department, The Queens University of Belfast, 214pp.

Dufour, M.J.D., Hallett, S.H., Jones, R.J.A. and Gibbons, J.W. (1998). Spatial Information Systems for Environmental Impact Assessment in the UK. In: *Land Information Systems: Developments for planning the sustainable use of land resources*. H.J. Heineke, W. Eckelmann, A.J. Thomasson, R.J.A. Jones, L. Montanarella and B. Buckley (eds). European Soil Bureau Research Report No. 4. EUR 17729 EN, p.403-418. Office for Official Publications of the European Communities, Luxembourg.

Gauld, J.H. and Paterson, E. (1996). Scotland. The information base for Scottish soils. In: *Soil databases to support sustainable development.* C. Le Bas & M. Jamagne (eds). European Soil Bureau Research Report No. 2. EUR 16371, p.93-97. Office for the Official Publications of the European Communities.

Hallett, S.H., Keay, C.A., Jarvis, M.G. and Jones, R.J.A. (1994). INSURE: Subsidence risk assessment from soil and climate data. Proceedings of the Association for Geographic Information (AGI). National Conference Markets for Geographic Information. Birmingham. 16.2.1 - 16.2.7.

Hallett, S.H., Thanigasalam, P. and Hollis J.M. (1995). SEISMIC: a desktop information system for assessing the fate and behaviour of pesticides in the environment. Computers and Electronics in Agriculture 13, 227-242.

Hodgson, J.M. (Ed.) (1991). *Soil Survey – a basis for European soil protection.* Soil and Groundwater Report 1. EUR 13340 EN, 214pp. Office for Official Publications of the European Communities, Luxembourg.

Hollis, J.M. and Avery, B.W. (1997). History of soil survey and development of the soil series concept in the U.K. In: D. H. Yaalon and S. Berkowincz (Eds.). History of Soil Science. Advances in Geo Ecology 29, 109-144.

Hollis, J.M., Keay, C.A., Hallett, S. H., Gibbons, J.W. and Court, A.C. (1995). Using CatchIS to assess the risk to water resources from diffusely applied pesticides. In: British Crop Protection Council monograph No. 62: Pesticide movement to water, 345-350

Jarvis, M.G. and Hedges, M.R. (1994). Use of soil maps to predict the incidence of corrosion and the need for iron mains renewal. Journal of the Institution of Water and Environmental Management 8, 68-75.

Jones, R.J.A. and Thomasson, A.J. (1985). *An agroclimatic databank for England and Wales*, Soil Survey Technical Monograph No. 16, Harpenden, UK, 45pp.

Jones, R.J.A., Hallett, S.H., Gibbons, JW. and Jarvis, M.G. (1995). *Subsidence risk –using a complex dataset to identify areas most at risk.* Proceedings of the AGI 95 Conference, 21-23 November 1995, Birmingham, UK, 2.4.1 – 2.4.6.

Jordan, C., Cruickshank, J.G., Higgins, A.J. and Hamill, K.P. (1997). The soil geochemical atlas of Northern Ireland. Department of Agriculture for Northern Ireland

Le Bas, C. and Jamagne, M. (eds) (1996). *Soil databases to support sustainable development.* (eds C. Le Bas and M. Jamagne). European Soil Bureau Research Report No.2. EUR 16371 EN, 145pp. Office of the Official Publications of the European Communities, Luxembourg.

MAFF. (1993). Code of good agricultural practice for the protection of soil. Ministry of Agriculture, Fisheries and Food, and Welsh Office Agriculture Department, 55pp

MAFF. (1997). Controlling soil erosion. Ministry of Agriculture, Fisheries and Food, 14 pp

McGrath, S.P. and Loveland, P.J. (1992). The Geochemical Atlas of England and Wales. Chapman and Hall, London. 102pp.

Muir, A. (1960). Soil survey in Britain. Soil Survey of Great Britain Report 13 (1960), 1-9. Agricultural Research Council

Palmer, R.C., Holman, I.P., Robins, N.S. and Lewis, M.A. (1995). Guide to groundwater vulnerability mapping in England and Wales. National Rivers Authority R and D Note 578/1/ST.

Proctor, M.E., Siddons, P.A., Jones, R.J.A., Bellamy, P.H. & Keay, C.A. (1998). LandIS - a Land Information System for the UK. In: Land Information Systems – Developments for planning the sustain use of land resources.. H. J. Heineke *et al.* (eds.). European Soil Bureau Research Report No.4. EUR 17729. p 219-234. Office for the Official Publications of the European Commission, Luxembourg.

RCEP. (1996). Sustainable use of soils. Royal Commission on Environmental Pollution. Nineteenth Report. HMSO London, 260pp.

SOAFD. (1992). Prevention of environmental pollution from agricultural activity. The Scottish Office Agriculture and Fisheries Department, 91pp.