Report on a workshop on the Development of a Scottish Soils Knowledge and Information Base (SSKIB)

Macaulay Land Use Research Institute, September 22, 2004.

by

Allan Lilly, Willie Towers, Ann Malcolm and Ed Paterson.

Table of Contents

	Page number
Introduction	1
Project objectives	2
Workshop presentations	2
Current threats to soils and protection measures	5
Discussion points, conclusions and next steps	5
References	8
Appendix 1 Delegate List	9
Appendix 2 Workshop programme	10
Appendix 3 Workshop presentations	12

Introduction:

The Scottish Soil Database and associated maps is one of the most comprehensive collations of national scale soil data in Europe. Since its inception in 1948 to the end of systematic survey in 1988, the Soil Survey of Scotland produced a range of digitised and paper maps at a number of scales from full national coverage at 1:250 000 scale to more local surveys at scales of 1:10 560 or larger. In addition a comprehensive database was developed that currently contains information on over 13 000 geo-referenced soil profiles. Although some digitising of detailed soil maps is currently being carried out and soil profiles are added to the database sporadically, the main emphasis of current interest is on the utilisation of the spatial and point data for a variety of purposes.

From interactions with a range of end-users within the Scottish Executive and agencies, it is clear that soil data are of considerable potential value to them in delivering their statutory and corporate objectives. This interest also extends to a number of UK government departments with specific responsibility to deliver key soil information to the EC during the formulation and development of its Soil Protection strategy. Similarly, many aspects of the implementation of the EC Water Framework Directive are dependent on an understanding of the spatial distribution and properties of soils within catchments. The soils data held by the Macaulay Institute puts Scotland in an excellent position to contribute to a UK perspective on soil protection. The Institute has good collaborative links on a number of projects with the National Soil Resources Institute (NSRI), who have been retained to provide similar soil information for England and Wales by Defra, the lead UK department for liaison with the European Environment Agency.

Since the end of the systematic survey of Scottish soils in 1988, the existing soil spatial and point data have been used in a number of projects and interpreted in a variety of different ways to provide more easily understood soils information for users in the academic world, government agencies and NGOs. Although some attempt has been made to co-ordinate this effort, there is no single, coherent attribute dataset that can be used to fulfil the requirements of many users.

The pedological basis of classification for soils in Scotland is flexible for use by the specialist but can be difficult for the non-specialist and prone to misinterpretation. In order to develop an information base which can be readily understood and used by a range of non-specialists, three elements require to be brought together in a coherent way, namely soil maps, soil data and the expert knowledge available at the Macaulay Land Use Research Institute. A key feature of the work is to systemise some of the knowledge held by individuals. Changes in priorities for soil research over the past 20 years has meant that knowledge gained during the systematic collection of soils data now resides within only a few individuals. Investment in data enhancement and digitising of soil maps has come from a variety of both public and private sources rather than through SEERAD ‘core’ funding.

This project aims to rationalise the existing derived soil data and to utilise existing soil knowledge to develop an integrated attribute database of soil information with a common base at the chosen spatial scale of 1:250 000. This map scale was selected as

it is the only scale of map that provides complete Scotland-wide cover, encompasses many of the most important and extensive soil types in Scotland and has also been the basis for many of the derived datasets .

Project objectives:

The primary objective of this project is to create an information base on Scottish soils that will take account of the increased requirement for soil data by a range of end-users. Specific aims of this project are to:

- consult with the principal end-users in Scotland via a workshop concerning their requirements for soil data now and in the immediate future and establish the feasibility of providing the required data and relating these to their existing data holdings,
- rationalise previous extensions to the Scottish Soils Database base held by the Macaulay Land Use Research Institute and collate metadata on verified datasets and on the methods used to derive the original base data,
- extend the chemical, physical and biological aspects of the information base using existing data, check thoroughly for errors and correct,
- assess critically the options for new measurements on archived soil samples and limited resampling of key soils taking into account the age and applicability of some existing data, and
- co-ordinate these activities with those that are being carried out at the National Soil Resources Institute, Cranfield University, in providing UK data through Defra to the European Environment Agency.

As part of the development of the Scottish Soils Knowledge and Information Base (SSKIB), funded through grant-in-aid by SEERAD, there is a commitment to engage with key end-users in order to determine their requirements for soil data now and in the immediate future and establish the feasibility of providing the required data and relating these to their existing data holdings. After consultation with potential end users, we will review the existing derived datasets, rationalise them and derive a common basis for an attribute dataset. This database will then be populated with existing and newly derived attributes to provide a comprehensive dataset of soil information suitable as input to a wide range of modelling activities.

Workshop Presentations

To start this process a workshop was held at the Macaulay Institute on Sept 22nd 2004 with key end-users from the public sector to summarise the current position of soils data and consult with them about future developments. The list of attendees, the programme for the day and the presentations given are summarised in the appendices to this report. The workshop was attended by delegates representing key departments within the Scottish Executive, the Scottish Environment Protection Agency, Scottish

Natural Heritage, the Forestry Commission, Local Authorities and NSRI (Appendix 1: delegate list). The programme (Appendix 2) was intended both to inform through a number of presentations (Appendix 3) and to stimulate discussion on end-user requirements. The presentations described the nature of the soils data held by the Macaulay Institute and some of the datasets derived from them. After a discussion where delegates outlined their data requirements, there were further presentations on the current threats to the Nation's soils and aims of the current research project to develop a soil information and knowledge base for Scotland. The knowledge and information base will differ from the database in one key respect, the information contained within is derived from the Scottish Soils Database and is a combination of summary statistics, interpretation and expert judgement. The following sections give a brief resume of the presentations made at the workshop and summarises the key discussion points and suggested courses of actions that emerged from them.

Scottish Soils Database

The Scottish soils database comprises observed and measured data on over 13 000 soil profiles and is held in an ORACLE relational database management system (RDBMS) with four principal tables.

- Basic — This table contains 39 separate attributes covering soil and site information collected for each of the recorded profiles.
- Mineral — This contains 46 largely morphological descriptors of each mineral horizon contained in the database.
- Organic — This table holds information on 23 attributes recorded for the organic horizons of the soil profiles.
- Analytical — 21 analytical attributes for each soil sample are recorded although in some cases the analytical records are incomplete.

The data have been collected over a number of years in several phases of survey and in different research projects. The provenance of each soil profile is recorded in order to distinguish between these various sources. These categories include profiles collected to characterize soil series, objectively sampled profiles that comprise the National Soil Inventory, profiles collected in order to describe soils at research sites as well as high resolution grid and transect data from other specific research projects. The raw data are held as a series of codes and require significant expertise to interpret them. Over 50% of the analytical data are from soil profiles sampled before 1970 and approximately half of the soil profile descriptions only exist as hard copy. A limited amount of georeferenced hydrological and geochemical data also exists and is stored in linked tables within the Oracle RDMS.

A significant amount of hard copy survey information from some of the major peat bogs in Scotland also exists but is not recorded in any electronic format.

Soil Maps and soil classification

Classification: The Scottish soil classification is based on the recognition of morphological features within the soil profile, in particular the nature and sequence of individual soil layers (horizons). It does not depend on the horizon achieving a

specified thickness, except in the case of peat, or having a specified chemical composition. However some of the concepts central to the classification, such as soil parent material, act to limit the variability in soil chemical and geochemical properties. Although unique to Scotland, information is available to enable the soils to be classified according to other UK and International classification systems.

Soil mapping units: The basic unit in the classification system is the soil series (taxonomic unit) and this is also the basic mapping unit for map scales of 1:63 360 and larger. It is perhaps unfortunate the term *series* applies to both a soil mapping unit and a taxonomic unit. The 1:250 000 maps have mapping units based on landscape units as the same recurring pattern of soils are found in association with similar landscapes throughout Scotland (Macaulay Institute for Soil Research, 1984). Soil maps give information on the *Soil Association*, which is a group of soils developed on the same or similar parent materials and which characteristically occur together in the landscape. The *Soil Series* (as a mapping unit) comprises mainly soils with similar type and sequence of horizons developed on similar parent material although it is accepted that there may be other soils present and are usually named after the locality in which they were first described (Futty and Dry, 1977). A *Soil Complex* is a mapping unit based on landform where the natural variability of the soils makes it impossible to map individual soils. Within the 1:250 000 scale maps the concept of the soil complex has been developed and extended to produce map units based on parent material (soil association), landform and soil type.

Extent of coverage: The 1:250 000 scale maps cover the entire country and are documented in a series of seven handbooks, one for each soil map sheet (Macaulay Institute for Soil Research, 1982, 1984). These maps have subsequently been digitised. Soil maps and, in some cases, accompanying memoirs, have been published at a scale of 1: 63 360, covering much of the cultivated areas of Scotland and adjacent hill land. Areas not covered at the 1:63 360 scale are available as provisional 1:50 000 uncoloured maps. Finally, maps are available for some areas, prepared from clean-copy field-scale maps, and are published at a scale of 1:25 000, many of which are now available in digital form. These broadly cover the same areas as the 1: 63 360 scale map coverage.

Derived datasets

In addition to the raw point and spatial data there have been a few key extensions to the soils database in the form of specific projects, often aimed at user-oriented re-classifications of the data (e.g. HOST – Hydrology of Soil Types). These derived datasets are generally based on an interpretation of the soil properties of individual soil series or soil horizons. Crucially, they often have process-based understanding at their core. Despite the fact that only few directly measured physical properties are available in the database, there have been significant developments in this area, principally the HOST classification (Boorman *et al.*, 1995). This approach uses morphological characteristics of soil horizons to assess the likely pattern of water movement through the soil and fits this to a series of conceptual models. Additional work has included the development and application of pedotransfer functions that enable unmeasured properties to be calculated from available data and knowledge.

Chemical data, largely derived from the analytical table were, for historical reasons, primarily aimed at properties broadly linked to measures of soil fertility. A dataset of soil carbon contents has been derived and work is currently underway to produce statistical summaries of the chemical status of the main soil horizons identified for each soil series that occurs within the 1:250 000 scale map. Maps of the soil geochemical signature have been produced from the soil geochemical database. An example of the incorporation of process-based knowledge in the chemical context can be found in the assessment of the sensitivity of Scottish soils to pollution by potentially toxic elements (PTE).

Current threats to soils and protection measures

Soil is essentially a non-renewable resource that is under pressure from land use and management, atmospheric deposition, urbanisation and global climate change. While earlier soil protection strategies concentrated on specific threats such as soil erosion, there is a now a need to consider the soil processes supporting the multiple functionality of soils. Soils provide a number of functions such as biomass production, environmental interactions as well as certain anthropogenic functions like provision of raw materials, a platform for man made structures and preservation of cultural heritage. Assessments of soil quality need to be based on soil process and function rather than indicators of quality based on composition alone.

There are a number of soil policies designed to protect soils or to provide a framework for soil protection (such as GAEC) and SSKIB will provide the data required to produce strategic assessments of those areas likely to be impacted by such policies. The development of the Scottish Soil Knowledge and Information Base is well placed to inform and provide input data to meet the requirements of the SEERAD Draft Research Strategy, particularly Programme Objective 7: Protecting the Nation's Soils.

Discussion Points, Conclusions and Next Steps

Stakeholder requirements

There was a general welcome for this initiative as it has clear links to broader Executive policies in relation to Freedom of Information and the network of Rural and Environmental Information. A number of the views expressed on data requirements reflected quite closely the functions that different agencies undertook and the environmental issues that required investigation, but there were also some generic issues common to all stakeholders. The main themes are as follows:

Issue 1: Diffuse pollution. This covered a number of different aspects including the risk of leaching of different contaminants (e.g. nitrate, pathogens), atmospheric deposition of metals and acid inputs (primarily N) and soil erosion and its downstream effects. Raw or derived soil data that would enable some quantitative assessment of risk to be made should, if possible, be made available as part of the integrated database.

Action: SSKIB team will review work already done in this area, for example on soil leaching potential, metal binding capacity and soil erosion and assess the feasibility of integrating the data under the proposed framework.

Issue 2: Soil quality indicators. This ranged from a need for indicators for semi-natural soils, where the main interest is in biologically mediated processes, to those which would help SEERAD define and implement the GAEC requirements on intensively managed soils. SEERAD also require some guidance on the impact of soil management to allow them to design and implement land management contracts.

Action**:** SSKIB team is currently working on a project to assess the conservation value of soil (SNH funded), is investigating the feasibility of assigning NVC types to major soil subgroups and soil series within this project and is part of a consortium investigating soil biological indicators. The SEERAD requirements identify some research needs – for example, 'what is Good Environmental and Agricultural Condition' – but these aspects are not currently part of the project specification for SSKIB and it would require additional staff resources and/or linkage to other SEERAD-funded research to address this issue.

Issue 3: Resolution of data: This project focuses on the 1:250 000 scale soil map and supporting attribute data. Some users identified the need for site-specific data for environmental assessment or for 1:10000 or 1:25000 scale soil maps for resource management decision making. Some indication of soil variability would also be valuable.

Action**:** Some of these requirements were beyond the scope of this project, although guidance can be given on the appropriateness of specific soil profiles in environmental assessment. In addition, the potential use of 1: 250 000 scale soils data in the growing area of Strategic Environmental Assessment was emphasised.

Some work on disaggregating the 1:250 000 scale soil map units using vegetation and/or topography is time-tabled within the project and in the longer term, this may help meet the requirement for more detailed spatial information. For each km square in the dataset, an indication will be given of the range, proportion and hence variability of the different soils within it. There is also the intention of supplying statistical summaries of each soil series.

Issue 4: Flexibility of use**:** There was a clear need for good metadata to support databases and the requirement to retain maximum flexibility in the data. Future uses of soils data (to support developing policies) are not always known. Scenario testing can be a useful policy appraisal option and soils knowledge and information would be required for running scenarios e.g. the effect of temperature changes on carbon stocks, soil leaching and storm events.

Action**:** The project intends to deliver data that are well-documented and accessible. The data are highly disaggregated and this has proved to be of the utmost importance in a number of previous applications.

Issue 5: Peat survey data: These data do not form part of the database at present and the data were collected using different protocols and methods and are catalogued in a different way from the soils data. It would not be possible to integrate these into the general framework discussed without preparatory work such as cataloguing and indexing existing hard copy data. Nevertheless, considerable interest was expressed in their content, their historical context (collected in the 1940s and 1950s) and their potential usefulness in climate change policy formulation in particular.

***Action*:** The SSKIB team will circulate more information on the type and range of data held, their geographical extent and potential methods of data capture. Funding will be sought for documenting and scanning the data, and options for digitising will be explored.

Discussion

Expertise It was felt that this initiative was timely as there is a diminishing pool of soil surveyors and scientists who have an intimate knowledge of how the soils data were collected and therefore how it can be interpreted. For example, there are differences in how soils maps were made pre 1970 and in how soil drainage was characterised. Important features such as these are not well documented.

One useful additional source of soils information are the field sheets which contain a large number of soil investigations - but these need a considerable amount of interpretation.

Urban soils In common with most soil databases the Institute data holdings lack information on urban soils. Experience from a study in Aberdeen suggests that soils from the rural hinterland can provide valuable background levels for urban soils but the generality of this observation remains to be tested. There was interest in whether urban soils could contaminate groundwater or what their role may be in diffuse pollution issues. This may be a function on how much ground disturbance there has been on the site and on the age of the building.

Biological indicators of soils Throughout Europe there is a considerable amount of interest in integrating biological indicators within soil monitoring schemes. However, there are significant difficulties in terms of spatial and temporal variability but equally there are significant opportunities in emerging molecular techniques. Current objectives within SSKIB are to consider vegetation, root distribution and evidence for bioturbation within profiles.

Network of Rural and Environmental Information in Scotland Some useful information on this initiative will be developed by Newall and Budge, IT consultants to SNH, in 3 Phases.

Phase 1 Data Cataloguing and Preparation (SE and SNH)
Phase 2 Consultation with other agencies
Phase 3 worth £333,000 - join Phases 1 and 2 together.

One of the outcomes would be an Extranet.

Relevance to the wider community There was a feeling expressed that these soil data, along with those from other initiatives such as the Network of Rural and Environmental Information in Scotland and the National Biodiversity Network will provide benefits to the wider community as well as the stakeholders represented at the meeting. These might include the Educational Sector (including the research community for whom a second workshop is anticipated) and to raise awareness amongst the general public of environmental data.

Next steps

A liaison group was established to ensure good lines of communication throughout the rest of the project. Members are:

Scottish Executive
Cameron Easton (Scottish Executive, NERIS)
Antje Branding (Scottish Executive, Environment Group)
Neil Henderson (Scottish Executive, Agriculture Group)
SEPA
Mark Aitken
SNH
Patricia Bruneau
Forestry Commission Scotland
Helen Mackay (Steve Brown to contact)
Steve Brown
Aberdeenshire Council
Gordon Mackie (Environment Manager, Aberdeenshire Council)
Links to COSLA will be explored by the SSKIB Group

Information to the Liaison Group will be supplied by e-mail and potentially through access to a password-protected website. An illustrative output of SSKIB is to be circulated when available to the members of the liaison group.

References:

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

Bown, C.J. and Heslop, R.F. 1979. The soils of the country around Stranraer and Wigtown (Sheets 1,2,3 and 4). Memoirs of the Soil Survey of Scotland. The Macaulay Land Use Research Institute, Aberdeen

Futty, D.W. and Dry, F.T. 1977. The soils of the country around Wick (Sheets 110, 116, and part 117). Memoirs of the Soil Survey of Scotland. The Macaulay Land Use Research Institute, Aberdeen

Macaulay Institute for Soil Research 1984. Organisation and methods of the 1:250 000 Soil Survey of Scotland. The Macaulay Institute for Soil Research, Aberdeen.

Appendix 1

List of Delegates

Name	**Affiliation**
Patricia Bruneau	SNH
Allan McKirdy	SNH
Mark Aitken	SEPA
Janette McDonald	SEPA
Elaine Simpson	SEPA
Antje Branding	SEERAD
Neil Henderson	SEERAD
Mike Parker	SEERAD
Steve Brown	Forestry Commission
Gordon Mackie	Aberdeenshire Council
Allan Lilly	Macaulay Institute
Ed Paterson	Macaulay Institute
Willie Towers	Macaulay Institute
Ann Malcolm	Macaulay Institute
Iain Wright*	Macaulay Institute
Steve Albon*	Macaulay Institute
Colin Campbell*	Macaulay Institute

* for part of workshop only.

Appendix 2

Scottish Soils Knowledge and Information Base workshop programme

22 September 2004, Macaulay Land Use Research Institute

10-10.30 am **Coffee and welcome**

10.30 – 12.15 **Current data holdings**

10.30 - 11.00 The Scottish soils database (Allan Lilly)

- Scottish Soil Database
    - National Inventory
    - Selected profiles
    - Grid and transect
    - Analytical data
    - Geochemical data
    - Soil hydrological data
    - Biological data
    - Peat survey data

11.00 – 11.30 Scottish soil classification and maps (Willie Towers)

- Soil classification and map keys
- 1: 250 000 scale maps
- 1: 63 360 and 1: 50 000 scale maps
- Relationship between the different map scales
- Others e.g. detailed (1:10 000) ad hoc and peat maps

11.30 – 12.15 Secondary and derived datasets (Allan Lilly)

- Non-spatial
    - Pedotransfer functions (PTFs) for soil hydrological data
    - Summary chemical data
    - HOST
    - Geochemical

- Spatially distributed datasets
    - Nitrate Vulnerable Zones (NVZ) texture maps
    - Soil Leaching Potential (SLP)
    - Geochemical

12.15 – 12.45 **Discussion on data required by delegates**

12.45 – 13.45 **Lunch with an opportunity to view and discuss maps, posters and data informally**…….

13.45 – 14.15 **Policy drivers affecting soil** (Ed Paterson)

14.15– 14.30 **Future plans for Scottish Soils Knowledge and Information base** (Allan Lilly)

- Make soils data more accessible
- Derive a common framework for the derived datasets
- Derive modal profiles
- Provide summary statistics
- Document the datasets

14.30 – 15.30 **Open discussion, summary, next steps and formation of a liaison group**

15:30 **Tea/Coffee and close**

Appendix 3

Presentations

Scottish soils database

Information held on Scottish soils

Soil database
- Over 13,000 soil profiles, each with up to 100 attributes
- Flagged subsets including National Soils Inventory
- Transect data, intensive grid sampling etc.

Soil maps
- Range of scales with appropriate classification
- Some digitised but not all

Derived datasets
- Hydrology of soil types (HOST)
- Soil Leaching Potential
- Soil Texture for NVZ support
- Predicted hydrological properties

Scottish Soil Database: Profiles

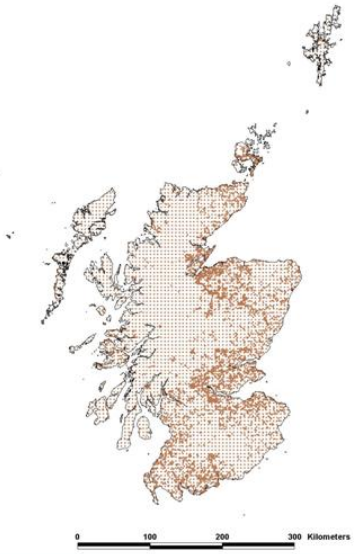
- Sources:
  - National Inventory
  - Selected profiles
  - Grid and transect
- Data:
  - Morphological
  - Analytical data
  - Geochemical data
  - Soil hydrological data
  - Soil biological data
    - Peat database

Distribution of all soil profiles held in the Scottish Soils Database:

- Inventory, selected and grid or transect
- 13 303 Profiles recorded
- 17 086 Mineral horizons
- 7 179 Organic horizons

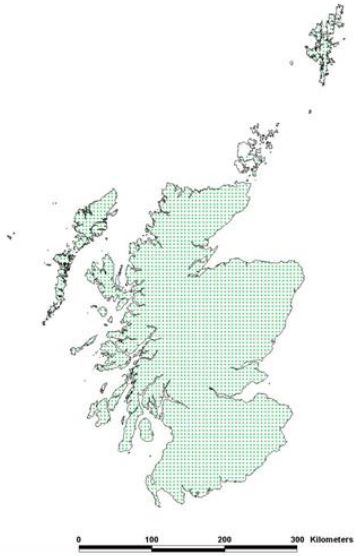
+ approx 33 350 hard copy horizon data

- 43 706 Records of analyses



Distribution of all soil inventory profiles held in th Scottish Soils Database:

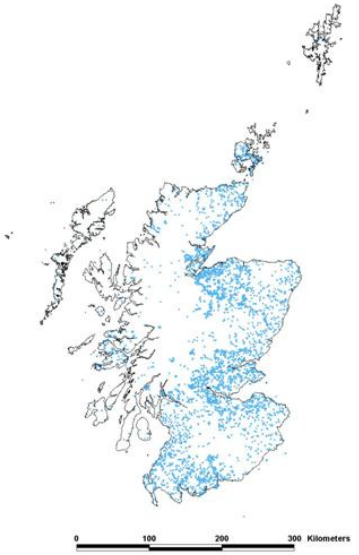
- Objectively sampled
- Aligned to 5km intersects of National Grid
- 3035 locations
- 2826 soil profiles
- 3730 records of analyses from 10km samples



Distribution of all non-inventory soil profiles held in the Scottish Soils Database:

- Subjective or grid/transect
- Georeferenced
- 10 477 soil profiles
- 39 976 records of analyses

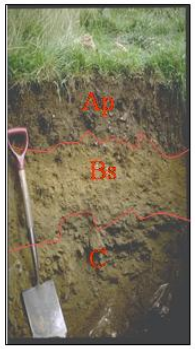
6 500 profiles are in hard copy
33 350 hard copy horizon descriptions



Scottish soil database:

Profile name:
Grid reference:
Surveyor:
Sample date:
Altitude:
Slope description:
Aspect & bearing:
Rocks and boulders:
Vegetation:
Flushing:
Site drainage:
Soil drainage:
Erosion:
Association/ Series:
Parent material:
Major soil subgroup:
Rock type:
Climate:
Land Capability Agriculture
Base of pit:
Bulk samples:

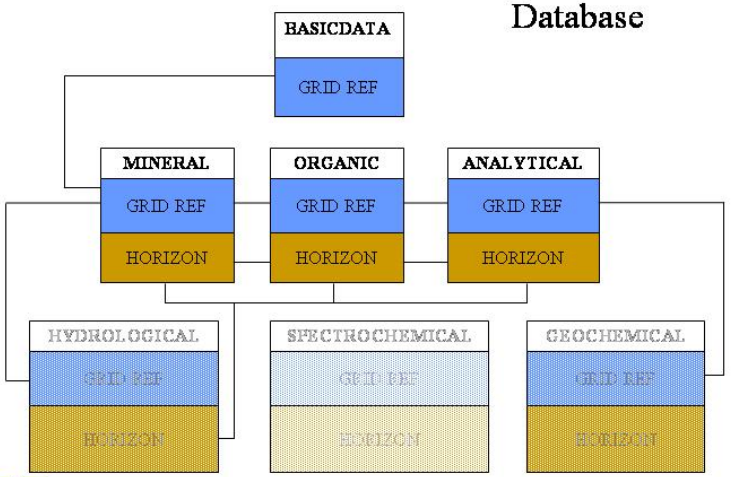
Each soil profile has up to 100 attributes



SYMBOL	LABNO
DEPTH	SYMBOL
COLOUR	LOSS ON IGNITION
MOTTLES	CALCIUM
TEX TURE	MAGNESIUM
STRUCTURE	SODIUM
MOIST	POTASSIUM
CONSISTENCE	HYDROGEN
ROOTS	SUM
STONES	SATN
BOUNDARY	pH
	CARBON
	NITROGEN
	OM
	TOTP
	ACET_P
	TOP
	BOTTOM
	SAND
	SILT
	CLAY

Scottish Soils Database structure:

Relational Database



Profile name:	MINEFIELD 1
Grid reference:	NS8465059850
Surveyor:	A. Lilly
Sample date:	20-08-91
Altitude:	230 m
Slope description:	4 degrees; convex, complex
Aspect & bearing:	SSE , 166 degrees
Rocks and boulders:	no rock outcrops, no boulders
Vegetation:	Permanent & old ley pastures of rye-grass and crested dogs-tail
Flushing:	none
Site drainage:	normal
Soil drainage:	imperfect
Erosion:	none
Association/ Series:	Rowanhill Caprington
Parent material:	**till**
Major soil subgroup:	noncalcareous surface-water gley
Rock type:	sandstone and shale
Climate:	Euoceanic very humid hemiboreal orohemiboreal
Land Capability Agri:	3.2W
Base of pit:	lowest horizon continues
Bulk samples:	10-20 35-45 60-70
Lab number range:	425446-448

A pg: 0 - 24 cm; very dark greyish brown, **10YR 3/2 matrix** colour; strong brown, **7.5YR4/6 mottle** colour; **sandy silt loam; few very fine prominent sharp mottles; moderate very coarse subangular blocky structure tending to strong fine subangular blocky structure; moist; friable;** few very fine fibrous roots; few medium subrounded stones; few very small subangular stones; sharp smooth boundary.

B g: 24 - 55 cm; brown, **7.5YR 5/2 matrix** colour; brown, **10YR 5/3 ped face** colour; strong brown, **7.5YR 5/6 mottle** colour; **sandy clay loam; abundant fine prominent clear mottles; strong very coarse prismatic structure; moist; firm;** few very fine fibrous roots; common small subangular stones; common medium subangular stones; clear smooth boundary.

THE MACAULAY INSTITUTE

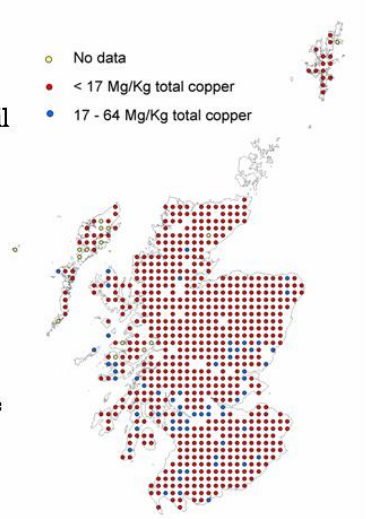
Geochemical data

- Early data was published by Mitchell, Ure and Berrow in a series of landmark papers
- Data largely obtained by spectrometric methods which gave total concentrations
- For subsoils, strong relationship to soil association but for topsoils relationship was much weaker
- Heavily biased towards lowland soils obtained from early survey activity
- Major difficulty in relating these data to current environmental standards because of methodology and lack of analytical quality control

THE MACAULAY INSTITUTE

Geochemical data

- Recent data based on National Soil Inventory (10km intersects)
- Samples from centre of topmost genetic horizon
- Analysis by ICP-OES of *aqua regia* digests for 19 elements
- Inclusion of analytical quality control
- Data held in ORACLE and can be linked to GIS



THE MACAULAY INSTITUTE

ISSUES:

Ageing data:

Approximately 50% of soil analytical data are pre -1970

Accessibility:

6 500 profile descriptions in hard copy only

'Raw' data interpreted for use by non-specialists

THE MACAULAY INSTITUTE

ISSUES:

User friendliness

- Data held as series of codes
- Transect and grid data distort statistical analyses
- Selected profiles can give bias

Appropriateness

How appropriate are the data for answering today's problems?
for example: lack of soil biological and hydrological data

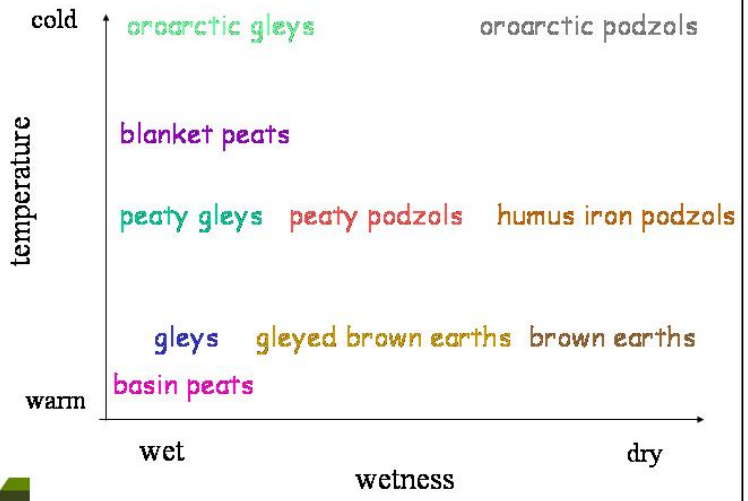
THE MACAULAY INSTITUTE

Scottish Soil Classification and Soil Maps

THE MACAULAY INSTITUTE
Craigiebuckler, Aberdeen, AB15 8QH, UK

Soil classification

- Based on morphological features recognised within soil profiles
- Sequence and nature of different horizons
- Comparison of profiles with central concepts of soil classes
- Typological rather than definitional

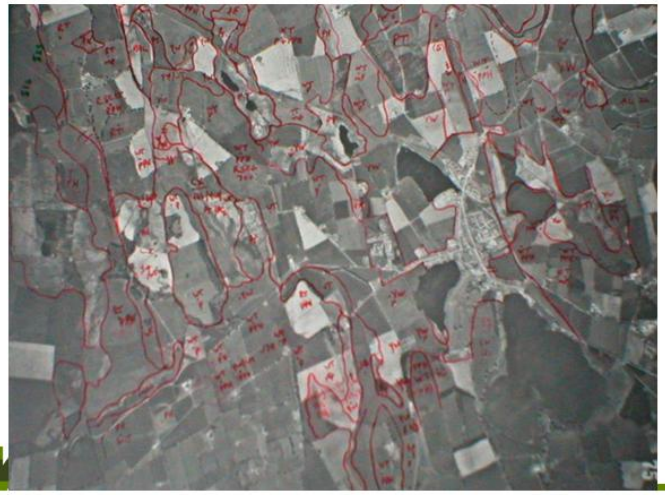


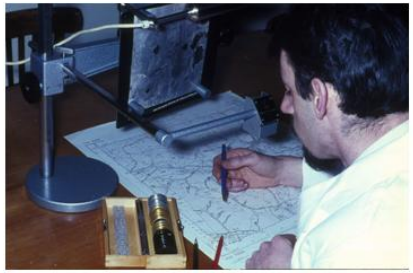
Soil classification

Level in Classification	Example	Description
Division	Leached soils (3)	Soils characterised by uniformly coloured B horizons, by an absence of free lime and by an acid reaction in their A and B horizons. The lower horizons may show some gleying
Major Soil Group	Podzols (3.3)	These soils have a surface organic horizon underlain by a grey bleached E horizon and a brightly coloured B horizon which often contains illuviated sequioxides of iron, aluminium and organic matter and which has a strongly acid reaction
Major Soil Subgroup	Humus-iron podzols (3.3.2)	These soils have a surface aerobic organic horizon and occasionally a thin Ah horizon. There is a pale E horizon overlying humus enriched and/or iron and aluminium enriched B horizon. The drainage of the soil may be free or inhibited.
Series	Countesswells	Freely drained humus-iron podzol developed on granitic parent material

Soil mapping: on field sheets

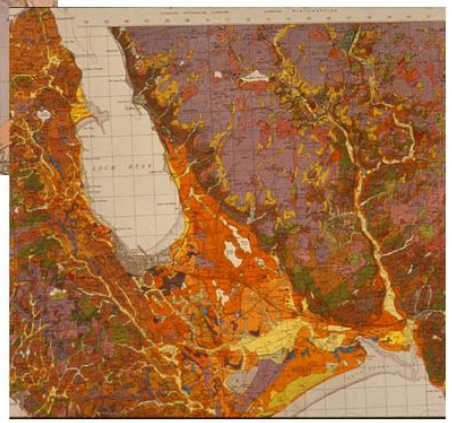
Or air photographs





Transfer of data from field survey

From field sheet to published map



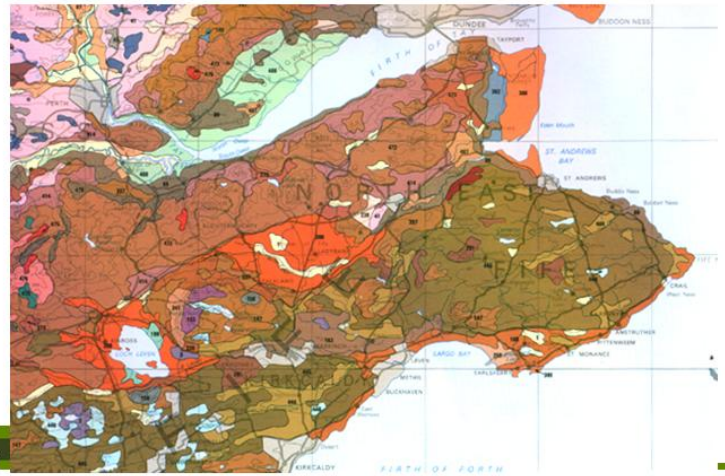
Terms used on soil maps

- Soil Association
  - a grouping of soils developed on similar parent material – lithogenic factors
- Soil Series
  - Soils with a similar type and arrangement of horizons developed on similar parent material – the major soil sub-group – pedogenic factors
- Soil Complex
  - Units comprising two or more soil series, often in a recurring pattern related to landform features

Soil maps – two principle published sets

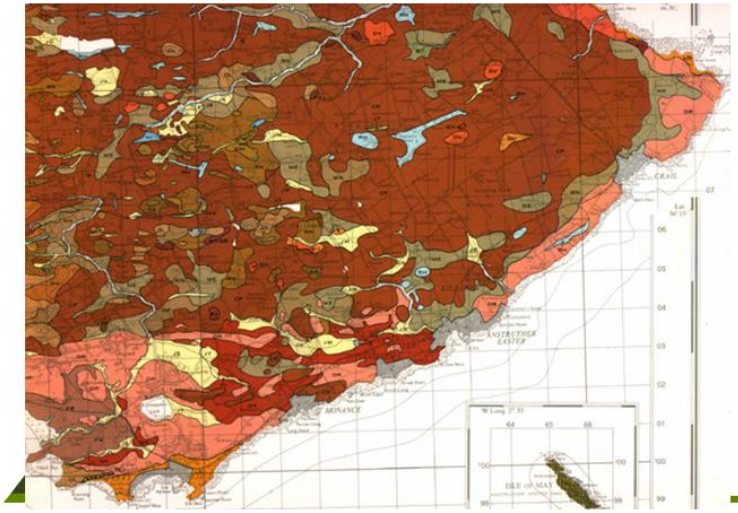
- 1:250 000 scale soil map
  - complete national coverage
  - fully digitised
  - most soil map units are complexes, based on major subgroups
- 1:63 360/1:25 000 scale
  - primarily improved agricultural land and upland fringes
  - partially digitised
  - map units based on soil series and complexes of soil series

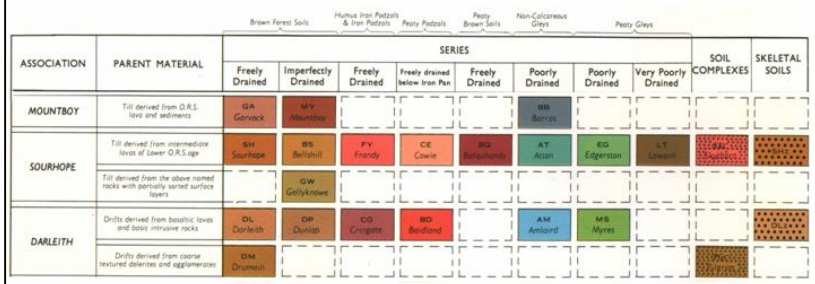
1: 250 000 scale soil map



ASSOCIATIONS	PARENT MATERIALS		COMPONENT SOILS	LANDFORMS	VEGETATION
ABERLOUR	Drifts derived from acid schists and granitic rocks	5	Noncalcareous gleys, peaty gleys; some humic gleys and peat	Valley sides with concave and regular, gentle and strong slopes; non-rocky	Rush pastures and sedge mires Arable and permanent pastures Bog heather moor and blanket bog
		6	Humus-iron podzols; some brown forest soils and gleys	Hills and valley sides with gentle and strong slopes; non-rocky	Arable and permanent pastures Dry Boreal heather moor
		7	Peaty podzols, peat; some peaty gleys and humus-iron podzols	Hills and valley sides with strong and steep slopes; non-rocky	Moist Boreal heather moor Blanket and upland blanket bog Bog heather moor
		8	Peaty podzols, peat, peaty gleys	Hummocky valley moraines	Moist Boreal heather moor Heath-rush - fescue grassland Bog heather moor and blanket bog
		10	Peaty podzols, humus-iron podzols; some peaty gleys and rankers	Hills and valley sides with strong and steep slopes; moderately rocky	Dry and moist Boreal heather moor Tussock-grass - white bent grassland
		11	Peaty gleys, peat; some peaty podzols and peaty rankers	Undulating hills with gentle and strong slopes; moderately rocky	Moist Boreal heather moor Blanket and upland blanket bog Bog heather moor
		12	Subalpine soils; some peat and rankers	Mountains with gentle to very steep slopes; non- to very rocky	Alpine lichen heath Lichen-rich Boreal heather moor Mountain blanket bog
		13	Peat, subalpine soils; some alpine soils	Mountains with gentle and strong slopes; non- to moderately rocky	Mountain blanket bog Alpine lichen heath Stiff sedge - fescue grassland
		14	Alpine soils	Mountain summits with gentle and strong slopes; non- and slightly rocky	Alpine lichen heath Stiff sedge - fescue grassland Alpine club-moss snow-bed
		15	Rankers, lithosols; some alpine soils	Mountain summits with strong to very steep slopes; very rocky	Blaeberry and bog whortleberry heath. Alpine lichen heath Stiff sedge - fescue grassland

1: 63 360 scale soil map





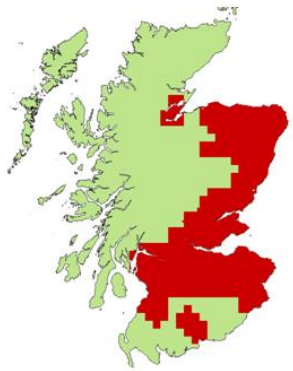
ASSOCIATION	PARENT MATERIAL	SERIES: Freely Drained (Brown Forest Soils)	SERIES: Imperfectly Drained (Brown Forest Soils)	SERIES: Freely Drained (Humus Iron Podzols & Iron Podzols)	SERIES: Freely drained below Iron Pan (Peaty Podzols)	SERIES: Freely Drained (Peaty Brown Soils)	SERIES: Poorly Drained (Non-Calcareous Gleys)	SERIES: Poorly Drained (Peaty Gleys)	SERIES: Very Poorly Drained (Peaty Gleys)	SOIL COMPLEXES	SKELETAL SOILS
MOUNTBOY	Till derived from O.R.S. lava and sediments	GA Garvock	MY Mountboy				BB Borras				
SOURHOPE	Till derived from intermediate lavas of Lower O.R.S.age	SH Sourhope	BS Bellshill	FY Frandy	CE Cowie	BQ Balquhomly	AT Arcan	EG Edgerston	LT Lowslin	BAC Balquhomly 2	
	Till derived from the above named rocks with partially sorted surface layers		GW Gellyknowe								
DARLEITH	Drifts derived from basaltic lavas and basic intrusive rocks	DL Darleith	DP Dunlop	CG Craigate	BD Bardfield		AM Amlaird	MS Myres			
	Drifts derived from coarse textured dolerites and agglomerates	DM Drumsoil									

Soil maps – differences and relationships

- 1:250 000 scale
  - Soil map units based on major soil subgroup(s)
  - Landform an explicit part of the legend – slope and rockiness classes
  - General (e.g.lowlands, foothills) and specific terms (raised beach, moraines) also used
  - Each unit has a description of the associated vegetation classes (after Birse and Robertson)

Soil maps – differences and relationships

- 1:63 360/1:25 000 scale
  - **primarily cover improved agricultural land and adjacent upland fringes**
  - **mapping carried out at 1: 25 000 scale**
  - **partially digitised**
  - **map units based on soil series**
  - **Some soil series separated into phases e.g. on stoniness, depth,**



1: 25 000 scale map coverage

Additional soil maps and surveys

- 1:50 000 provisional series
- 'ad hoc surveys; 1:10 000 scale or larger (largely unpublished)
  - National Nature reserves e.g. Inverpolly, Rum..
  - Research farms e.g. Achany, Lephinmore, Mylnefield….
  - Estates e.g. Mar, Rahoy, Glenfeshie
  - Pre-development surveys e.g. Sullom Voe, Flotta, A9 upgrading
  - Many LCA and open-cast coal surveys

Peat survey maps

- To quantify the area, volume and quality of some of the major bogs across Scotland
  - For use as fuel or in horticulture
- All in hard copy (as are the associated attribute data)
- Of value in climate change studies?

Secondary and derived datasets

Derived datasets: For example

Non-Spatial:

- Predicted soil hydrological properties
- Summary chemical data

Spatial:

- NVZ texture maps
- SLP maps
- Soil quality indicators

Structure of derived non-spatial datasets

Primarily based on soils within the 1:250 000 scale spatial dataset

'typical' horizon sequences were assigned

attributes derived for each horizon

SERIES	SYMBOL	TOP	BOTTOM	CLAY	SILT	SAND	CA	MG	NA
COUNTESSWELLS	Ap	0	30	6	34	60	4.31	1.14	0.20
	Bs	30	65	5	32	63	0.66	0.16	0.10
	BCx	65	100	6	22	72	0.65	0.13	0.06
DARLEITH	Ap	0	25	15	37	48	13.57	3.19	0.25
	B	25	50	15	35	50	9.25	2.49	0.24
	C	50	100	15	35	50	13.66	5.40	0.29
ETC									

Predicted soil hydrological properties:

Estimates of soil moisture retention

- Available water capacity
- Field Capacity
- Saturation

Based on:

- Soil texture
- organic matter contents

But, these are based on data from England and Wales or Europe

We have a research project that is aiming to validate these predictions for Scottish soils

Example summary chemical data:

Based on the 43 706 records of analyses

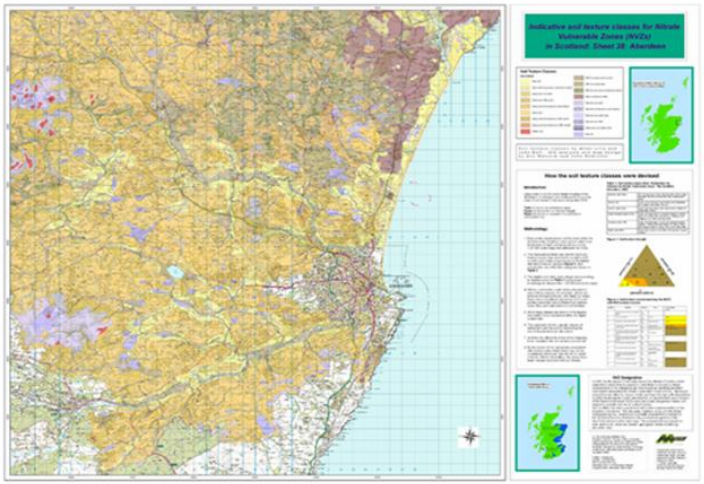
Geometric means, means, median and standard deviations for 14 chemical properties

SERIES	SYMBOL	TOP	BOTTOM	CLAY	SILT	SAND	CA	MG	NA
COUNTESSWELLS	Ap	0	30	8	34	60	4.31	1.14	0.20
	Bs	30	65	5	32	63	0.66	0.16	0.10
	BCx	65	100	6	22	72	0.65	0.13	0.06
DARLEITH	Ap	0	25	15	37	48	13.57	3.19	0.25
	B	25	50	15	35	50	9.25	2.49	0.24
	C	50	100	15	35	50	13.66	5.40	0.29
ETC									

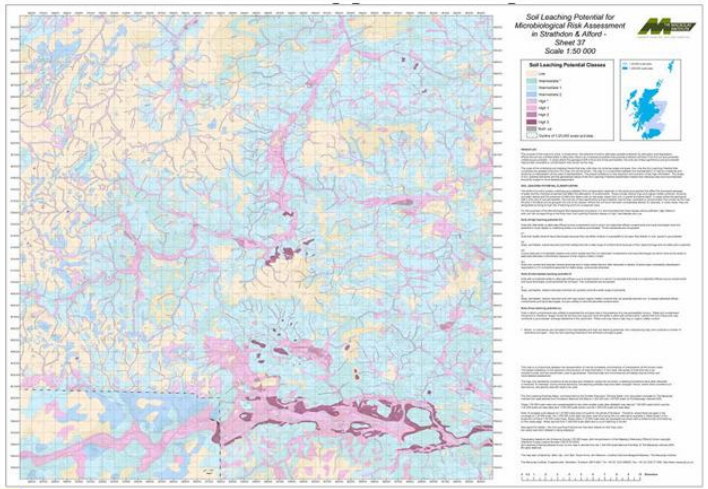
Includes an extensive evaluation of Carbon contents

Examples of Spatial datasets:

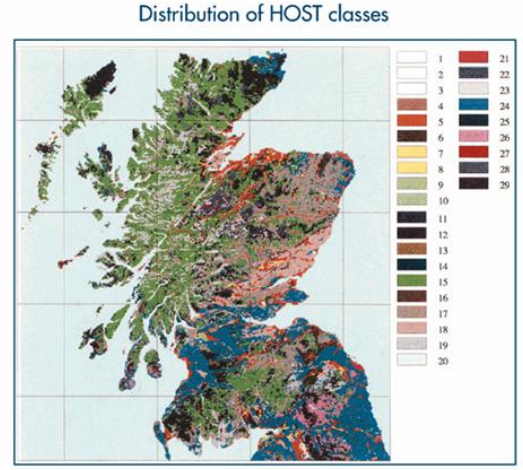
Soil texture maps to support NVZ Action Programme



Soil leaching potential



Hydrology of soil types (HOST)



Data sources:

- **Spatial distribution of soils**
  (from 1: 250 000 scale soil maps of the UK)
- **Soil morphological data**
  (from over 24 000 soil profile descriptions)
- **Soil hydrological properties**
  (from a database of over 4000 soil moisture retention curves and bulk densities)
- **Event hydrographs from the National Water Archive**
  (BFI, SPR)

Institute of Hydrology

HOST is:

- **based on the known relationships between soil morphology and soil hydrology**
- **based on the conceptualisation of water movement through soil and substrates**
- **calibrated against catchment indices**
- **applicable to a wide range of projects**

Institute of Hydrology

Profile name:	MINEFIELD 1
Grid reference:	NS8465059850
Surveyor:	A. Lilly
Sample date:	20-08-91
Altitude:	230 m
Slope description:	4 degrees; convex, complex
Aspect & bearing:	SSE , 166 degrees
Rocks and boulders:	no rock outcrops, no boulders
Vegetation:	Permanent & old ley pastures of rye-grass and crested dogs-tail
Flushing:	none
Site drainage:	normal
Soil drainage:	imperfect
Erosion:	none
Association/ Series:	Rowanhill Caprington
Parent material:	till
Major soil subgroup:	noncalcareous surface-water gley
Rock type:	sandstone and shale
Climate:	Euoceanic very humid hemiboreal orohemiboreal
Land Capability Agri:	3.2W
Base of pit:	lowest horizon continues
Bulk samples:	10-20 35-45 60-70
Lab number range:	425446-448

A pg: 0 - 24 cm; very dark greyish brown, **10YR 3/2 matrix** colour; strong brown, **7.5YR4/6 mottle** colour; **sandy silt loam; few very fine prominent sharp mottles; moderate very coarse subangular blocky structure tending to strong fine subangular blocky structure; moist; friable;** few very fine fibrous roots; few medium subrounded stones; few very small subangular stones; sharp smooth boundary.

B g: 24 - 55 cm; brown, **7.5YR 5/2 matrix** colour; brown, **10YR 5/3 ped face** colour; strong brown, **7.5YR 5/6 mottle** colour; **sandy clay loam; abundant fine prominent clear mottles; strong very coarse prismatic structure; moist; firm;** few very fine fibrous roots; common small subangular stones; common medium subangular stones; clear smooth boundary.

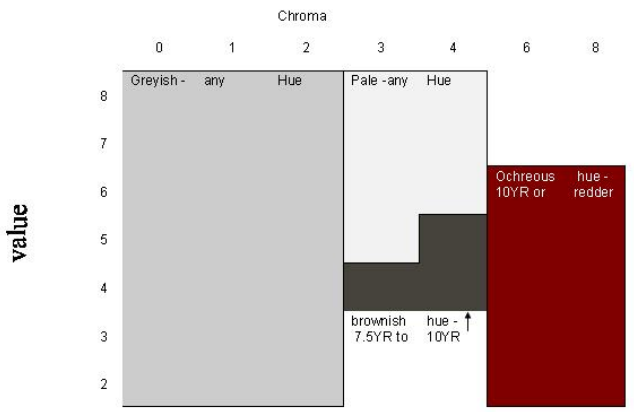
C g: 55 - 85 cm; dark yellowish brown, **10YR 4/4 matrix** colour; grey, **10YR 5/1 ped face** colour; strong brown, **7.5YR 5/6 mottle** colour; **sandy clay loam; common fine distinct sharp mottles; massive structure; moist; firm;** no roots; many large angular undifferentiated sandstone stones; common very small subangular undifferentiated shale stones .

Pedotransfer rules to determine permeability:

	Fine	Medium	Coarse	Very coarse
Granular	permeable			
Subangular blocky			slowly permeable if >18% clay and weakly developed structure	
Angular blocky	slowly permeable if >18% clay and weakly developed structure			
Prismatic			slowly permeable if >18% clay	
Platy				
Massive	slowly permeable if >18% clay *or* a silty loam, sandy silt loam or sandy loam texture *and* at least a firm consistence			

After MAFF 1988.

Pedotransfer rules to determine gleying:



Background levels of contaminants in Scottish soils

- Soil Association used as the first discriminating attribute – subsoil geochemical signature inherited from parent rock
- Further separation based on presence or absence of organic surface horizon

Corby and related soil associations

More info:
http://www.sepa.org.uk/publications/reports4sepa/contaminants_scottish_soils.pdf

Soil PTE concentrations (mg/kg):

Mineral surface horizons: (map units 113, 114, 115*, 116* 121, 122, 125, 128, 136)

	Cd	Cu	Cr	Pb	Ni	Zn
Median	0.13	2.7	29.9	17.2	10.0	32.9
Lower quartile	0.11	1.4	16.4	15.3	5.0	25.2
Upper quartile	0.15	4.5	31.6	20.5	13.3	42.0
Minimum	0.05	0.2	2.3	13.3	1.0	6.9
Maximum	0.25	10.5	43.7	30.7	19.4	44.6
No of samples	12	12	12	12	12	12

Organic surface horizons: (map units 115 - 126, 123, 124, 126, 127, 129, 131 - 137)

	Cd	Cu	Cr	Pb	Ni	Zn
Median	ND	5.0	3.9	39.5	3.2	30.6
Lower quartile	ND	3.0	2.9	26.2	2.4	25.6
Upper quartile	ND	6.4	6.9	76.8	4.3	51.0
Minimum	ND	1.2	1.5	14	1.4	12.5
Maximum	ND	14.9	30	213	9.8	122
No of samples	ND	19	19	19	19	19

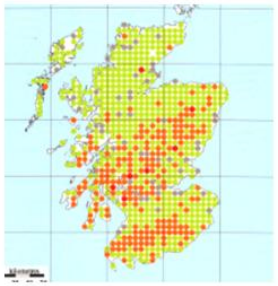
Subsoil (B) horizons:

	Cd	Cu	Cr	Pb	Ni	Zn
Mean	ND	8.8	59.5	20.0	23.3	47
Range	ND	1 - 50	14 - 150	6 - 70	3 - 80	37 - 72
No of samples	ND	175	81	80	181	3

ND - Not determined

Soil Quality Indicators

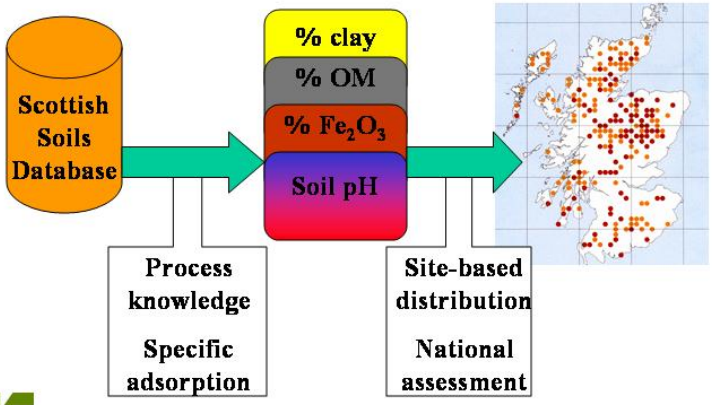
Pb/ compositional



Pb/ process-based

Pb content suggests that many soils in Scotland are at limits but examination of binding capacity suggests that hazard is much reduced.

Soil sensitivity to pollutants



Assessment of zinc binding capacity for two contrasting soils

	Soil A	Soil B
pH ($CaCl_2$) of topsoil	6.1	4.9
Binding strength score	*4.5*	*2.0*
Organic matter content (%)	9	6
Binding strength score	*0.5*	*0*
Topsoil texture	Sandy clay loam	Loamy sand
Binding strength score	*0.5*	*0*
Topsoil colour (surrogate for iron oxide conc)	7.5YR3/3	10YR3/2
Binding strength score	*0.5*	*0*
Total score	***6.0***	***2***
Binding strength	**Very strong**	**Weak**

Soils – current concepts, policy drivers and integrative opportunities

THE MACAULAY INSTITUTE *Craigiebuckler, Aberdeen, AB15 8QH, UK*

Rationale

- Sustainability is a key policy driver for both UK and devolved governments
- Maintenance of environmental capital is an important objective in strategies for sustainable development
- For an essentially non-renewable resource such as soil, soil protection has an important role to play
- However, for a living, dynamic resource with many functions, such as soil, what do we mean by protection and how can it be achieved?

Threats to soil resource

- Inappropriate land use and management regime
- Atmospheric deposition and effects on biogeochemical cycles and nutrient status
- Exceeding the capacity of soils to act as a biogeochemical reactor in processing wastes
- Extraction and utilisation of peatlands
- Direct and indirect impacts of climate change
- 'Hard' development, urbanisation

Soil protection - development of concepts

- Early work was aimed at specific, perceived threats to the soil resource e.g. loss of arable soil due to erosion
- Later, work on soil acidification highlighted the importance of soil processes in the assessment of wider environmental damage, e.g. vegetation and waters
- In the future, the concept of soil quality based on functions and processes can provide a suitable basis for a holistic approach to soil protection

Functions of soils (Blum 1993)

Three ecological functions

- Biomass production
  - Arable crops
  - Forestry
  - Forage crops
- Environmental interaction
  - Diffuse pollution to waters
  - Transformation of wastes
  - Carbon storage
- Support for ecological habitats and biodiversity

Functions of soils (Blum 1993)

Three anthropocentric functions

- Provision of raw materials
  - sand, gravel, clay
- Platform for man-made structures
  - Housing development
  - Road construction
- Cultural heritage
  - Preservation of artefacts
  - Markers of land management and cultivation

Soil function, processes and properties

Functional Area	Issue	Key process	Properties
Environmental Services	Response to pollutants	Adsorption	Soil pH OM content Reactive surfaces Clay content
	Transport to waters	Leaching	Soil wetness Soil Texture Soil Structure Plant cover
	Transformation of pollutants	Microbial	Microbial activity Microbial diversity

Soil Quality

- Soils are multifunctional and soil quality must be an integrative concept that reflects the functions undertaken by soils in the environment
- Indicators of soil quality are needed to indicate
  - Current state, Direction of change, Exceedance of Critical limits
- Indicators based on composition have significant limitations, particularly as environmental regulation moves towards a risk based approach
- For the assessment of trade-offs in land use – need to consider how to value soil as an environmental asset

Integrating an economic approach

(Taken from work by Ian Hodge, 1993)

Total economic value = Use values + Non-use values

USE VALUES

- DIRECT USE VALUES
  - Marketed outputs; crops, meat, timber, energy
  - Unpriced benefits; landscape, rural culture, recreation
- ECOLOGICAL FUNCTION VALUES
  - Benefits; carbon storage, water quality, flood control, waste assimilation

Valuing Environmental Assets

Total economic value = Use values + Non-use values

NON-USE VALUES

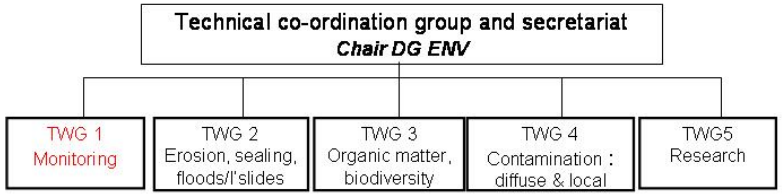
- OPTION VALUES
  - Benefits gene pool, future drugs, recreation options
- EXISTENCE VALUES
  - Benefits satisfaction from knowledge of existence
- BEQUEST VALUES
  - Benefits stewardship and inter-generational equity

Soil protection - policy background

- Soil Charter (Council of Europe, 1972, FAO-UN 1981)
- Sustainable Development (UN Agenda 21, 1992; UK Strategy, 1994; Indicators, 1996)
- Sustainable Use of Soils (RCEP Report, 1996)
- EU Thematic Framework for Soil Protection (2002)
- Soil Strategy for England (2003)
- Impacts of other EU Directives and policies, e.g. Water Framework Directive and CAP reform

EC Thematic Framework for Soil Protection

5 Technical Working Groups



SNH and SEPA are represented in TWG 1 and TWG 3, respectively

Soil monitoring

- Desire for a harmonised system across Europe BUT what are the issues?
  - Grid based monitoring? 16km spacing?
  - Parameters to be measured?
  - How to overcome soil variability?
  - Subsidiarity for member states and/or devolved administrations?
  - Representivity to ensure that all the soil resource is included?

Timetable: at Summer 2004

(with thanks to Peter Loveland)

Aim: Single, strategic package = Soil Protection Framework

Including: Soil monitoring; Composts; Sewage sludge regulations and links to other Directives e.g. WFD, CAP

Final reports of WGs – May 2004
EU Consultation May – Sept./Oct. 2004
"Opinion" – November 2004 ???
Draft Directive – first quarter/half 2005 ???
Implementation – 2007/2008???

THE MACAULAY INSTITUTE *Craigiebuckler, Aberdeen, AB15 8QH, UK*

CAP reform – GAEC measures

Issue	Standard	Measure	Guideline
Soil Erosion: Protect soil through appropriate measures.	Minimum land management reflecting site specific conditions.	2) In areas prone to wind erosion you must take steps to reduce the risk of soil loss in spring.	2) There are measures available to minimise soil erosion by the wind. These are — maintaining crop cover, using coarse seedbeds, shelter belts, nurse crops or mulches. You should undertake all or some of these measures if there is a risk of soil erosion by the wind.
Soil Structure: Maintain soil structure through appropriate measures.	Appropriate machinery use.	13) Do not carry out any cultivations if water is standing on the surface or the soil is saturated.	13) By avoiding field cultivations in wet conditions erosion, compaction and rutting of the soil will be avoided. Minimise frequent vehicle movements over the same area of land, especially in poor conditions. Consider the use of low ground pressure tyres, dual wheels or tracked vehicles to minimise impact on soils. Saturation is indicated by the appearance of water when pressure is added e.g. from a footprint.

14 of the 23 measures are soil-related.

Soil Action Plan for England

- Sets out 53 actions
- Spread across a number of soil issues
  - **Core actions**
  - **Soils for agriculture and forestry**
  - **Soils and biodiversity**
  - .....
- Will be reviewed in 2006 with the intention of drawing up a second plan with a longer forward vision

Soil policy in preparation for Wales, what about Scotland?

SEERAD Draft Research Strategy

- Programme 3: Environment – Land Use and Rural Stewardship
  - Programme Objective 7: Protecting the Nation's Soils
- Three Cross-cutting programmes
  - Responding to climate change
  - Protecting Scottish biodiversity
  - Sustainable rural development

Programme Objective 7: Protecting the Nation's Soils – Illustrative outputs

- Methods to measure 'health' and status
- Conservation value of soil
- Natural and cultural heritage value of soils
- Climate change and soils….

- Scottish Soil Information and Knowledge Base can play a significant role in scoping this programme in terms of the Nation's soils

Scottish Soil Knowledge and Information Base - SSKIB

Background:

- Increased requirement for data on Scottish soils from a range of non-soils specialist end-users: Current soil classification is not 'user-friendly'
- Scotland has a comprehensive soils dataset but the data have been collected over a long time and have suffered from a lack of investment
- Although the derived datasets are rooted in a common database, they have differing frameworks
- To meet the needs of end-users there is now a requirement to reconsider the form in which this data are supplied and the way in which they are linked and their currency

Deliverables:

- Information base that will describe the soil resource of Scotland in a form that will be of direct value to end-users
- Based on the 1:250 000 scale national soil map
- For each series, the identification of a modal profile
- For each series, a statistical summary of analytical and other data
- Documentation of the various datasets in a consistent and accessible way
- An assessment of opportunities for future data enhancement and measurements

Development issues

- Soil classification is the key to understanding and use but is not 'user-friendly'
- Database has grown organically but there is now a need for commonly agreed framework
- Spatial heterogeneity of map units should be quantified and encapsulated in project outputs

Liaise with NSRI on developments in digital soil mapping

Continued engagement of end-users

Development issues (future beyond 2006)

- Approximately 50% of soil analytical data are pre -1970
- Archival soil material and data
- Approximately 50% of the detailed soil mapping is pre-1970
- Soil biological data – vegetation communities
- Addition of peat data?
- Urban or highly disturbed soils
- Soil science community is shrinking