

Soil and Earth Science Information

Note SESIN 31 - Stirling





Scottish Natural Heritage
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COMMISSIONED REPORT

Commissioned Report 673

Soil and Earth Science Information Note
SESIN 31 - Stirling

For further information on this report please contact:

Dr Patricia Bruneau
Scottish Natural Heritage
231 Corstorphine Road
EDINBURGH
EH12 7AT
Telephone: 0131 3162618
E-mail: patricia.bruneau@snh.gov.uk

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COMMISSIONED REPORT

Summary

Soil and Earth Science Information Note SESIN 31 – Stirling

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The “Soil and Earth Science Information Note” series aims to facilitate access to and understanding of soil and relevant Earth Heritage information for non-soil specialists dealing with spatial planning and environmental assessment in Scotland.

The demand for information on geodiversity (defined as the diversity of rocks, minerals, fossils, landforms, sediments and soils in an area, together with natural processes, such as erosion and landslips that may still be active) has arisen from requirements to account for soil issues in strategic and environmental impact assessment.

Safeguarding geodiversity is as relevant as safeguarding biodiversity to ensure appropriate delivery of ecosystem services and functions for the benefit of Scotland's people and environment. Therefore being able to understand the role and organisation of geodiversity resources around us will help in tasks such as:

- Spatial planning – ensuring appropriate location and extent of a development footprint.
- Managing soil carbon resources – knowing where peatlands are located to manage and restore peat soil, and minimise GHG releases from soil.
- Protecting features of scientific, cultural and historical interest, outside of the suite of designated areas (including SNH natural heritage features of national importance, Scottish Natural Heritage, 2011)
- Promoting sustainable use of natural resources, allowing space for natural processes to adapt to change (e.g. soft engineering for flood defence) and protecting environmental services delivery.

Changes in the licensing agreements for use of digital soil information, held by the James Hutton Institute and others, and the development of environmental web portals for Scotland (SEWEB; SSW) have promoted easier access to data. However, such data are not always directly usable by non-soil specialists and strategic decision makers.

This SESIN series of reports provides a snapshot of the main soil resources available in digital and paper format for a defined geographical context (i.e. local authority boundaries). The description of classification and data interpretation is allied to information made accessible by Scottish Government and partners on the Scotland's Environment Web site (SEWeb) and its daughter web site the Scottish Soil Website (SSW). Each of the 32 local authority areas in Scotland is described in a separate report. The report provides detail on available hard copy and digital information relevant to the area, summary tables of key resources and illustrative maps.

Further details on the various datasets used in this report are provided in “Soil and Earth Science Information Note SESIN 1” (Bruneau *et al.*, 2013). This provides a non-specialist guide to the main field and mapping classifications used in Scotland to describe soil and derived information alongside practical examples on how to use such information.

For further information on this project contact:

Dr Patricia Bruneau , Scottish Natural Heritage, Silvan House, 3rd floor
231 Corstorphine Road, Edinburgh, EH12 7AT.

Tel: 0131 3162600 or patricia.bruneau@snh.gov.uk

For further information on the SNH Research & Technical Support Programme contact:

Knowledge & Information Unit, Scottish Natural Heritage, Great Glen House, Inverness, IV3 8NW.

Tel: 01463 725000 or research@snh.gov.uk

Other planned publications in the same series intended date of publication in bracket when available

SNH CR643 – Soil and Earth Science Information Note SESIN 1 – Explanatory note (Jan 2014)

SNH CR644 – Soil and Earth Science Information Note SESIN 2 – Aberdeen City
SNH CR645 – Soil and Earth Science Information Note SESIN 3 – Aberdeenshire
SNH CR646 – Soil and Earth Science Information Note SESIN 4 – Angus
SNH CR647 – Soil and Earth Science Information Note SESIN 5 – Argyll and Bute
SNH CR648 – Soil and Earth Science Information Note SESIN 6 – Clackmannanshire
SNH CR649 – Soil and Earth Science Information Note SESIN 7 – Dumfries & Galloway
SNH CR650 – Soil and Earth Science Information Note SESIN 8 – Dundee City
SNH CR651 – Soil and Earth Science Information Note SESIN 9 – East Ayrshire
SNH CR652 – Soil and Earth Science Information Note SESIN 10 – East Dunbartonshire
SNH CR653 – Soil and Earth Science Information Note SESIN 11 – East Lothian
SNH CR654 – Soil and Earth Science Information Note SESIN 12 – East Renfrewshire
SNH CR655 – Soil and Earth Science Information Note SESIN 13 – Edinburgh City
SNH CR656 – Soil and Earth Science Information Note SESIN 14 – Falkirk
SNH CR657 – Soil and Earth Science Information Note SESIN 15 – Fife
SNH CR658 – Soil and Earth Science Information Note SESIN 16 – Glasgow City
SNH CR659 – Soil and Earth Science Information Note SESIN 17 – Highland
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SNH CR663 – Soil and Earth Science Information Note SESIN 21 – Na h-Eileanan Siar
SNH CR664 – Soil and Earth Science Information Note SESIN 22 – North Ayrshire
SNH CR665 – Soil and Earth Science Information Note SESIN 23 – North Lanarkshire
SNH CR666 – Soil and Earth Science Information Note SESIN 24 – Orkney Islands
SNH CR667 – Soil and Earth Science Information Note SESIN 25 – Perth & Kinross
SNH CR668 – Soil and Earth Science Information Note SESIN 26 – Renfrewshire
SNH CR669 – Soil and Earth Science Information Note SESIN 27 – Scottish Borders
SNH CR670 – Soil and Earth Science Information Note SESIN 28 – Shetland Islands
SNH CR671 – Soil and Earth Science Information Note SESIN 29 – South Ayrshire
SNH CR672 – Soil and Earth Science Information Note SESIN 30 – South Lanarkshire
SNH CR673 – Soil and Earth Science Information Note SESIN 31 – Stirling (Dec 2013)
SNH CR674 – Soil and Earth Science Information Note SESIN 32 – West Dunbartonshire
SNH CR675 – Soil and Earth Science Information Note SESIN 33 – West Lothian

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1. BACKGROUND

This series was prepared to promote greater awareness of and to promote sustainable management options within and outwith the conservation designation framework for the soil and Earth science natural heritage features of national importance. These features are a component of the geodiversity of Scotland (defined as rocks, minerals, fossils, landforms, sediments and soils in an area, together with natural processes, such as erosion and landslips, that may still be active).

Both biological and non-soil geodiversity interests are defined and catalogued for the purpose of statutory and regulatory designations, but there is no equivalent of a 'biodiversity duty' for geodiversity interests outside designated sites. Despite progress in policy integration and awareness raising of soils issues following the publication of the Scottish Soil Framework (2009), there is still no national or international policy framework for the protection and sustainable management of soils. Soils are not designated in protected sites and there is little consensus on how to assess the conservation values of soils in Scotland.

In the late 1990's, SNH undertook a series of research projects to inventory the distribution and relationships between soil and natural heritage features. This was set up to explore the development of a framework and methodology for assessing soils of nature conservation value across the whole of Scotland (Gauld *et al*, 2000). Later a more detailed descriptive spatial inventory of soils of nature conservation value in five selected Natural Heritage Futures areas, which are representative of soils and habitats in Scotland were set up, covering Moray Firth, Cairngorms Massif, Eastern Lowlands, West Argyll & Islands and the Borders Hills (Gauld *et al*, 2003). The State of Soil report (Dobbie *et al*, 2011) provides a detailed assessment of roles and threats to soil in Scotland.

The above understanding of soil has been used to identify soil nature conservation interests of national importance. This report provides a standard and reproducible approach to assessing the nature and extents of soil and other geodiversity interest in Stirling Council area.

1.1 Why do we need to care for soil and Earth heritage?

Geodiversity is recognised in today's society for its wider social, economic and environmental roles. Safeguarding geodiversity is as relevant as safeguarding biodiversity to ensure appropriate delivery of ecosystem services and functions for the benefit of Scotland's people and environment.

Therefore, being able to understand the role and organisation of geodiversity resources will help in tasks such as:

- Development & planning system
 - Knowing the spatial distribution of soil types will help guide the appropriate location of development setting and help minimise their environmental footprint.
 - Knowing where geodiversity processes are active is key to giving space for nature to adapt to change and ensure sustainability of development.
- Managing the impact of land use change on the wider environment and soil functions
 - Knowing the values of soil and land likely to be impacted by land use will help identify land and soil of high conservation (e.g. rare soil), scientific (Geological Conservation Review (GCR) sites) or economic values (e.g. prime agricultural land).
- Managing soil carbon resources and peatland restoration
 - Knowing the location of peatland is essential for any attempt to manage and restore peat soils and enhance carbon sequestration in natural system.

- Knowing where carbon rich soils are located help to minimise loss of carbon to the wider environment (erosion and greenhouse gases (GHG) released from the soil).
- Protecting features of scientific, cultural and historical interest outside the suite of designated areas (including SNH natural heritage features of national importance)
- Promoting sustainable use of natural resources and allowing space for natural processes to adapt to change (e.g. soft engineering for flood defence)

1.2 SNH natural heritage features of national importance

SNH has developed an approach to determine where impacts from development proposals on the natural heritage raise issues of national importance that may warrant an objection by SNH in consultation processes (Scottish Natural Heritage, 2011). Such cases will be relatively infrequent, but are important in helping fulfil SNH's statutory remit to secure the conservation, enhancement, understanding, enjoyment and sustainable use of Scotland's natural heritage. Identifying national importance is relatively straightforward in cases involving protected areas of national or international importance for their natural heritage (i.e. Natura Sites designated under the European Birds and Habitats Directives, Sites of Special Scientific Interests (SSSI) designated under the Nature Conservation (Scotland) Act 2004, Priority Habitats in support of the Convention for Biological Diversity). Where cases do not affect these protected areas, additional judgements have to be made, not only about the degree of impact but also about the importance of the natural heritage resource/s affected (as this has not already been flagged up through a designation process).

At present, the case for most objections will rest mainly on nature conservation grounds. However, as thinking and practice on ecosystem goods and services are developed the assessment of national importance may involve consideration of the functional importance of biodiversity and geodiversity resources.

There are 4 types of features listed under the section Geodiversity of outstanding conservation importance in the SNH guidance. Three of the four Earth science features of National Importance are defined here as 'Rare' soil. The last type are the remaining geological and geomorphological sites, listed in the Geological Conservation Review (GCR) which are not at present underpinning an SSSI designation.

1.2.1 'Rare soil' as a natural heritage feature of national importance

In order to understand what a rare soil is, it is important to be clear what soils are. There are extensive literature and on-line resources to learn about the basis of soil science and the soils of Scotland (see Bruneau *et al*, in press for detail on wider soil resources). In summary;

- Soils are composed of a range of minerals, gases and fluids interacting with living organisms (e.g. plant roots and fungi, microbes, soil dwelling fauna) and dead organic matter. The proportion of the various constituents will determine the broad nature of soil (e.g. mineral, peaty and peat soil referring to increasing organic matter content) and its functionalities (e.g. low levels of gases and fluids implies a compacted soil).
- Soils are not static but they take a very long time to evolve under natural conditions, growing at a rate of a few mm per year since the last glaciation around 15,000 years ago. Climatic conditions are one factor in controlling the rate of soil formation. Low temperature and low rainfall tends to slow soil formation.
- Soils are three-dimensional entities and their depths can vary from a few centimetres (some mountain soils) to several metres (deep peat).
- Soils are generally organised in vertical layers (or **soil horizons**) that reflect how the soil forms (more organic at the surface, more mineral at depth). The organisation and depth of these layers define the **soil type**.

- Soils are also organised within landscape and geological gradients in often gradual transitions between different soil types. The unique relationship between a soil type with a geological parent material defines the **soil series**.
- The soil chemical properties (hence its inherent fertility) are in part controlled by the underlying geology (e.g. calcareous (high pH) soil on limestone, acid soil on granite).

Because of these, Scotland's soils are mostly more acidic, poorly drained and highly organic than elsewhere in UK.

The definition of "rare soil" used here, is not based solely on an arbitrary frequency threshold. Instead, the definition of rare soil considers the roles and values of soils associated with key ecosystems services (Dobbie, Bruneau, & Towers, 2011) with special attention to the multi-functional dimension of soils and the benefits they provide to society. These values usually transcend the physical boundaries of protected sites. The key criteria for the definition of 'rare soil' or soil of conservation value are:

- Geodiversity type a) Soils with high organic content (peat and peaty soil types). This relates to the role of soil in climate change control; soil as a carbon stores, soil as an emitter of GHG, soil as a sink for new carbon (sequestration).
- Geodiversity type b) Soils directly associated with a habitat of conservation value or a key geodiversity feature. This relates to the role of soil in supporting habitats, nutrient cycles, water quality and as an information repository on quaternary climate change.
- Geodiversity type c) Prime agricultural land. This is related to the role of soil in food and fibre production.

1.2.2 Geodiversity as a natural heritage feature of national importance

Geodiversity is the variety of rocks, minerals, fossils, landforms, sediments and soils, together with the natural processes which form and alter them. The conservation of geological and geomorphological sites is part of the responsibilities of the UK statutory nature conservation agencies. A major initiative to identify and describe the most important geological and geomorphological sites in Britain began in 1977, with the launch of the Geological Conservation Review (GCR). The GCR is designed to identify sites of national and international importance needed to show all the key scientific elements of the Earth heritage of Britain. These sites display sediments, rocks, fossils, and features of the landscape that make a special contribution to our understanding and appreciation of Earth science and the geological history of Britain, which stretches back hundreds of millions of years. (Joint Nature Conservation Committee, n.d.).

Sites are selected for around 100 categories (or GCR 'Blocks') encompassing the range of geological and geomorphological features of Britain. Information on all GB GCR blocks is available from JNCC website (<http://jncc.defra.gov.uk/default.aspx?page=2947>). SNH is responsible for the maintenance of the GCR Scottish site database, with each GCR site being allocated a unique number which links to a single geological or geomorphological feature of interest. Digital site boundaries for all Scottish GCR sites and associated attribute tables are available free of charge from the SNH download portal (NaturalSpace - <https://gateway.snh.gov.uk/natural-spaces/index.jsp>).

The responsibility for the legal protection of GCR sites, where these are features notified within SSSIs, lies with the statutory nature conservation agencies. In contrast to the rest of the GB many of the GCR sites in Scotland have not been formally designated as SSSIs. All of the 982 notified geological features in SSSIs in Scotland are underpinned by a confirmed

GCR site. In the majority of cases, GCR sites which are included within the boundary of a SSSI have been notified as interest features of the SSSI.

The key criterion for the selection of Earth science features is:

Geodiversity type d) *Un-notified* GCR sites – GCR sites which are currently outside the boundary of a SSSI or not notified as an interest features in the SSSI.

These *Un-notified* GCR sites may be considered as awaiting notification as features of interest in an SSSI, and are listed as Earth science natural heritage features of national importance.

1.3 Common problems with access and use of soil and Earth science data

When presented with a request to use environmental data, most users are faced with the same basic questions.

- Where can I find the data I need?
- Why is there no data for my area?
- What does it mean? and,
- How can I use it to solve my problem?

Problems are often compounded by the apparent difference in the convention used by specialist to describe, classify and display soils in Scotland. For example:

- Some problems relate to the constraints imposed by the scale of field survey and the scale of displaying information; thus are not unique to soil mapping.
- Other differences are due to how soil survey and soil research in Scotland has evolved since its inception in the 1940's.. Soil survey has witnessed changes to the scientific understanding of soil resources and the emergence of new tools and methods to survey, record and display environmental information.
- The need to transfer information from hard copy to digital format has also required some reorganisation and sometimes simplifying of the soil information originally surveyed.
- And not least, information is not always available at the scale required by users either because it has never been surveyed or the data are too old and no longer fit-for purpose.

The "Soil and Earth Science Information Note SESIN 1" (Bruneau *et al.* in press) is designed to answer those generic questions.

2. SOIL AND GEODIVERSITY RESOURCES AND USAGE

This section provides a summary of soil and geodiversity information available in the Stirling area. Information about all the datasets discussed in this report is detailed in issue 1 of the “Soil and Earth Science Information Note” series (Bruneau *et al.* in press). It provides a non-specialist guide to the main field and mapping classifications used to describe soil and derived information in Scotland, alongside practical examples on to how to use such information.

This report is not intended to provide a detailed description of the soils and geology of Scotland and it is not a science text book. It is intended primarily as a guide to the information accessible in paper and digital format in Scotland, providing simple descriptions on how it can be used by non-soil specialists.

2.1 Soil and geodiversity resources available for Stirling - Hard copy maps

The foundation to all soil and geological information discussed here is the work of the field surveyors, examining soil profiles and drawing boundaries between different soil types or geology strata and their effort in recording, or sampling for further laboratory analysis, the properties of the features observed. The information collected can then be used to develop and produce maps and cartographic information of the surveyed attributes and populate a database of feature properties.

This original information can also be used to produce thematic or derived information. Thematic data or maps display properties of interest that were surveyed or analysed (e.g. soil pH). Derived information is taken from survey data in conjunction with additional information (e.g. climate, slope). This is usually done to provide an assessment or model of how soil performs for specific uses (e.g. land capability for agriculture classification).

Table 1. Hard copy map – available coverage in Stirling.

Scale of mapping	Soil survey map	Derived soil maps		BGS geology survey map* (drift – Solid)
		Land Capability for Agriculture	Land Capability for Forestry	
1:10,000	n.a.	n.a.	n.a.	Partial (66%)
1:25,000	Partial (<10%) (various)	n.a.	n.a.	n.a.
1:50,000	Partial (>50%) sheet 57,58, 65	Partial (>50%) Sheet 57, 58, 65	n.a.	Partial (66%) S39W&E,S38W&E, S30E,S31W&E
1:63,360	Partial (>50%) sheet 47, 39, 31, 30/29	n.a.	n.a.	Full Sheet 30, 31,38,39, 47
1:250,000	Full Sheet 4, 5 & 6	Full Sheet 4, 5, 6	Full Sheet 4, 5 & 6	Full 56N 04W Tay Forth, 56N 06W Argyll

n.a. = no published maps at this scale available

* maps were originally produced as full sheets (E and W), but are now published by BGS as two separate sets.

- Soil Survey of Scotland and derived maps

The systematic survey of Scotland's soils by the Macaulay Institute for Soil Research (now The James Hutton Institute – the Hutton¹) started in the 1940s. By the end of the 1970s around 50% of the country was covered with detailed 1:25,000 scale field maps and published at the 1:63,360 scale.

Only around 50% of Stirling is covered by large scale soil maps, mostly the Carse of Stirling and the Campsie Fells. The first of the soil maps were published on Ordnance Survey 1:63,360 (1 inch) scale topographical maps. Sheet 39 (Stirling) was published in 1965 (revised in 1981), sheet 31 (Airdrie) in 1976, sheet 47 (Crieff) in and sheet 30/29 (Rothesay – Glasgow) in 1985.

Following the completion, in the 1980's, of a generic inventory of Scotland's soils, coloured maps and associated handbooks were published at 1:250,000 scale (Soil Survey of Scotland, 1984). Stirling is covered by part of Sheet 5 East of Scotland map and handbook (Walker *et al.*, 1982), Sheet 4 Western Scotland and handbook (Bidby *et al.*, 1982) and Sheet 6 South West Scotland and handbook (Bown *et al.*, 1982). Additional soil maps at 1:50,000 scale (40 km x 30 km) compiled for this inventory are available as provisional black and white maps for the part of Stirling not covered by the 1-inch soil maps.

A range of derived maps were published following the completion of the systematic inventory of Scotland's soils in the 1980's. This includes Land Capability maps for Agriculture and Forestry (LCA and LCF) published as 1:250,000 scale maps. The 1980's 1:250,000 LCA maps replaced the earlier and obsolete Land Use Capability (LUC) maps. In part of Stirling covered by detailed soil field surveys, 1:50,000 LCA maps were also published. These maps provide additional information on LCA subclasses (defined by the limitation type that allocates a parcel of land to a class) not available at the 1:250,000 scale.

- Geological survey maps

Scotland was surveyed in the late 19th century by the Geological Survey of Scotland (now British Geological Survey – BGS²). Historical geological maps were published at Ordnance Survey 1:63,360 (1-inch) scale for the whole of Scotland. More recent surveys are published at a 1:50,000 scale as full east-west sheet covering 40 km x 30 km areas providing a partial coverage for Scotland. These maps display the bedrock geology (e.g. solid map) and/or deposits which may overlay the bedrock (e.g. drift map). A 1:10,000 scale map series is also available for the part of Stirling that offers large-scale geological mapping (excluding Highland part). Each map covers 25 square kilometre (Wilson, 1977).

2.2 Soil and geodiversity resources available for Stirling - Digital datasets

Digital datasets come either as geographical data which requires the use of specialised geographical information system (GIS) software to visualise their content (e.g. ARCMAP) or as point data which will be accessible with 'simpler' spreadsheet applications (e.g. MS Excel) or database management system (e.g. ORACLE).

- Geographical dataset

Most of the soil and geodiversity information held by the Hutton, BGS and other UK institutions are now available as digital datasets (Table 2). Following on from the Open Government Licensing Framework and EC INSPIRE Directive 2007, access to some of this

¹ http://www.macaulayscientific.com/products_maps_list.php

² http://shop.bgs.ac.uk/Bookshop/tenk_home.cfm

information by non-commercial users is now accessible free of charge through various web based applications, to view maps and download data. Copyrights are retained by the original providers and commercial users of digital dataset are still subject to licensing fees.

Table 2. GIS and other thematic spatial digital data - available coverage in Stirling.

scale	Geological survey ^a	Soil survey	Derived information			
			Land Capability for Agriculture	Land Capability for Forestry	Peat depth	Soil carbon richness
1:25,000	n.a.	45.7%	n.a.	n.a.	n.a.	45.7%
1:50,000	100%	n.a.	29.4%	n.a.	n.a.	n.a.
1:250,000	n.a.	100%	100%	100%	100%*	100%
Larger scale	100% (1:625,000)	100%** (1:1,000,000)	n.a.	n.a.	n.a.	n.a.

n.a. No digital dataset available at this scale

^a Mostly only available as free web map services (an image of a map)

* This is a composite dataset and although it covers the whole of Scotland, not all peat bodies have been surveyed and information presented here is only indicative.

** Map available from European Soil Database (ESDB) (http://eusoils.jrc.ec.europa.eu/ESDB_Archive/ESDB/index.htm)

In Scotland, soil and geodiversity digital data can be view and downloaded on-line from the Scottish Environment Website (SEWEB) – www.environment.scotland.gov.uk and its soil daughter web page the Scottish Soil Website (SSW)– www.soils-scotland.gov.uk.

BGS soil data (soil being defined here as a geological construct) can be visualised on the NERC soil portal (<https://www.bgs.ac.uk/nercsoilportal/>) and OpenGeoscience (www.bgs.ac.uk/opengeoscience/home.html). Most of the BGS maps are only freely available to view or use in web mapping services (georeferenced map images).

Information on the location of the Geological Conservation Review (GCR) sites is also available in digital format and can be downloaded from SNH Natural Spaces website, which provides an online data download facility giving access to a wide range of datasets including protected areas, habitats and species, landscape, open space and access (<https://gateway.snh.gov.uk/natural-spaces/index.jsp>).

- Point dataset

The National Soils Database is the main soil point dataset in Scotland. It includes the National Soil Inventory for Scotland (NSIS1), a dataset of site, soil and analytical data collected between 1978 and 1988 from sites located on a regular 5 km grid across Scotland and a partial resampling of the dataset (NSIS2) undertaken in 2010-12 on a 20km grid across all of Scotland. Only NSIS1 is currently available on-line on SSW (<http://www.soils-scotland.gov.uk/data/nsis>) .

However, the Scottish Soils Knowledge and Information Base (SSKIB) provides average and standard deviation of key chemical and physical properties for all soil profiles surveyed in Scotland. SSKIB is a summarised point database which underpinned the interpretation of the 1:250,000 scale soil maps. It differentiates between the properties of cultivated and semi-natural soils (see example in Annex 1). SSKIB combines information collected from over

13,000 locations and over 40,000 individual samples covering all of Scotland's soil types. This information has been collected by the Hutton and its predecessors over a 70-year period. The database is available as a web interface and mobile device apps called "Soils Indicators For Scottish Soils" application (SiFSS) (<http://sifss.hutton.ac.uk/>).

The BGS National Geoscience Datacentre is a UK service that provides a wide range of freely available geoscience information allowing viewing maps and downloading of some selected datasets. BGS holds over 400 datasets, including environmental monitoring data; digital databases; physical collections (borehole core, rocks, minerals and fossils); records and archives.

3. THE SOILS IN STIRLING

This section provides a detailed description of the soils of the Stirling area and how the information can be used by non-soil specialists to locate and assess the values as natural heritage features of national importance. Detail on soil classification and typology can be accessed from Scottish Soil Website (www.soils-scotland.gov.uk) and SESIN 1 (Bruneau *et al.*, in press).

3.1 Information on soil type distribution

3.1.1 Information covering the whole of Stirling - Soil type - 1:250,000 scale data

As shown in *Table 1* and *Table 2* the only dataset covering the whole of Stirling is the 1:250,000 scale soil survey map. This dataset is suitable for a broad assessment of the extent and location of soils of interest, large scale spatial planning and to draw comparisons with national patterns. The accuracy of this interpretation is constrained by the minimal size of mapping unit (50-100 hectares depending on shapes) and the classification system with most map units being complexes containing more than one soil type. Nevertheless, there are many instances of polygons smaller than this.

At this scale, the primary attribute of the soil digital dataset is the '**soil map unit**'. There are 582 soil map units (including rock and built up areas) identified in Scotland. Each is defined by a unique combination of soil types (up to 6), parent material and landforms. For example:

- Unit 490 consists of a combination of soil 'Brown forest soil; some humus-iron podzols and non-calcareous gleys' on parent material defined as 'drift derived from lower Old red sandstones conglomerates and lavas' and is associated with landforms of 'undulated lowlands and foothills with gentle and strong; non-rocky',
- Unit 348 consists of a unique soil type 'Brown earth' on parent material 'raised beach sands and gravels derived from greywackes and shales' and is associated with landforms of 'raised beach terraces with gentle slopes'.

Individual soil types and parent material combinations define the **soil series** of Scotland (numbering in 1000s). The proportion of all soil series, within most soil map units, is estimated. The first of the soil types listed in each soil map unit is the dominant soil type which is used in the legend of *Figure 1* and in *Table 3*. This may be less than 50% of soil mapped in each unit.

Because the geological type is one of the key criteria in soil typology, some level of 'regionalism' is expected in the soil series distribution across Scotland. This will reflect the broad geological patterns in Scotland. Therefore, the concentration of certain soil map units around specific locations / geological types should be seen primarily as an artefact of the classification system rather than an indication of rarity of the soil type.

Of the 582 soil map units recorded in Scotland, 83 are found in the Stirling area. Three of these are unique to or predominantly found in the area (over 90% of all Scottish occurrences located in the area). They are:

- Unit 496 (humus-iron podzol of the Shields soil series) of the STONEHAVEN Association located to the east of Loch Lomond
- Unit 494 (peaty podzol) of the STONEHAVEN Association south of Loch Venacher,
- Unit 277 (peaty podzol of equal proportion of the Boquhapple soil series and the Lenniaston soil series) of the GOURDIE/ CALLANDER/ STRATHFINELLA Association north of Callandar.

Another 4 map units are more commonly found in Stirling (>50% of all occurrence).

- Unit 344 (peaty gley of the Limpithill soil series and peat in equal proportion) of the KIPPEN/ LARGS Association. This accounts for 1/3 of all occurrence of Limpithill soil series.
- Unit 493 (humus-iron podzol of the Lurgan soil series and the Shields soil series) of the STONEHAVEN Association. This accounts for 2/3 of the occurrence of the Lurgan soil series.
- Unit 46 (peaty gley of the Sherrifmuir soil series with peat in equal proportion) of the BALROWNIE Association.
- Unit 168 (brown forest soil of the Doune soil series) of the DOUNE Association. This accounts for half of the occurrence of the Doune soil series.

The information shown below is available on-line on SSW at <http://www.soils-scotland.gov.uk/data/soil-survey>.

Table 3. Soil type in Stirling, derived from 1:250,000 scale GIS dataset with qualifiers for national interest features in Stirling (carbon rich soil category and rarity criteria).

Dominant soil type description	Soil Association	Soil map unit number	Area (ha)	Scotland proportion %	Carbon Category*	Rarity / value
Immature soil - Rankers	STRICHEN	515	95	11	1	No
Immature soil - Alluvial soils	ALLUVIAL SOILS	1	4089	3	1	Yes
Immature soil - Brown rankers	STRICHEN	508	43	1	1	No
Immature soil - Rankers	STRICHEN	509	2003	21	1	No
	BALROWNIE	43	882	13	1	No
	CARPOW/ PANBRIDE	89	2002	12	1	No
		147	332	1	1	No
	DARLEITH/ KIRKTONMOOR	150	4108	17	1	No
		156	51	4	1	No
		158	2990	6	1	No
	DARVEL	163	727	3	1	No
		164	237	2	1	No
	DOUNE	168	2170	56	1	No
	DREGHORN	169	445	3	1	No
	FOUDLAND	240	605	33	1	No
	GLENEAGLES/ AUCHENBLAE/ COLLIESTON/ DARNAWAY	273	571	4	1	No
	GOURDIE/ CALLANDER/ STRATHFINELLA	274	5929	29	1	No
	KIPPEN/ LARGS	337	4210	32	1	No
		472	188	0	1	No
	SOURHOPE	474	395	2	1	No
		479	507	4	1	No
	STONEHAVEN	490	879	5	1	No
		495	83	25	1	No
	STRICHEN	505	7079	17	1	No
Subtotal Brown earth			34390			
Leached soil - Brown earth (previously known as Brown forest soils)	BALROWNIE	41	12647	13	1	No
	DARLEITH/ KIRKTONMOOR	148	614	5	1	No
	LAURENCEKIRK	368	305	3	1	No
	ROWANHILL/	444	994	2	1	No

Dominant soil type description	Soil Association	Soil map unit number	Area (ha)	Scotland proportion %	Carbon Category*	Rarity / value
with gleying	GIFFNOCK/ WINTON	445	1349	1	1	No
	SORN/ HUMBIE/ BIEL	466	1285	6	1	No
	STIRLING/ DUFFUS/ POW/ CARBROOK	487	2226	1	1	No
Subtotal Brown earth with gleying			19421			
Leached soil – Humus-iron podzols	BALROWNIE	44	514	9	1	Und
	CORBY/ BOYNDIE/ DINNET	98	1157	2	1	Und
	FOUDLAND	250	859	9	1	Und
		243	1799	2	1	Und
	GOURDIE/ CALLANDER/ STRATHFINELLA	276	633	8	1	Und
	KIPPEN/ LARGS	341	269	23	1	Und
		493	1750	62	1	Und
	STONEHAVEN	496	231	100	1	Und
		498	3628	4	1	Und
	STRICHEN	503	15666	37	2	Und
Subtotal Humus-iron podzol			26507			
Leached soil – Peaty podzols	ABERLOUR	10	53	2	3	No
	ARKAIG	26	7	<0.1	5	No
	BALROWNIE	45	846	41	4	No
	CORBY/ BOYNDIE/ DINNET	101	294	1	4	No
	DARLEITH/ KIRKTONMOOR	153	746	13	4	No
		154	2377	19	5	No
	FOUDLAND	159	121	1	3	No
		245	91	1	5	No
		252	726	16	4	No
	GOURDIE/ CALLANDER/ STRATHFINELLA	277	57	99	4	No
	KIPPEN/ LARGS	343	501	35	5	No
	SOURHOPE	476	632	6	4	No
	STONEHAVEN	494	337	100	3	No
		499	963	2	3	No
	STRICHEN	500	3189	18	5	No
		504	10142	18	5	No
		506	17075	33	3	No
Subtotal Peaty podzol			38158			
Leached soil - Subalpine soils	ABERLOUR	12	60	4	5	Yes
	FOUDLAND	255	312	7	5	Yes
	STRICHEN	512	7138	22	2	Yes
513		980	4	5	Yes	
Subtotal subalpine soil			8491			
Leached soil – Alpine soils	STRICHEN	514	360	8	1	Yes
Gley soil – Non-calcareous gleys	BALROWNIE	42	5298	38	1	No
	DARLEITH/ KIRKTONMOOR	149	2721	15	1	No
	FOUDLAND	241	1774	13	2	No
	GOURDIE/ CALLANDER/ STRATHFINELLA	275	1889	26	4	No
	KIPPEN/ LARGS	338	942	24	1	No
	ROWANHILL/ GIFFNOCK/ WINTON	446	275	<0.1	1	No
	SORN/ HUMBIE/ BIEL	467	1595	11	1	No

Dominant soil type description	Soil Association	Soil map unit number	Area (ha)	Scotland proportion %	Carbon Category*	Rarity / value
	STIRLING/ DUFFUS/ POW/ CARBROOK	488	10308	33	2	No
	STRICHEN	497	5105	11	1	No
Subtotal Non-calcareous gley			29907			
	BALROWNIE	46	2621	82	5	No
	DARLEITH/ KIRKTONMOOR	155	534	4	5	No
	FOUDLAND	246	849	10	5	No
		253	979	3	4	No
Gley soil – Peaty gleys	KIPPEN/ LARGS	344	1979	49	5	No
	SORN/ HUMBIE/ BIEL	470	235	6	4	No
		501	4427	39	5	No
	STRICHEN	502	2053	41	5	No
		507	12275	15	5	No
		510	2216	7	5	No
		511	97	1	5	No
	Subtotal Peaty gley			28264		
Organic soil – Peat	ORGANIC SOILS	3	2933	4	6	Yes
		4	21749	3	6	Yes
Subtotal Organic soil			24682			
Total all soil			216409	Und = Rare only if undisturbed * carbon category defined in section 3.4		
Built up	Built up	608	1088			
Open water	Open water	601	7304			
Rock and scree	Rock and scree	602	412			
Total area mapped			225214			

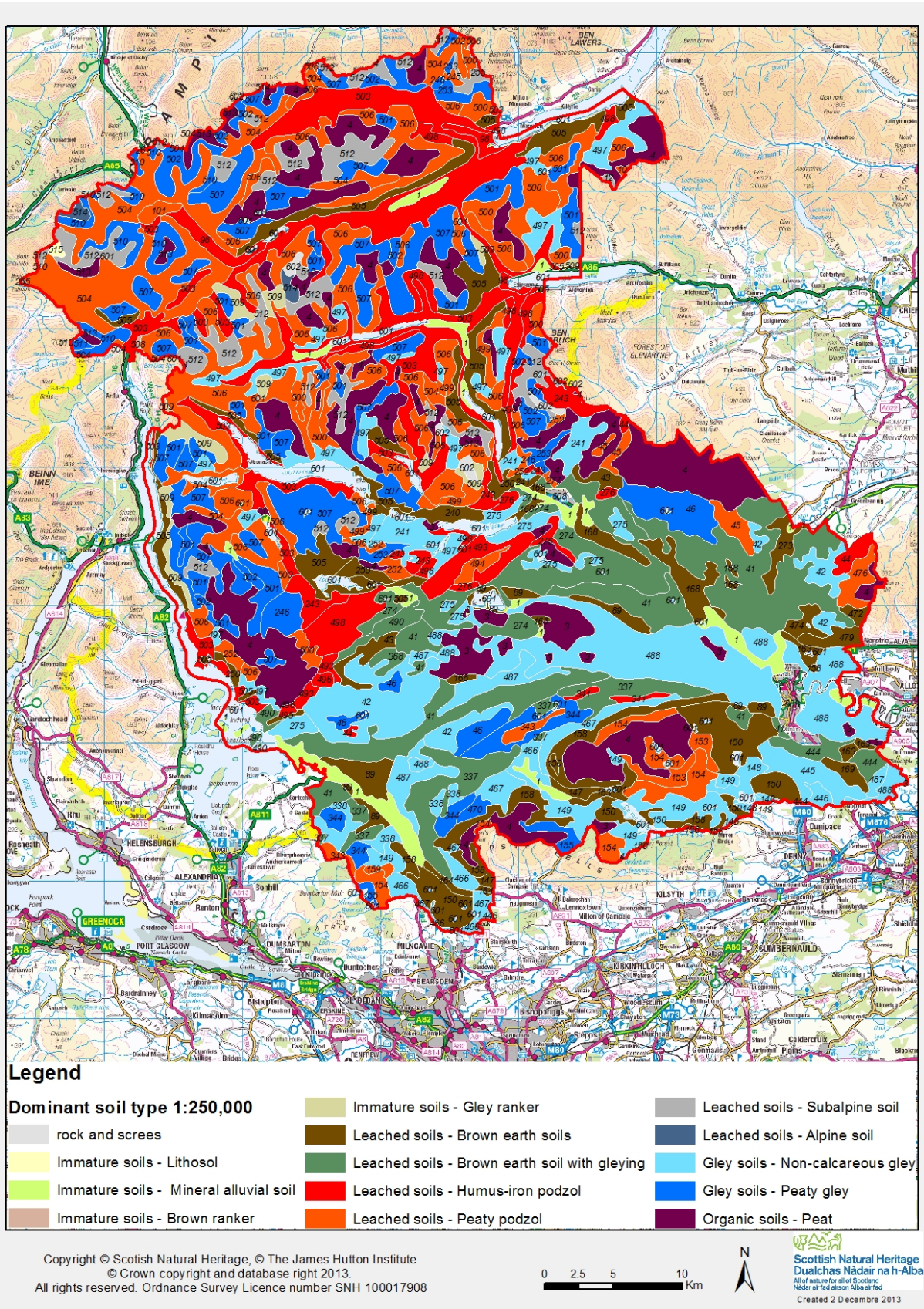


Figure 1. Dominant soil types in Stirling, derived from 1:250,000 scale GIS dataset. Showing soil map unit number in italics.

3.1.2 Information covering only part of Stirling - Soil type - 1:25,000 scale data

As shown in *Table 1* and *Table 2* this dataset covers only part of Stirling. This dataset is suitable for more detailed assessment of extent and location of soils of interest. The accuracy of this interpretation is mostly only constrained by the minimal size of the mapping unit (5-10 hectares) as, with the exception of complex soils, all map units refer to individual soil types albeit with some variation within them.

On the 1:25,000 scale soil map, the primary attribute of the digital dataset is the soil series, which in most cases represents a one-to-one relationship between a single soil type and a parent material. However field surveys were not always able to define and map one-to-one relationships. This may happen where:

- Complex landforms have given rise to different soil types across short distances (e.g. drumlins). This requires more detailed field assessment and lower resolution mapping
- No clear transition between two adjacent soil types can be identified (so-called intergraded soils). It is not possible to draw a boundary between soil types.

These areas are recorded as soil complexes soils. There are 6 soil complexes in the South West part of Stirling.

Table 4 and *Figure 2* show the distribution of soil types occurring in Stirling. At time of publication, this information was not yet available in SSW.

3.1.3 Soil types directly associated with habitats of conservation importance or a key geodiversity feature.

The rarity/value assessment is based on the dominant soil type characteristics and applied equally to all similar soils in Scotland. Using available literature and expert judgment, the following soils in Stirling were identified as soils with natural heritage features of national importance. This includes, but is not limited to:

- Estuarine and lacustrine raised beach silts and clays, within the Carse of Stirling including saline alluvial soil (along the Forth river bank).
- Alluvial soil (because of link with flood risk). Alluvial soils on raised beaches are also associated with other biodiversity and geomorphological interests.
- Alpine and subalpine soils are often associated with other biodiversity and geomorphological interests and may also be of greater values in part due to their relative rarity at national and international level.
- Morainic deposits on lower hillslopes in Glen Lochay, Braes of Balquhidder. Unique relationship between soil type formation and Ice ages landforms.
- Localised areas of peat in western upland areas. Value as a carbon sink, biodiversity resource, hydrological role and its potential for peatland restoration.
- Basin peat deposits e.g. around Flanders Moss. Value as a carbon sink, biodiversity resource and its hydrological role.
- Brown earths under long-established oakwood on Loch Lomond islands. Long established land use has helped to protect soil from disturbance associated with cultivation. May provide a record of undisturbed types.

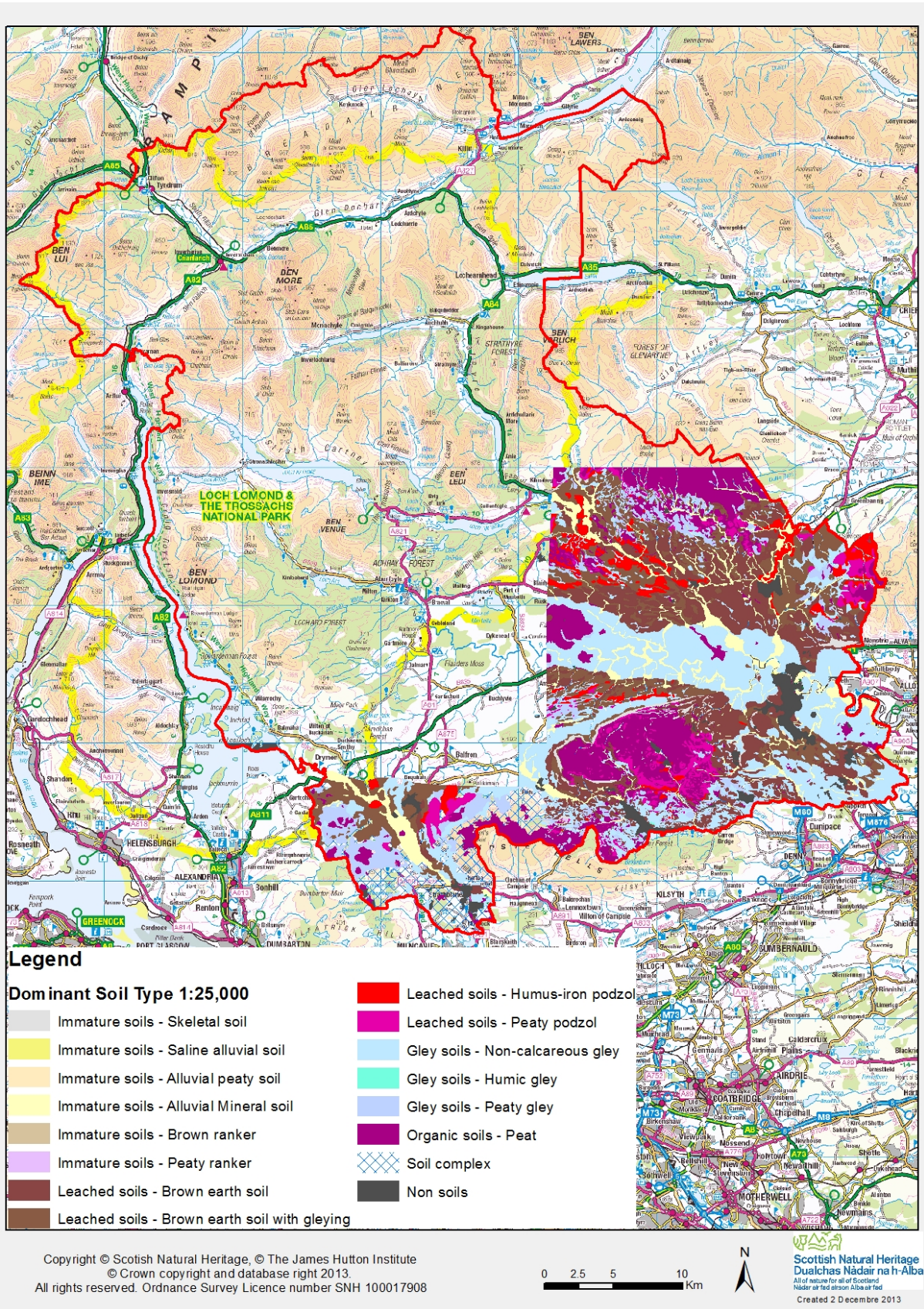


Figure 2. Soil types in Stirling, derived from 1:25,000 scale GIS dataset.

Table 4. Soil series and soil types in Stirling, derived from the 1:25,000 scale dataset, with qualifiers for national interest features (carbon rich soil category and rarity criteria).

Dominant soil type	Soil Association	Soil series		Area (ha)	Carbon category*	Rarity / value	
		Name	Code				
Skeletal soil	DARLEITH	Darlskel	DLz	590	1	No	
	SOURHOPE	Sourskel	SHz	128	1	Yes	
Immature soil – Saline alluvial soil	SALTINGS	Saline alluvial soil	-	128	1	Yes	
Immature soil – Alluvial fan soil		Yetts	ALf	0.1	1	Yes	
		Heavyside	JH	333	1	Yes	
Alluvial soil (clayey-Poorly drained)	ALLUVIAL SOIL	Peebles	JP	267	1	Yes	
Alluvial soil (loamy-Freely drained)		Traquair	JT	176	1	Yes	
Alluvial soil (loamy-Poorly drained)		Lochside	JL	8	1	Yes	
Alluvial soil (sandy-Imperfectly drained)		Kaime	JK	159	1	Yes	
Alluvial soil (silty-Poorly drained)		Bindal	JB	43	1	Yes	
Mineral alluvial soil (Freely drained)		Not named	ALF	13	1	Yes	
Mineral alluvial soil (undifferentiated)		Undif alluvium	AL	3990	1	Yes	
Peaty alluvial soil (Poorly drained)		Lap	JO	3	3	Yes	
Peaty alluvial soil (undifferentiated)		Pal	PAL	132	3	Yes	
Immature soil – Peaty ranker		DARLEITH	Caorach	CR	61	3	Yes
Immature soil – Brown ranker		DARLEITH	Glenaros	GZ	7	1	No
Leached soil – Brown earth (previously known as Brown forest soil)		BALROWNIE	Buchanyhill	BU	64	1	No
			Dunblane	DB	4095	1	No
		CARPOW	Carpow	CX	337	1	No
		DARLEITH	Darleith	DL	3605	1	No
	DOUNE	Doone	DN	1544	1	No	
	DREGHORN	Dreghorn	DR	809	1	No	
	DARVEL	Darvel	DV	421	1	No	
	FORFAR	Airtully	AY	16	1	No	
	GIFFNOCK	Forestmill	FJ	74	1	No	
	KIPPEN	Fourmerk	FK	322	1	No	
	KIRKTONMOOR	Faulds	FS	223	1	No	
	SOURHOPE	Sourhope	SH	846	1	No	
	Leached soil – Brown earth (previously known as Brown forest soil) with gleying	BALROWNIE	Balrownie	BL	2957	1	No
		Kippendavie	KV	864	1	No	
CALLANDER		Callander	CL	1590	1	No	
CARPOW		Carey	CJ	434	1	No	
FORFAR		Ruthven	RU	274	1	No	
GIFFNOCK		Kennet	KT	768	1	No	
KIPPEN		Butterwell	BW	201	1	No	
		Kippen	KP	1918	1	No	
KIRKTONMOOR		Glins	GN	212	1	No	
ROWANHILL		Sauchieburn	SB	49	1	No	
		Taiglim	TM	44	1	No	
SOURHOPE		Bellshill	BS	140	1	No	

Dominant soil type	Soil Association	Soil series		Area (ha)	Carbon category*	Rarity / value
		Name	Code			
Leached soil – Humus-iron podzol	BALROWNIE	Aldbar	AD	5	1	Und
		Muirhead	MR	325	1	Und
	CALLANDER	Lenniaston	LX	1192	1	Und
	DARLEITH	Cringate	CG	73	1	Und
		Tomtain	TT	70	1	Und
	DOUNE	Gart	GT	193	1	Und
	GLENEAGLES	Gleneagles	GE	459	1	Und
	KIPPEN	Redbrae	RD	428	1	Und
	KIRKTONMOOR	Moorhouse	MH	64	1	Und
SOURHOPE	Frandy	FY	211	1	Und	
Leached soil – Peaty podzol	BALROWNIE	Shindour	SD	511	3	No
	CALLANDER	Boquhapple	BO	88	3	No
	DARLEITH	Baidland	BD	1220	3	No
	DARVEL	Tulloch	TH	16	3	No
	KIPPEN	Garrigue	GX	499	3	No
	SOURHOPE	Cowie	CE	330	3	No
Gley soil – Non-calcareous gley	BALROWNIE	Lour	LR	787	1	No
	CALLANDER	Oglegarth	OG	391	1	No
	CARBROOK	Carbrook	CK	551	1	No
		Harviestoun	AM	16	1	No
	DARLEITH	Amlaird	HV	226	1	No
		Amlaird	AM	1213	1	No
		Dunlop	DP	882	1	No
	DARVEL	Ardoch	AH	<1	1	No
	GIFFNOCK	Aberdona	AA	266	1	No
	KILMARNOCK	Kilmarnock	KK	59	1	No
	KIPPEN	Armore	AO	611	1	No
	KIPPEN	Quinloch	QL	63	1	No
	LANFINE	Lanfine	LF	42	1	No
	ROWANHILL	Caprington	CP	1300	1	No
	SORN	Glenpark	GP	560	1	No
Sorn		SR	749	1	No	
STIRLING	Stirling	SG	8008	1	No	
Gley soil – Peaty gley	BALROWNIE	Sheriffmuir	SU	1205	3	No
	CALLANDER	Balvorist	BV	312	3	No
	DARLEITH	Myres	MS	853	3	No
	KIPPEN	Limpithill	LH	1682	3	No
	LANFINE	Distinkhorn	DK	9	3	No
	ROWANHILL	Glaisnock	GQ	132	3	No
	STIRLING	Poldar	PL	60	3	No
	SORN	Weitshaw	WW	208	3	No
		Edgerston	EG	70	3	No
SOURHOPE	Lawsuit	LT	19	3	No	
	DARLEITH	Dunwan	DW	5	1	No
Gley soil – Humic gley	KIRKTONMOOR	Kirktonmoor	KR	<1	1	No
Organic soil – Peat	PEAT <100CM	Basin	PT1	522	6	Yes
	PEAT >100CM	Blanket	PT1	800	6	Yes
	PEAT	Basin peat	PT	2413	6	Yes
	PEAT	Blanket peat	PT	6537	6	Yes
Complex soil Brown earth soil and non- calcareous gleys with brown rankers	BALROWNIE	Boturich	BCc	42	1	No

Dominant soil type	Soil Association	Soil series		Area (ha)	Carbon category*	Rarity / value
		Name	Code			
Complex soil Brown rankers and brown earth soils	DARLEITH	Balglass		3483	1	No
			BZc			
Complex soil Humus-iron podzol, peaty ranker, peaty podzol, peaty gley and peat	GIFFNOCK	Craigmaddie		90	5	No
			MCc			
Complex soil Peaty podzol, peaty gley and peat	KIPPEN	Gallangad		54	5	No
			Portkil	GJc	71	1
Complex soil Humus-iron podzol and brown earth with peaty podzol			PLc			
Complex soils Mixed alluvial soils	Mixed bottom land	Mobol	mbl	821	1	No
Made up ground (opencast)	Reinstated soil	Open cast	OC	2	1	no
Und = rare only if undisturbed		All soils		68649		
* carbon category defined in section 3.4		Other mapped (loch, build up)		2004		
		Not mapped area		154574		

3.2 Soil parent material

In the Scottish soil classification, the 'soil association' is defined by the nature and type of soil parent material or substrate material on which the soil formed. This may be a single geological formation or a combination of geological material with similar properties or occurring in close proximity. As defined from the 1:250,000 soil map, there are 112 different types of parental material in Scotland of which 22 are recorded in Stirling. Soil parent material and soil association are also used in the 1:25,000 scale maps classification.

The most common soil parent material is Quaternary till or drift. In Stirling, soil, on drift or till, occupies over 77% of the area (shown in order by increasing acidity in Table 5. Other significant parent materials include fluvial and marine sediments (8.5%) and organic material (11.7). Organic material is recorded as parent material when the depth of the organic deposits exceeds 0.5 m.

Figure 3 shows the type and distribution of geological parent material for the soil associations identified in the Stirling area. The parent material is ranked along an acidity gradient. Soil properties are strongly influenced by the nature of the underlying geology, therefore broad differences in substrate acidity will result in marked differences in soil acidity and fertility.

This above assessment is based on expert judgement and is not a substitute to using BGS drift and solid material mapped information. For further detail, BGS 1:50,000 scale hard geology and superficial maps can be access via Scottish Environment Website (SEWeb) and BGS data portal (OpenGeoscience).

Table 5. Soil Association – parent material and their percentage coverage in Stirling, derived from 1:250,000 scale GIS dataset.

	Soil Association	Soil parent material	Area (ha)	% mapped
^a	Drift derived parent material			
1	LAURENCEKIRK	Drifts derived from Lower Old Red Sandstone marls and mudstones	305	0.1
2	DARLEITH/ KIRKTONMOOR	Drift derived from basaltic rocks	14592	6.5
3	ROWANHILL/ GIFFNOCK/ WINTON	Drifts derived from Carboniferous sandstones, shales and limestones	2619	1.2
3	SOURHOPE	Drifts derived from Old Red Sandstones intermediate lavas	1723	0.8
3	SORN/ HUMBIE/ BIEL	Drift derived from Lower Carboniferous and Upper Red Sandstones sediments and lavas	3114	1.4
3	FOUDLAND	Drifts derived from slates, phyllites and other weakly metamorphosed argillaceous rocks	7994	3.5
3	STONEHAVEN	Drift derived from Lower Old Red Sandstones conglomerates and lavas	3280	1.5
3	BALROWNIE	Drifts derived mainly from sandstone of Lower Red Sandstone age, often water modified	22807	10.1
3	KIPPEN/ LARGS	Drift derived mainly from Upper Old Red Sandstone sandstones	7902	3.5
5	ABERLOUR	Drift derived from acid schist and granitic rocks	114	<0.1
5	ARKAIG	Drifts derived from schist, gneisses, granulites and quartzites principally of the Moine series	7	<0.1
5	GOURDIE/ CALLANDER/ STRATHFINELLA	Drifts derived from acid metamorphic rocks and Lower Old Red Sandstone sediments with igneous rocks	8508	3.8
5	STRICHEN	Drifts derived from arenaceous schists and strongly metamorphosed argillaceous schist from the Dalradian series	90907	40.4
	Fluvioglacial and raised beach			
10	CORBY/ BOYNDIE/ DINNET	Fluvioglacial and raised beach sands and gravels derived from acid rocks	1452	0.6
10	DARVEL	Fluvioglacial sands and gravels derived mainly from carboniferous rocks	964	0.4
10	DOUNE	Fluvioglacial sands and gravels derived from acid schist and Lower Old Red Sandstones sediments and lavas	2170	1.0
10	GLENEAGLES/ AUCHENBLAE/ COLLIESTON/ DARNAWAY	Fluvioglacial sands and gravels derived from Old Red Sandstone sediments and lavas and acid schists	571	0.3
10	CARPOW/ PANBRIDE	Raised beach sands and gravels derived mainly from Old Red Sandstone sediments and lavas	2002	0.9
10	DREGHORN	Raised beach sands and gravels derived mainly from Carboniferous rocks with some Old Red Sandstones material	445	0.2
11	STIRLING/ DUFFUS/	Estuarine and lacustrine raised beach	10308	4.6

	Soil Association	Soil parent material	Area (ha)	% mapped	
	POW/ CARBROOK	silts and clays			
	Organic soil				
12	ORGANIC SOILS	Organic deposit	24682	11.0	
	Recent deposits				
13	ALLUVIAL SOILS	Recent riverine and lacustrine alluvial deposits	4089	1.9	
a					
(map category as in figure 3)					
		Others non soil	5854		
		All soil mapped	210555		
		Total area mapped	216409		
<hr/>					
Summary per parent material type			All drift derived	163872	77.8
			Fluvioglacial and raised beach	17912	8.5
			Organic soils	24682	11.7
			Alluvial soils	4089	1.9

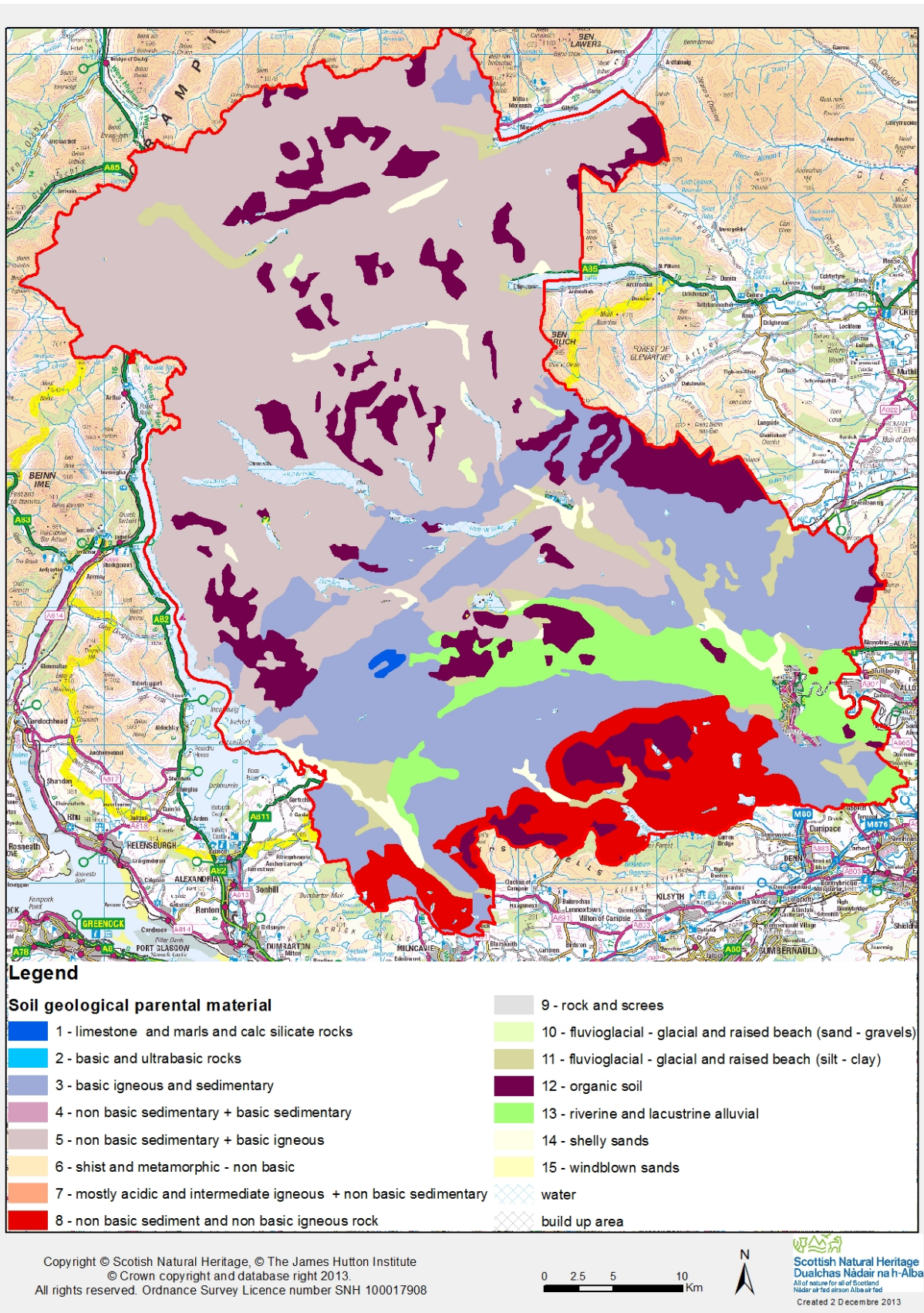


Figure 3. Soil parent material in Stirling, derived from 1:250,000 scale GIS dataset.

3.3 Land capability for food and fibre production

Land Capability for Agriculture (LCA) and Land Capability for Forestry (LCF) classifications are interpretations of soil maps using additional data such as landform, climate and slope to derive new thematic maps. They provide an assessment of the increasing degree of limitation imposed by these factors on agriculture and forestry respectively. Land classification is not a recommendation for a particular use of land. It identifies only the suitability for a given land use from a biophysical perspective with no consideration to the current use and legal or societal constraints on land management. The 1:50,000 LCA digital dataset does not include information on subclass categories recorded on the 1:50,000 hard copy maps. The 1:250,000 scale dataset is accessible via the SSW web portal.

Prime agricultural land is defined as land in LCA class 1 to 3.1. This represents land capable of producing a very wide to moderate range of crops with consistent high yields in most years. For further details on the land capability classifications please refer to "Soil and Earth Science Information Note 1" (Bruneau *et al.* in press).

3.3.1 Land Capability for Agriculture (LCA) -1:250,000 scale data

As shown in Table 6 and Figure 4, at this scale of mapping there is no prime agricultural land mapped in Stirling. The Carse of Stirling area displays large expanses of LCA class 3.2 (>28000 ha) in the valley bottom with the agricultural quality of land generally decreasing with altitude. The accuracy of this assessment is constrained by the minimum size of the mapping unit, 50-100 hectares. This dataset can be accessed SSW at <http://www.soils-scotland.gov.uk/data/lca250k>.

Table 6. Distribution of LCA class in Stirling, derived from 1:250,000 scale GIS dataset for Stirling.

LCA class: Land capable of		Area (ha)	% in LA	% of soil mapped
1	very wide range of crops	0	0	0
2	wide range of crops	0	0	0
3.1	moderate range of crops (consistent high yield)	0	0	0
3.2	moderate range of crops (average production)	28126	12.5	13.0
4.1	narrow range of crops (high grass yield but use & conservation limitation)	14487	6.4	6.7
4.2	narrow range of crops (more severe use & conservation limitation)	14589	6.5	6.7
5.1	improved grassland (good establishment of grass sward)	1979	0.9	0.9
5.2	improved grassland (moderate access limitation)	17413	7.7	8.0
5.3	improved grassland (serious access limitation)	16645	7.4	7.7
6.1	rough grazings (high portion of palatable herbage)	14910	6.6	6.9
6.2	rough grazings (moderate quality herbage)	33936	15.1	15.7
6.3	rough grazings (low grazing values)	71223	31.6	32.9
7.0	limited agriculture values	3416	1.5	1.6
Other land – non soil		8701	3.9	
Total soil mapped		216723	96.1	
Total area mapped		225424		

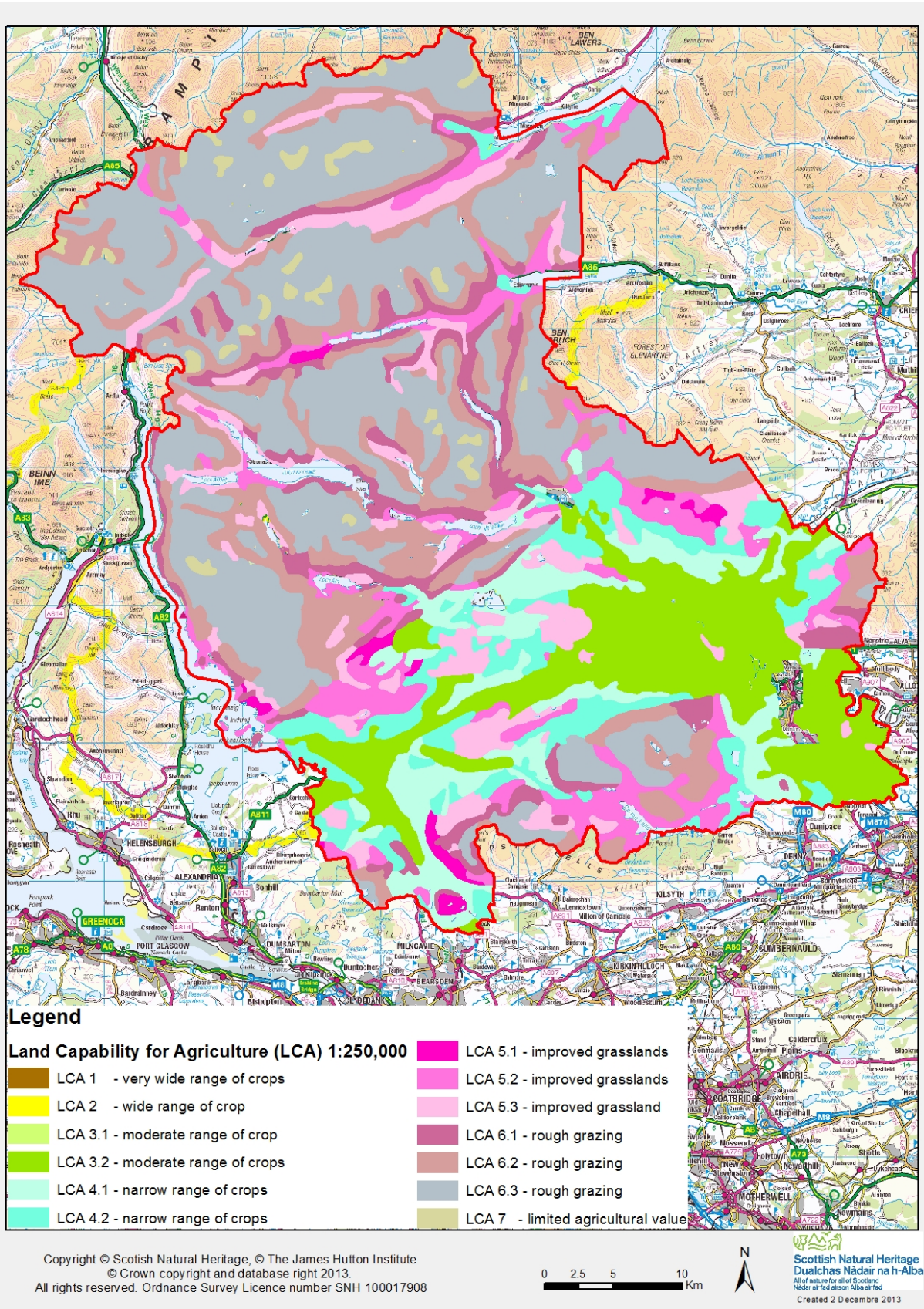


Figure 4. Land Capability for Agricultural (LCA) in Stirling, derived from 1:250,000 scale GIS dataset.

3.3.2 Land Capability for Agriculture (LCA) - 1:50,000 scale data

The 1:50,000 scale LCA dataset only covers 28% of the Stirling, focussing on the more productive land in the Carse of Stirling. As shown in *Table 7* and *Figure 5* at this scale some 450 ha prime agricultural land is recorded in patches to the South of Stirling and the riverside to the immediate west of Stirling. The accuracy of this assessment is constrained by the minimum size of mapping unit, 20-50 hectares.

Table 7. Distribution of LCA class in Stirling, derived from 1:50,000 scale GIS dataset for Stirling.

	LCA class : Land capable of	Area (ha)	% in LA	% of soil mapped
1	very wide range of crops	0	0	0
2	wide range of crops	<1	0.0	0.0
3.1	moderate range of crops (consistent high yield)	449	0.2	0.7
3.2	moderate range of crops (average production)	14855	6.6	23.6
4.1	narrow range of crops (high grass yield but use & conservation limitation)	7951	3.5	12.6
4.2	narrow range of crops (more severe use & conservation limitation)	6473	2.9	10.3
5.1	improved grassland (good establishment of grass sward)	716	0.3	1.1
5.2	improved grassland (moderate access limitation)	7431	3.3	11.8
5.3	improved grassland (serious access limitation)	8362	3.7	13.3
6.1	rough grazings (high portion of palatable herbage)	1380	0.6	2.2
6.2	rough grazings (moderate quality herbage)	7186	3.2	11.4
6.3	rough grazings (low grazing values)	8064	3.6	12.8
7.0	limited agriculture values	185	0.1	0.3
	Other land – non soil	3239	1.4	
	Total soil mapped	66292	28.0	
Total area mapped		225424		

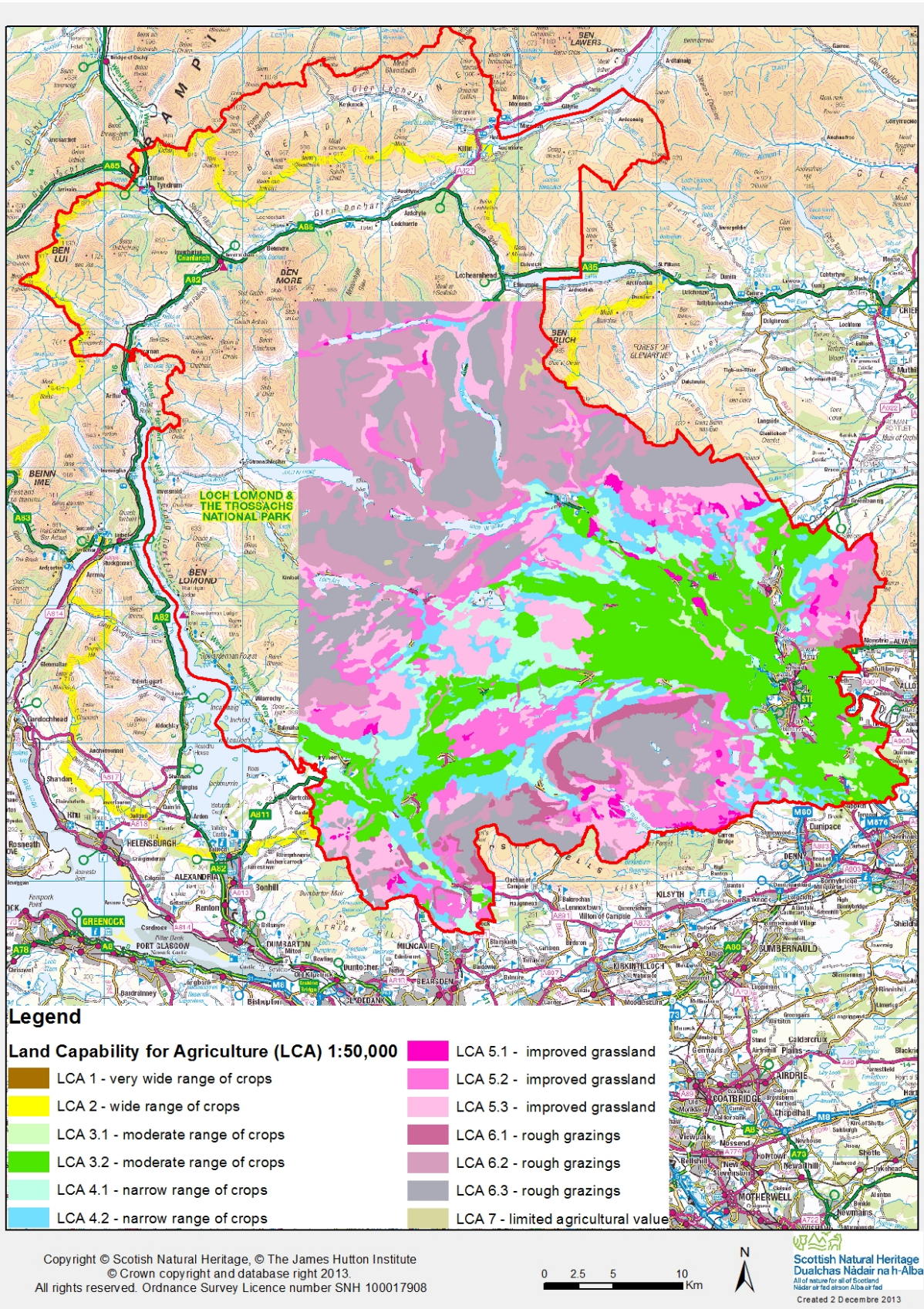


Figure 5. Land Capability for Agricultural (LCA) in Stirling, derived from 1:50,000 scale GIS dataset.

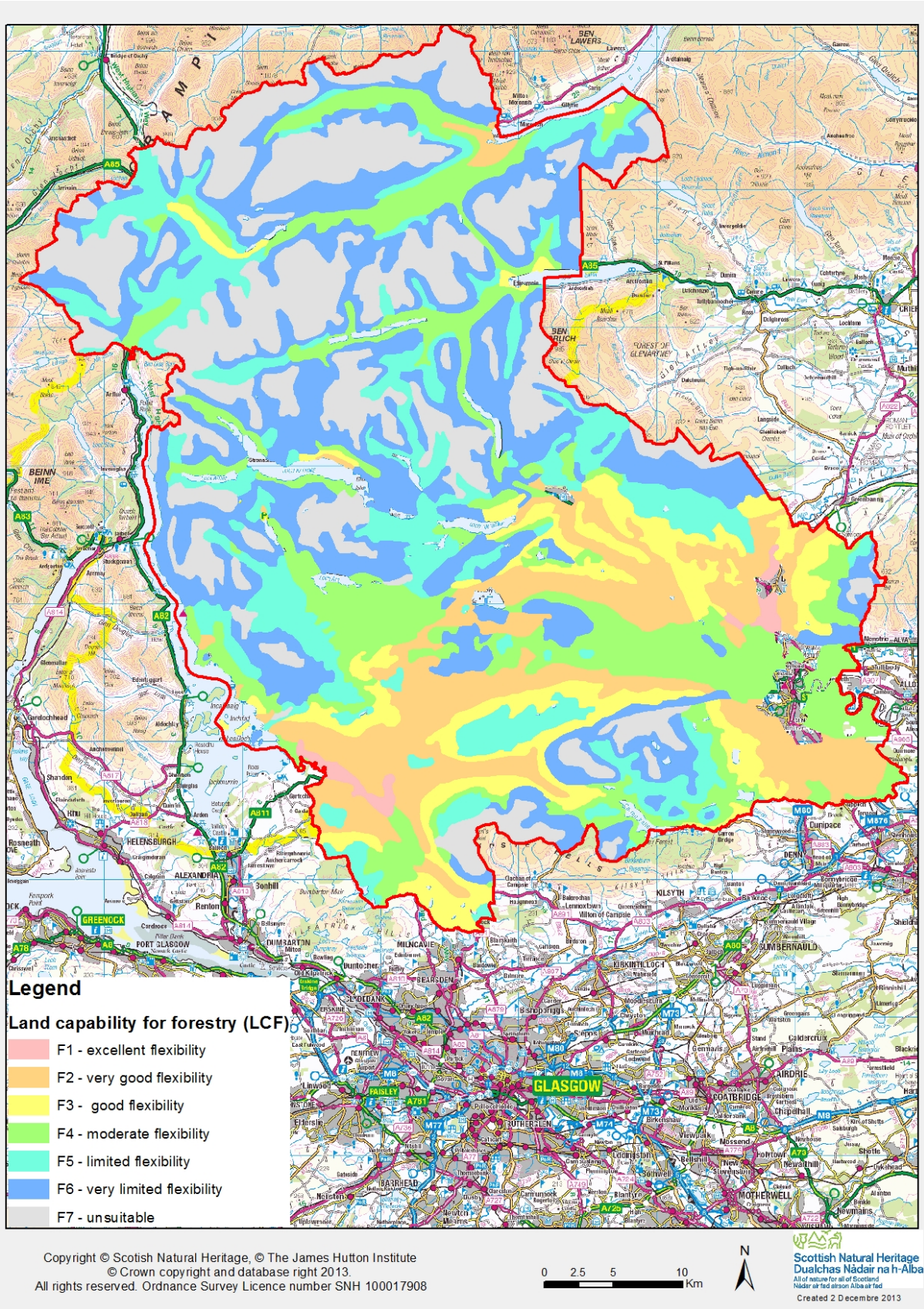


Figure 6. Land Capability for Forestry (LCF) flexibility for the growth and management of tree crops in Stirling, derived from 1:50,000 scale GIS dataset.

3.3.3 Land Capability for Forestry (LCF) - 1:250,000 scale data

As shown in *Figure 6* and in *Table 8* all LCF classes are represented in the Stirling area. The Carse of Stirling area displays extensive land mapped with good to excellent flexibility for tree crops (class F1 to F3). In the Upland part of the county, areas mapped as good flexibility for tree crops are mostly located on valley floors with the valley head and slopes becoming less suitable for tree crops as altitude and gradient increase. This dataset can be accessed from SSW at <http://www.soils-scotland.gov.uk/data/soil-lcf>.

Table 8. Distribution of LCF class in Stirling, derived from 1:250,000 scale GIS dataset.

LCF class for growth and management of tree crops	Area (ha)	% in LA I	% of soil mapped
1 – excellent flexibility	1523	0.7	0.7
2 – very good flexibility	27628	12.3	12.8
3 – good flexibility	1879	8.3	8.7
4 – moderate flexibility	36587	16.2	17.0
5 – limited flexibility	32002	14.2	14.8
6 – very limited flexibility	53022	23.5	24.6
7 – unsuitable	46107	20.5	21.4
Other land – non soil	9634	4.3	
Total soil mapped	215627	95.7	
Total area mapped	225261		

3.4 Soil carbon richness

The soils of Scotland store over 3,000 Mt of carbon which is equivalent to over 150 times the total annual UK GHG emissions. Most of the soil carbon stock is associated with the accumulation of the peat layer which contains over 60% of organic matter (dry weight). Soils with a peat layer greater than 50 cm are mapped as peat or organic soil in the Soil Survey classification for Scotland. Over 2/3rds of the soil carbon in Scotland is stored in peat soil. Soils with a peat layer less than 50 cm are referred as peaty or organo-mineral soils and account for most of the remaining soil carbon in Scotland.

3.4.1 SNH carbon richness of soil mapping unit

The soil carbon richness of soil mapping unit typology identifies the likelihood of the presence of peat deposits. It was developed to map the full extent of peatlands in Scotland and is freely available (Scottish Natural Heritage, 2011). The typology is currently based on information derived from the digitised 1:250,000 soil map. This enables a comparable display of soil carbon richness for the whole of Scotland (*Table 9, Figure 7*). Categories 6 and 5 will always be associated with carbon rich soil (peat soil and peaty soil with peat). Categories 3 and 4 are also potentially associated with high carbon levels. The data can be accessed from SSW (<http://www.soils-scotland.gov.uk/data/soil-carbon>).

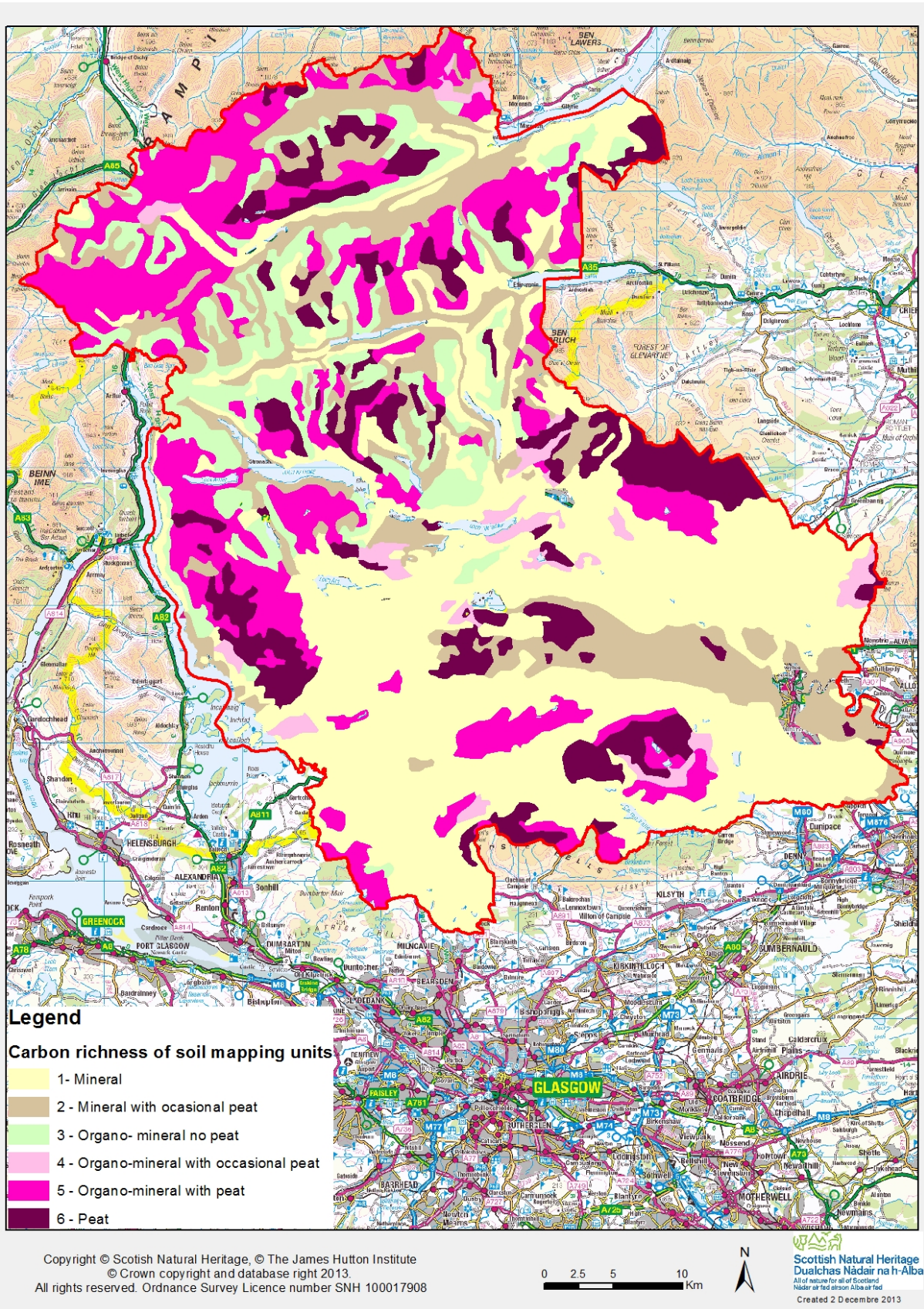


Figure 7. Carbon richness of soil mapping units in Stirling, derived from 1:250,000 scale GIS dataset only.

Table 9. Distribution of carbon richness soil map unit category in Stirling, derived from 1:250,000 scale GIS dataset.

Category	Area (ha)	% of LA	Average in Scotland
1 - mineral soil	81323	36.1%	41.0%
2 - mineral soil with occasional peat	34886	15.5%	4.7%
3 - organo-mineral no peat	18549	8.2%	9.6%
4 - organo-mineral with occasional peat	6404	2.8%	6.1%
5 - organo –mineral and peat	44710	19.9%	28.6%
6 - peat only	24682	11.0%	10.0%
Total area mapped	225214		

Peat and peaty soils (categories 3 to 6) cover up to 94,345 ha in Stirling based on the 1:250,000 scale soil map. There are 24,682 ha of peat soil (category 6) and an additional 44,710 ha of peaty soil with peat (category 5) covering a total of 40% of the Council area. Organo-mineral soil with occasional peat and organo-mineral with no peat occupied respectively 6404 ha and 18549 ha. Over 45% of soils in the Stirling area are mineral soils.

The same approach has been repeated with the 1:25,000 scale soil dataset which only covers part of Stirling (Table 10). At this scale, the soil carbon richness is derived from the individual soil series (only 3 options possible: category 1, 3 and 6) or the soil complex unit (6 possible categories as for the assessment at the 1:250,000 scale). The use of a combined 1:250,000 and 1:25,000 dataset for the whole of Scotland is under review and no further detail is available at time of publication.

Table 10 Distribution of carbon richness soil map unit category in Stirling, derived from 1:25,000 scale GIS dataset.

Category	Areas (ha)	% of mapped area
1 - mineral soil	48266	70.8%
2* - mineral soil with occasional peat	828	1.2%
3 - organo-mineral no peat	7357	10.8%
4* - organo-mineral with occasional peat	0	0.0%
5* - organo –mineral and peat	1412	2.1%
6 - peat only	10273	15.1%
Total area mapped	68135	

* only applicable to soils complexes series

Figure 8 merges the information on the carbon richness of the soil series mapped at 1:25,000 with carbon richness of soil map unit mapped at 1:250,000. The distribution of peat soil is one of the key factors in the identification of the extent of Scottish Peatlands (Bruneau & Johnson, in press). With the exception of the soil complexes, the use of 1:25,000 scale data reduces the uncertainty on the location of peat in Stirling and therefore provide a step forward to the most reliable estimate of peatland distribution (with the understanding that some peat is not mapped at the 1:250,000 scale).

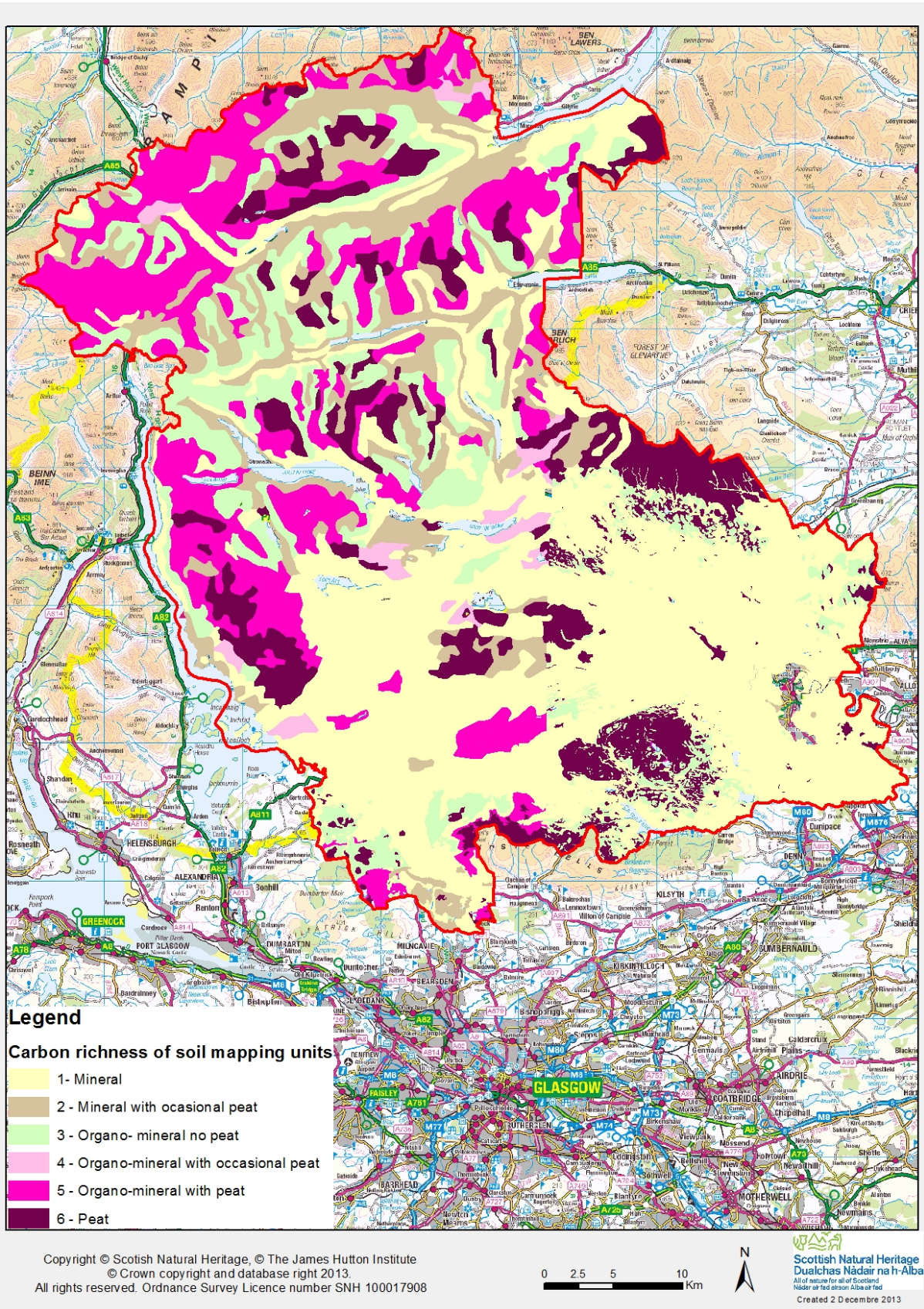


Figure 8. Carbon richness of soil mapping units in Stirling, derived from 1:250,000 and 1:25,000 scale GIS datasets combined.

The changes in the distribution of carbon rich soil mapping unit is shown in *Figure 9* and in *Table 11*.

The differences observed are mainly due to the reduction of extend of the complex soils (in categories 2, 4 and 5) from 17000 ha to less than 2200 ha. This provides better information on the location of the mineral, peaty and peaty soils.

There is some degree of overlap between areas mapped as peat on the 1:25,000 and 1:250,000 scale but also differences resulting from difference in both survey and mapping accuracy. As shown in *Figure 9* in the area covered by the 1:25,000 scale data, most of the change occurred at the edge of the large areas of peat. For example 11,020 ha are mapped at 1:250,000 scale as peat soils or peaty soils with peat (category 6 and 5), but at 1:25,000 scale, only 6648 ha remained unchanged (as original class 5 (in medium green) or 6 (in light purple)). In addition, 4372 ha are reassessed as mineral or peaty soil with no peat. Some 2640 ha mineral or peaty soil with no peat at 1:250,000 scale are also reclassified as peat or peaty soil with peat at 1:25,000 with an additional 2940 ha of peaty soil with peat being reassessed as peat only.

Table 11. Total change in area of mineral soil (categories 1 and 2), peaty soil (categories 3, 4 and 5) and peat soil (category 6) between 1:250,000 and 1:25,000 GIS datasets.

		1:25,000 scale		
		Mineral (1-2)	Peaty (3-4-5)	Peat (6)
1:250,000 scale	Mineral (1-2)	46444	4067	1630
	Peaty (3-4-5)	1738	4081	2505
	Peat (6)	571	620	6138

3.4.2 Recorded peat deep

Although there is no comprehensive peat depth survey in Scotland, information on the depth of peat deposits is available from a range of historical and contemporary field surveys. Various estimates of the variation of peat depth have been collated by the Hutton into a single dataset. The peat depth dataset is based on information derived from the digitised 1:250,000 soil map (*Figure 10, Table 12*).

Table 12. Total change in area of mineral soil (categories 1 and 2), peaty soil (categories 3, 4 and 5) and peat soil (category 6) between 1:250,000 and 1:25,000 GIS datasets

	number	Total area	Average depth of all peat unit	Max depth recorded
Map units with recorded peat	170	66,803 ha	0.72 m	4.42 m

The total volume of peat stored can be calculated by multiplying depth of peat by area. An estimate of 486.4 million m³ is recorded in the Stirling area. This is equivalent to 32 Mt of carbon assuming a bulk density for peat of 0.14 g/cm³. This represents around 2 % of total soil carbon in Scotland.

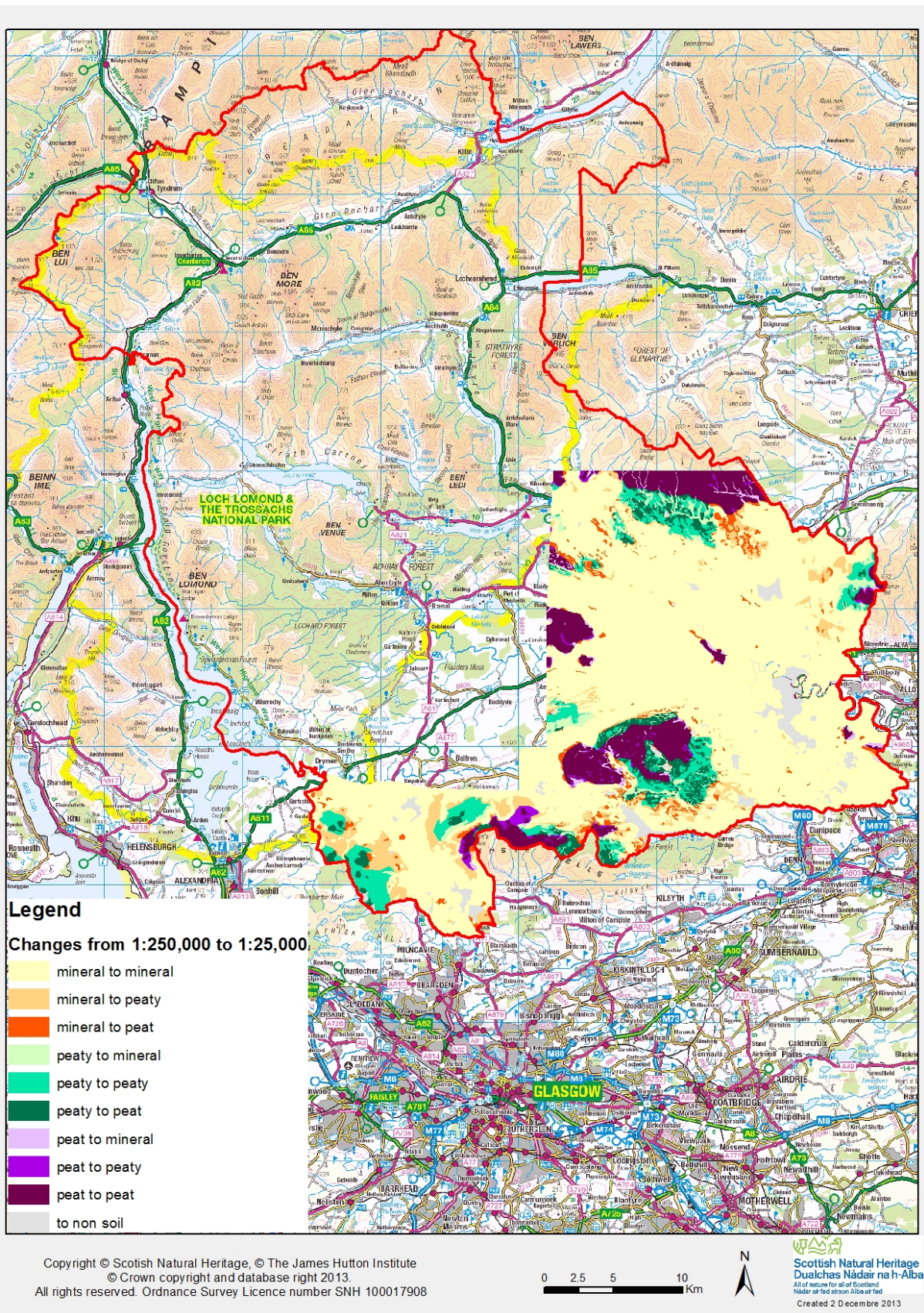


Figure 9. Change in Stirling of the distribution of Carbon richness of soil mapping unit from 1:250,000 to 1:25,000 scale.

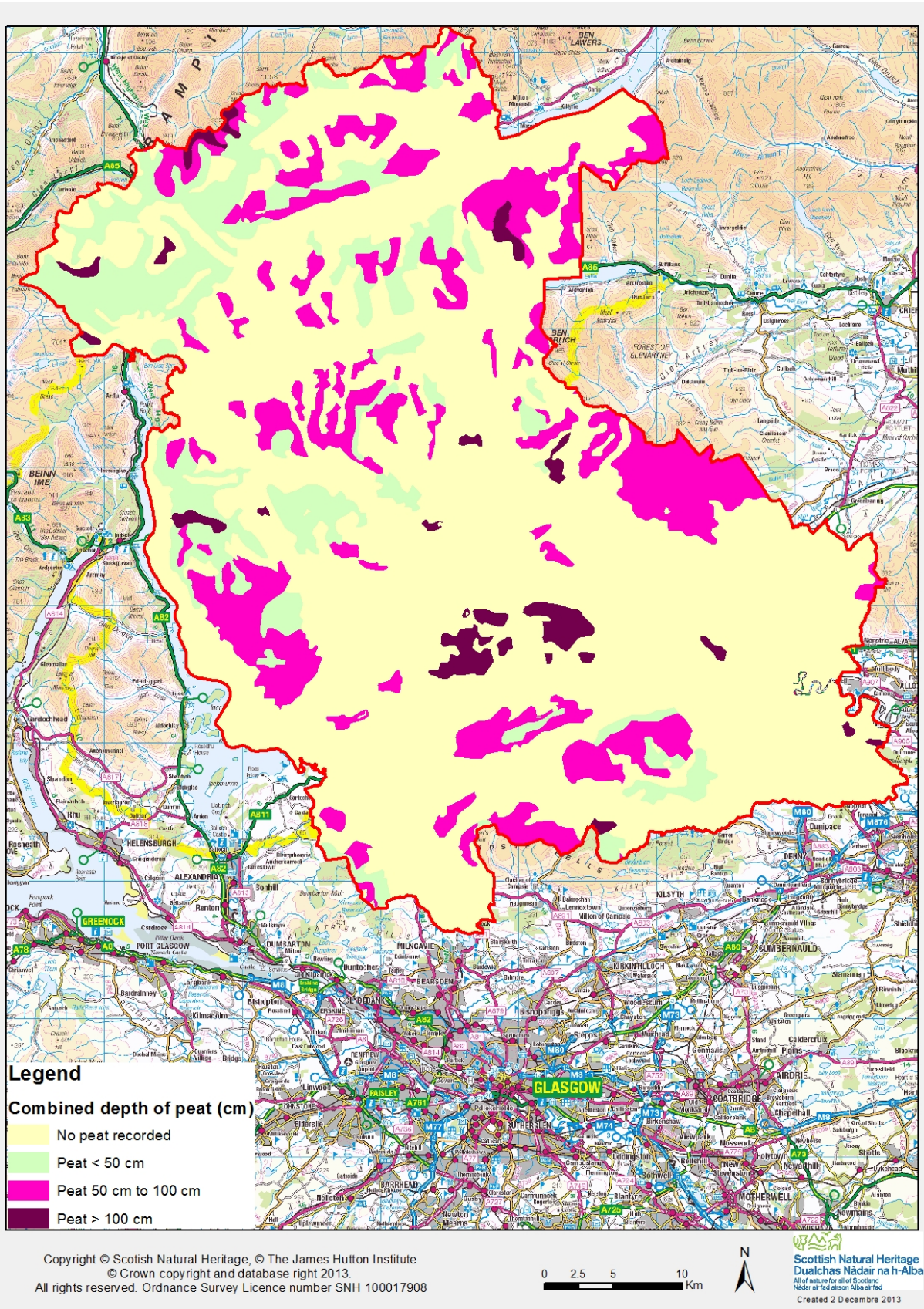


Figure 10. Recorded peat depth in Stirling, based on the Hutton composite scale peat depth GIS dataset.

3.5 Summary of soil features of national interest in Stirling

The soil information presented above is used in many decision support tools or locational guidance e.g. WISE peat (Artz *et al.*, 2013), SNH strategic locational guidance for onshore wind farms in respect of the natural heritage (<http://www.snh.gov.uk/planning-and-development/renewable-energy/onshore-wind/>), SEPA National flood risk assessment (http://www.sepa.org.uk/flooding/flood_risk_management/national_flood_risk_assessment.a_spx).

The table 13 below summarises the extent of the soil natural heritage features of national importance as described in section 1.2.1 of this report. Type a) (soils with high organic content) estimate is also being used to revise information on peatland distribution in Scotland (see Bruneau & Johnson, in press for detail).

Table 13. Summary of soil features of national importance in Stirling.

		Description of sources of information	Area coverage in Stirling
Type a) Carbon richness		Based on Table 9 (1:250,000 scale)	Peat 24,682 ha (11.0%) with an additional 44,710 ha (19.9%) of peat and peaty soils mixed
		Based on Table 10 (soil type 1:25,000 scale) (partial coverage – lowland only)	Peat 10,273 ha with an additional 144 ha of peat and peaty soils mixed
		Combined data from 1:25,000 and 1:250,000 scale	Peat 27,618 ha with an additional 39,717 ha of peat and peaty soils mixed
Type b) Rare soils		Based on soil type in Table 3 (scale of assessment 1:250,000)	Soil 37,621 ha (17.4%) With an additional 26,507 ha (12.2%) (if soil is undisturbed)
		Based on soil type Table 4 (1:25,000 scale) (partial coverage – lowland only)	Soil 15,713 ha With an additional 3,090 ha (if soil is undisturbed)
Type c) Prime agricultural land.		At 1:250,000 scale there is no Prime agricultural land mapped. The 1:50,000 scale map, which only covers the lowland areas, shows a small amount of Prime agricultural land.	At least 449 ha (2%) mostly in Carse of Stirling.

4. GEOLOGICAL CONSERVATION REVIEW SITES IN STIRLING

SNH was responsible for the digitisation of all Scottish Geological Conservation Review (GCR) sites boundaries onto 1:10,000 OS map (map uncertainty up to 5ha) (<https://gateway.snh.gov.uk/natural-spaces/index.jsp>).

There are 34 GCR sites in Stirling (*Table 14*) occupying 1.6% of the area. 21 of the 34 GCR sites are notified as features in geological SSSIs (SSSIs total area 126 ha) or mixed SSSIs (SSSIs total area 3,552 ha). Two of the GCR sites are notified in more than one SSSI (River Endrick GCR site and Western Forth Valley GCR site). The location of GCR sites and SSSIs are shown in *Figure 11*. By comparison, biological SSSIs alone occupy 14,695 ha (6.7%) of Stirlingshire.

The conservation of geological and geomorphological SSSIs is part of the statutory responsibility of SNH. The underpinned GCR should therefore be warranted an appropriate level of protected and consideration. When preparing an impact assessment on potentially damaging operations, it is important to recognise that no unique sensitivity value can be allocated to individual geological and geomorphological features of interests. The intensity and likelihood of damage will depend on the nature of threats and pressures and the specifics of the sites. However, some general sensitivity rules can be inferred from the nature of the interests. For example, static geodiversity interests (e.g. rock exposures, mineralogy interest) will behave differently from dynamic ones (e.g. river geomorphology, mass movement). This will directly influence the level of resilience and natural recovery embedded in the natural system.

When considering the wider geodiversity interest, the consequence of disturbance to geodiversity interest features with a finite extent (e.g. a small exposures in palaeontology and mineralogical sites, which are unique features in Scotland) are likely to be much greater than for sites with greater geographical extent or duplicated occurrence of features of interests.

The location of the site in the vicinity of a potential threat (e.g. the bank of a river and risk of flooding) will also modify the general sensitivity of GCR sites.

It is also important to note that new geological and geomorphological interests may be created by apparent damage to a site, e.g. exposure of a new rock face can also provide opportunity for new findings. (Scottish Geodiversity Forum, 2012)

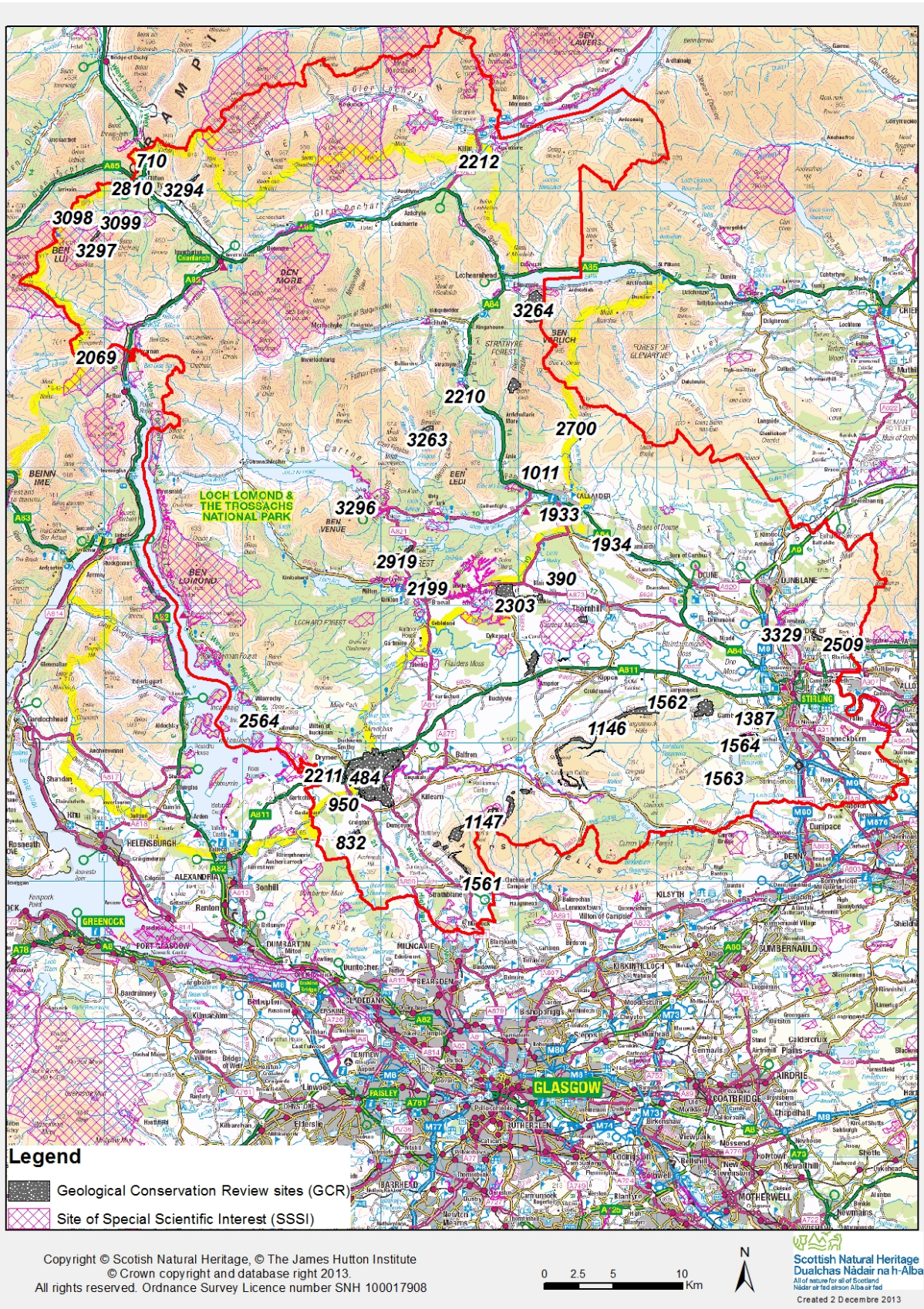


Figure 11. Location of Geological Conservation Review (GCR) sites in Stirling.

Table 14. Geological conservation review sites in Stirling.

BLOCK	SITE_NAME	GCR site number	Name of SSSI(s) where GCR underpinned the notified features of interest in SSSI(s)	Dynamics or static features	Area (ha)	
Arenig-Llanvirn	LIME CRAIG QUARRY	2199	LIME CRAIG QUARRY SSSI	static	4.3	
	GARABAL HILL TO LOCHAN STRATH DUBH-UISGE	2069	GARABAL HILL SSSI	static	0.9	
		1011	LENY QUARRY SSSI.	static	4.1	
	CAMPISIE FELLS		1147	BALGLASS CORRIES SSSI	static	14.7
						7.8
						4.3
						206.5
						27.9
						5.0
						3.6
16.8						
0.9						
266.7						
Caledonian Igneous Cambrian	TOUCH, FINTRY & GARGUNNOCK HILLS	1146	DOUBLE CRAIGS SSSI	static	8.2	
					116.6	
					28.4	
					3.0	
					12.9	
					7.6	
					4.8	
					6.4	
					28.6	
					0.6	
Dalradian	AUCHTERTYRE	3294	Not notified in SSSI	static	32.0	
	BEALACH NAM BO	3296	Not notified in SSSI	static	91.8	
	BEN OSS	3297	BEN LUI SSSI	static	18.0	
	DUKE'S PASS (formerly Aberfoyle Slate Quarries)	2919	Not notified in SSSI	static	162.0	
	KELTIE WATER, CALLENDER	2700	Not notified in SSSI	static	15.2	
	Touchadam	1564	SAUCHIE CRAIG WOOD SSSI	static	2.2	
	Dinantian of Scotland	BALLAGAN GLEN	1561	BALLAGAN GLEN SSSI	static	6.2
GARGUNNOCK BURN		1562	Not notified in SSSI	static	1.3	
TODHOLES		1563	Not notified in SSSI	static	5.8	
Fluvial Geomorphology of Scotland	FALLS OF DOCHART	2212	FALLS OF DOCHART SSSI	dynamic	2.2	
	RIVER BALVAG DELTA	2210	LOCH LUBNAIG MARSHES SSSI	dynamic	41.4	
	RIVER ENDRICK ('Endrick Water' in GCR vol)	2211	ENDRICK MOUTH AND ISLANDS SSSI and ENDRICK WATER SSSI.	dynamic	93.1	
Mass Movement	BENVANE (BEINN BHAN)	3263	Not notified in SSSI	dynamic	138.8	
	GLEN AMPLE	3264	Not notified in SSSI	dynamic	284.9	
Mineralogy of Scotland	CONONISH MINE	3098	Not notified in SSSI	static	59.0	
	Creag Bhocan	3099	BEN LUI SSSI	static	18.7	
	TYNDRUM MAIN MINE	2810	Not notified in SSSI	static	72.0	
Non marine	WOLF'S HOLE QUARRY	3329	Not notified in SSSI	static	14.5	
					1.2	

BLOCK	SITE_NAME	GCR site number	Name of SSSI(s) where GCR underpinned the notified features of interest in SSSI(s)	Dynamics or static features	Area (ha)
Devonian					
Old Red Sandstone Igneous	SHERIFFMUIR ROAD TO MENSTRIE BURN	2509	Not notified in SSSI	static	216.5
Ordovician Igneous	BALMAHA & ARROCHYMORE POINT	2564	CONIC HILL SSSI	static	10.7
					0.5
					3.5
Palaeozoic Palaeobotany	BALLANUCATER FARM	390	BALLANUCATER SSSI.	static	0.9
	AUCHENECK	832	AUCHENECK SSSI	dynamic	102.7
	CROFTAMIE	950	Not notified in SSSI	dynamic	0.6
	GARTNESS	484	ENDRICK WATER SSSI	dynamic	1024.3
	MOLLANDS	1933	MOLLANDS SSSI	dynamic	7.9
Quaternary of Scotland	TYNASPIRIT	1934	TYNASPIRIT SSSI	dynamic	1.8
	WESTERN FORTH VALLEY	2303	FLANDERS MOSS SSSI and LAKE OF MENTEITH SSSI	dynamic	83.9
					5.0
					0.5
					24.6
					282.6
Silurian-Devonian Chordata	WOLF'S HOLE QUARRY	357	WOLF'S HOLE QUARRY SSSI.	static	0.8
Total					3612.6 (1.6% of LA)
Total in underpinning SSSI					2565.4 (71% of GCRs area)

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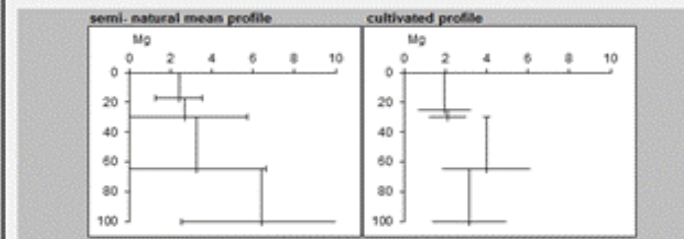
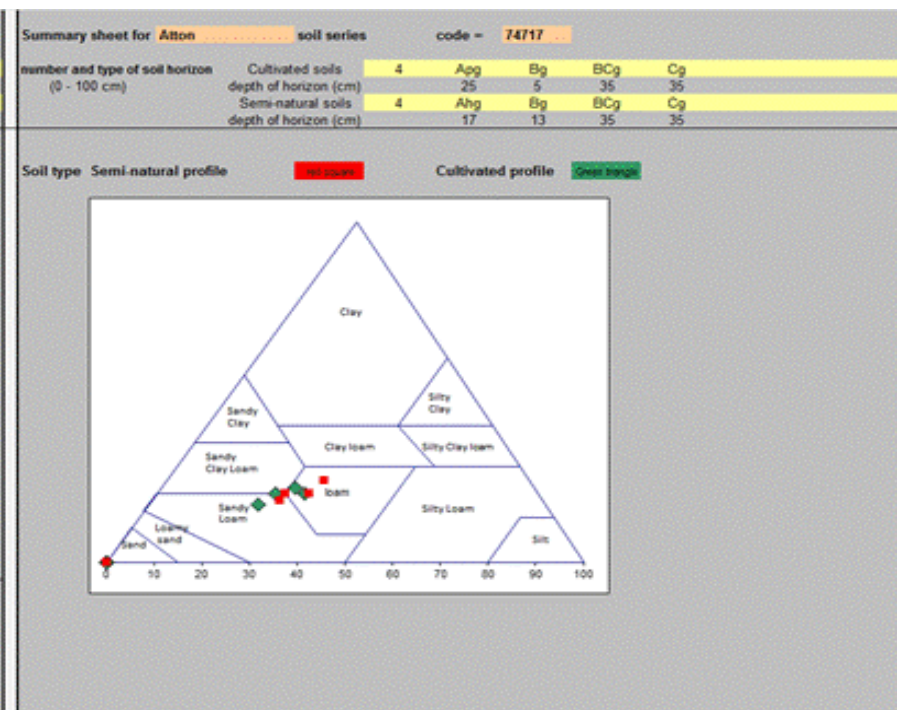
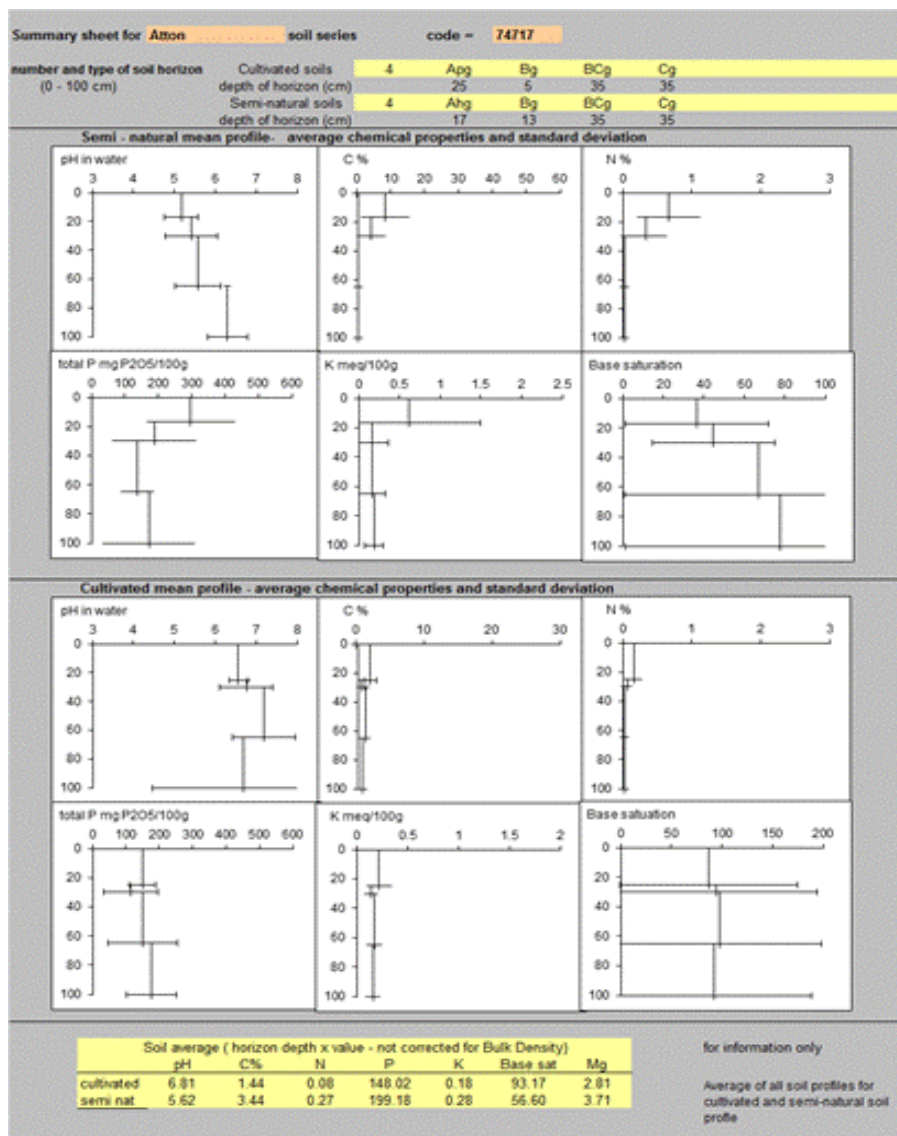
SSW. n.d. *Scottish Soil Data website*. Retrieved from www.soils-scotland.gov.uk.

Walker, A.D, Campbell, C.G.B., Helsop, R.E.F., Gauld, J.H., Laing, D., Shipley, B.M. & Wright, G.G. 1982. *Soil and Land Capability for Agriculture – Eastern Scotland*. Soil Survey of Scotland. The Macaulay Institute for Soil Research, Aberdeen.

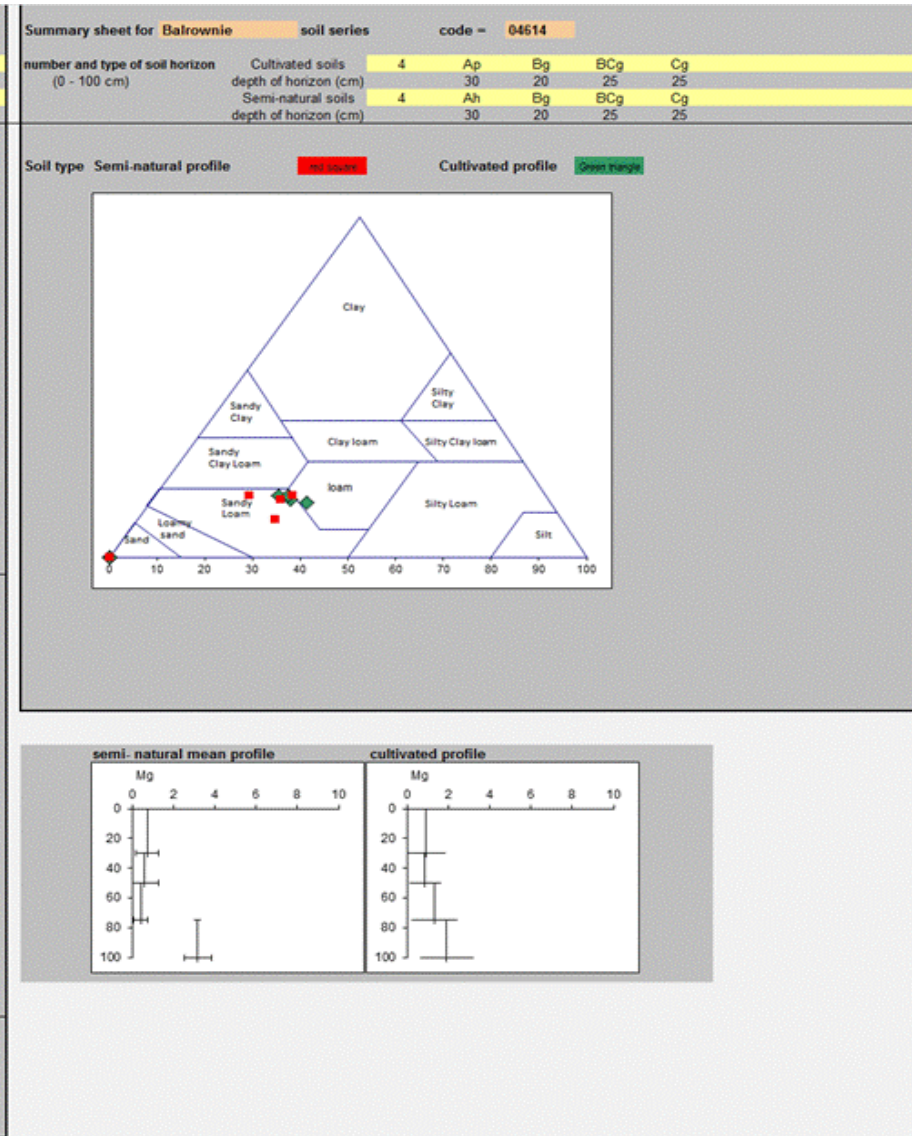
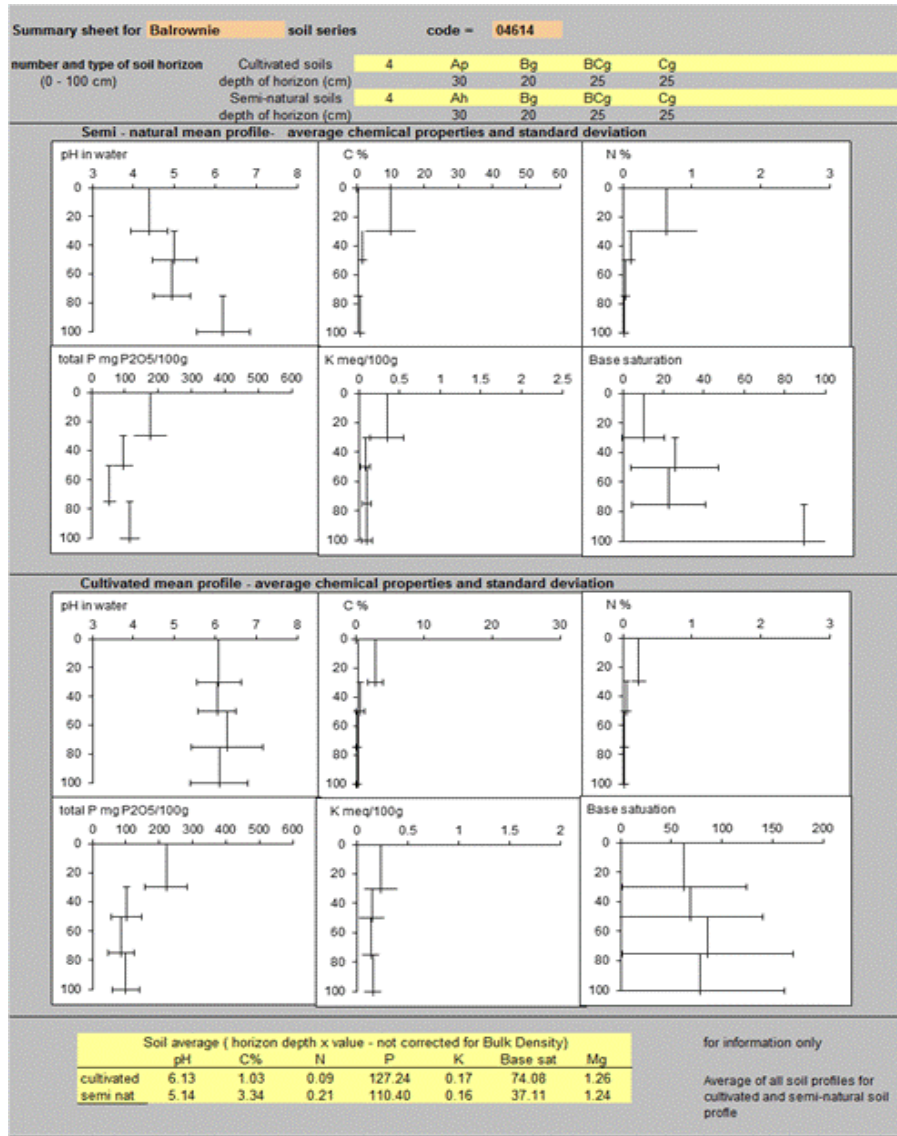
Wilson, R. B. 1977. *History of the Geological Survey in Scotland*. Edinburgh: Institute of Geological Sciences.

ANNEX 1 - KEY SOIL BASELINE PROPERTIES (EXTRACT FROM SSKIB DATABASE)

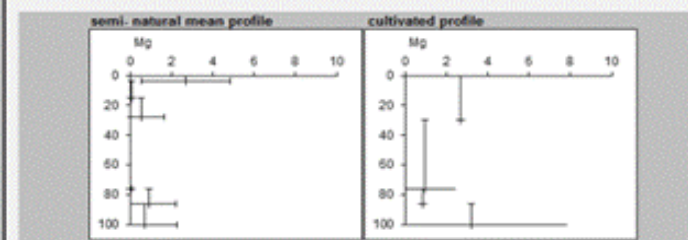
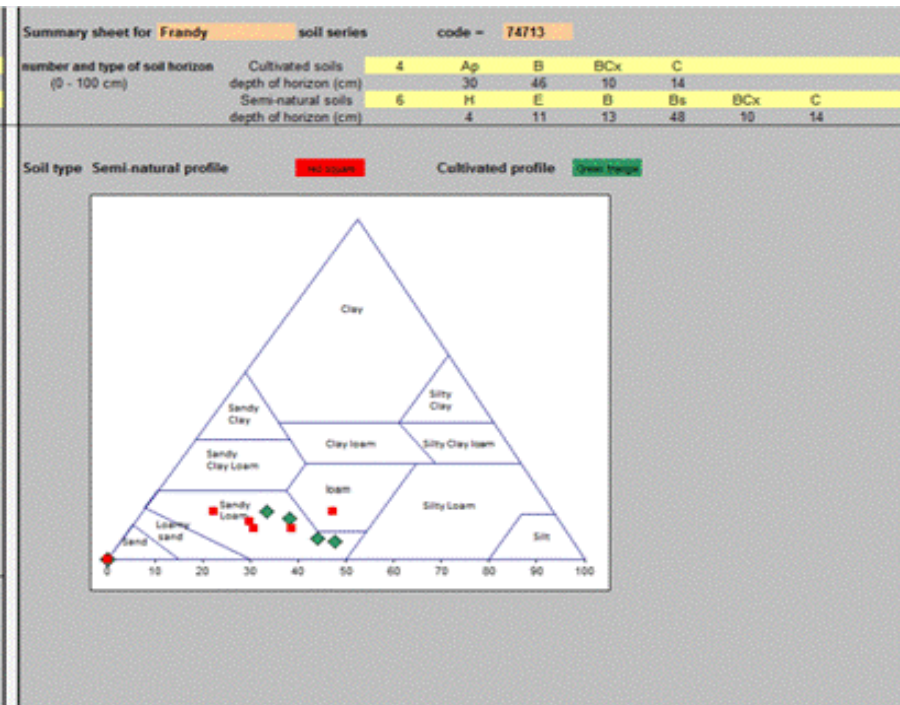
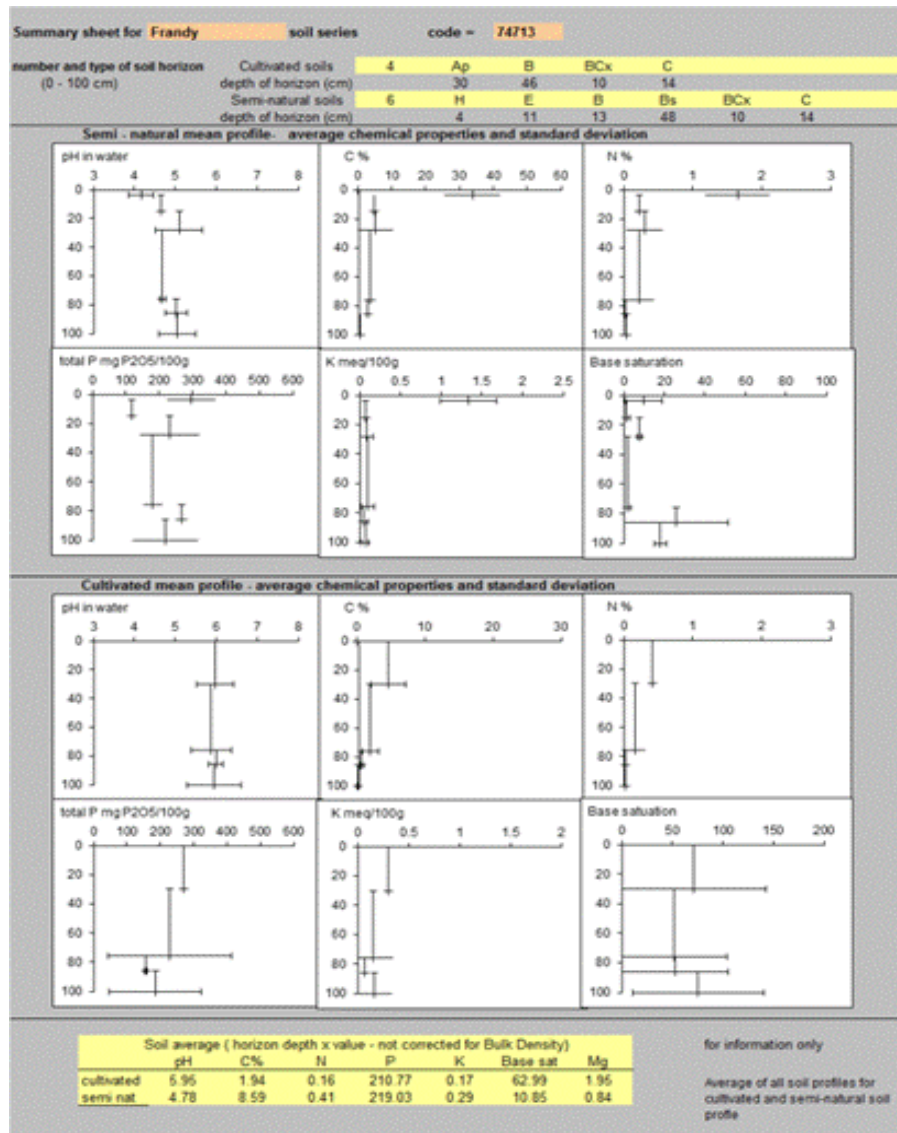
Atton soil series (Non-calcareous gley)



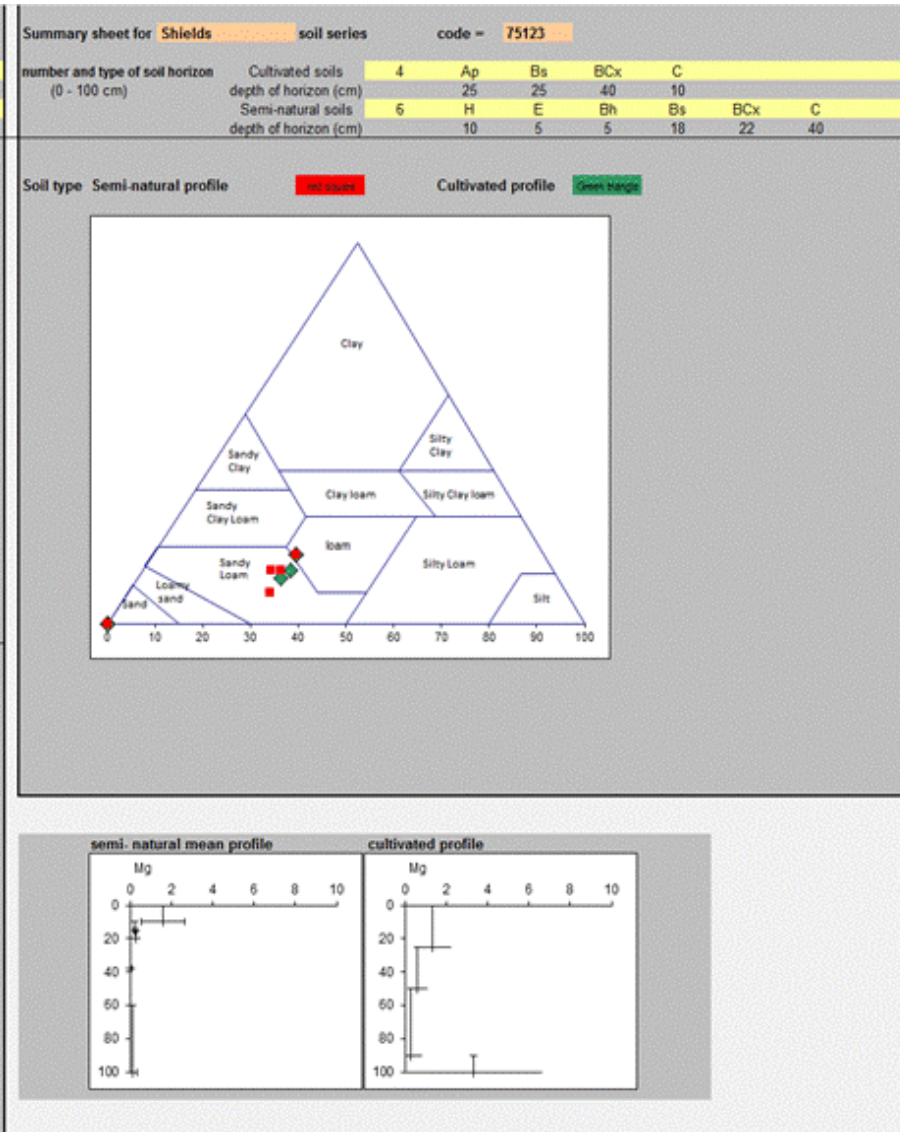
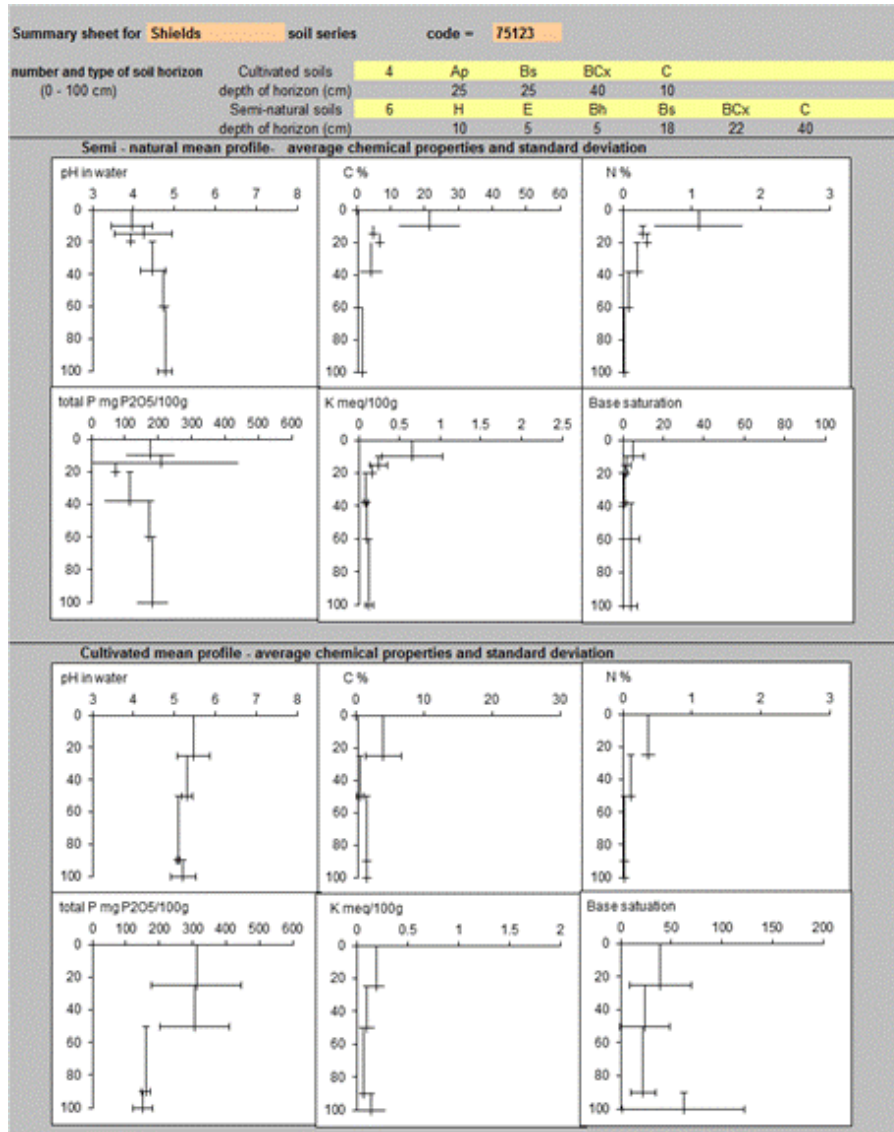
Balrownie soil series (Brown earth with gleying)



Frandy soil series (Humus-iron podzol)



Shields soil series (Humus-iron podzol)

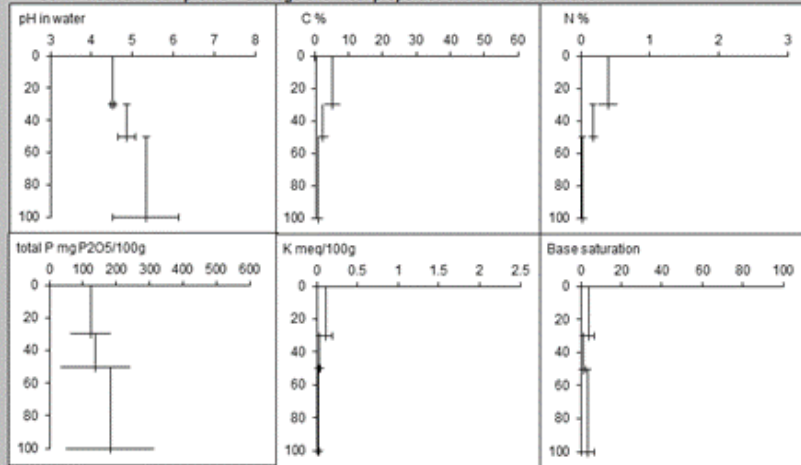


Doune soil series (Brown earth soil)

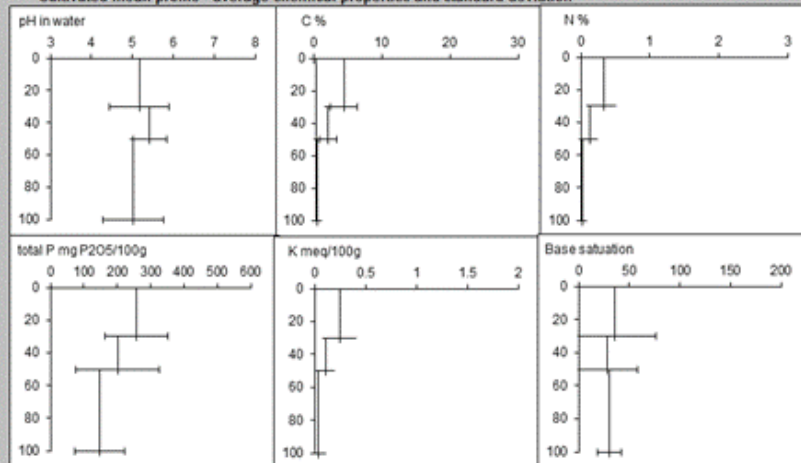
Summary sheet for Doune soil series code = 14122

number and type of soil horizon (0 - 100 cm)	Cultivated soils	3	Ap	B	C	0
	depth of horizon (cm)	30	20	50		
	Semi-natural soils	3	Ah	B	C	
	depth of horizon (cm)	30	20	50		

Semi - natural mean profile - average chemical properties and standard deviation



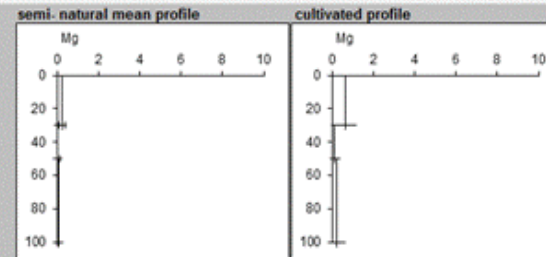
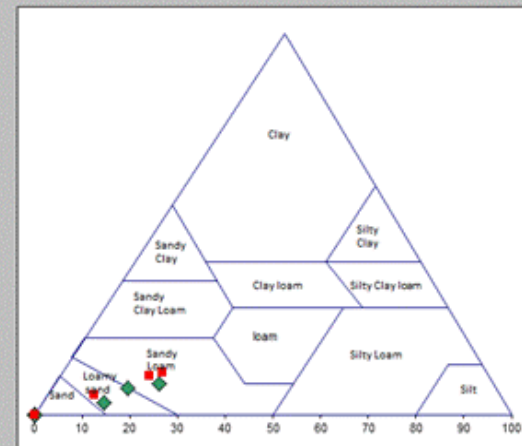
Cultivated mean profile - average chemical properties and standard deviation



Summary sheet for Doune soil series code = 14122

number and type of soil horizon (0 - 100 cm)	Cultivated soils	3	Ap	B	C	0
	depth of horizon (cm)	30	20	50		
	Semi-natural soils	3	Ah	B	C	
	depth of horizon (cm)	30	20	50		

Soil type Semi-natural profile **Loam loam** Cultivated profile **Open Range**

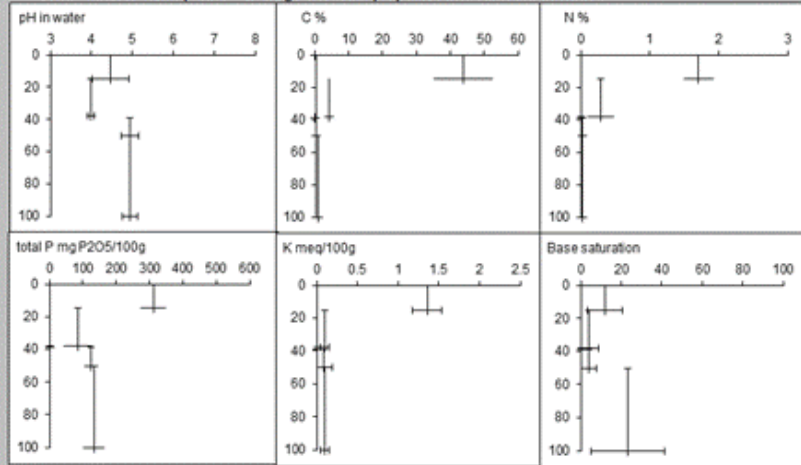


Stonehaven(PP) soil series (Peaty podzol)

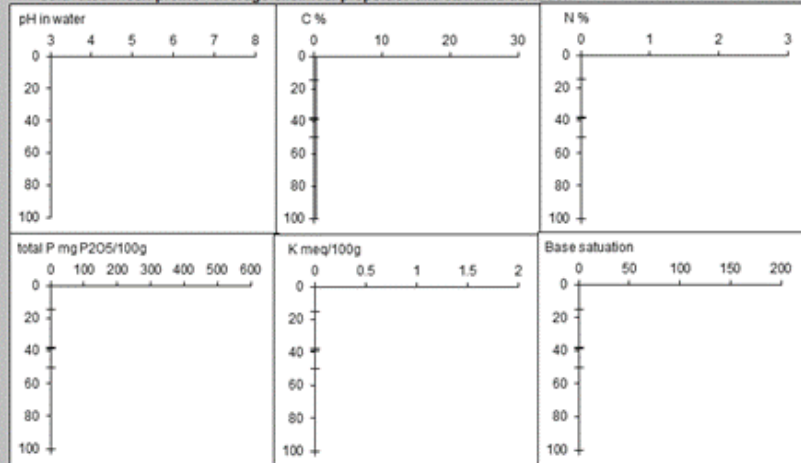
Summary sheet for **STONEHAVEN(PP)** soil series code = **75133**

number and type of soil horizon	Cultivated soils	5	Op	Eg	Bf	Bs	BC
(0 - 100 cm)	depth of horizon (cm)	15	23	1	11	50	
number and type of soil horizon	Semi-natural soils	5	O	Eg	Bf	Bs	BC
(0 - 100 cm)	depth of horizon (cm)	15	23	1	11	50	

Semi - natural mean profile - average chemical properties and standard deviation



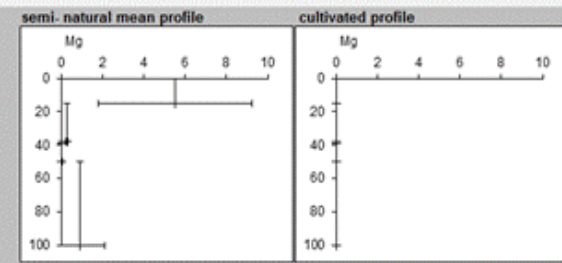
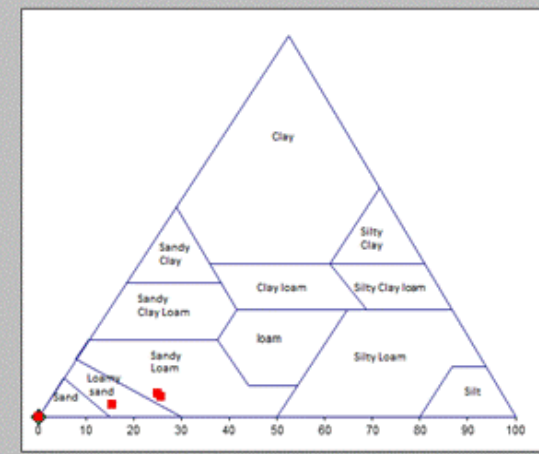
Cultivated mean profile - average chemical properties and standard deviation



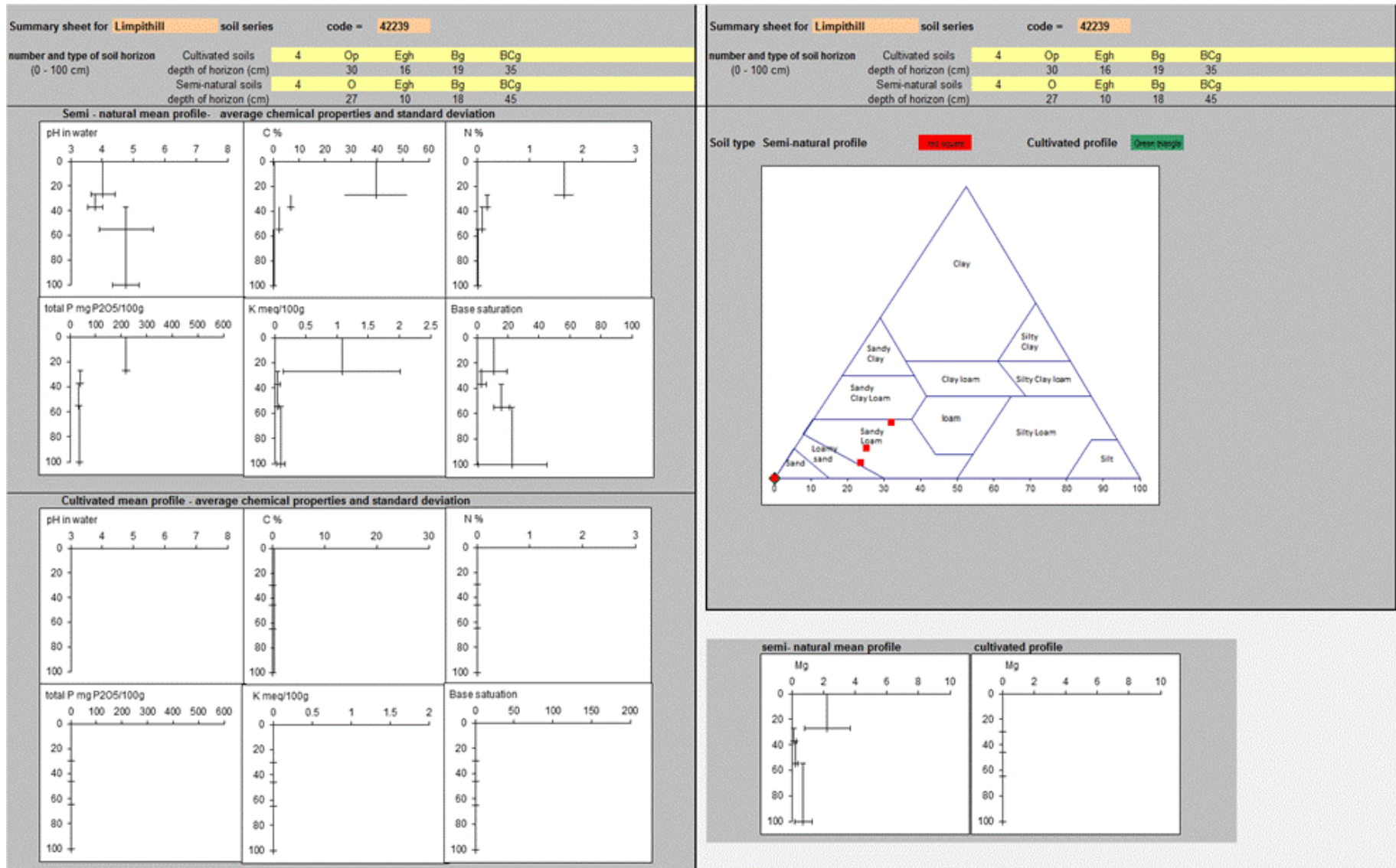
Summary sheet for **STONEHAVEN(PP)** soil series code = **75133**

number and type of soil horizon	Cultivated soils	5	Op	Eg	Bf	Bs	BC
(0 - 100 cm)	depth of horizon (cm)	15	23	1	11	50	
number and type of soil horizon	Semi-natural soils	5	O	Eg	Bf	Bs	BC
(0 - 100 cm)	depth of horizon (cm)	15	23	1	11	50	

Soil type Semi-natural profile red square Cultivated profile green square



Limpithill soil series (Peaty gley)



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Policy and Advice Directorate, Great Glen House,
Leachkin Road, Inverness IV3 8NW
T: 01463 725000

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