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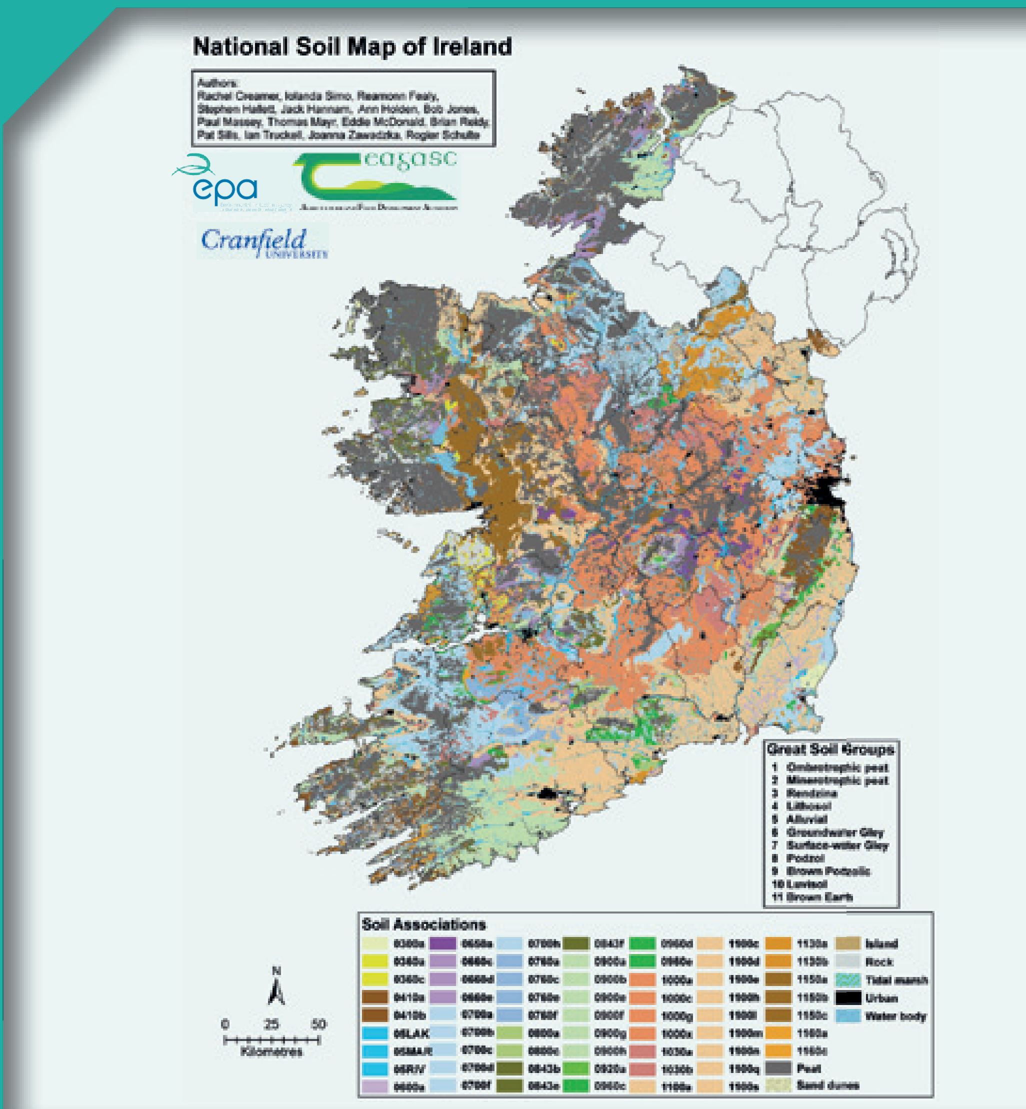
# Irish Soil Information System

## Synthesis Report




Comhshaol, Pobal agus Rialtas Áitiúil
Environment, Community and Local Government

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The Environmental Protection Agency (EPA) is a statutory body responsible for protecting the environment in Ireland. We regulate and police activities that might otherwise cause pollution. We ensure there is solid information on environmental trends so that necessary actions are taken. Our priorities are protecting the Irish environment and ensuring that development is sustainable.

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- Office of Environmental Enforcement
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The EPA is assisted by an Advisory Committee of twelve members who meet several times a year to discuss issues of concern and offer advice to the Board.

**EPA Research Programme 20014-2020**

# Irish Soil Information System

# Synthesis Report

# (2007-S-CD-1-S1)

***End of project Reports available for download at [http://erc.epa.ie/safer/reports](http://erc.epa.ie/safer/reports)***

***Soil Information System available at: [http://soils.teagasc.ie](http://soils.teagasc.ie)***


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by
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## DISCLAIMER



The EPA STRIVE Programme addresses the need for research in Ireland to inform policymakers and other stakeholders on a range of questions in relation to environmental protection. These reports are intended as contributions to the necessary debate on the protection of the environment.

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# Executive Summary

The Irish Soil Information System (ISIS) project was established in 2008, following a comprehensive inventory of Irish soil data compiled by Daly and Fealy (2007), which had highlighted that soil data coverage of Ireland was incomplete in both detail and extent. The ISIS project was funded under the Environmental Protection Agency STRIVE Research Programme 2007–2013 and co-funded by Teagasc. It was led by Teagasc with the participation of researchers from Cranfield University (UK) and University College Dublin. The overall objective of the ISIS project was to conduct a programme of structured research into the national distribution of soil types and construct a soil map, at 1:250,000 scale, which would identify and describe the soils according to a consistent national legend. This map is now available in digital format and forms the basis of a new soil information system for Ireland (http://soils.teagasc.ie).

The ISIS project has used existing data and maps from the previous National Soil Survey (NSS) conducted by An Foras Talúntais (AFT) (forerunner organisation to Teagasc). The NSS produced: mapping at 1:126,720 scale for 44% of the country; a General Soil Map of Ireland and a National Peatland map, both at 1:575,000 scale; and other miscellaneous large-scale mapping of experimental farms. In addition, ISIS has included more recent map products, such as the Indicative Soil Map (1:150,000) and Subsoil mapping (1:50,000) (Fealy and Green, 2009) with national coverage using GIS and remote-sensing techniques.

Comparison of soil information at a European scale has led to the requirement for the harmonisation and coordination of soil data across Europe, and, in light of the demands for soil protection on a regional basis within member states, there is a growing need to support policy with a harmonised soil information system. The European Soil Bureau Network (ESBN) Technical Working Group dealing with Soil Monitoring and Harmonisation recommended a soil map of Europe at a scale of 1:250,000 as an economically feasible intermediate scale that can identify specific problems at regional scale (Montanarella and Jones, 1999).

The ISIS project adopted a combined methodology that used novel predicted mapping techniques in tandem with traditional soil-survey applications. This unique combination at a national scale has resulted in the development of a new national soil map for Ireland. Building upon the detailed work carried out by the AFT survey (referred to as *Terra Cognita*), the ISIS project generated soil-landscape models (describing which soils occur in which landscapes) at a generalised scale of 1:250,000 for the counties of Carlow, Clare, Kildare, Laois, Leitrim, Limerick, Meath, Offaly, Tipperary North, Waterford, Westmeath, Wexford, West Cork, West Mayo and West Donegal. These soil-landscape models (also referred to as 'soilscapes') were used as the baseline data for statistical models (known as random forests, bayesian belief networks and neural networks; see main text for technical details) to predict soil map units in counties where no map was available (referred to as *Terra Incognita*). To validate the methodology, this work was supported by a 2.5-year field survey, in which 11,000 locations were evaluated for soil type, using an auger-bore survey approach. These data were used to check the predicted soil mapping units (associations) for counties Cavan, Dublin, East Cork, East Donegal, East Mayo, Galway, Kerry, Kilkenny, Louth, Monaghan, Roscommon, Sligo, Tipperary South and Wicklow, where a detailed soil survey map was not available. Where new soil information was generated, due to previously unknown combinations of soil-landscape units, profile pits were selected at representative locations across the country. These 225 pits were described and sampled in detail and were used to generate a new soil classification system for the country. The final product (Fig. A) is a unique combination of new and traditional methodologies and soils data from both the AFT and the ISIS project. The final soil association map of Ireland consists of 58 associations (excluding areas of alluvium, peat, urban, rock or marsh) that arise from the 213 soil series. Associated representative profile information is available in the online soil information system.

A key component of the ISIS project has been the development of a soil and land information system and associated public website. This system has been designed to hold the complete set of information deriving both from the ISIS field programme and modelling activity, as well as the previously existing legacy soils information available for Ireland. Drawing on this information system, the website is designed to hold and disseminate this information online both in cartographic and tabular form to stakeholders and the public in general. Before this development, there was no harmonised computerised system in place to hold and manipulate national Irish soils data. The information system therefore addresses the pressing need and requirement for a publicly accessible, integrated IT framework to serve the many and varied stakeholders having an interest in soils information in Ireland.

This report is the Integrated Synthesis report. All Final Technical Reports arising from the ISIS project are available from: http://erc.epa.ie/safer/reports

# 1 Introduction

## 1.1 Background

Soil is a vital non-renewable resource essential to human life and the ecosystems that support it. Increasingly, soil is recognised as a habitat in its own right as well as a foundation for others. Living soil systems deliver valuable ecosystem services (biodiversity, clean air and water, food security and cultural heritage). Soil performs a variety of crucial functions in the environment and for the economy, and thus its sustainable management should be ensured. European policy recommends that soil should be of equal status to that of air and water. Better scientific information will ensure that soil is managed in a more sustainable manner at local, regional and continental levels as part of sustainability goals (c.f. Lisbon Objectives [http://europa.eu/legislation/lisbon]. The impact of global change (climate, technological,

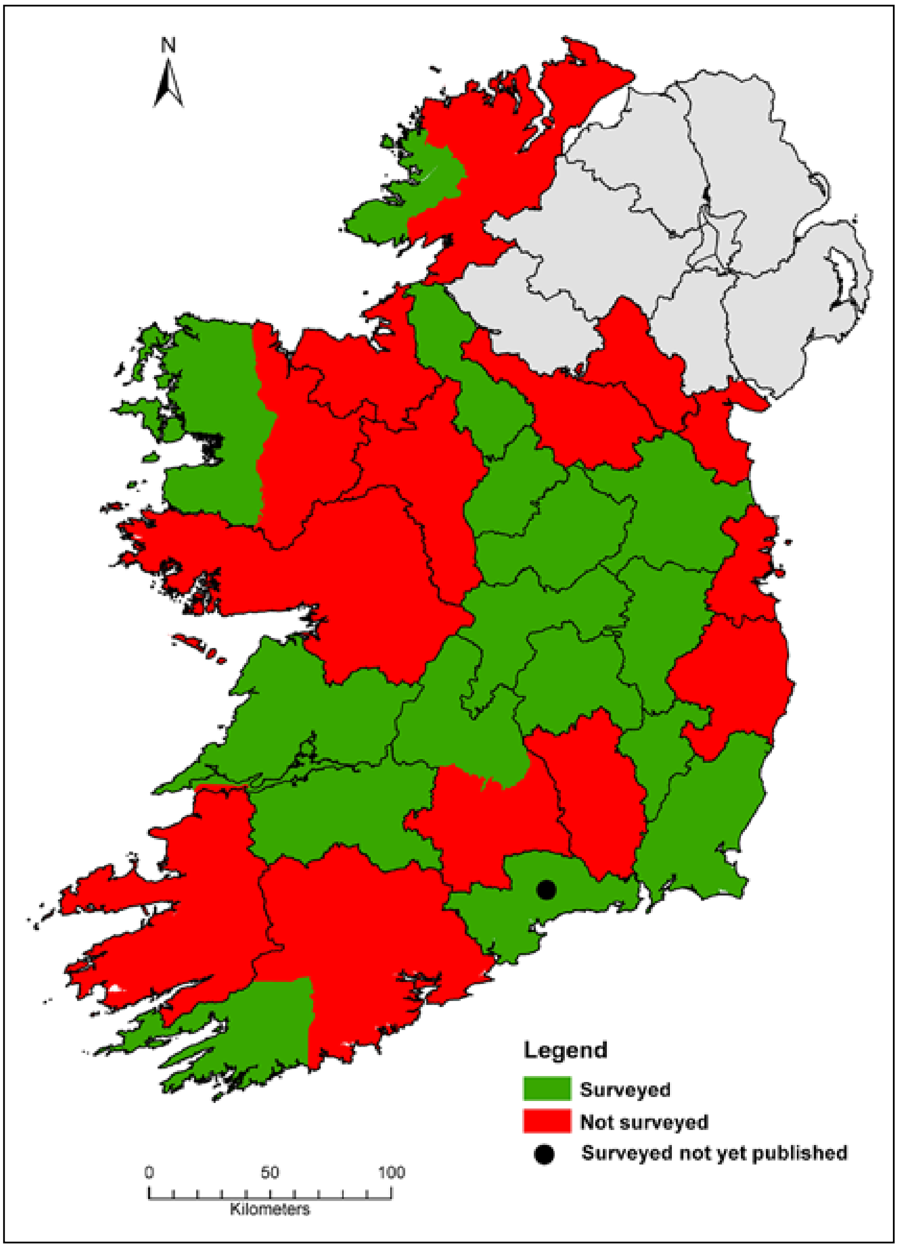


**Figure 1.1. An Foras Talúntais (AFT) mapped areas of Ireland prepared in 2008. Green represents areas surveyed in detail by AFT; red represents areas that had not been mapped in detail.**

socio-economic) on soil resources makes this a priority. Appropriate scale information on soils will inform many existing and developing policies for sustainability targets, such as the Water Framework Directive (WFD), Nitrates Directive, Sewage Sludge Directive, Kyoto Protocol reporting, etc.

In 2007, it was recognised that the current General Soils Map was not suitable for future reporting requirements for sustainability targets. Soils information was revived in Ireland in anticipation of implementation of the proposed European Soil Framework Directive (SFD). Approximately 44% of Ireland was surveyed in the 1950s, 1960s and 1970s by An Foras Talúntais (AFT), mostly at a scale of 1:126,720, with the publication by the end of the 1980s of most of the county soil maps and accompanying bulletins (Fig. 1.1).

A comprehensive inventory of soil data in Ireland, compiled by Daly and Fealy (2007), highlighted that soil data coverage at national level was incomplete in both detail and extent. Interest in completing a strategic soil mapping exercise to cover the whole of Ireland revived in response to the increasing demand for an updated National Soil Map of Ireland (at 1:250,000 scale) to replace the General Soil Map. This proposed map would be compatible with existing soil survey coverage in other member states of the European Union.

## 1.2 Ireland Soil Information System (ISIS) Project

The overall objective of the Ireland Soil Information System (ISIS) project was to conduct research into the national distribution of soil types and construct a soil map, at 1:250,000 scale, that would identify and describe the soils according to a consistent national legend. A digital version of such a map would form the basis of a new soil information system for Ireland. To achieve this objective, the ISIS research project was funded by the Environmental Protection Agency (EPA) Ireland in 2008 as part of the STRIVE Programme.

This report is the Integrated Synthesis report. All Final Technical Reports (Table 1.1) arising from the ISIS project are available from: http://erc.epa.ie/safer/reports

Datasets and other resources generated by the ISIS project are also available from http://erc.epa.ie/safer and the soils information system available at: http://soils.teagasc.ie

**Table 1.1. ISIS Final Technical Reports (http://erc.epa.ie/safer/reports).**

| ISIS Final Technical Report | Title |
|---|---|
| ISIS Final Technical Report 1 | *Interim classification, Harmonisation and Generalisation of County Soil Maps of Ireland* |
| ISIS Final Technical Report 2 | *Interim Classification and Rationalisation of Soil Series in Ireland* |
| ISIS Final Technical Report 3 | *Soilscapes for Terra Cognita Ireland* |
| ISIS Final Technical Report 4 | *Soilscapes Extrapolation (Terra Incognita) Ireland* |
| ISIS Final Technical Report 5 | *Predictive Mapping* |
| ISIS Final Technical Report 6 | *User Guide for Representative Soil Profile Data Capture System* |
| ISIS Final Technical Report 7 | *Irish Soil Information System: Laboratory Standard Operating Procedures* |
| ISIS Final Technical Report 8 | *Correlation of the Irish Soil Classification System to World Reference Base - 2006 System* |
| ISIS Final Technical Report 9 | *ISIS National Soil Series – Description and Classification of Representative Profiles* |
| ISIS Final Technical Report 10 | *Soil Profile Handbook* |
| ISIS Final Technical Report 11 | *Methodology for the Validation of Predictive Mapping* |
| ISIS Final Technical Report 12 | *Multiple Classifier System* |
| ISIS Final Technical Report 13 | *Irish Soil Information System Legend* |
| ISIS Final Technical Report 14 | *Systems Analysis and Design* |
| ISIS Final Technical Report 15 | *ISIS SISCore Data Model* |
| ISIS Final Technical Report 16 | *Building the Database* |
| ISIS Final Technical Report 17 | *Irish Soil Information System Users Guide* |

## 1.3 Soil Landscapes of Ireland

The economy of Ireland is supported by a diverse range of agricultural production systems across the country. These include land dominated by tillage, which uses the free-draining soils of the south-east; the intensive livestock farming on the limestone-rich lowland grasslands of the south and midlands; and the more extensive hill farming and forestry on the acid and peat soils of the hills, mountains and western seaboard. These broad landscape categories were originally defined in the General Soils Map of Ireland (Gardiner and Radford, 1980). Understanding the factors that are important in the formation of these soils provides an insight into the soil properties. This, in turn, can inform the categorisation and classification of soils in terms of soil management and suitability for various uses.

The soils and dominant agricultural activities in any area are influenced by a number of factors, including:

- The type of rocks (geology) or sediments that soils are formed on;
- Position in the landscape (topography);
- Climate, most importantly rainfall and temperature;
- Influence of humans; and
- Duration of soil development.

These factors clearly interact and therefore determine the formation of soils. For example, in mountainous areas soils are influenced by both topography and climate in addition to the underlying geology (Fig. 1.2).,

The most obvious influence on soil formation in Ireland is geology. Where soils are formed directly over in situ rock material ('bedrock'), the mineralogical composition determines the nature of the overlying soils. In Ireland, the physical and chemical properties of the bedrock vary, often over short distances. For example, calcareous limestone underlies large areas of the midlands, while acidic sandstones and shales are found in the south-west. Acid igneous rocks such as granite are found in the Wicklow mountains and metamorphic rocks, such as gneiss, schist and quartzite provide the striking landscapes in the north and west, for example in Connemara, West Mayo and Donegal.

The Irish landscape has been considerably altered several times due to glacial and interglacial episodes. The ice sheets retreated from all but the highest ground about 13,000 years ago. Glaciers scoured rock materials from the bedrock as they moved across the landscape. This material was crushed and ground to produce finer gravels, sands, silts and clays. These deposits, often many metres thick, were then deposited over the bedrock as clay-rich glacial till; or in lakes as fine clays; or as coarse-grained sands and gravels by fluvio-glacial actions such as in the long esker ridges of the lowlands. Other features such as drumlins were also formed beneath the glacier as it moved across the landscape. During warmer periods glacial deposits were partially washed away by melt water issuing from the edge of the melting glaciers, forming a hummocky landscape with freely draining soils that allow excess surface water to percolate rapidly downwards to groundwater reservoirs. In contrast, the glacial tills tend to comprise heavier textured soils, which in most cases result in a slowly permeable subsoil that causes impeded drainage.

The other striking influence on soil formation in Ireland is climate, notably rainfall. There is a large range in annual precipitation, from as low as 800–900 mm per annum (*p.a.*) along the south-east coast, to over 2000 mm *p.a.* in mountainous areas along the western seaboard. This humid environment has resulted in extensive peat formation both on the western coastal lowlands and in the uplands throughout Ireland (Fig. 1.3).

Using the landscape categories recognised by Gardiner and Radford (1980), a range of soil types can be identified in association with the distinctive broad landscapes (see Fig. 1.4a to 1.4f). These are:

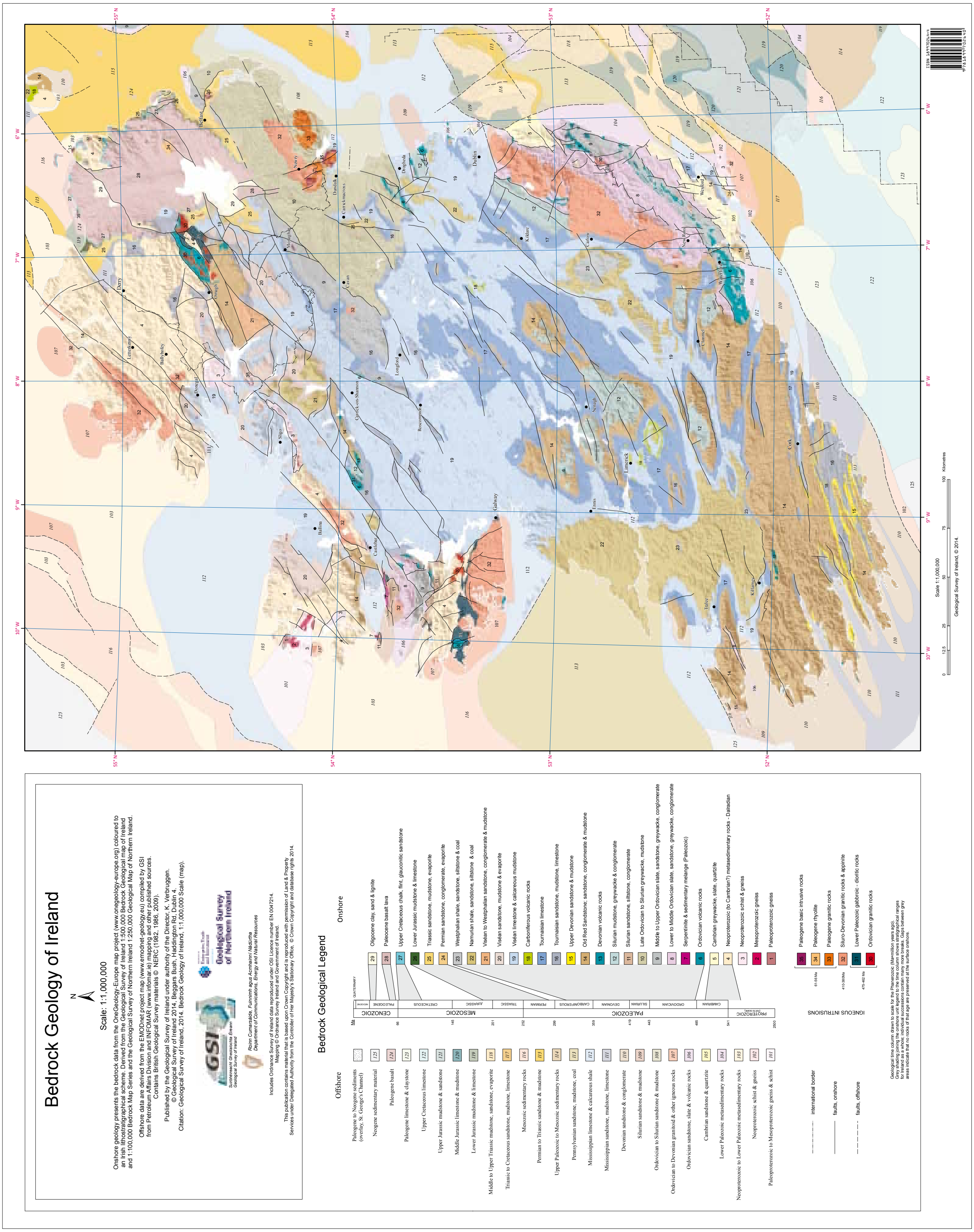


**Figure 1.2. Geology Map of Ireland. Source: Geological Survey of Ireland, 2014. Bedrock Geology of Ireland, 1:1,000,000 Scale (map).**

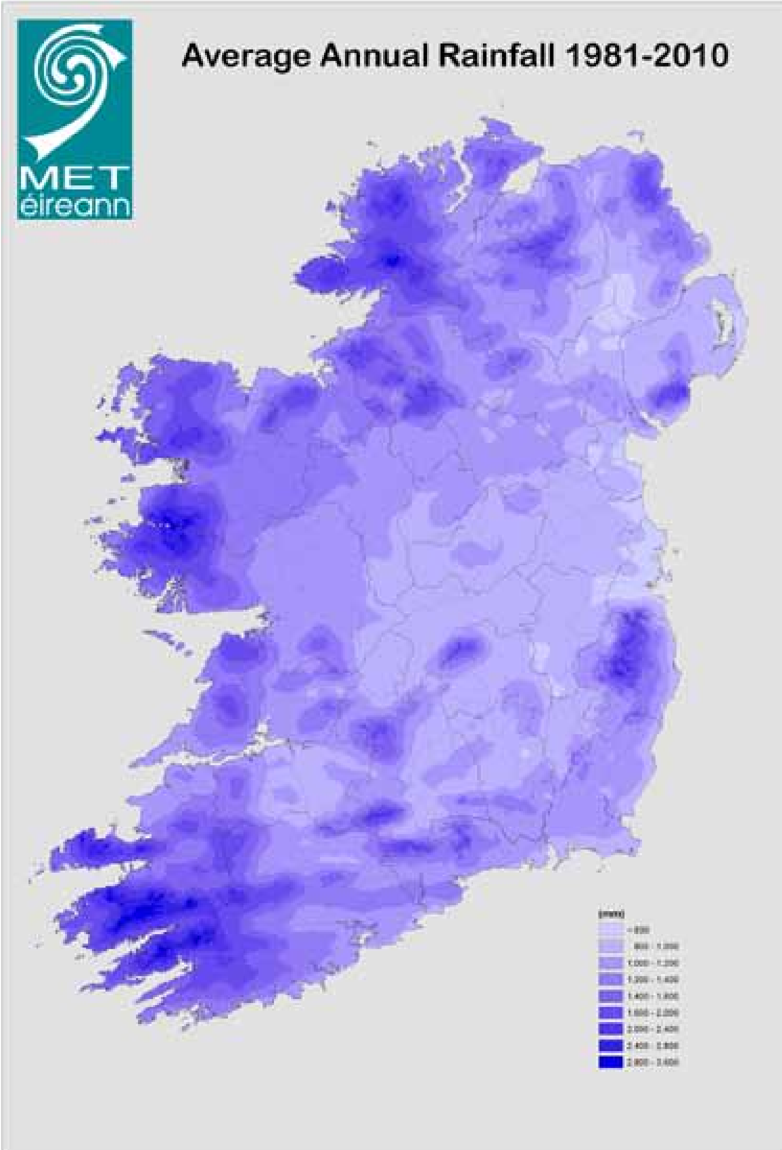


**Figure 1.3. Average rainfall distribution across Ireland. Source: http://www.met.ie/climate/rainfall.asp**

1 Mountain landscapes (Fig. 1.4a) support shallow soils (Lithosols) mostly on steep slopes at > 500 m elevation. Wet soils (Groundwater and Surface-water Gleys) and acidic soils (Podzols) are present where slopes are less steep. Blanket Peat occurs on flat and gently undulating plateaus.

2 Hill landscapes (Fig. 1.4b) at altitudes from 150 to 365 m with soils generally developed from shale, sandstone or occasionally granite. These soils are mainly acidic in nature, including Brown Podzolics and Brown Earths, and some Surface-water Gleys.

3 The Drumlin landscape (Fig. 1.4c) was formed during the most recent period of glacial advance. Drumlins are small oval-shaped hills that stand out as an undulating landscape. They were formed from glacial deposits, sometimes with a rock core. These deposits vary in thickness; thin deposits over rock cores tend to have drier soils on the drumlin slopes such as Luvisols, Brown Earths and Brown Podzolics, whereas drumlins with thick glacial deposits have wetter soils (Surface-water Gleys). Wet soils (Groundwater Gleys and Peats) are usually found at the base of the Drumlin where water running off the slopes accumulates.

4 Flat to undulating lowland landscapes (Fig. 1.4d) in limestone-dominated areas give rise to very shallow soils (Rendzinas) where limestone bedrock is close to the surface, but deeper soils (Luvisols and Surface-water Gleys) develop on the limestone-dominated glacial till that covers much of the limestone bedrock.

**Figure 1.4a. Mountain and hill.**

**Figure 1.4b. Hill landscapes.**

**Figure 1.4c. Drumlins.**

**Figure 1.4d. Flat to undulating limestone lowlands.**

**Figure 1.4e. Acidic lowlands.**

**Figure 1.4f. Alluvial and valley landscapes.**

5 Acidic soil lowland landscapes (Fig. 1.4e) are underlain by glacial deposits made up of sandstones and shales, or granite or igneous and metamorphic materials, from surrounding hill and mountains. These soils tend to be significantly more acidic than those underlain by limestone. Brown Earths and Brown Podzolics form in coarser till material and finer material (i.e. in shale areas) gives rise to wetter soils such as Surface-water and Groundwater Gleys.

6 Alluvial and Valley landscapes (Fig. 1.4f) are found in small areas all over the country often at the base of the hills/mountains and on the floodplain and terraces of the major river valleys. The associated soils are mainly Groundwater Gleys, Alluvial Soils and Peat.

# 2 Interpretation of Previous Soil Surveys

The development of a 1:250,000 map for Ireland required the digitisation and development of a supporting database of all the legacy soil survey data, collected and published between the 1950s and 1980s by An Foras Talúntais (AFT), forerunner to Teagasc and the former National Soil Survey of Ireland. All this information is considered to be *Terra Cognita* within the context of the ISIS project. The aim was to develop a consistent set of soil maps and information for the counties where previous detailed mapping had been conducted by AFT, which could be used as a basis for the modelling into areas without county-level soil maps.

*Terra Cognita* comprises the following 16 counties or part thereof (Fig. 1.1):

1 Carlow, Clare, Kildare, Laois, Limerick, Longford, Offaly, Meath, Tipperary North, Waterford, Westmeath and Wexford that were surveyed at 1:10,560 scale; for each county there is a soil map published at 1:126,720 scale in conjunction with the Ordnance Survey of Ireland, and an accompanying Soil Survey Bulletin published by AFT, describing the soil series and complexes in detail with their analytical data.

2 West Mayo for which there is a published soil map at 1:126,720 scale, but no detailed Soil Survey Bulletin.

3 Leitrim, which was surveyed as a part of a Natural Resources Survey and for which there is a published soil map at 1:126,720 scale and 40 representative soil profiles with associated analytical data.

4 West Donegal, which was surveyed as a part of a Natural Resources Survey and thus has less detailed soil descriptive information and fewer representative soil profiles than for the other mapped counties but there is a soil map published at 1:63,360 scale.

5 West Cork was also surveyed as part of a Natural Resources Survey, but there are no representative soil-profile descriptions or analyses in the published report nor is there a published soil map of the whole area. Soil maps of the individual townships were pieced together to produce the West Cork soil map reproduced here, with non-published materials describing soils.

For some *Terra Incognita* counties, reconnaissance soil surveys exist. At the end of the rationalisation, classification and standardisation of the *Terra Cognita* county data, the reconnaissance soil map for Co. Longford was examined and found to be sufficiently detailed for the map units to be directly correlated to the national legend soil associations.

## 2.1 Primary Development of a Soil Map

Soil development depends on the interactions of climate, parent material/geology topography and vegetation over time – in a few cases the influence of human activity is important. The interactions of these factors give rise to one of the most characteristic features of soils – horizonation, i.e. digging down below the upper few centimetres reveals that the soil changes in characteristic ways and that it has a layered appearance.

The combined number, properties and arrangement of these layers or horizons allow the soil in a location to be given a specific name – the ‘soil series’. These series can cover an area ranging from a few hectares to several hundred hectares. It is the job of a soil surveyor to identify these soil series by exploring the landscape, to name them in agreement with accepted criteria and to produce a map showing their distribution in the landscape. If the maps are at a suitable scale, e.g. 1:25,000 then each series can be delineated in considerable detail. However, for smaller scales, e.g. 1:250 000, it is not cartographically possible to show this level of detail and it is common practice to group similar soil series into ‘soil associations’. A soil association describes a range of soil series that occurs in a mapping unit and is associated with a particular landscape – that is, soils that are often found to co-occur in particular landscapes. Soil associations usually have between two and ten series co-occurring in a particular landscape pattern. The first soil series described is the most dominant and the soil association is usually named after this series. The second and third series will also occur commonly, with any remaining series occurring in no particular order, though they are expected to be found.

At the 1:250,000 scale (which underpins this project), the resulting map is a soil map based upon soil associations of soil series. The technical details of this process are given in the sections that follow.

## 2.2 Data Capture and Collation

The documents and data for *Terra Cognita* required organisation, digitisation and standardisation of the information. Descriptive information was extracted from the various AFT county bulletins and entered into the ISIS MS Access database. This is included in the final 'core' Soil Information System (SISCore). Legacy representative soil-profile data for these series were also captured.

## 2.3 Map Generalisation

It was essential to use the existing detailed soil county maps from *Terra Cognita* to inform the development of the new ISIS map (developed at a scale of 1:250,000). This required a harmonisation (to ensure consistency) of the existing county maps at a scale of 1:250,000. The original AFT county maps were created over a period of time by different authors and so, as new data became available, updates to the classification were published in more recent county maps but were missing from older county maps. Review and modification of the national soil classification was required to guide the process of harmonisation and rationalisation of those soil series which were similar in description but named differently on different maps. This took place before the generalisation of the county soil maps (from scale 1:126,720 to scale 1:250,000). The next step was to amalgamate the national soil series into soil associations to develop the eventual mapping units of the final National Soil Map.

### *2.3.1 Classification and Rationalisation of Soil Series*

As a basis for surveying the soils of *Terra Cognita* counties, AFT used a simple high-level soil classification with nine 'Great Soil' groups – Lithosols, Regosols, Rendzinas, Brown Earths, Grey Brown Podzolics, Brown Podzolics, Podzols, Gleys and Peat. In some county legends, Alluvial Soils are recognised as a separate Great Soil group.

It was necessary to produce a preliminary soil classification to assist the rationalisation of the soil series and to generalise the map units of the AFT data. The original AFT classification of soils adopted the system of Great Soil Groups, Groups and Series. To enable a more systematic classification approach, this project introduced soil subgroups, which are defined primarily using field descriptions, and provide information on the major processes occurring in situ, without requiring the detailed laboratory analyses needed for soil series.

Existing soil survey county maps were rescaled (from a scale of 1:126,720 to 1:250,000), to produce a new harmonised Soil Map of *Terra Cognita* and its associated database. This required a systematic process of visual examination of the soil map polygons, eliminating areas <0.075 $km^2$, combining polygons where soil series had been amalgamated, smoothing map unit boundaries to ensure suitability for reproduction at a 1:250,000 scale, and harmonising borders to allow the joining-together of adjacent soil county maps.

The downscaling process resulted in the amalgamation of soil series, to the extent that more than 370 soil series descriptions taken from the AFT county maps (Fig. 2.1) were initially rationalised (similar series descriptions were amalgamated into one soil series) down to 155 National Soil Series (Fig. 2.2).

For the purpose of constructing a national soil map at 1:250,000 scale, a **draft** national legend was compiled from analysis of the soil patterns in *Terra Cognita*. For example, a common freely drained Luvisol developed in fine loamy drift with limestone (Elton series) had been identified in several counties. It was found to be associated in that landscape with several other series such as the Straffan series and Howardstown series. Therefore, an 'Elton Association' was set up, with Elton being the dominant series, and the other series added in no particular order.

The generalised mapping units and soil associations using the draft working soil classification were used for the basis of the predictive mapping and the fieldwork data-collection programme. Figure 2.3 describes the workflow for the interpretation and capture of the legacy (AFT) soil information.

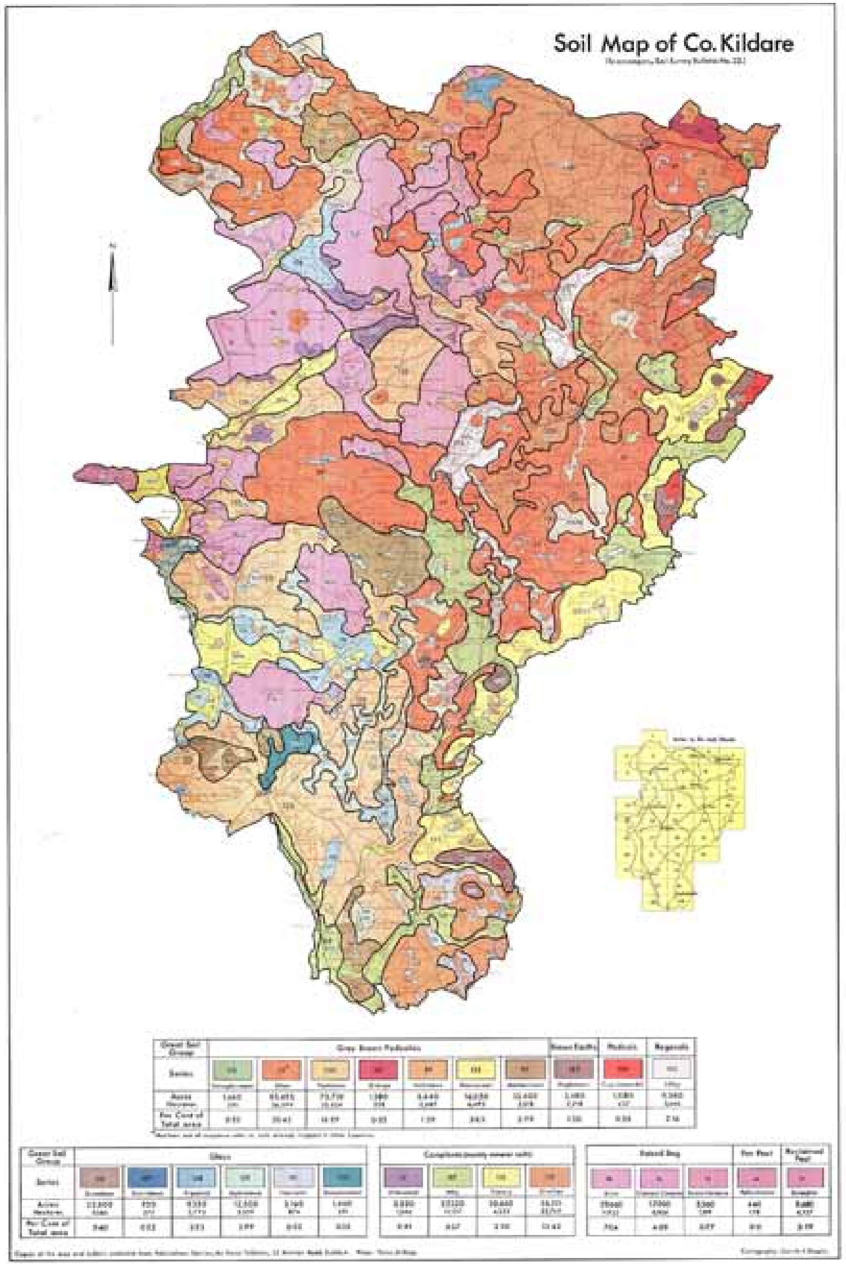


Figure 2.1. Soil map of Co. Kildare from An Foras Talúntais (1970).

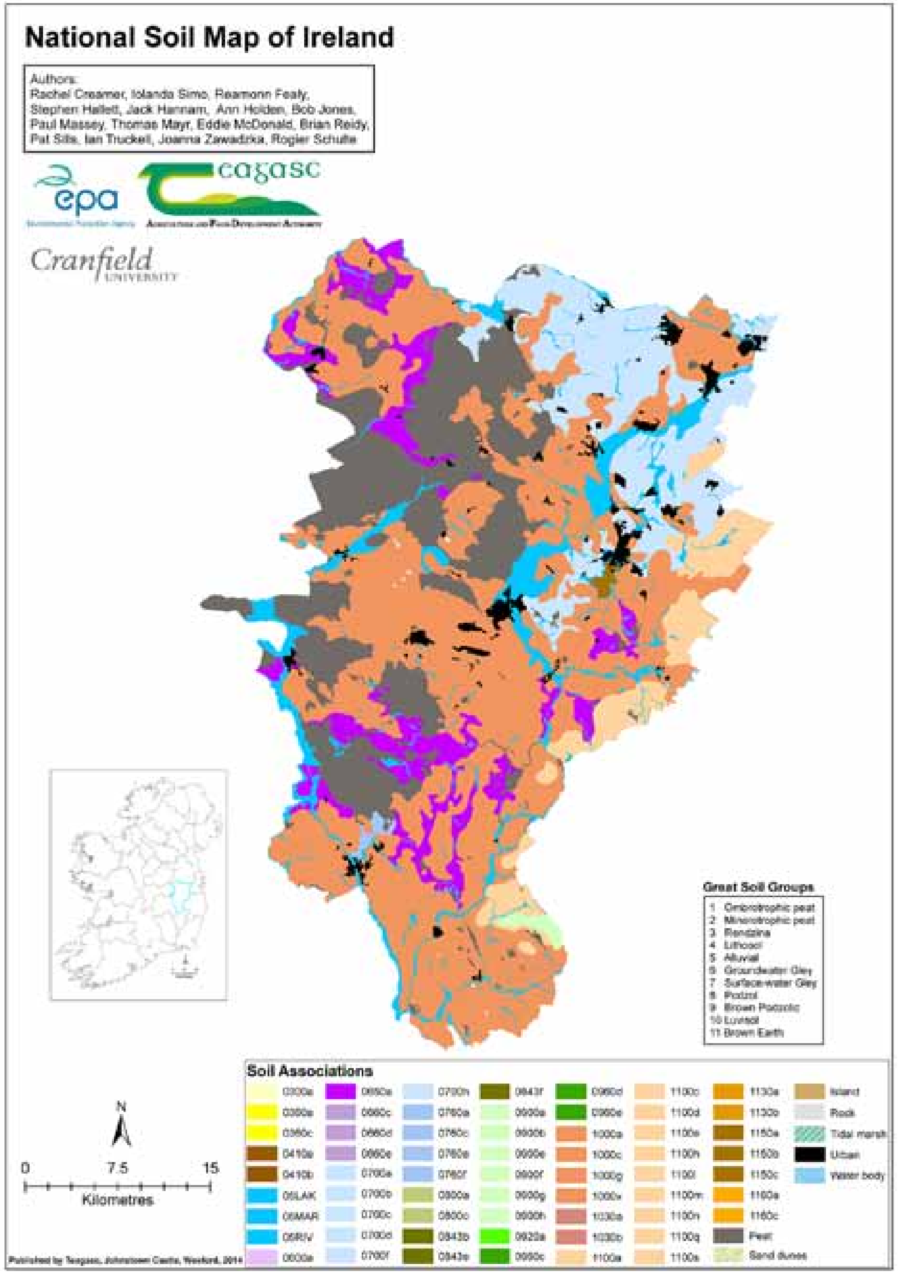


Figure 2.2. Soil map of Co. Kildare from National Soil map of Ireland (2014).

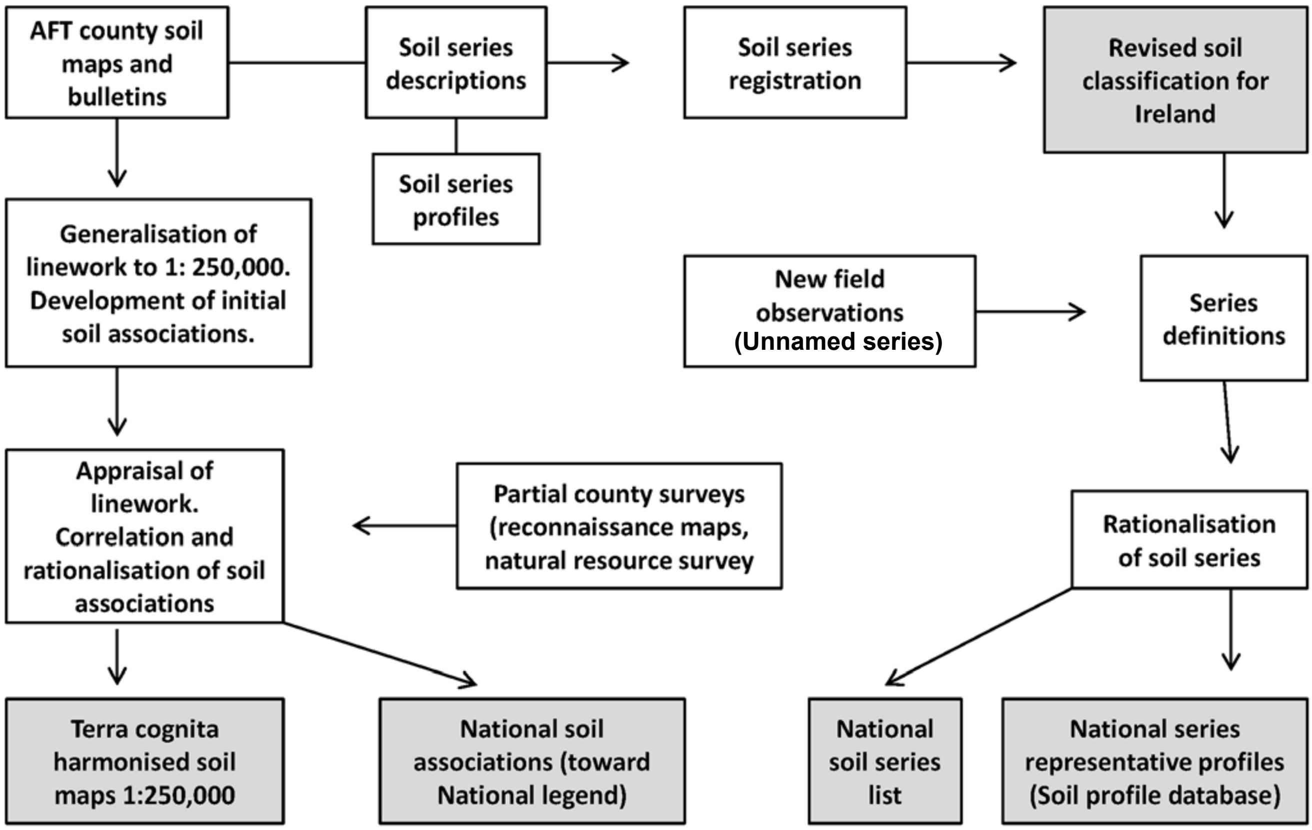


**Figure 2.3. Workflow for the interpretation and harmonisation of the AFT soil legacy data. (The classification system refers to the project working classification system used prior to final map development).**

# 3 Predictive Mapping

The concept of a soilscape is a broad soil-landscape unit that encompasses a number of soil associations. They groups soils formed primarily on similar substrate types linked to large-scale landscape features and derived from expert judgement as part of the generalisation and harmonisation of the county soil maps in *Terra Cognita* (ISIS Final Technical Report 3). These areas stratified the landscape into regions where specific models could be developed for characteristic soil-landscapes identified in *Terra Cognita*. Table 3.1 provides an overview of the soilscapes.

Once the soil landscapes (soilscapes) had been identified, it was possible to use the information to predict similar soilscapes in areas previously not mapped by AFT. This process is called 'predictive mapping'.

**Table 3.1. Soilscapes of Ireland and main affiliated Great Soil Groups.**

| | Soilscape name | Description |
|---|---|---|
| 1b | Limestone till lowlands with Basin Peat and limestone outcrops | Luvisols, Rendzinas on outcropping limestone pavements & peat |
| 1cn | Limestone till lowlands, predominantly Luvisols | Luvisols, Surface- & Groundwater Gleys & Basin Peat; Brown Earths associated with eskers; Lithosols & Brown Earths associated with limestone bedrock |
| 1dn | Limestone till lowlands with wet soils and Basin Peat | Luvisols commonly associated with Gleys and Basin Peat |
| 2b | Upland gneiss, schist, granite bedrock and igneous & metamorphic drift. Some shale bedrock | Brown Podzolics & Brown Earths predominate with altitudinal sequence of upland peat, Lithosols & Podzols. |
| 2c | Upland sandstone and shale/slate bedrock & drift with siliceous stones | Brown Podzolic soils with Surface & Groundwater Gleys predominant, with Peat and Podzols |
| 4 | Wet groundwater-fed lowlands in mainly limestone drift | Groundwater Gleys in drift with limestones & Basin Peats much of which is cutover or milled |
| 5 | Plateau, drift with limestone | Luvisols & Surface-water Gleys, upland peat in places, Brown Earths on steeper slopes |
| 6 | Wet (surface-water) lowland limestone drift | Surface-water Gleys & Luvisols |
| 8 | Undulating shale/slate bedrock; mixed drift (drift with IGM or limestone) deposits, also outwash environments | Brown Earths on lower slopes over bedrock; Luvisols commonly associated with fluvioglacial outwash gravels & some Groundwater Gleys |
| 9e | Undulating shale/slate hills, drift with siliceous stones | Well-drained soils in drift with some Groundwater Gleys in depressions |
| 9f | Undulating shale/slate hills, drift with igneous and metamorphic stones | Well-drained Brown Earths on undulating land. Groundwater Gleys found in depressions |
| 10 | Clayey or loamy till, with outwash sands & gravels | Surface-water Gleys in clayey marine drift; well-drained sandy Brown Podzolics on outwash sands & gravels |
| 11 | Slob land (reclaimed coastal flats) | Alluvial & drained Alluvial Soils |
| 12a | Upland sandstone bedrock and drift with siliceous stones | Altitudinal sequence of Brown Podzolics, Podzols & Peat, some Surface-water Gleys on lower slopes |
| 15 | Low lying, drift with siliceous stones | Alluvial Gley soils in fluvial depressions. |
| 16 | Undulating lowlands, drift with siliceous stones | Brown Earths, Brown Podzolics with Podzols on upper slopes; Surface-water Gleys in depressions |
| 17n | Lowland raised bog, industrial peat | Lowland peat, some Luvisols, Surface-water Gleys occurring in depressions |
| 20n | Wet flat lowlands, predominantly drift with siliceous stones | Surface-water, Ground-water & Alluvial Gleys, some Basin Peat; Brown Podzolics, Luvisols & Brown Earths on better-drained slopes |
| 22 | Upland shale bedrock and drift with siliceous stones | Brown Earths on lower slopes, Blanket Peat on hill tops, Podzols on steeper slopes & Groundwater Gleys in depressions |

*Table 3.1 cont. overleaf*

| | | |
|---|---|---|
| 23 | Clayey lowland drift with limestone | Surface-water Gleys on drift, interspersed with Luvisols & small areas of Alluvial Gleys. |
| 24n | Wet undulating shale; drift with siliceous stones | Surface-water Gleys & degrading peat; Brown Podzolics & Brown Earths |
| 25 | Well-drained shale hills; drift with siliceous stones in lowlands | Brown Earths on bedrock; Surface-water Gleys on drift; Luvisols & Brown Podzolics sporadically found. |
| 26n | Wet upland shale hills and drift with siliceous stones in lowlands | Groundwater & Surface-water Gleys on lower slopes, with Brown Earths & Brown Podzolics on better drained slopes; Upland (Blanket) Peat; some Basin Peat & Podzols |
| 27 | Limestone pavement | Rendzinas, Calcareous Brown Earths & Luvisols in drift |
| 28 | Undulating sandstone bedrock, with compact siliceous drift | Brown Podzolics mainly on drift, Blanket Peat on upper slopes & Lithosols; Surface-water Gleys in lowland areas |
| 29n | Mountainous areas with peat and sandstone and shale outcrops. | Upland Blanket Peat with extensive bedrock with Histic Lithosols and Podzols; Humic Brown Earths on moderate slopes |
| 30 | Drumlin areas with wet soils | Surface-water Gleys predominant in drift with limestones & in drift with siliceous stones; Basin Peat in depressions between drumlins |
| 31n | Blanket Bog over granite and igneous and metamorphic rocks | Deep Blanket Peat in uplands (> 400 m), & lowland (< 400 m) in West of Ireland; some eroding & cutover peat |
| 32 | Mountainous areas igneous/ gneiss/sandstone/ shale bedrock. | Blanket Peat & Podzols in Mountainous areas, with outcropping rock. Windblown sands dunes on the coast. |
| 33 | Upland Blanket Peat and Stagno-Podzols | Upland Blanket Peat, commonly cut-over, interspersed with Stagno-Podzols |
| 34 | Limestone outcrops | Brown Earths on limestone (not pavement) & peat, some cutover |
| 35 | Peat over rock (granite and acid metamorphic rocks) | Thin peat over rock on steep exposed slopes, with Blanket Peat, some eroding & cutover |
| 36n | Valleys and depressions in drift from acid igneous rocks | Predominantly Brown Earths & Brown Podzolic soils, with Surface- & Groundwater Gleys; peat |
| 37n | Acid igneous rocks. Rock outcrops in upland and lowland areas. Sand dunes in coastal areas | Upland (> 400 m) with lowland (< 400 m) shallow peat soils beside Lithosols, Podzols, Humic Groundwater Gleys, Brown Podzolic soils & occasionally Brown Earths |
| 39 | Limestone drift and some blanket peat | Humic Surface-water Gleys, on drift with limestones & occasionally drift with siliceous stones, Rendzinas, Luvisols and Blanket Peat |

McBratney (2003) proposed a method (after Zakharov) to describe empirically the relationships between soil and other spatially distributed environmental factors. This is described in the equation below and is used as a basis for deriving soil information from other spatially available datasets.

$$Sc, Sa = f(s, c, o, r, p, a, n)$$

where: *Sc* is soil class, *Sa* is a soil attribute, *s* is soil (e.g. small-scale soil maps); *c* is climate, local climatic properties; *o* is organisms, vegetation, fauna, and human activities; *r* is topography; *p* is parent material, lithology; *a* is age, time; and *n* is space, spatial position.

The equation above forms the basis of the predictive mapping developed in the ISIS project to identify soil patterns in areas that had previously not been surveyed. Initially, broad soilscapes were developed from the generalised AFT maps. These represented areas where it was expected that different models would be required to explain the relationship between the soil and other environmental data. In order to apply the predictive models, relationships needed to be established in areas containing both detailed soil information (Sc above, represented by the generalised AFT maps) and spatial environmental data (s,c,o,r,p,a,n, in the equation above). These areas were denoted *Terra Cognita* and formed a set of training data to allow the establishment of predictive models in each soilscape. Areas where the predictive modelling was deployed were denoted *Terra Incognita* (Fig. 3.1). The 'scorpan' factors were

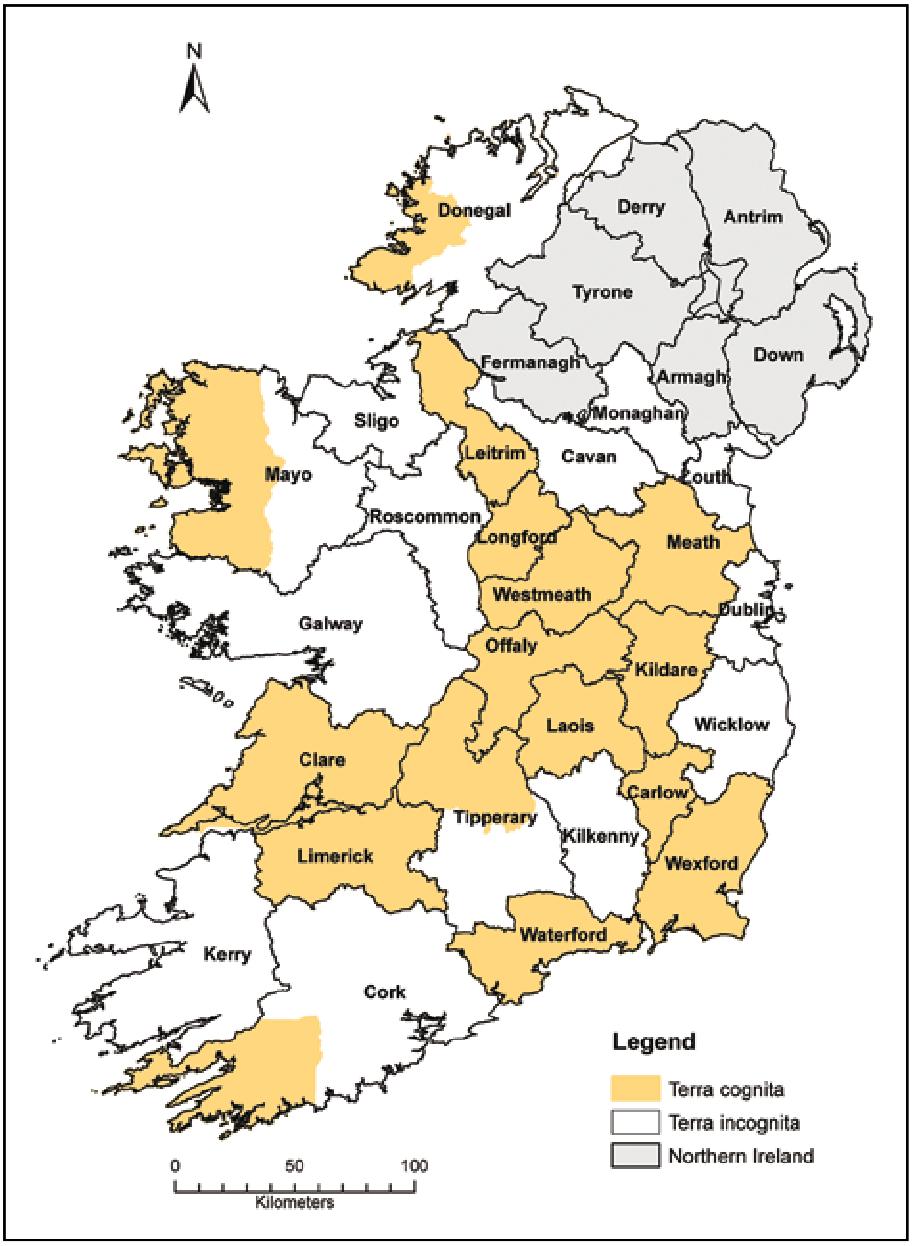


**Figure 3.1. Areas of *Terra Cognita* (where predicted models were developed) and *Terra Incognita* (where predictive mapping was deployed).**

represented by 31 environmental supporting data layers developed from spatial datasets representing terrain (Digital Terrain Model, DTM), geology (parent material), climate, vegetation, land use and soil data. These covariates required preparation, evaluation and collation before being suitable for use in the predictive mapping exercise (Interim Working Draft Report [available from the Soil Information System: (http://soils.teagasc.ie) only]: Mayr et al., 2011). Once these models had been established they were applied in *Terra Incognita* to predict the soil types (soil associations).

## 3.1 Soilscapes

To deploy predicted models for soil associations in *Terra Incognita* it was necessary to first extrapolate the soilscapes into *Terra Incognita*. This was achieved by two modelling approaches: the first was based on the similarity to the reference areas in *Terra Cognita* (feature space analysis, FS) and the second by developing a rule-based model (random forest, RF) that infers a relationship between the environmental covariates and the soil distribution (ISIS Final Technical Report 4). This resulted in two soilscape maps being developed by each modelling approach.

## 3.2 Inference Modelling and Prediction into *Terra Incognita*

A training dataset was constructed for each soilscape in *Terra Cognita* (Fig. 3.2); this linked the soil associations in the soilscape and the corresponding environmental covariates. A number of models were developed for each soilscape based on two fundamental inference systems that use different statistical concepts to infer relationships. The first, BBN, makes predictions based on probabilities from measured data but can also incorporate expert opinions to condition the relationships. Two types of BBN model were developed and differentiated by the optimisation of the variables included in the model. The second inference system was RF which uses a classifier approach, where multiple decision trees derive a relationship between the variables.

For each of the extrapolated soilscape maps, the models were implemented in each predicted soilscape to determine the soil associations in *Terra Incognita*. This resulted in five model realisations or mapped outputs for the predicted soil associations in *Terra Incognita* (ISIS Final Technical Report 5).

## 3.3 Validation of Predictive Soil Maps

The predictive modelling process produced a representation of the likely soil distribution across *Terra Incognita*. However, this was purely a prediction and needed validating, in order to confirm the correctness of the observation. The method developed to validate the predicted map was a direct comparison between the soil observation at an auger borehole and the composition of the predicted soil association.

An auger survey, identifying soil series at a given point, was conducted from 2010 to 2013 to ascertain the composition of the main soil associations occurring across the country. The auger survey was carried out in *Terra Incognita* (Fig. 3.3) to provide spatial data to check the predictive soil map. The whole country was delineated into 10 x 10 km map sheets and three days were allocated to establishing the major soil series found within that map sheet. The auger survey resulted in approximately 11,000 records being collected for the country.

Auger survey data was used in the validation process to elucidate the variation of soils found in given landscape units. In the first instance, the soil series identified in the auger survey was compared with the soil series that comprised the association units on the predicted map in which the auger borehole was located. Where a soil series agreed with the soil series in the predicted map association for that area, a score of 1 was given; where the series disagreed, a score of ‘0’ was given. For each soil association, total scores were summed for all auger bores within a predicted soil association and this was compared to the total number of auger bores made. This provided an assessment of the confidence of the predicted map in these soil associations (ISIS Final Technical Report 11).

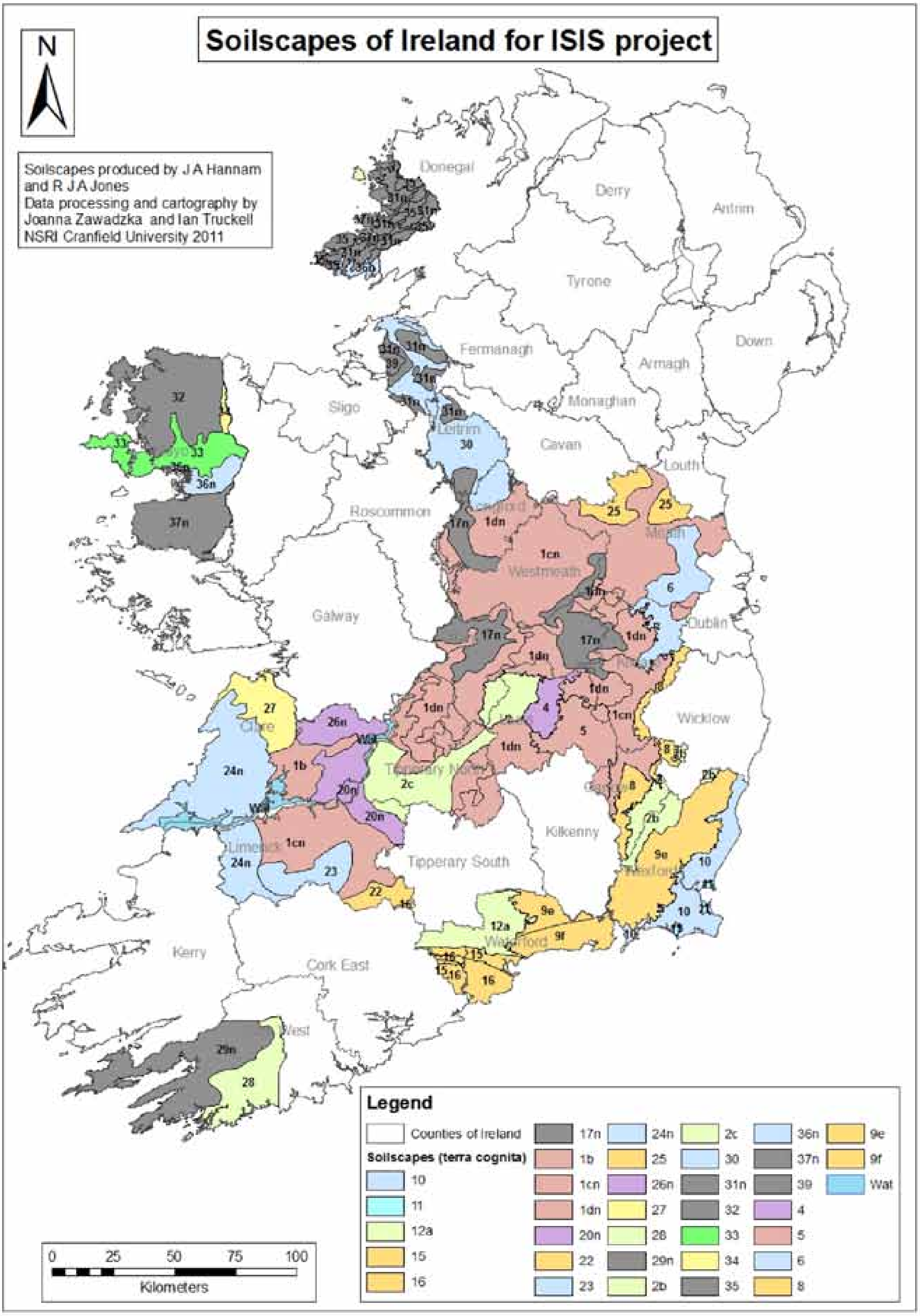


**Figure 3.2. Distribution of soilscapes in *Terra Cognita*.**

## 3.4 Initial Validation Approach

The procedure is detailed as follows:

1 The auger bore observation data were overlaid onto the predicted soil map to obtain the predicted National Soil Association delineated for each site of an auger bore observation;

2 The output of this intersection is a list of the geo-referenced auger bores, series and predicted National Soil Association codes from the predicted map;

3 The auger bore soil series records were compared to the national legend matrix to determine if they were present;

4 The result is a score of ‘1’ if the auger bore soil series code corresponds to any soil series code in the extended legend for the intersected National Soil Association or a score of ‘0’ if the auger bore soil series code does not correspond to any soil series code in the extended legend for the intersected National Soil Association. As such, the output returns the score (of 0 or 1) for each observation that has been intersected with the predicted map;

5 Outputs were merged for counts of score 1 and score 0 for each association;

6 The score counts were summarised for each association, resulting in total number of observations, number with score 1 and accuracy for the association (derived below).

Assessment of the accuracy of the predicted maps was achieved on an association basis and for the whole mapped area. This is represented simply as the ratio of the number of bores that match the extended legend membership (those with score 1) to the total number of bores.

The accuracy assessments were influenced by the total number of bores recorded for each association.

Association accuracy = (n bores with score 1 in association x) / (total number of bores in association x)

Map accuracy = (total number of bores with score 1) / (total number of bores)

The results are reported on three levels:

1 All observations;

2 Associations with > 50 observations; and

3 Associations with > 100 observations.

This process was completed initially by looking at national representation, but then repeated using regional datasets, as this found common repeating patterns in the data. Finally, where appropriate, scores were evaluated on a county basis.

### *3.4.1 Predicted Fusion Map and the Amalgamation of Predicted and Existing Soil Mapping*

The accuracy of the five predicted maps was assessed using the validation methods above. Each model output provided different overall accuracies, but the difference in spatial distribution of accuracy is also an important indicator of performance. This suggested that it was not appropriate to choose only one model. Therefore, a method was developed to ‘fuse’ the model outputs so that the best performing areas from each map were selected and used to develop a final map output (ISIS Final Technical Report 5). The fusion model is based on the national accuracy assessment of the five predictive soil association maps and resulted in a single predictive map that represented the respective soil associations with the highest accuracy score.

The 'fusion map' was validated using the same validation approach outlined above. It is important, however, to consider both the accuracy values as well as the number of auger bores available for a particular association, as both 0% or 100% accuracy levels can easily be achieved with a very low number of auger bores.

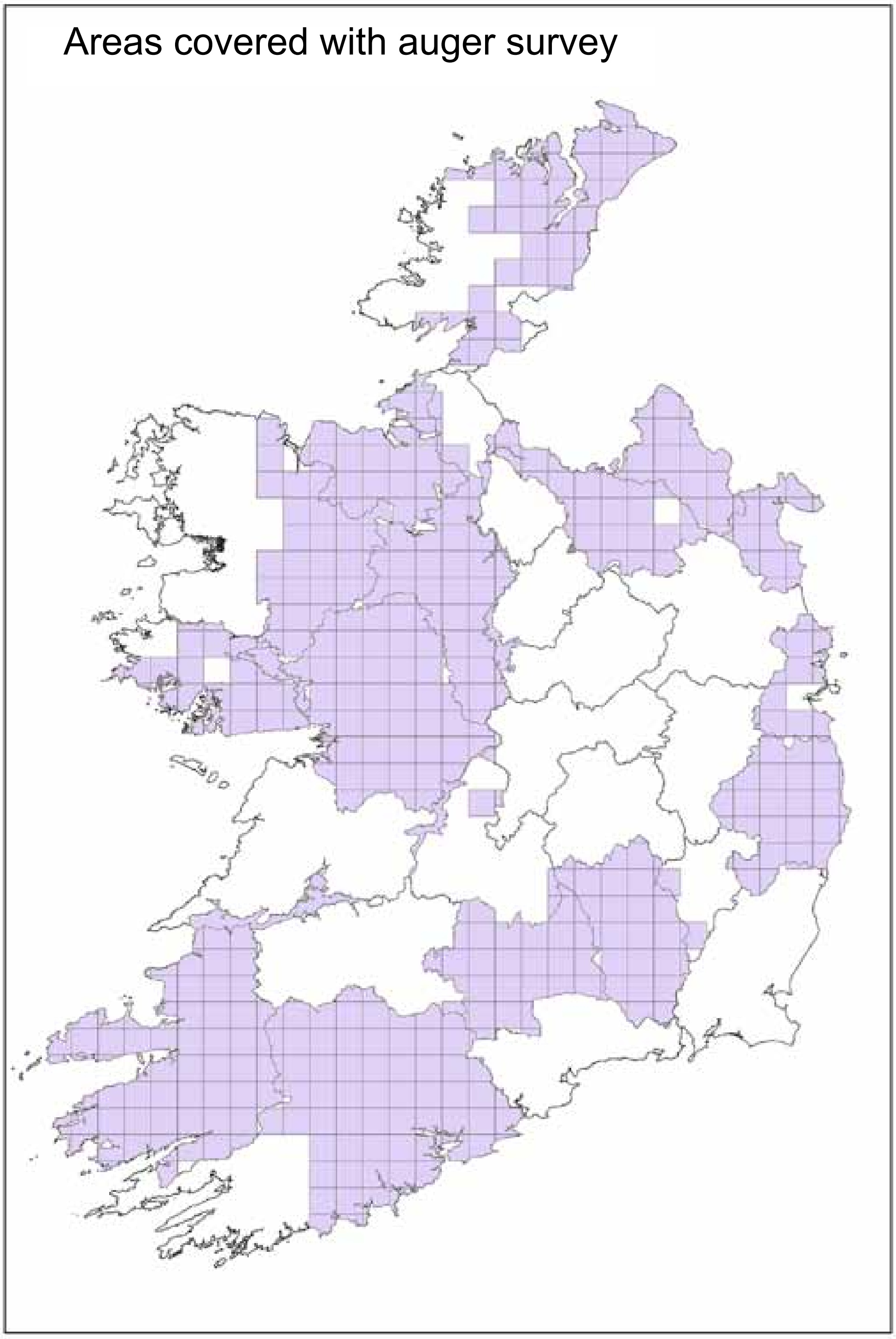


**Figure 3.3. Areas covered with auger survey across Ireland.**

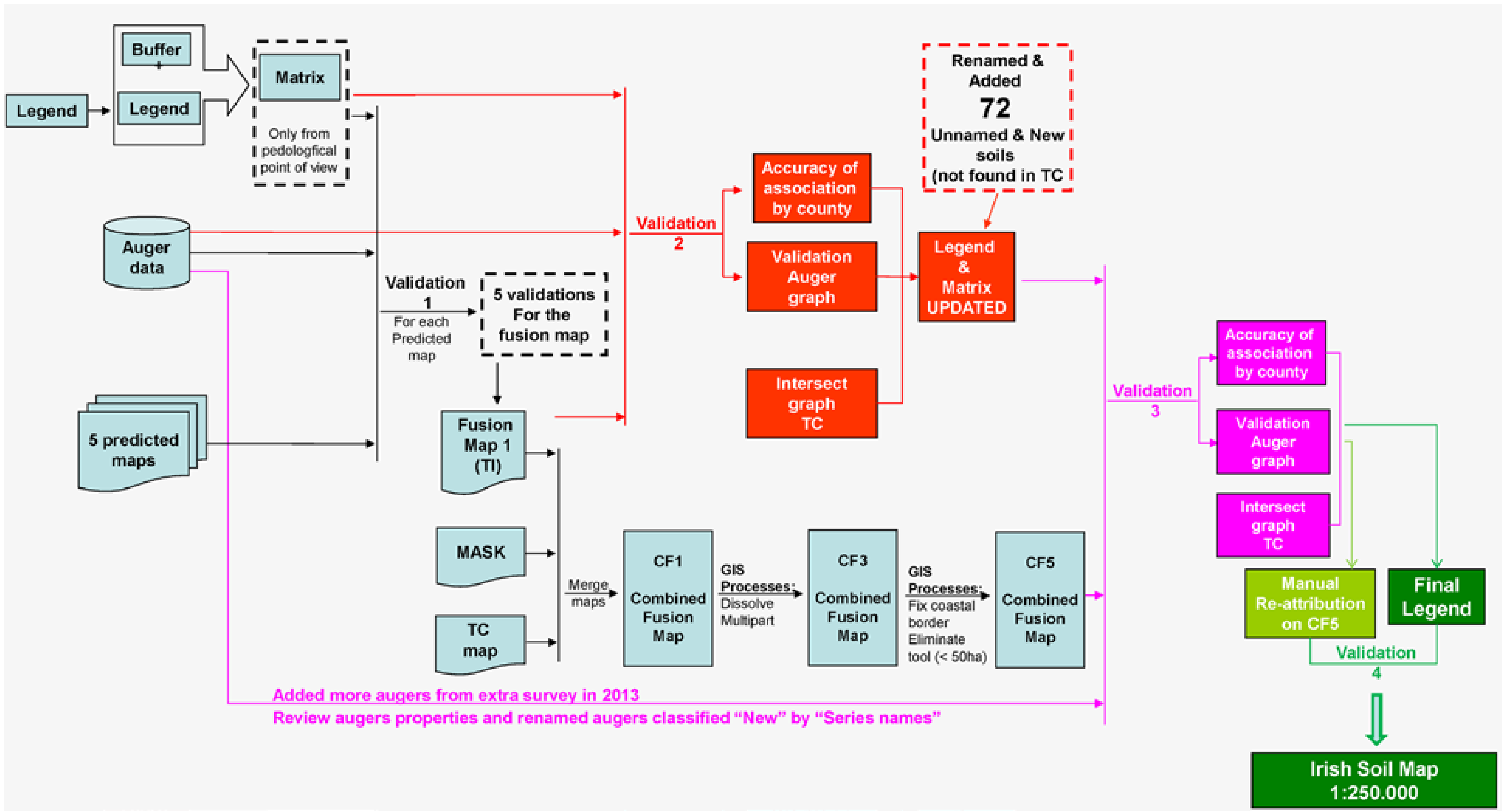


**Figure 3.4.** Workflow process for map creation and validation.

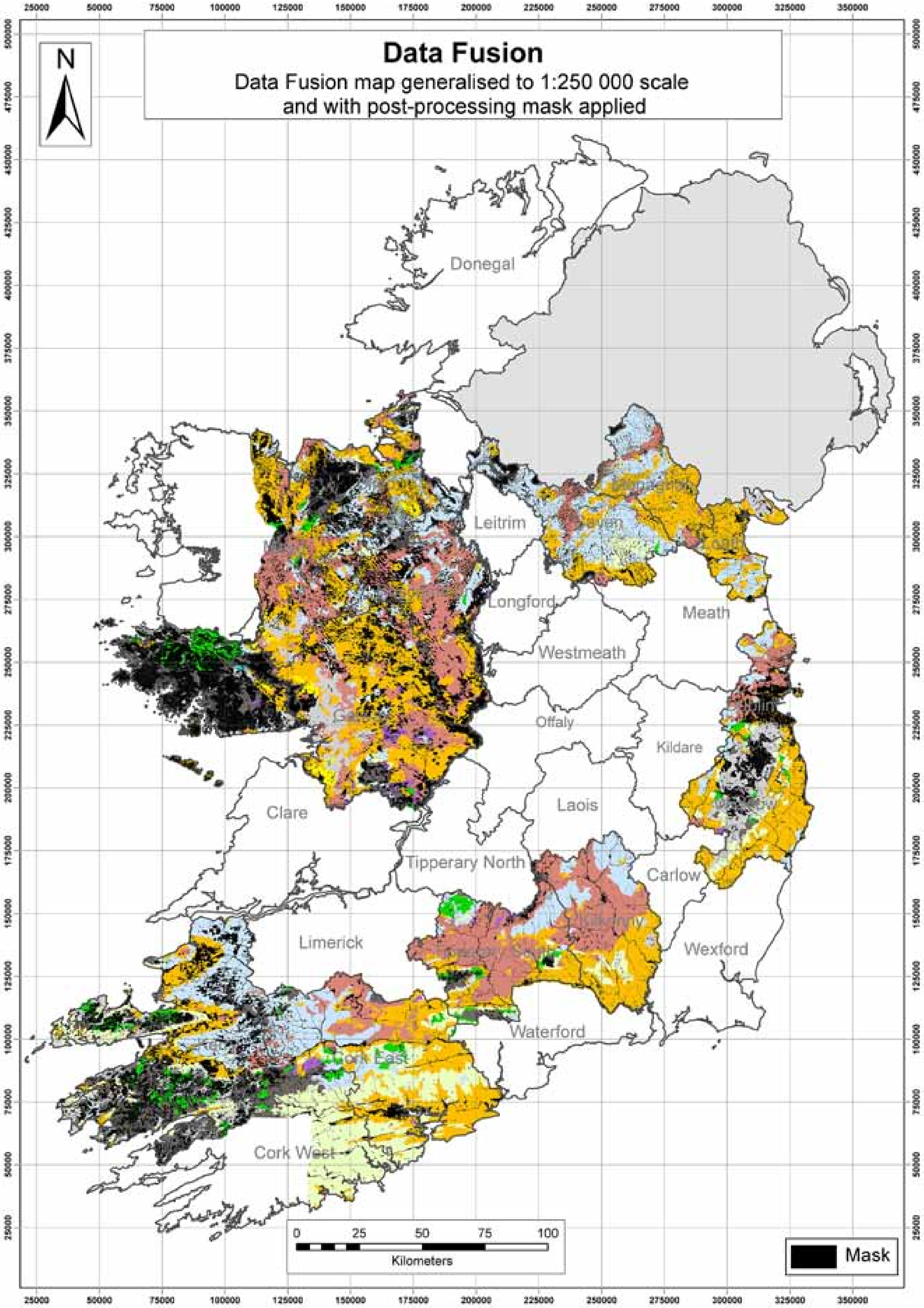


**Figure 3.5. Data fusion – predicted soil associations.**

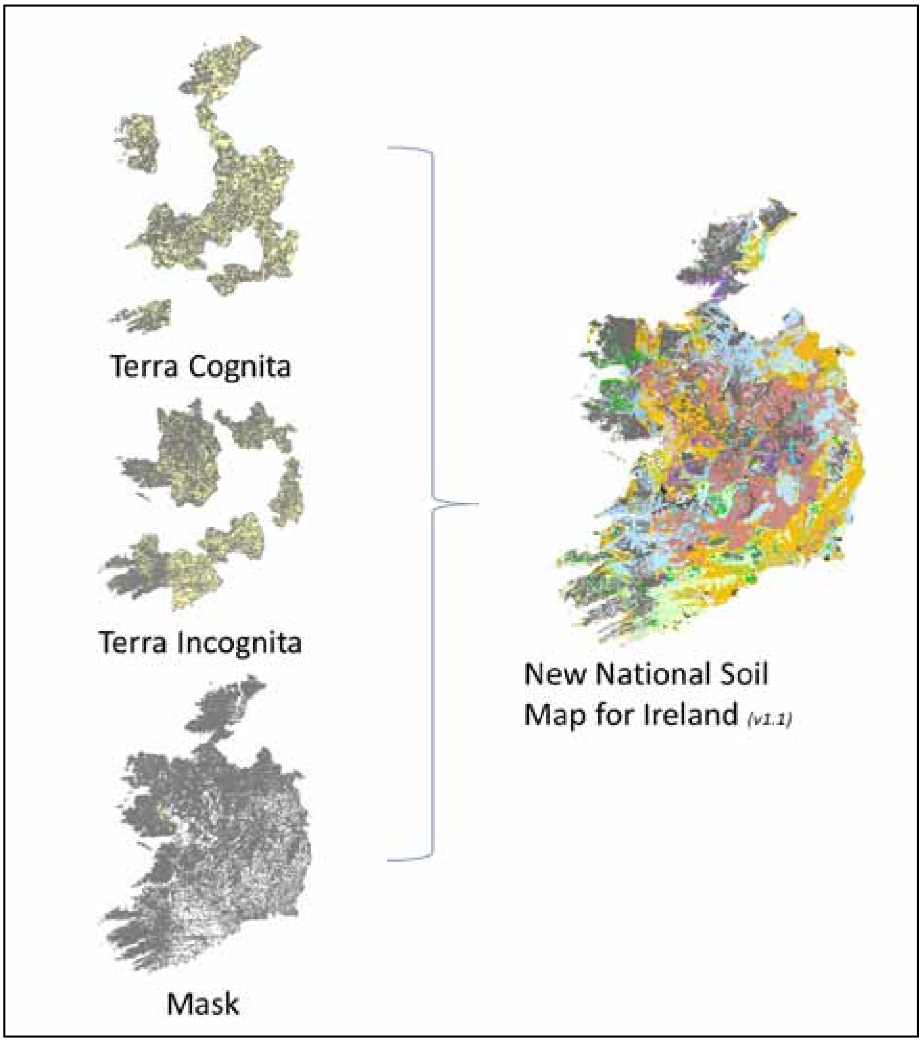


**Figure 3.6. Process for map amalgamation.**

The 'fusion process' was then undertaken to derive a final predictive map (F1) (Figs 3.4, 3.5) for *Terra Incognita*.

The final draft predictive Soil Map of Ireland comprises the amalgamation of the fusion map (*Terra Incognita*) (ISIS Final Technical Report 12), with the generalised soil map of the counties previously surveyed by AFT (*Terra Cognita*) and the revised mask (mask includes areas of Peat, Rock, Alluvium, Water, Sand/ Dunes, Tidal Marshes, and Urban) (Fig. 3.6). The amalgamation process went through a number of iterations based primarily on dissolving multipart polygons, eliminating small polygons (< 50 ha) and matching the predicted maps to the coastal outline (Fig. 3.4).

### *3.4.2 Adding New Soil Series to the Legend and Matrix*

The initial legend was based on information from *Terra Cognita*. This did not include information on all soilscapes and therefore it was expected that some new soil associations would be needed in the final map. These only became apparent as more field data was collected from the auger campaign and later verified with soil profile pit descriptions. To deal with this, a matrix was compiled based on the legend of the National Soil Associations for comparison with the auger bore records.

### *3.4.3 Validation of the Combined Fusion Map*

The combined fusion map was validated using the same approach as outlined in Section 3.4 above, but using a revised legend which incorporated those associations that had not previously been described in *Terra Cognita*. This step also re-assessed the composition of existing national soil association units derived from *Terra Cognita*, and while the core composition of the associations were appropriate, many series were missing.

## 3.5 Manual Re-attribution on the Map

The validation approach was run again with the final draft soil association legend. The result showed inconsistencies in some of the predicted polygons, such as association predicted 0460a (Rineanna series lead) changed to association 1150b (Faoldroim series lead). These polygons were manually reattributed; in some cases to the nearest appropriate polygon (neighbouring soil association) and in other cases to the most suitable association where membership of a series was consistent with the auger records.

### *3.5.1 Updating the Final Map Legend*

During the auger survey a large number of new series were defined that had not been previously described. Where these soils occurred commonly (> 20 augers recognised) modal profiles were described (Appendix 2) and sampled to allow detailed descriptions of these new series, such as Brockagh series, which is a Typical Podzol over sandy drift with igneous and metamorphic stones (Fig 3.7).

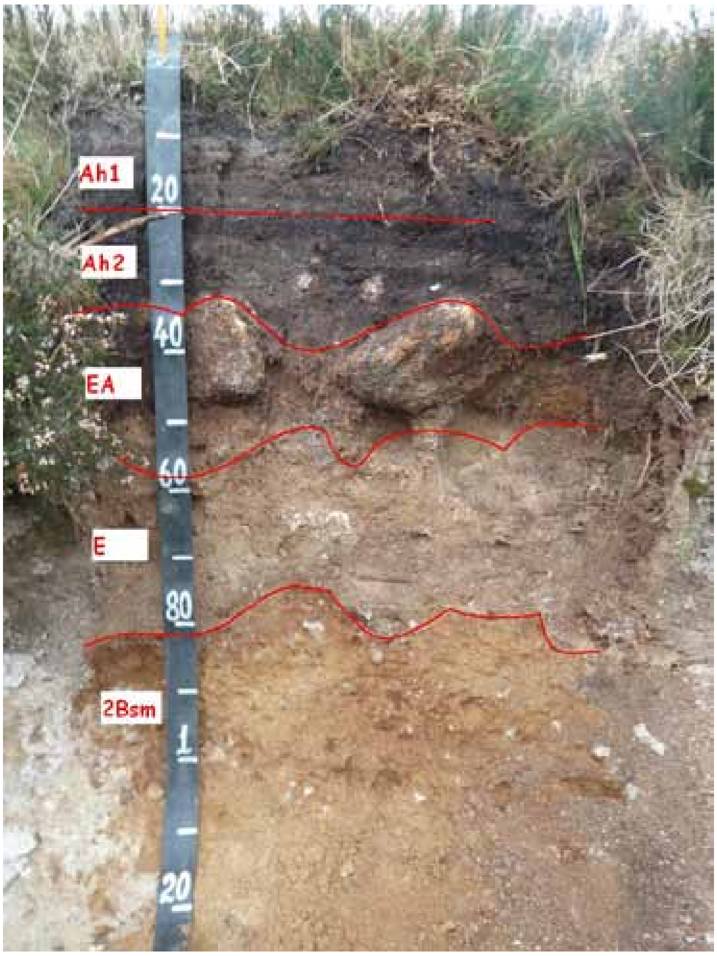


**Figure 3.7. Representative soil profile, Brockagh series.**

These series were incorporated into the final draft legend, which now allows for up to 12 series to be present within a soil association. In areas where new combinations of soil series were described, primarily due to changes in parent material, new associations were created for these areas, as they had not been described during AFT survey.

## 3.6 ISIS Soil Map of Ireland

The finalised Soil Map of Ireland (Fig. 3.8) was validated using the same approach as outlined above (validation process), but using only the final legend.

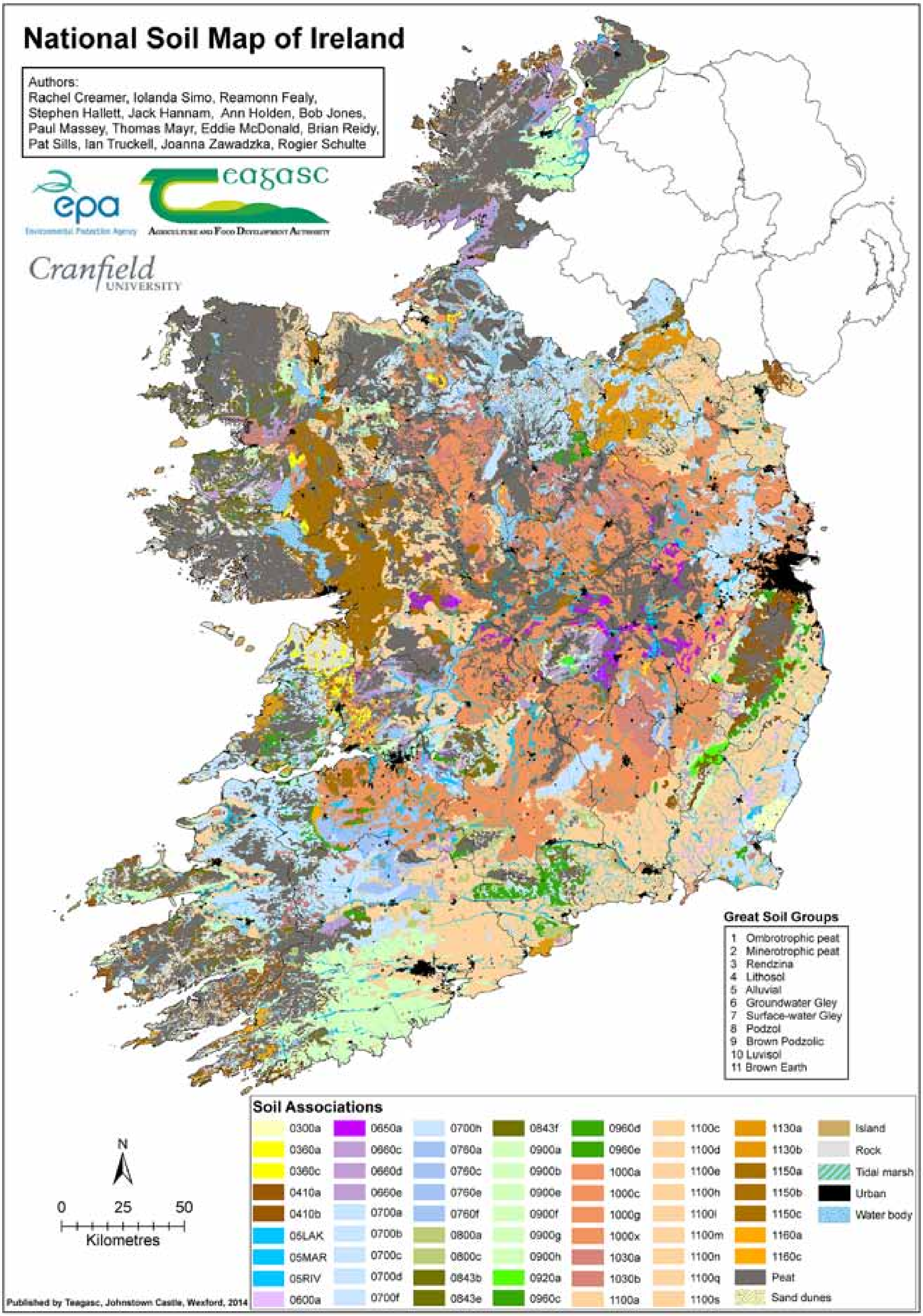


**Figure 3.8. Soil map of the Republic of Ireland (2014).**

# 4 Soil Classification

## 4.1 General Soil Classification

Soil classification is the organisation of similar soils into categories dependent upon their formation, climate and management. Eleven Great Soil Groups are now recognised in Ireland (compared to the nine recognised by AFT): these are often found in key landscape positions as illustrated diagrammatically in Fig. 4.1.

The ISIS project recognises three levels of classification:

- **Great Groups** – organised based on dominant soil-forming factors into 11 categories (Fig. 4.2). These include: (i) Ombrotropic Peat Soils; (ii) Mineratrophic Peat Soils; (iii) Rendzinas; (iv) Lithosols; (v) Alluvial Soils; (vi) Groundwater Gleys; (vii) Surface-water Gleys; (viii) Podzols; (ix) Brown Podzolics; (x) Luvisols and (xi) Brown Earths.
- **Subgroups** – are defined within a Great Group for soils which display similar diagnostic features (diagnostic features are the main characteristics of a soil profile which describe the main soil-forming processes taking place) (Table 4.1). Sixty-six subgroups have been described within the ISIS project. These are based on the diagnostic differences found within the 11 Great Groups. Details of the subgroups can be found in Appendix 1.
- **Series** – are defined as soil profiles which display a combination of similar soil properties (e.g. texture and parent material) within a subgroup classification. In total, 213 soil series have been described in the ISIS project. Of these, 73 series originated and are represented by descriptions and data from AFT. A total of 127 series were described and analysed during the ISIS project and 13 series have been identified repeatedly (> 20 records) by auger descriptions, but no profile description exists as yet. This will be completed in 2014. A full list of soil series and their definitions is provided in Appendix 1.

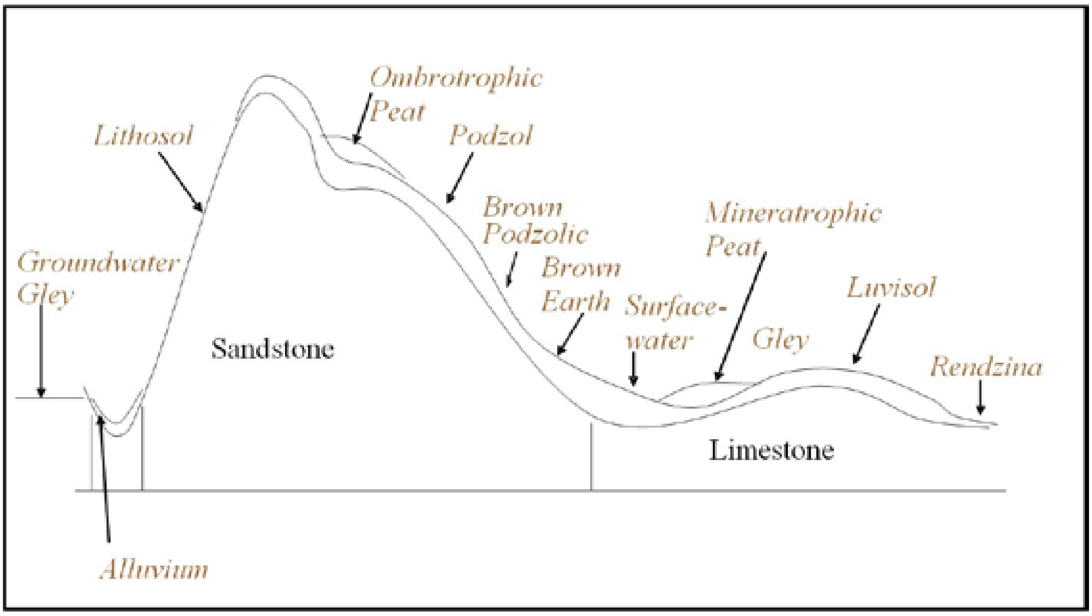


**Figure 4.1. Soil Great Groups described across a landscape position.**

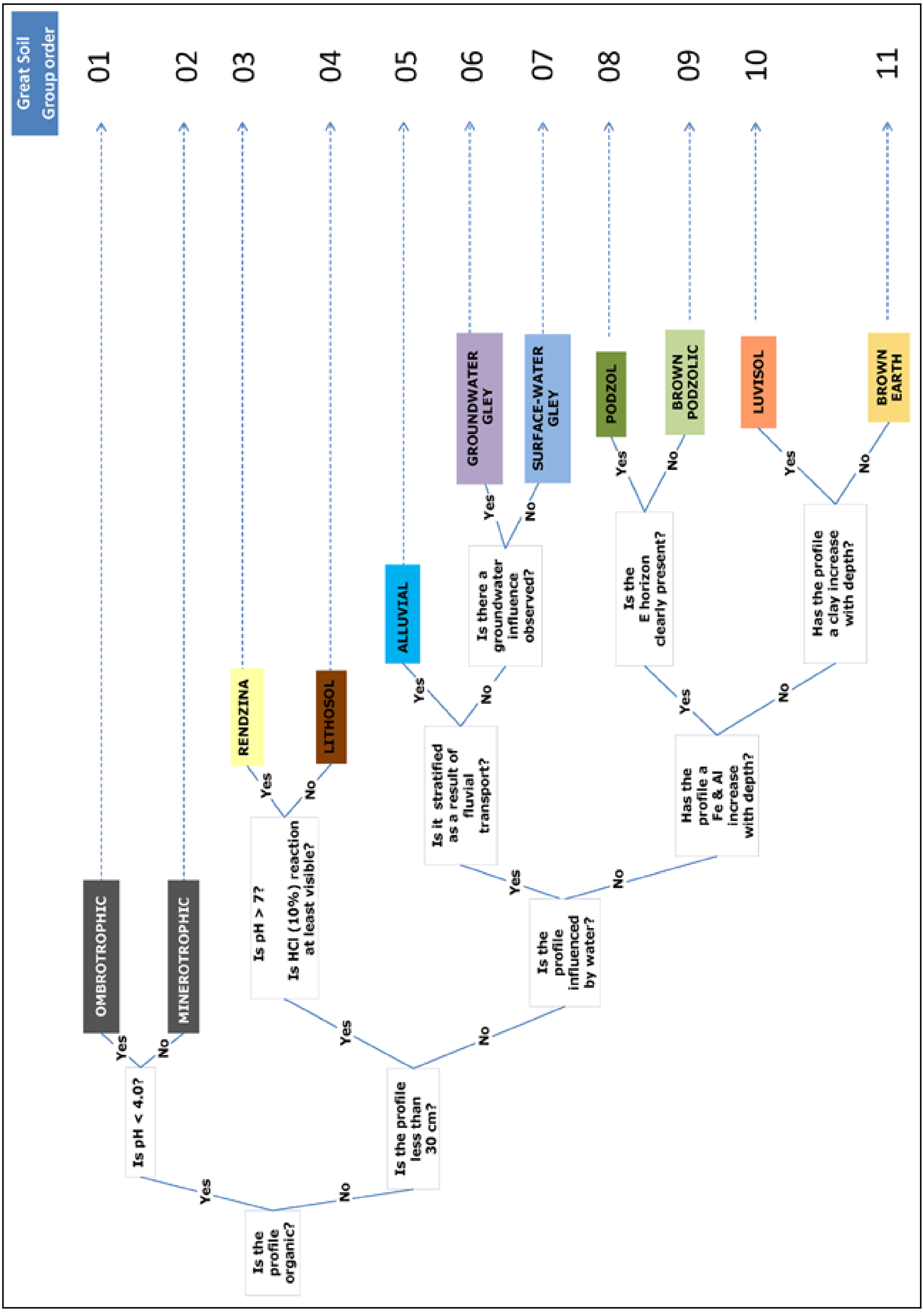


Figure 4.2. ISIS classification key for Irish Soil Great Groups.

**Table 4.1. ISIS diagnostic features description.**

| Code | Diagnostic feature | Description |
|---|---|---|
| 0 | None | No distinguishing characteristics associated with this feature. |
| 1 | Histic | A peaty (> 20% OC) (O) horizon 7.5–40 cm thick, overlying mineral soil or rock material. Normally occurs at the surface or beneath a thin layer of more or less decomposed litter (L and F horizons). |
| 2 | Gleyic | Occurs in soils affected by seasonal or continuous waterlogging. Presence of manganese concretions or iron/ manganese nodules or grey colouring from continuous presence of a water table fluctuating can be indicative of wetness. |
| 3 | Stagnic | A subsurface horizon at least 15 cm thick, starting within 40 cm depth which displays evidence of reduced Fe/Al as a result of a perched water table from a significant barrier to water movement when the soil is saturated. |
| 4 | Fe/Al accumulation | A B horizon in which amorphous materials containing aluminium and/or iron that has accumulated, either by illuviation or by biochemical weathering in situ. |
| 5 | Calcareous | Soils in which a calcareous horizon (i.e. containing significant amounts of calcium carbonate, in other words lime or chalk) is present within 40 cm of the surface, have a calcareous B horizon and are formed in calcareous parent materials. |
| 6 | Humic | Contains an A horizon with significant organic matter, but also some mineral matter (includes Bh horizon in Podzols). |
| 7 | Drained | Drained soils are primarily where human activity has altered the hydrological status of the soil from poorly to imperfectly to moderately drained. |
| 8 | Cut-over | Surface peat has been removed by hand-cutting methods but the peat thickness still meets the criteria for peat soils. |
| 9 | Anthropic | Most commonly Anthropic features are used to describe a terric horizon (from Latin *terra*, meaning earth) which is a human-induced surface horizon > 40 cm thick. |

Figure 4.3 gives an example of a soil profile with the designated horizons and some diagnostic features present. This soil profile is classified as Mylerstown series, Calcareous Groundwater Gley, loamy drift with limestones.

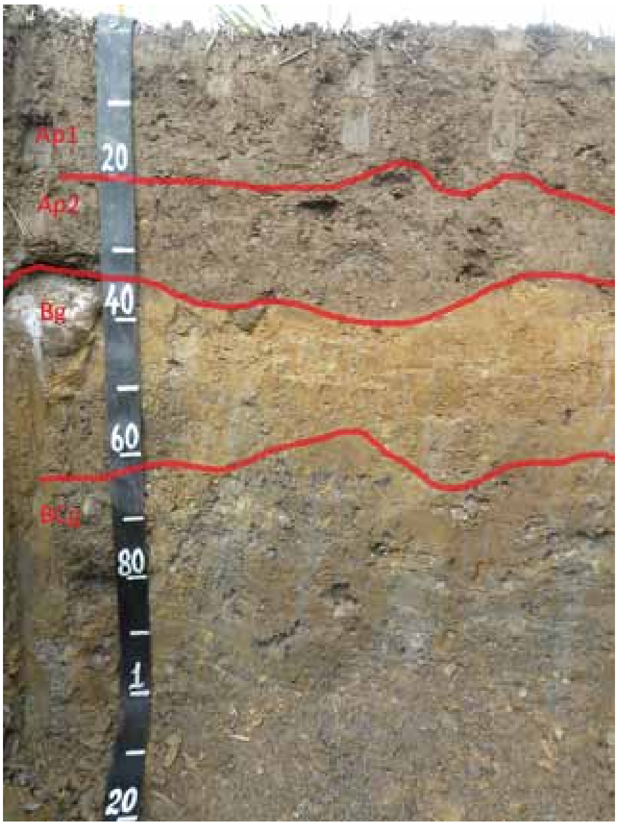


**Figure 4.3. Soil profile of Mylerstown series. Ap1: plough layer 1, Ap2: plough layer 2, Bg:Mineral subsurface horizon with stagnic conditions, BCg: Transitional mineral subsurface horizon between a B and a C with stagnic conditions. (See ISIS Final Technical Report 10 for description of layers and coding.)**

# 5 Development of Representative Soil Profiles

During 2012/2013, a number of profile pits were excavated if a particular soil series was deemed representative (i.e. it occurred frequently across the soil auger survey), and/or had not been described in sufficient detail (physical, chemical and biological parameters) in previous AFT county surveys. As part of this process, newly described soils were also correlated to World Reference Base classification system (International Union of Soil Sciences Working Group World Reference Base for Soil Resources [WRB], 2006), (ISIS Final Technical Report 8). In addition, WRB correlation was completed on all representative profiles selected from the AFT data.

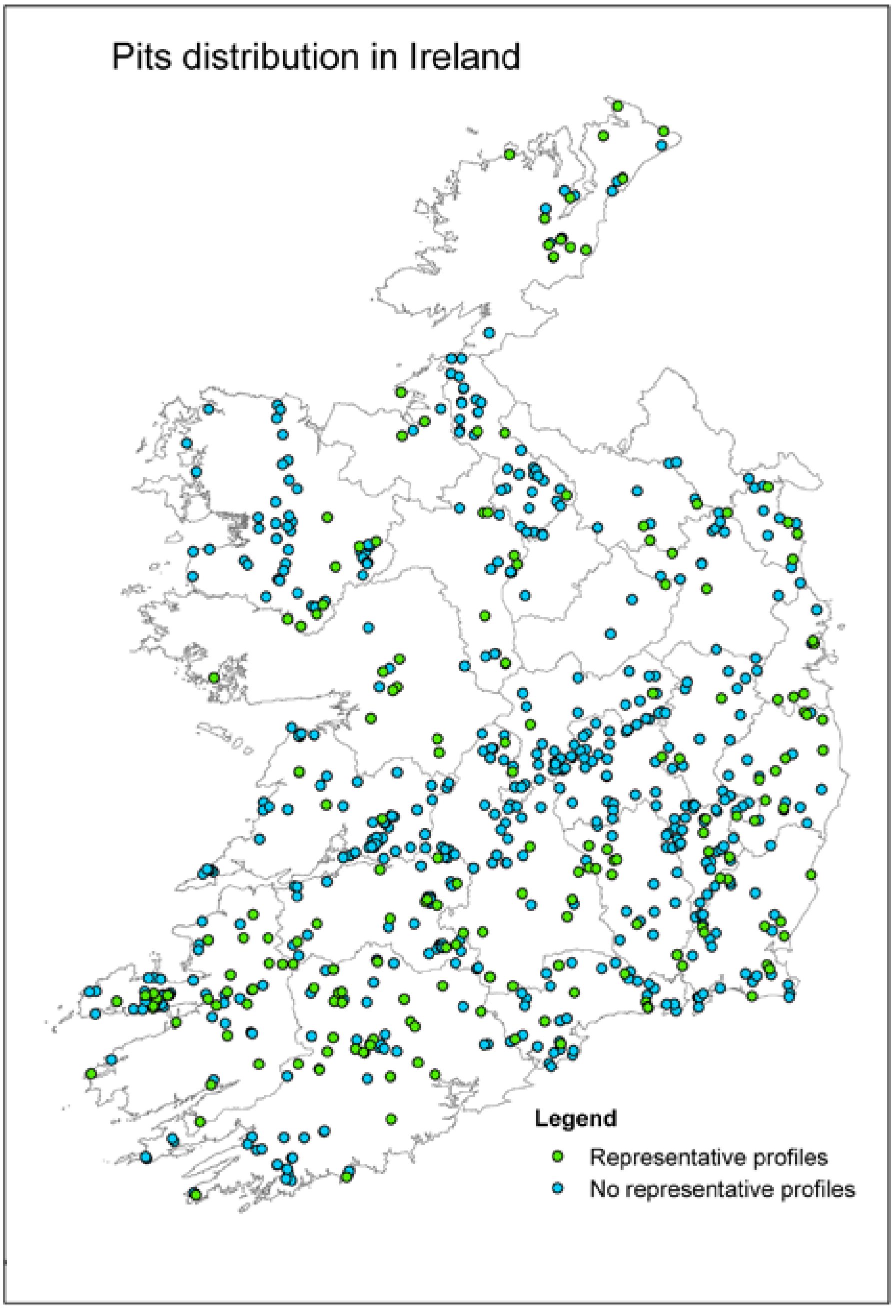


**Figure 5.1. Pits distribution in Ireland. Green dots indicate profile pits considered representative of a soil series. Blue dots indicate sites where profile pits were taken, but descriptions were not considered representative.**

## 5.1 Fieldwork Preparation

After acknowledging budgets, laboratory and personnel capacity, a template of proposed fieldwork was described allowing for 120 pits in 2012 and 180 pits in 2013 (Fig. 5.1). A field manual was developed (ISIS Final Technical Report 10) to aid in soil classification and sampling procedures. A database with a user interface was developed to record all data onto a rugged tablet in the field (ISIS Final Technical Report 6). A barcode labelling system was also devised to ensure that sample labelling did not generate any sample errors. This system was unique and allowed samples to be allocated barcodes and scanned in the field with a handheld scanner directly onto the tablet and allow the same sample to be traced throughout the laboratory process.

Where possible, clusters of auger bores were favoured: 10 km x 10 km map sheets were printed with proposed points and an overall route plotted. Some soil series were common throughout the country whereas others were more localised – for example, the north-west. Other soils had national occurrence but were sporadic locally; this was particularly the case for Groundwater Gleys (Gleysols), which are generally associated with low-lying areas and local depressions in the landscape. These particular soils required more attention to the local landscape setting and were the last to be described. Logistically, ten profile pits were attempted per week. Lithosols (Leptosols), Rendzinas (Leptosols) and Ombric/Mineratrophic peats (Histosols) were dug by hand and clustered together at the start and the end of weeks (when they occurred) allowing digger excavation continuously on other days to reduce costs.

## 5.2 Site and Soil Description

Upon arriving onsite, the GPS location was determined and the area augured to ensure it matched the description. The principal landscape features were recorded: relief, topography, aspect and land use; and the pit was excavated to a depth of approximately 1.2 m. On some occasions it was useful to excavate >1.2 m, for example to examine the parent material below drift. The profile face was cleared and photographed and the parent material noted (Fig. 3.4). The profile was described both overall and per horizon by two surveyors. Horizons were described in detail, with characteristics of texture, structure, colour, carbonates, stone content and type, root content and depth and presence of biota recorded. If a water table was present its depth was recorded. Reduced conditions were tested using α-α dipyridyl in solution which was directly applied onto a soil sample that was taken from the part of the horizon in question.

## 5.3 Sampling of Horizons

### 5.3.1 *Chemical Properties and Soil Textural Analysis*

Each horizon was sampled for laboratory analysis, which assessed pH (in $H_2O$ and $CaCl_2$), total carbon content, total nitrogen, organic carbon, organic matter content (through loss-on-ignition method), cation exchange capacity (CEC), base saturation (BS), Fe/Al (through oxalate extraction) and texture. This composite sample required approximately 2 kg of fresh soil from each horizon. If horizons were < 5 cm thick, it was not possible in all cases to obtain a composite sample. All samples were barcoded and logged on site into the profile description database. The details of the analytical methods applied can be found in the ISIS *Standard Operating Procedure Handbook* (ISIS Final Technical Report 7).

### 5.3.2 *Physical Properties*

Bulk density was sampled with fixed volume stainless steel rings (98 $cm^3$). Three rings were taken per horizon to determine the degree of variation of bulk density within a given soil profile and horizon. Data for bulk density are reported as the average value ($cm^3$) for each horizon and standard deviation (to explain variation). Bulk density measurements can be conducted if it is suspected that soil is compacted or as part of fertiliser or irrigation management plans factsheet.

### 5.3.3 *Biological Properties*

Additional samples were taken to determine a normal operating range (NOR) of microbial/faunal communities and functional measures for Irish soils. This has not been previously conducted at such a large scale in Ireland. Biological samples required special handling in the field, due to issues of contamination across both horizons and profiles and special preservation measures (samples taken for DNA analyses needed to be frozen immediately on extraction). Three types of samples were collected for this purpose:

1 1 kg sample of fresh soil from surface horizons to a depth of 20 cm was kept at 4°C for; microbial biomass C, Multiple Substrate Induced Respiration (MSIR), potential nitrification and nematode assemblages (trophic groups and molecular profiling);

2 Frozen samples (200 g) from all horizons for: Phospholipid Fatty Acids (PLFA) and DNA extractions for Terminal Restriction Fragment Length Polymorphism (TRFLP);

3 Micro-arthropods samples were collected using fixed-volume stainless steel rings (98 $cm^3$) from the surrounding surface soil (non-compacted) to the profile pit. A total of six samples was taken per site (3 x 0–5 cm depth and 3 x 5–10 cm depth). Samples were only taken from sites post-July 2013.

The analyses of these samples were carried out by PhD students and contract research staff.

### 5.3.4 *Carbon Fractions*

Fresh samples were also collected for a PhD project studying the range of carbon fractions associated with the different soil types described in ISIS. This required a 1 kg sample to be kept at 4°C from each horizon. These samples are being fractionated using a range of physical methods (Elliott, 1986; Besnard et al., 1996; Six et al., 2000) and chemical techniques (HCl and hot water extractable C).

### 5.3.5 *Laboratory Procedures*

Composite samples were dried and sieved to < 2 mm, in preparation for the analyses described in Section 5.3.1. Prior to receiving the samples, procedures had been developed to align AFT methodologies (which were no longer available or practical) with currently available methods (International Standards were used, where available). A balance had to be found between maintaining AFT integrity for comparative purposes and following more modern international standards (ISO). In some cases, neither option was available and new analytical methods had to be developed that used external sample standards to validate methods. Samples were sent to external laboratories to cross-check some of the in-house method developments. Subsets of AFT samples were also analysed using the new methods to compare the results from the previous AFT methodology.

### 5.3.6 *Profile Classification – Review Process*

Once the laboratory data were available, soil-profile descriptions were reviewed to ensure the correct soil classifications had been assigned. Field-based descriptions can only be based on relatively general diagnostic criteria and do not allow for the consideration of detail which is derived from laboratory analyses. A detailed log was established of changes to the classification, utilising the data from the laboratory.

In cases where the diagnostic assessment had changed as a result of the laboratory data, the classification was updated. At times this meant that the original combination of soil properties (series) sought in the field had not been obtained and further field campaigns were required to locate a soil profile fitting the correct description. In some instances the soil type was so difficult to find that it was deemed unrepresentative and was removed from the active list of series. Where a soil description was appropriate and deemed a good example of that series, it was considered representative. These representative soils were then assigned names, usually from the local townland, to give them defined series identification. Any other soils described that met the definition would be assigned the same series name (Table 5.1). A final report of all representative profile descriptions was developed (ISIS Final Technical Report 9).

**Table 5.1. Extract as example of representatives profiles developed. Full list in Appendix 1.**

| Soil subgroup | National series | Definition |
|---|---|---|
| **Ombrotrophic Peat** | | |
| Natural Ombrotrophic Peat Soils | Knockmealdown | Peat over rock |
| Natural Ombrotrophic Peat Soils | Aughty | Peat (Blanket Bog) |
| Natural Ombrotrophic Peat Soils | Allen | Peat (Raised Bog [moss]) |
| Drained Ombrotrophic Peat Soils | Aughty drained | Peat (Blanket Bog) |
| Drained Ombrotrophic Peat Soils | Garrynamona | Peat (Raised Bog) |
| Cut-over Ombrotrophic Peat Soils | Aughty cutover | Peat (Blanket Bog) |
| Cut-over Ombrotrophic Peat Soils | Gortnamona | Peat (Raised Bog, surface drained, hand-cut) |
| Cut-over Ombrotrophic Peat Soils | Turbary | Peat (Raised Bog, undrained, hand-cut) |
| Industrial Ombrotrophic Peat Soils | Clonsast | Peat (Raised Bog, industrial milled and machined) |
| **Mineratrophic Peat** | | |
| Natural Mineratrophic Peat Soils | Kilbarry | Peat over river alluvium |
| Natural Mineratrophic Peat Soils | Pollardstown | Peat (Fen, undrained) |
| Drained Mineratrophic Peat Soils | Banagher | Peat (Fen) |
| **Rendzinas** | | |
| Typical Rendzinas | Ballydeloughy | Loamy over limestone bedrock |
| Typical Rendzinas | Seafield | Sandy stoneless drift |
| Histic Rendzinas | Castletaylor | Loamy over limestone bedrock |
| Humic Rendzinas | Burren | Fine loamy over limestone bedrock |
| Humic Rendzinas | Crush | Coarse loamy over calcareous gravels |

## 5.4 Soil Archive

All remaining soil from the 2 kg composite sample was stored in the soil archive. Neutral storage containers (hermitically sealed jars), sealed to prevent gaseous exchange, are stored in archive units at a constant temperature in a facility on the site of Johnstown Castle. The storage units are guaranteed to support the weight of the soil samples and containers over decades and protect from direct sunlight. The barcode used in the field and in the laboratory has been used in the archive. The archive is built to facilitate up to 4,000 samples which allows for more samples to be added from future surveys; access is controlled by a Management Committee. The archive ensures that if new methods of analysis or different properties of the soils are to be investigated, there is a secure soil source with fixed conditions available and an associated database and digital soil information system to complement it.

## 5.5 Optical Sensing and Chemometric Analysis of Soil Properties

In addition to the chemical, physical and biological analyses mentioned above, a post-doctorate student based at University College Dublin (UCD) developed an infrared spectroscopy assessment of Irish soils, using samples from an earlier field survey. By combining spectral and reference analytical data, a multivariate model can be used for the prediction of soil properties from the spectra of new samples. Advancement of these techniques in soil science, which are currently only utilised in soil research applications, will reduce or eradicate the need for lengthy and expensive chemical analysis of soils in the future.

Infrared spectroscopy offers a rapid, non-destructive technique for soil analysis with minimum sample preparation (drying and homogenisation). A sample is characterised by its electromagnetic absorption where fundamental vibrations of molecules associated with particular chemical groups occur in the mid-infrared (2,500–25,000 nm), with combinations of these fundamental vibrations in the near-infrared (700–2,500 nm) and electronic transitions in the visible regions (400–700 nm) of the electromagnetic spectrum. As the ISIS soil database was undergoing development during the 2009 to 2011 timeframe of this contracted research, a representative sample set (n = 400) was selected from an existing national soil database archive as a training dataset. This dataset contained the following analyses: soil organic carbon, pH, available P, Mg, K, and elemental concentrations Al, As, Ba, Ca, Cd, Ce, Co, Cr, Cu, Fe, Ga, Ge, Hg, K, La, Li, Mg, Mn, Mo, Na, Nb, Ni, P, Pb, Rb, S, Sb, Sc, Se, Sn, Sr, Ta, Th, Ti, Tl, U, V, W, Y, Zn. It was determined early in the project that geochemical information was not adequately present in the near-infrared region, and so the project focused on the prediction of soil organic carbon from visible near-infrared spectra.

Follow-on work using this dataset is currently being conducted at the University of Sydney with instrument capacity in near-infrared, mid-infrared and x-ray spectroscopy to develop predictive models (Cubist, Partial Least Squares Regression with/without bagging) for soil geochemistry on a national scale. Chemometrics is the use of mathematical and statistical methods to improve the understanding of chemical information and to correlate quality parameters or physical properties to analytical instrument data. The chemometric modelling procedure developed in the statistical software R[1] will be transferable for soil properties measured in ISIS in the future (pH, total C, total N, organic C, organic matter content, CEC, BS, Fe/Al and texture) which are known to be successfully predicted from NIR spectra (Viscarra Rossel et al., 2006).

This project was the first attempt to investigate the application of optical sensing and chemometric analysis of Irish soils. To determine which instrument platform was most appropriate for the visible near-infrared analysis of soil organic carbon, a cost-benefit analysis was performed which included standard point spectroscopy instruments as well as the state-of-the-art hyperspectral imaging at UCD. Hyperspectral imaging was identified as the most rapid and cost-effective technique. It has the potential to scan 720 samples per day at 90% less cost than the traditional wet-chemistry Walkley-Black method and thus superseding the measurement capacity of point spectroscopy (O'Rourke and Holden, 2011). There are two potential approaches in which hyperspectral imaging could be employed for soil analysis: (i) the average spectrum could be extracted from each soil image or (ii) the spatial component could be utilised to yield more information about the sample.

For Approach 1, the minimum sample size required to extract accurate soil information was tested. The conclusion was that sample throughput could be further increased with a small reduction in accuracy (O'Rourke et al., 2011), which may be applicable for such soil properties in which the threshold value and not the absolute concentration are required, i.e. indexing of soil nutrients. The utility of this method was tested on a dataset of forest topsoils for which total C, organic C and inorganic C could be predicted with equal accuracy to that of studies in other countries (O'Rourke and Holden 2012, see Appendix 4). It was demonstrated that spectral imaging had the ability to be as accurate as point spectroscopy, when equal spectral ranges were considered (Askari et al. 2014; under review). This presents the potential for hyperspectral imaging to be used accurately in Approach 2, opening up the possibility of mapping the concentrations of properties of interest in intact soils at the sub mm scale to further our understanding of the distribution of chemical and physio-chemical properties in the soil. This has been demonstrated to date by mapping soil C in homogenised soil samples (O'Rourke et al. 2014, under review).

This work is now being continued and applied to the ISIS samples taken from the profile pits. Teagasc has scanned all 800 soil samples taken from the representative profile pits through a near-infrared spectrophotometer. The data are currently being analysed against the chemical and physical analyses completed for the classification of soils.

1 http://www.r-project.org/

# 6 Development of a Digital Soil Information System

## 6.1 Information System Requirement and Rationale

Historically, soil data held in Ireland was map or paper based with few digital records. Soil maps were digitised during the 1990s and county monographs were scanned into PDF format. However, no harmonised system was available where existing data could be interrogated electronically, or where the output of any interrogation could be displayed within a modern, publicly accessible, integrated IT framework. Ireland required a coherent framework for the presentation and updating of its soil information so that such data could be made readily available to all those concerned with the soil environment, and its interactions with air and water, including scientists, engineers, planners, policy-makers and the general public. Such a system should allow for the integration and presentation of data, the re-arrangement and re-classification of data for analytical and display purposes and the use of such information in process-based and socio-economic modelling of scenarios for policy and 'what-if' scenario appraisal. The structuring of soil data to facilitate incorporation and management within a Geographic Information Systems (GIS) framework will greatly enhance access to, and use of, the soil data resource in Ireland. Such access will ultimately provide an educational function that will enhance the understanding of our natural environment.

The ISIS project was tasked with designing and implementing a central system core for the Irish Soil Information System (SIS-Core) together with the ancillary data-management tools needed to capture, load and manage soils data to this repository. The SIS-Core represents the principal source of data. It was essential that the design and implementation was consistent with the principles of Directive 2007/2/EC, Infrastructure for Spatial Information in the European Community (INSPIRE).

## 6.2 Technical Systems Architecture

The GIS components of the system are built on the ArcGIS Server GIS platform from Environmental Systems Research Institute (Esri), following the recommendations of Daly and Fealy (2006). This offers a range of design and application advantages, while also providing the basis for future extension and incorporation of advanced data interrogation and modelling tools. Underpinning the SIS system is an enterprise class relational database management system (RDBMS)-using MS SQL Server 2008 R2. This holds and manipulates the variety of data types, scales and sources required, including attribute characteristic tables to hold the descriptive property elements required in the data schema.

The SIS configuration entails three interconnected and dedicated hardware platforms. First, the database server holds the RDBMS; second, the GIS services applications server holds the ArcGIS Server spatial software technology from ESRI Inc. Together, these servers facilitate storage, management and dissemination of the primary spatial and apatial datasets generated and used by the SIS activities. Related to the key dissemination activities, a third web-enabled GIS server enables access to the system from public web browsers. Data uploads are facilitated from the back-end GIS and database servers to load data on this public-facing server. This configuration allows an enhanced approach to security while minimising the complexity that might be involved in implementing alternative configurations.

## 6.3 Database Schema Design

The database structural design was undertaken using Enterprise Architect software. The final schema of the database serves both of the distinct output databases in ISIS. These comprise SIS_CORE (the database holding the formal institutional record of the ISIS project) and a subset SIS_PUBLIC (the database holding the information used in building the public ISIS portal). SIS_PUBLIC contains a subset of data, omitting items considered to be sensitive or confidential in nature (e.g. farmer names, absolute coordinates of soil samples, etc.). SIS_CORE contains full data records for each table in the database (Fig. 6.1).

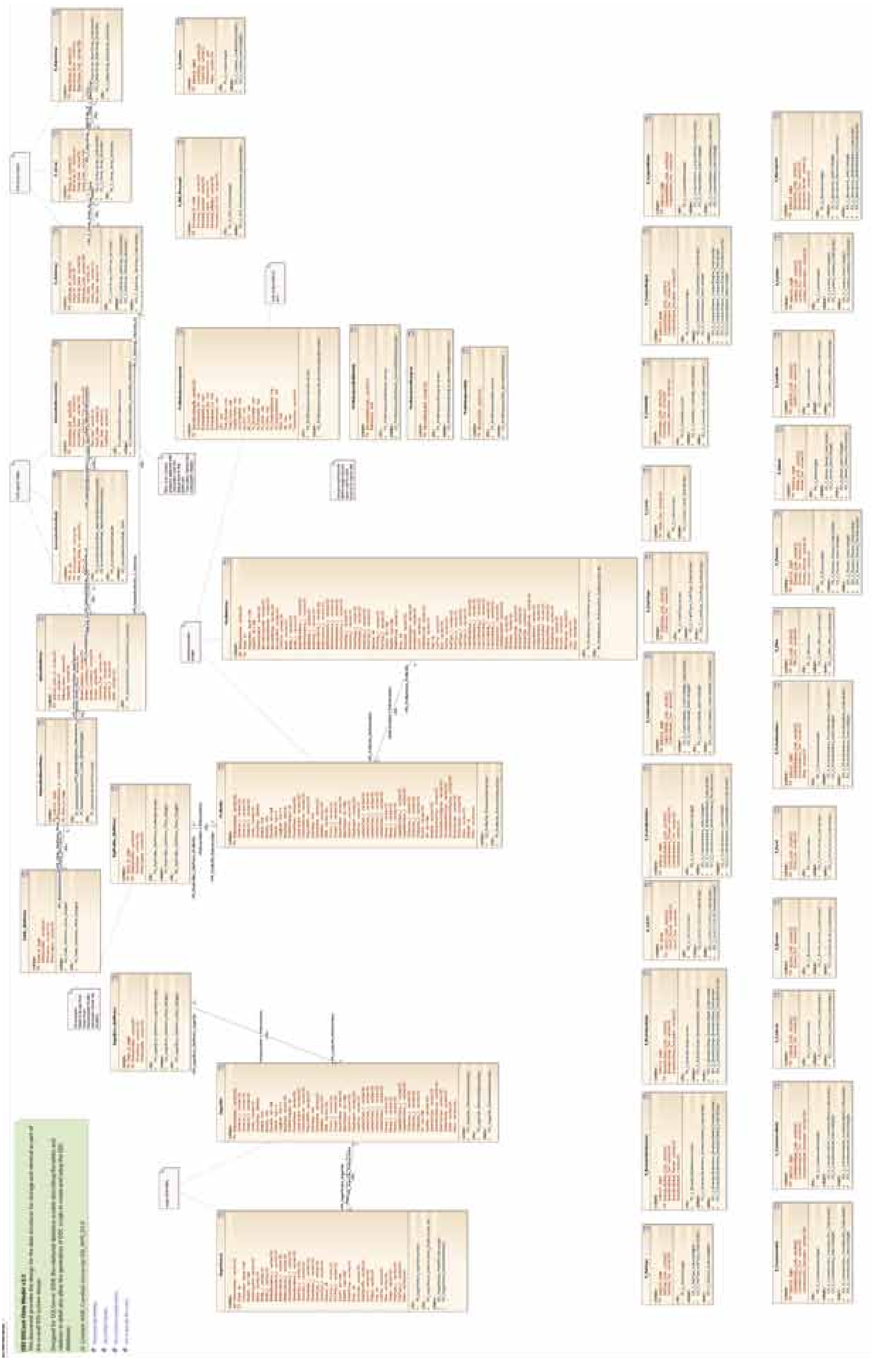

Figure 6.1. Design of the ISIS database schema.

## 6.4 Establishing the Geodatabase

The new digital 1:250,000 scale soil association map arising from activities in other work packages has been imported, processed and cleaned and converted into an ArcGIS file geodatabase (FGDB). This FGDB is deployed on the public-facing web server.

The ArcGIS server, which is also hosted on the web server, has been used to publish and manage a map service derived from the 1:250,000 map. The service has been cached to ensure efficiency and speed of delivery at browser level and to ensure enhanced viewing experience for the user.

## 6.5 Web Portal Development and Deployment

The original ISIS design envisaged the construction of a viewer tool which would provide basic access to the data holdings, both as published web-based services and also to facilitate simple online mapping. The ISIS web application (http://soils.teagasc.ie) has been developed to provide a public window onto the work and outcomes of the ISIS project, and as a vehicle for stakeholders and interested parties to access and interact with the new national 1:250,000 soil association map of Ireland and its related attribute data. In addition, the website also provides the means to upload and access legacy soils information for Ireland.

Design of the web application reflected the philosophy that it should, where possible, be 'database driven' (ISIS Final Technical Report 17). This was to ensure an approach that will support and facilitate the maintenance and upkeep of the system while enabling on-going updates of core underlying data into the future.

The site now comprises a comprehensive yet simple-to-use map viewer application that allows the user to explore the new 1:250,000 soil association map, and to 'drill down' into the data to identify further detail relating to the soil associations, member soil series and taxonomic groupings (Fig. 6.2). Representative profile information is also accessible, allowing soil properties to be reported and compared. Further functionality is currently planned for accessing and downloading existing legacy county soil map data. Reports may be generated for individual representative soil profiles. These highlight collated site and laboratory-derived assessments of soil property. Also included in these reports are the photographs of representative sites and landscapes.

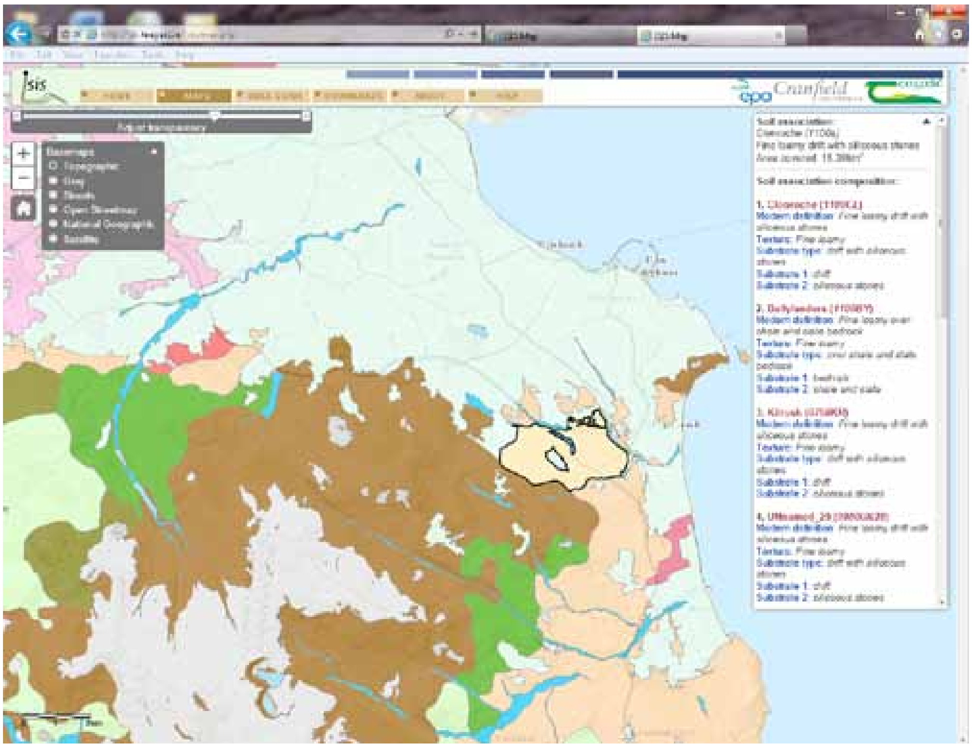

**Figure 6.2. ISIS web portal viewer.**

# 7 Final Remarks and Recommendations

Ireland, like all other EU member states, faces the contemporary challenge of meeting a range of agri-environmental objectives in the context of the increasing food production in a post-quota environment. Examples include the need to obtain 'good quality' status for all water bodies, as specified by the Water Framework Directive, the need to protect biodiversity under the Habitat and Birds Directives, the potential for offsetting agricultural greenhouse gas (GHG) emissions through carbon sequestration and the need for sustainable recycling of nutrients under the Nitrates and Sewage Sludge Directives. It has been well documented that the capacity of land to deliver on each of these requirements depends primarily on soil properties and hence soil type. Therefore, meeting all targets simultaneously requires optimisation of the suite of soil functions delivered by each soil.

The key outputs from the ISIS project include:

- A publicly available 1:250,000 soils map of Ireland together with its associated soil information system;
- Contributions to developments internationally in soils research;
- Advancement of national capacity in the soils thematic area;
- Creation of a common framework for the provision of soil data community in order to maximise the stakeholder benefit to be derived from this data.

This project has uniquely combined at a national level a combination of digital soil-mapping techniques with traditional soil survey. This is the first of its kind to be done at national level and in Europe.

It is paramount that the new complete 1:250,000 soils map (and soil information system) will be a significant national resource for research, policy-making and land-use practices, specifically in relation to the environment and agriculture, since soils are the elemental drivers of the majority of agri-environmental processes.

End-user application of ISIS will be specifically relevant at scales appropriate to the 1:250,000 scale at which the soil associations are mapped; examples of such initiatives from the research and policy community potentially include:

- The new EU-wide delineation of the Less Favourable Areas (European Commission; Department of Agriculture, Food and the Marine);
- Soil-specific nutrient advice (Teagasc);
- Refinement of Ireland's GHG inventories (towards Tier 3 Kyoto reporting) (EPA; GHG-Network Ireland, coordinated by Teagasc);
- River Basin District Management Plans under the Water Framework Directive: identification of critical source areas and targeting of potential supplementary measures (local authorities, Department of the Environment, Heritage and Local Government [DECLG], EPA).

Many of these initiatives are dependent on the map products to be derived from ISIS project.

To deliver the data in a format usable to the stakeholder community, it is recommended that a number of attribute maps be derived from the ISIS soil map to provide soil attribute data to the end-user. At a stakeholder workshop in September 2013[2] it was recommended that the following maps be derived from the ISIS soil map:

- Soil subgroup – will provide a less technical diagnostic map which will inform on soil organic matter status of the soil and general drainage capacity, whether affected by surface water stagnation or groundwater;
- pH – a series of pH maps will be developed, which provide the ranges of pH expected within different associations and a modal pH map which will use the modal profile associated with the lead series of each mapped association;
- Soil texture map – a soil texture map can be derived for the principal soil series of each association. This would only be indicative, as many associations compose of both fine loamy and coarse loamy soils.

2 http://www.epa.ie/researchandeducation/research/soilsandlanduse

- Drainage – the current soil drainage map produced by Teagasc in the 1990s is based upon expert judgement, whereby three drainage categories were applied to the modal Great Groups of the mapped associations on the 1:550,000 General Soils Map of Ireland. This map is currently based upon a modal profile of a Great Group Association and therefore is extremely coarse in detail. Since the development of this map, two further drainage categories have been derived by Premrov et al. (2010) and Kerebel et al. (2013), respectively.
- Soil carbon (organic matter) stocks – a number of methods can be applied to produce a soil carbon stock map and several maps have been presented for Ireland or components of Irish soils to date (NSDB, Soil C). However, it is essential that soil bulk density is measured in relation to the soil C concentration to calculate a correct volume for stocks. This has been completed for most soils in Ireland, with the exception of organic soils, due to previous work done by Hammond (1979).
- Soil depth – this data would be interpolated from existing maps and the updated Quaternary geology map due for release in March 2014 by the Geological Survey of Ireland. Approximations of depth associated with modal soils for associations would be categorised to provide an overview of soil depth.
- Bulk density – bulk density data has been collected on representative profiles during the ISIS field programme of representative profile pits. However, this data does not exist for the AFT detailed soil series maps (*Terra Cognita*) produced from the 1950s to 1990s. Therefore, a comparison of datasets to derive soil bulk density values for soils in *Terra Cognita* where appropriate modal profiles do not contain the data will be needed.

In addition, there are a number of laboratory-based opportunities for the data derived for developing the ISIS map. These include improving nutrient efficiency advice for farmers, using samples from the profile field campaign detailed analyses can now be linked to soil properties. This includes measurements such as P availability, N mineralisation etc.

Finally, it is recommended that there is a great potential for developing further IT applications from the data derived for the ISIS project:

- Development of a more sophisticated reporting module capable of outputting custom mapping and reporting material for the varied anticipated user communities. For example, the land-information portal LandIS (http://www.landis.org.uk/services/index.cfm) is capable of producing a series of fully customisable stakeholder reports (up to *c*.50 pages) providing a full report for a user-specified location.
- Further work could now be undertaken to partition the data in ISIS into 'data families'; these can then be made available for access by interested parties, as is done in LandIS (http://www.landis.org.uk/data/datafamilies.cfm).
- Steps should be put in place to facilitate the integration and harmonisation of adjunct databases relating to soil themes from other soil research products in Ireland. There is an opportunity to draw together a number of databases together which will lead to efficiencies and improved data management, but which will also facilitate potential future public access to these data.

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# Acronyms and Glossary

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|---|---|
| **α-α dipyridyl test** | Method applied for testing the presence of FeII ions by spraying the freshly exposed soil surface with a 0.2% (M/V) α-α dipyridyl solution in 10% (V/V) acetic acid solution. The test yields a striking reddish-orange colour in the presence of FeII ions. Care is necessary as the chemical is slightly toxic. |
| **Alluvium** | A loose, unconsolidated soil or sediments that has been eroded, reshaped by water in some form, and re-deposited in a non-marine setting. |
| **(AFT) An Foras Talúntais** | Forerunner to Teagasc. |
| **Association** | Type of soil map unit, which contains three or more (max. 12) dissimilar soil series occurring in a regular distribution pattern but too difficult to separate at national scale. |
| **Auger bore survey approach** | Description of soil properties through samples collected by a screw-like instrument (auger) that allows the extraction of a column of soil at a point. Augering is a much quicker and cheaper method of observing changes in soil characteristics with depth compared to digging soil profiles. However, unlike a soil profile – which exposes a relatively large area of the soil – only the characteristics of the sampling point can be observed with an auger. |
| **Amorphous organic matter** | Standard name used for all particulate organic components that appear structureless at the scale of light microscopy. |
| **Bayesian belief network (BBN) model** | Belief networks are a vital tool in probabilistic modelling and Bayesian methods, so BBN covers two important fields: probability theory and graph theory. BBN makes predictions based on probabilities from measured data but can also incorporate expert option to condition the relationships. |
| **Bedrock** | Solid rock present beneath any soil, sediment or other surface cover. In some locations it may be exposed at Earth's surface. |
| **Blanket Peat** | Ombrotrophic Peat soils are rain-fed peat soils in upland positions (Blanket Peat). They are an organic-rich soils with an O horizon > 40 cm, found within the upper 80 cm. Ombrotrophic soils are oligotrophic with a pH < 4.0 (in CaCl2 1:2.5 undried, equivalent to pH 4.5 in 1:2.5 $H_2O$) throughout the Reference Section (Jones et al. 2011). Basic peat formations recognised in the Western seaboard and the upland of regions in Ireland. |
| **BS** | Base Saturation. |
| **CEC** | Cation exchange capacity. Extent to which the adsorption complex of a soil is occupied by a particular cation. |
| **Chemometric modelling** | Mathematical and statistical methods/models applied to improve the understanding of chemical information and to correlate quality parameters or physical properties to analytical instrument data. |
| **Combined fusion map** | Combined fusion map is the result of merging fusion map (includes *Terra Cognita* and *Terra Incognita*) with the mask map (includes alluvium, water, sand/dunes, tidal marshes, outcrops/rock and urban areas). |
| **Database schema** | Structure described in a formal language supported by the database management system (DBMS) and refers to the organisation of data as a blueprint of how a database is constructed. |
| **Drumlins** | Small oval shaped hills which stand out on an undulating landscape. They were re-formed from glacial deposits, sometimes with a rock core. |
| **DTM** | Digital Terrain Model. |

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| **EPA** | Environmental Protection Agency. |
| **ESBN** | European Soil Bureau Network. |
| **Eluviation** | Removal of soil material in suspension (or in solution) from a layer or layers of a soil. Usually, the loss of material in solution is described by the term 'leaching'. |
| **Esker** | Long, narrow, sinuous and steep-sided ridge composed of irregularly stratified sand and gravel deposited as the bed of a stream flowing in an ice tunnel within or below the ice (subglacial) or between ice walls on top of the ice of a wasting glacier, and left behind as high ground when the ice melted. Eskers range in length from less than 1 km to more than 160 km, and in height from 3 to 30 m. |
| **Feature space analysis (FS** | Assessing how closely a piece of land is related to a reference area in terms of environmental features space. Feature space analysis is based on some environmental covariates. |
| **Fusion map** | Map that was developed selecting the most appropriate predicted association from the five original predicted map products. |
| **GIS** | Geographical Information System is a computer system designed to capture, store, manipulate, analyse, manage, and present all types of geographical data. |
| **GIS framework** | Contains all the core GIS functionalities and raster data, vector data and attribute data. |
| **Glacial till** | Unsorted material (sediments) deposited directly by glacial ice and showing no stratification. |
| **GPS** | Global Positioning System |
| **Great Soil Group** | Organised group of soils based on dominant soil forming factors, into 11 categories, including (i) Ombrotropic Peat Soils, (ii) Mineratrophic Peat Soils, (iii) Rendzinas, (ix) Lithosols, (v) Alluvial Soils, (vi) Groundwater Gleys, (vii) Surface-water Gleys, (viii) Podzols, (ix) Brown Podzolics, (x) Luvisols and (xi) Brown Earths. |
| **Harmonised data** | Datasets should be harmonised to the extent possible to allow integration of national datasets. Harmonisation seeks to bring together various types, levels and sources of data in such a way that they can be made compatible and comparable, and thus useful for decision-making. |
| **HCl** | Hydrochloric acid. |
| **Horizon** | A layer generally parallel to the soil surface, whose physical characteristics differ from the layers above and beneath. Each horizon has a specific horizon notation, which follows the more modern terminology for soil description and which forms part of the definitions of the diagnostic features. The capital letters (L, F, H, O, A, B, E, C, R) represent the master horizons, and base symbols (other characters) added in order to complete the designation. [(See **Soil Profile Handbook** for description of layers and coding (http://erc.epa.ie/safer/reports]). |
| **Hyperspectral imaging** | Analyst may choose to take as many data spectrum measured at a particular chemical component in spatial location at time; this is useful for chemical identification and quantification. |
| **ISIS** | Irish Soil Information System |
| **ISO** | International Standards. |
| **Illuviation** | Material displaced verticality across the soil profile by water movement. These materials have been deposited in the lower layers of the soil profile from upper layers. |
| **Legacy soil series** | Soil series obtained from An Foras Talúntais (AFT) soil data. |

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| **Marsh** | Defined as wetlands frequently or continually inundated with water, often treeless and generally characterised by a growth of grasses, sedges, cattails, and rushes. Marshes receive most of their water from surface water, and many marshes are also fed by groundwater. |
| **Multipart polygons** | Spatially separate polygons sharing the same attributes and stored as a single feature. |
| **National soil series** | Consists of soil within a subgroup that have horizons similar in colour, texture, structure, reaction, consistence, mineral and chemical composition and arrangement in the profile. Series names are place names of towns, lands, etc. from the area where the soil was first defined. Series are defined on the basis of the following hierarchically, Great group, subgroup, texture and parent material. |
| **Nested sampling (NS)** | Directly estimating how the likelihood function relates to prior mass. Nested sampling (NS) is one such contemporary strategy targeted at calculation of the Bayesian evidence, but which also enables posterior inference as a by-product, thereby allowing simultaneous parameter estimation and model selection. |
| **Neural network model** | Computing system made up of a number of simple, highly interconnected processing elements that process information by their dynamic state response to external inputs (Hecht-Nielsen, R.). |
| **NIR Spectra** | Near-infrared (NIR) radiation. |
| **NOR** | Normal Operating Range. |
| **Optical sensing** | Any method by which information that occurs as variations in the intensity, or some other property, of light is translated into an electric signal. |
| **Peat** | Biogenic deposit which developed in the post-glacial (Holocene) period i.e., within the past 10,000 years. This soil is composed of organic material derived for the most part, from partially decomposed plant remains that accumulated under waterlogged conditions, either as autochthonous peat in the position of growth or as constituents of sub-aquatic sediments such as organic lake muds (Avery, 1980). |
| **Point spectroscopy** | Measurement of radiation intensity as a function of wavelength and are often used to describe experimental spectroscopic methods. |
| **Profile pit** | Excavation of soil at a field site, generally to depths of approximately 1 m, but can be extended until an impenetrable layer is reached. Soil pits are used to easily observe all of the soil horizons from the parent material to the surface for soil description and soil sampling. |
| **Random forest model (RF)** | Uses a classifer approach where multiple decision trees deive a relationship between the variables. RF ensembles a classifier that consists of many decision trees and outputs the class that is the mode of the class's output by individual trees. |
| **Representative profile** | A good example of the series. Modal representative soils were assigned names from the local townland to give them defined series identification. |
| **Revised mask** | Result of a number of updates that were made to the original post-processing mask. |
| **RDBMS** | Relational database management system. |
| **SFD** | European Soil Framework Directive. |
| **SIS** | Soil Information System. |
| **SIS-Core** | Central system core for the Irish Soil Information System. Database holding the formal institutional record of the ISIS project. |
| **SIS-PUBLIC** | Subset of SIS-Core holding the information used in building the public ISIS portal. |

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|---|---|
| **Small polygons** | Delineations of polygons on the map that are smaller than 50,000 $m^2$. |
| **Soil association** | Mapping unit that describes a range of soil series (soil with a particular set of properties) associated in a landscape, i.e. they are often found to co-occur in particular landscapes. Soil associations usually have between two and ten series co-occurring in a particularly landscape pattern. The first soil series described is the most dominant and the soil association is usually named after this series. The second and third series will also occur commonly, with any remaining series occurring in no particular order, but are expected to be found. |
| **Soil carbon fraction** | Physical fractionation of soil, resulting in carbon associated with different aggregate sizes and chemical fractionation of the soil, resulting in different soil organic matter pools which can be related to recalcitrance. |
| **Soil class** | Soil type. |
| **Soil classification** | Grouping of soils with a similar range of properties (chemical, physical and biological) into units that can be geo-referenced and mapped. |
| **Soil complexes** | Type of map units in soil surveys of delineation, each of which shows the size, shape and location of a landscape unit composed of two or more dominant components with predictable phase and composition, and a miscellaneous area, plus allowable inclusions. The individual bodies of components soils and miscellaneous areas are too small to be delineated at national scale. |
| **Soil map polygons** | Delineations on the map shown by a close boundary on a soil map that defines the area, shape and location of a map unit within a landscape. |
| **Soil profile** | If you look in a soil pit you will see various layers in the soil – these layers are called 'soil horizons'. The arrangement of these horizons in a soil is known as a 'soil profile'. A vertical section of the soil that exposes a set of horizons from the ground surface to the C horizon or to the parent rock. Soil scientists (pedologists) observe and describe soil profiles and soil horizons to classify and interpret the soil for various uses. |
| **Soil series** | Defined as soil profiles that display a combination of similar soil properties (e.g. texture and parent material) within a subgroup classification. |
| **Soil subgroup** | Defined within Great Group for soils that display similar diagnostic features (the main characteristics of a soil profile that describe the main soil-forming processes taking place). Sixty-six subgroups have been described within the ISIS project. These are based on the diagnostic differences found within the 11 Great Groups. |
| **Soilscapes** | Soil-landscape models/broad soil-landscape units. A soilscape is a broad soil-landscape unit that encompasses a number of soil associations. It groups soils formed primarily on similar substrate types linked to large-scale landscape features. |
| **STRIVE** | Science, Technology, Research and Innovation for the Environment programme. |
| **TEAGASC** | Agriculture and Food Development Authority. |
| **Trophic groups** | Group of organisms consuming resources from a similar level in the energy cycle. |
| **UCD** | University College Dublin. |
| **Urban soil** | Material that has been manipulated, disturbed or transported by human activities in the urban environment; used as a medium for plant growth. |
| **WFD** | Water Framework Directive. |
| **Wet Chemistry Walkley-Black Method** | Used for determining Soil Organic Matter (OM), this utilises a specified volume of acidic dichromate solution reacting with a determined amount of soil in order to oxidise the OM. |
| **WRB** | World Reference Base Classification. |

# Appendix 1 Irish Soil Subgroups and Series

| Soil subgroup | National_Series | Definition |
|---|---|---|
| Ombrotrophic Peat | | |
| Natural Ombrotrophic Peat Soils | Knockmealdown | Peat over rock |
| Natural Ombrotrophic Peat Soils | Aughty | Peat (Blanket Bog) |
| Natural Ombrotrophic Peat Soils | Allen | Peat (Raised Bog [moss]) |
| Drained Ombrotrophic Peat Soils | Aughty drained | Peat (Blanket Bog) |
| Drained Ombrotrophic Peat Soils | Garrynamona | Peat (Raised Bog) |
| Cut-over Ombrotrophic Peat Soils | Aughty cutover | Peat (Blanket Bog) |
| Cut-over Ombrotrophic Peat Soils | Gortnamona | Peat (Raised Bog, surface drained, hand-cut) |
| Cut-over Ombrotrophic Peat Soils | Turbary | Peat (Raised Bog, undrained, hand-cut) |
| Industrial Ombrotrophic Peat Soils | Clonsast | Peat (Raised Bog, Industrial milled and machined) |
| Mineratrophic Peat | | |
| Natural Mineratrophic Peat Soils | Kilbarry | Peat over river alluvium |
| Natural Mineratrophic Peat Soils | Pollardstown | Peat (Fen, undrained) |
| Drained Mineratrophic Peat Soils | Banagher | Peat (Fen) |
| Rendzinas | | |
| Typical Rendzinas | Ballydeloughy | Loamy over limestone bedrock |
| Typical Rendzinas | Seafield | Sandy stoneless drift |
| Histic Rendzinas | Castletaylor | Loamy over limestone bedrock |
| Humic Rendzinas | Burren | Fine Loamy over limestone bedrock |
| Humic Rendzinas | Crush | Coarse loamy over calcareous gravels |
| Lithosols | | |
| Typical Lithosols | Altahalla | Loamy over lithoskeletal gneiss and schist |
| Typical Lithosols | Figar | Loamy over sandstone bedrock |
| Typical Lithosols | Glenlane | Loamy over shale bedrock |
| Typical Lithosols | Castletown | Decalcified loamy over lithoskeletal limestone |
| Typical Lithosols | Cappacorcoge | Loamy over non-calcareous gravels |
| Histic Lithosols | Carrigvahanagh | Peat over lithoskeletal acid igneous rock |
| Histic Lithosols | Ballintroohan | Peat over lithoskeletal gneiss and schist |
| Histic Lithosols | Bantry | Peat over sandstone and shale bedrock |
| Humic Lithosols | Kilkieran | Loamy over lithoskeletal acid and basic igneous bedrock |
| Humic Lithosols | Knockeyon | Loamy over lithoskeletal sandstone |
| Humic Lithosols | Knockshigowna | Loamy over lithoskeletal shale and slate bedrock |
| Humic Lithosols | Rineanna | Decalcified loamy over lithoskeletal limestone |
| Alluvial | | |
| Typical Alluvial Gleys | Kilgory | Sandy river alluvium |
| Typical Alluvial Gleys | Lyre | Loamy river alluvium |
| Typical Alluvial Gleys | Boyne | Silty river alluvium |
| Typical Alluvial Gleys | Vicarstown | Clayey river alluvium |
| Typical Alluvial Gleys | Kilmannock | Silty estuarine alluvium |
| Typical Alluvial Gleys | Lurganboy | Loamy marine alluvium |

*Cont. overleaf ...*

| Soil subgroup | National_Series | Definition |
|---|---|---|
| Typical Alluvial Gleys | Gurteen | Loamy lake alluvium |
| Typical Calacareous Alluvial Gleys | Kilmore Slob | Loamy marine alluvium |
| Typical Calacareous Alluvial Gleys | Dunsany | Clayey lake marl |
| Histic Calcareous Alluvial Gleys | Abhainn | Peat over lake alluvium |
| Humic Calcareous Alluvial Gleys | Cornafulla | Loamy river alluvium |
| Humic Calcareous Alluvial Gleys | Drombanny | Loamy lake alluvium marl |
| Humic Calcareous Alluvial Gleys | Coolaknick | Silty lake alluvium |
| Humic Alluvial Gleys | Kilcullen | Loamy river alluvium |
| Humic Alluvial Gleys | Feale | Silty river alluvium |
| Humic Alluvial Gleys | Camoge | Clayey river alluvium |
| Humic Alluvial Gleys | Wexford slob | Silty marine alluvium |
| Humic Alluvial Gleys | Griston | Sandy lake alluvium |
| Humic Alluvial Gleys | Ardglass | Loamy lake alluvium |
| Humic Alluvial Gleys | Millquarter | Silty lake alluvium |
| Humic Alluvial Gleys | Coolalough | Clayey lake alluvium |
| Typical Drained Alluvial Soils | Finisk | Fine loamy over non-calcareous gravels |
| Typical Drained Alluvial Soils | Aherlow | Sandy river alluvium |
| Typical Drained Alluvial Soils | Clohamon | Loamy river alluvium |
| Typical Drained Alluvial Soils | Suir | Silty river alluvium |
| Groundwater Gleys | | |
| Typical Groundwater Gleys | Glandine | Loamy over sandstone bedrock |
| Typical Groundwater Gleys | Lissagriffin | Coarse loamy over shale bedrock |
| Typical Groundwater Gleys | Knockroe | Coarse loamy drift with siliceous stones |
| Typical Groundwater Gleys | Kilpierce | Fine loamy drift with siliceous stones |
| Histic Groundwater Gley | Derrynasaggart | Coarse loamy over sandstone bedrock |
| Histic Groundwater Gley | Annagh | Coarse loamy drift with siliceous stones |
| Stagnic Grounwater Gleys | Heathtown | Fine loamy drift with siliceous stones |
| Stagnic Grounwater Gleys | Greenane | Loamy drift with limestones |
| Humic Stagnic Groundwater Gleys | Bree | Coarse loamy drift igenous and metamorphic stones |
| Humic Stagnic Groundwater Gleys | Corlea | Fine loamy drift with siliceous stones |
| Calcareous Groundwater Gleys | Mylerstown | Loamy drift with limestone |
| Histic Calcareous Groundwater Gleys | Cloonmore | Fine loamy over limestone bedrock |
| Humic Calcareous Groundwater Gleys | Ballintemple | Coarse loamy drift with limestone |
| Humic Calcareous Groundwater Gleys | Ballyshear | Fine loamy drift with limestone |
| Humic Groundwater Gleys | Callan | Loamy over gneiss and schist bedrock |
| Humic Groundwater Gleys | Knuttery | Loamy over sandstone and shale bedrock |
| Humic Groundwater Gleys | Ballywilliam | Coarse loamy drift with igneous and metamorphic stones |
| Humic Groundwater Gleys | Puckane | Coarse loamy drift with siliceous stones |
| Humic Groundwater Gleys | Tourmakeady | Fine loamy drift with siliceous stones |
| Humic Groundwater Gleys | Noonan | Fine silty drift with siliceous stones |
| Humic Groundwater Gleys | Newtown | Coarse loamy drift with limestone |
| Humic Groundwater Gleys | Roosky | Fine loamy drift with limestone |
| Humic Groundwater Gleys | Ballyknockan | Sandy stoneless drift |

| Soil subgroup | National_Series | Definition |
|---|---|---|
| Surface-water Gleys | | |
| Typical Surface-water Gleys | Kilcreen | Coarse loamy over gneiss and schist bedrock |
| Typical Surface-water Gleys | Ballyphilip | Fine loamy over sandstone and shale bedrock |
| Typical Surface-water Gleys | Lismeelcunnin | Fine silty over shale bedrock |
| Typical Surface-water Gleys | Ballybrannagh | Clayey over shale bedrock |
| Typical Surface-water Gleys | Tramore | Loamy drift with igneous and metamorphic stones |
| Typical Surface-water Gleys | Newport | Coarse loamy drift with siliceous stones |
| Typical Surface-water Gleys | Kilrush | Fine loamy drift with siliceous stones |
| Typical Surface-water Gleys | Coolykereen | Fine silty drift with siliceous stones |
| Typical Surface-water Gleys | Drumkeeran | Clayey drift with siliceous stones |
| Typical Surface-water Gleys | Macamore | Fine loamy over calcareous Irish sea till |
| Typical Surface-water Gleys | Straffan | Fine loamy drift with limestone |
| Humic Surface-water Gleys | Ballyhaise lithic phase | Fine loamy over sandstone and shale bedrock |
| Humic Surface-water Gleys | Rahelty | Clayey over shale bedrock |
| Humic Surface-water Gleys | Ballynabreen | Coarse loamy drift with igneous and metamorphic stones |
| Humic Surface-water Gleys | Gortaclareen | Fine loamy drift with siliceous stones |
| Humic Surface-water Gleys | Cluggin | Clayey drift with siliceous stones |
| Humic Surface-water Gleys | Ballygree | Fine silty drift with siliceous stones |
| Humic Surface-water Gleys | Ballinamore | Fine loamy drift with limestone |
| Humic Surface-water Gleys | Howardstown | Clayey drift with limestone |
| Podzols | | |
| Typical Podzols | Ballyscanlon | Loamy over acid igneous rock |
| Typical Podzols | Black Rock Mountain | Loamy over gneiss and schist bedrock |
| Typical Podzols | Drumslig | Loamy over sandstone bedrock |
| Typical Podzols | Roddenagh | Loamy over shale and slate bedrock |
| Typical Podzols | Brockagh | Sandy drift with igneous and metamorphic stones |
| Typical Podzols | Ballycondon | Loamy drift with siliceous stones |
| Gleyic Podzols | Brackloon | Sandy over sandstone bedrock |
| Stagnic Podzols | Coumduff | Loamy over sandstone and shale bedrock |
| Stagnic Iron-pan Podzols | Blackstairs | Sandy over acid igneous bedrock |
| Stagnic Iron-pan Podzols | Monavullagh | Sandy over sandstone bedrock (conglomerate) |
| Stagnic Iron-pan Podzols | Forth Commons | Loamy over sandstone bedrock |
| Stagnic Iron-pan Podzols | Knockastanna | Loamy over shale bedrock |
| Stagnic Iron-pan Podzols | Glenary | Loamy drift with siliceous stones |
| Humic Podzols | Barnamire | Sandy over acid and basic igneous bedrock |
| Humic Podzols | Carrickbyrne | Loamy over acid and basic igneous bedrock |
| Humic Podzols | Gortaloughhane | Loamy over sandstone bedrock |
| Humic Podzols | Ardrinane | Sandy over sandstone bedrock |
| Humic Podzols | Ballyglasheen | Loamy over shale and slate bedrock |
| Humic Podzols | Carrowgavneen | Loamy drift with igneous and metamorphic stones |
| Humic Podzols | Portlaw | Loamy drift with siliceous stones |
| Humic Podzols | Glenbough variant | Sandy stoneless drift |

*Cont. overleaf ...*

| Soil subgroup | National_Series | Definition |
|---|---|---|
| Brown Podzolics | | |
| Typical Brown Podzolics | Tiknock | Loamy over acid and basic igneous bedrock |
| Typical Brown Podzolics | NBP2 | Loamy over gneiss and schist bedrock |
| Typical Brown Podzolics | Clonin | Loamy over sandstone bedrock |
| Typical Brown Podzolics | Rathduff | coarse loamy over shale and slate bedrock |
| Typical Brown Podzolics | Cupidstownhill | Fine loamy over shale bedrock |
| Typical Brown Podzolics | Kiltealy | Sandy drift with igneous and metamorphic stones |
| Typical Brown Podzolics | NBP4 | Loamy drift with igneous and metamorphic stones |
| Typical Brown Podzolics | Tomies | Sandy drift with siliceous stones |
| Typical Brown Podzolics | Cooga | Coarse loamy drift with siliceous stones |
| Typical Brown Podzolics | Ross Carbery | Coarse loamy compact drift with siliceous stones |
| Typical Brown Podzolics | UN29 | Fine loamy drift with siliceous stones |
| Typical Brown Podzolics | Screen | Sandy stoneless drift |
| Gleyic Brown Podzolics | Clonegall | Coarse loamy drift with siliceous stones |
| Stagnic Brown Podzolics | Flemingstown | Loamy over sandstone and shale bedrock |
| Stagnic Brown Podzolics | Corriga | Fine loamy drift with siliceous stones |
| Humic Stagnic Brown Podzolic | Bawn | Loamy drift with igneous and metamorphic stones |
| Humic Stagnic Brown Podzolic | Loughatooma | Coarse loamy drift with siliceous stones |
| Humic Stagnic Brown Podzolic | Ardmoelode | Fine loamy drift with siliceous stones |
| Humic Brown Podzolics | Knockaceol | Coarse loamy over sandstone bedrock |
| Humic Brown Podzolics | Borrisoleigh | Fine loamy over shale and slate bedrock |
| Humic Brown Podzolics | Knockboy | Coarse loamy drift with siliceous stones |
| Humic Brown Podzolics | Rathkenny | Fine loamy drift with siliceous stones |
| Luvisols | | |
| Typical Luvisols | Cloongeel | Fine loamy over sandstone bedrock |
| Typical Luvisols | Dromkeen | Fine loamy over shale bedrock |
| Typical Luvisols | Patrickswell lithic phase | Fine loamy over limestone bedrock |
| Typical Luvisols | Ballynamona | Fine loamy drift with igneous and metamorphic stones |
| Typical Luvisols | Dungarvan | Coarse loamy drift with siliceous stones |
| Typical Luvisols | Dunboyne | Fine loamy drift with siliceous stones |
| Typical Luvisols | Kellistown | Coarse loamy drift with limestone |
| Typical Luvisols | Elton | Fine loamy drift with limestone |
| Gleyic Luvisols | Johnstown | Coarse loamy drift with siliceous stones |
| Gleyic Luvisols | Crossabeg | Fine loamy drift with siliceous stones |
| Humic Gleyic Luvisols | Ardeen | Coarse loamy drift with siliceous stones |
| Stagnic Luvisols | Milltown | Coarse loamy over gneiss and schist bedrock |
| Stagnic Luvisols | Laughil | Coarse loamy drift with siliceous stones |
| Stagnic Luvisols | Crosstown | Fine loamy drift with siliceous stones |
| Stagnic Luvisols | Gortavoher | Fine silty drift with siliceous stones |
| Stagnic Luvisols | Rathowen | Fine loamy drift with limestone |
| Humic Stagnic Luvisol | Ballyduff | Fine loamy over shale bedrock |
| Humic Luvisols | Lisdillure | Coarse loamy over limestone bedrock |

| Soil subgroup | National_Series | Definition |
|---|---|---|
| Brown Earths | | |
| Typical Brown Earths | Knocksquire | Coarse loamy over acid igneous bedrock |
| Typical Brown Earths | Ballymacool | Coarse loamy over gneiss and schist bedrock |
| Typical Brown Earths | Ballyglass | Coarse loamy over sandstone bedrock |
| Typical Brown Earths | Broomhill | Fine loamy over sandstone bedrock |
| Typical Brown Earths | Kells | Coarse loamy over shale bedrock |
| Typical Brown Earths | Ballylanders | Fine loamy over shale and slate bedrock |
| Typical Brown Earths | Ladestown | Loamy over calcareous gravels |
| Typical Brown Earths | Borris | Coarse loamy drift with igneous and metamorphic stones |
| Typical Brown Earths | Kill | Fine loamy drift with igneous and metamorphic stones |
| Typical Brown Earths | Ballyvorheen | Sandy drift with siliceous stones |
| Typical Brown Earths | Clashmore | Coarse loamy drift with siliceous stones |
| Typical Brown Earths | Clonroche | Fine loamy drift with siliceous stones |
| Typical Brown Earths | Mullabane | Coarse loamy drift with limestone |
| Typical Brown Earths | Kennycourt | Fine loamy drift with limestone |
| Typical Brown Earths | Dovea | Fine silty drift with limestone |
| Gleyic Brown Earths | Eskaheen | Loamy drift with igneous and metamorphic stones |
| Gleyic Brown Earths | Knock | Coarse loamy drift with siliceous stones |
| Gleyic Brown Earths | UN16 | Fine loamy drift with siliceous stones |
| Gleyic Brown Earths | Ballylusky | Fine loamy drift with limestone |
| Humic Gleyic Brown Earths | NewInn | Coarse loamy drift with siliceous stones |
| Stagnic Brown Earths | Glantane | Coarse loamy over sandstone bedrock |
| Stagnic Brown Earths | Duarrigle | Fine loamy over shale bedrock |
| Stagnic Brown Earths | Knockreagh | Fine silty over shale bedrock |
| Stagnic Brown Earths | Curracitty | Clayey over shale bedrock |
| Stagnic Brown Earths | Labadoo | Coarse loamy drift with igneous and metamorphic stones |
| Stagnic Brown Earths | Tooreenbane | Coarse loamy drift with siliceous stones |
| Stagnic Brown Earths | Moord | Fine loamy drift with siliceous stones |
| Stagnic Brown Earths | Castlemoyle | Coarse loamy drift with limestone |
| Stagnic Brown Earths | Musicfield | Fine loamy drift with limestone |
| Humic Stagnic Brown Earths | Killyfinla | Loamy over sandstone bedrock |
| Humic Stagnic Brown Earths | Gneaves | Fine loamy drift with siliceous stones |
| Typical Calcareous Brown Earths | Coolnaha | Coarse loamy over limestone bedrock |
| Typical Calcareous Brown Earths | Ballincurra | Fine loamy over limestone bedrock |
| Typical Calcareous Brown Earths | Kilfenora | Clayey drift over limestone bedrock |
| Typical Calcareous Brown Earths | Baggotstown | Coarse loamy over calcareous gravels |
| Typical Calcareous Brown Earths | Cullahill | Coarse loamy drift with limestone |
| Typical Calcareous Brown Earths | Faoldroim | Fine loamy drift with limestone |
| Stagnic Calcareous Brown Earths | Carnakelly | Coarse loamy drift with limestone |
| Stagnic Calcareous Brown Earths | Feltrim | Fine loamy drift with limestone |
| Humic Calcareous Brown Earths | Hundredacres | Coarse loamy over calcareous gravels |

*Cont. overleaf ...*

| Soil subgroup | National_Series | Definition |
|---|---|---|
| Humic Calcareous Brown Earths | Knockaun | Fine loamy over calcareous gravels |
| Humic Calcareous Brown Earths | Carroward | Coarse loamy drift with limestone |
| Humic Brown Earths | Carrigogunnel | Coarse loamy over lithoskeletal basic igneous rock |
| Humic Brown Earths | Wonderhill | Fine loamy over lithoskeletal basic igneous rock |
| Humic Brown Earths | Crossabeagh | Coarse loamy over sandstone and shale bedrock |
| Humic Brown Earths | Brosna | Fine loamy over sandstone bedrock |
| Humic Brown Earths | Renaghmore | Fine loamy over shale bedrock |
| Humic Brown Earths | Aille | Coarse loamy over limestone bedrock |
| Humic Brown Earths | Blackhill | Loamy drift with igneous and metamorphic stones |
| Humic Brown Earths | Dooaghs | Sandy drift with siliceous stones |
| Humic Brown Earths | Schull | Coarse loamy drift with siliceous stones |
| Humic Brown Earths | Ashgrove | Fine loamy drift with siliceous stones |
| Humic Brown Earths | NBE17 | Loamy drift with limestone |

# Appendix 2 Example of a Modal Profile Description

**SERIES: KNOCKEYON**

**Reference profile:** RPQ40BR01
**County:** Kerry
**Weather:** Overcast
**Elevation:** 100

**TOPOGRAPHY**
**Position:** Middle slope
**Slope degree:** 14
**Slope Form:** Straight
**Aspect:** S

**PARENT MATERIAL**
**Substrate Type:** Bedrock
**Substrate Subgroup:** Sandstone

**TEXTURAL CRITERIA**
**Textural Class:** Loamy
**Texturally contrasting:**

**LAND USE**
**Land use:** Grassland Improved
**Human technologies:** Levelling, Clearing,
**Vegetation:** Grassland, Rushes
**Species:** Iris, Fushcia

**WATERTABLE** None

**ROCK OUTCROPS** None

**SURFACE STONE** Few

**IRISH CLASSIFICATION (2013)**
**Soil subgroup:** 04.6.0 Humic Lithosol
**National Soil Series:** Knockeyon
Loamy over lithoskeletal sandstone bedrock

**WRB CLASSIFICATION (2006)**
Lithic Mollic Leptosol

**DESCRIPTION**

**0–6 cm Ap**

**MATRIX COLOR:** 10YR33. **STONES (%):** Common, 2–6 cm, Angular, Sandstone; Common, 6–20 cm, Flat/platy, Sandstone. **TEXTURE:** Sandy loam. **STRUCTURE:** Moderate, Sub-angular blocky, Fine. **CONSISTENCY:** Friable. **PLASTICITY:** Non-plastic. **STICKINESS:** Non-sticky. **ROOTS:** Few, Medium. **PACKING DENSITY:** Medium. **POROSITY:** High. **MACROPORES:** Common. **BOUNDARY:** Abrupt, Irregular.

**6 cm + R**

## LABORATORY ANALYSIS

| Horizlon | pH | Total (%) | | Organic carbon (%) | Loss-on-ignition (%) |
|---|---|---|---|---|---|
| | | Nitrogen | Carbon | | |
| 1(Ap) | 5.3 | 0.59 | 6.67 | 5.76 | |

| Horizon | Exchangeable COMPLEX | | | | | |
|---|---|---|---|---|---|---|
| | CEC (cmol $kg^{-1}$) | Exchangeable Bases (cmol $kg^{-1}$) | | | | Base Saturation (%) |
| | | Na+ | K+ | Mg2+ | Ca2+ | |
| 1(Ap) | 10.28 | 0.23 | 0.26 | 1.68 | 8.67 | Sat. |

| Horizon | PARTICLE SIZE (%) | | | Textural class USDA | Bulk Density g/ $cm^3$ | Standard deviation |
|---|---|---|---|---|---|---|
| | Sand 2000–50 µm | Silt 50–2 µm | Clay <2 µm | | | |
| 1(Ap) | 59 | 25 | 16 | Sandy Loam | 0.65 | 0.03 |

# Appendix 3 Soil Association List

| Soil Association | Series leader | Description |
|---|---|---|
| 0300a | Seafield | Podzols, Brown Podzolics and Groundwater Gleys with sandy textures associated to stoneless drift |
| 0360a | Burren | Rendzinas and decalcified Lithosols on outcropping limestone, Luvisols and Brown earth associated with limestone bedrock and Peat |
| 0360c | Crush | Rendzinas and Calcareous Brown Earth on calcareous gravels and limestone bedrock, with inclusions of Luvisols and Brown Earths on drift with limestones |
| 0410a | Carrigvahanagh | Peat associated with Lithosols, Brown Podzolics, Podzols and Brown Earths over igneous and metamorphic stones, with inclusions of Groundwater Gleys |
| 0410b | Bantry | Peat associated with Lithosols on sandstones and shale bedrock with inclusions of Podzols and Brown Podzolics on sandstones and shale bedrock |
| 05LAK | Gurteen | Alluvial and drained alluvial soils of fine textures and base rich |
| 05MAR | Wexford Slob | Alluvial and drained alluvial soils on reclaimed coastal flats |
| 05RIV | Boyne | Alluvial and drained alluvial soils on river floodplain with base rich and medium to coarse textures |
| 0600a | Kilpierce | Poorly drained soils composed of Groundwater Gleys, Luvisols and Brown Earths soils, which are restricted to depressions and the less favourable slopes on drift with siliceous stones. |
| 0650a | Mylerstown | Poorly drained soils consisting of Calcareous and Humic Calcareous Grondwater Gleys and Luvisols on drift with limestones |
| 0660c | Puckane | Poorly drained soils composed by Humic Groundwater Gleys, Surface-water Gleys, on drift with siliceous stones and Peat, with inclusions of Humic Lithosols and Humic Brown Podzolics on drift with siliceous stones |
| 0660d | Puckane | Poorly drained soils located in the uplands composed by Humic Groundwater Gleys, Podzols and Brown Podzolics on drift with siliceous stones and Peat |
| 0660e | Ballywilliam | Poorly drained soils located in the uplands composed by Humic Groundwater Gleys, Brown Earths and Lithosols on drift with igneous and metamorphic stones with some inclusions of Brown Podzolics and Surface-water Gleys. |
| 0700a | Macamore | Surface-water Gleys in clayey marine drift; well drained sandy Brown Podzolics on outwash sands and gravels |
| 0700b | Kilrush | Surface-water Gleys, Brown Earths and Brown Podzolics on drift with siliceous stones, and inclusions of Groundwater Gleys |
| 0700c | Drumkeeran | ‘Heavy’ soils with clayey and fine textures. Association composed commonly of Surface-water Gleys and in lesser proportions, Luvisols, with inclusions of Brown Earths. |
| 0700d | Straffan | Surfacewater and Luvisols commonly associated with fluvioglacial outwash gravels and Calcareous Brown Earths on lower slopes over limestones bedrock |
| 0700f | Newport | Surface-water Gleys on lower slopes and Humic Brown Podzolics and Podzols in upper altitude, all on drift with siliceous stones |
| 0700h | Kilrush | Surface-water Gleys associated with Luvisols, on drift with siliceous stones and Basin Peat |
| 0760a | Gortaclareen | Mostly Surface-water Gleys associated with Brown Earths, over shale and slate bedrock and on drift with siliceous stones |
| 0760c | Howardstown | Surface-water Gley and Luvisols in Clayey lowlands on drift with limestones with inclusions of Calcareous Brown Earth |
| 0760e | Ballinamore | Humic Surface-water Gleys and Humic Groundwater Gleys, on drift with limestones, and Peat |

| Soil Association | Series leader | Description |
|---|---|---|
| 0760f | Driminidy | Humic Surface-water Gleys and Humic Brown Earths on moderate slopes; upland with Blanket Peat with extensive bedrock with Histic Lithosols and Podzols. |
| 0800a | Black Rock Mountain | Podzols on drift with igneous and metamorphic stones in uplands and peat; and Lithosols over gneiss and schist on slopes |
| 0800c | Ballycondon | Podzols and Brown Podzolics on drift with siliceous stones and sandstone bedrock and peat |
| 0843b | Knockastanna | Podzols and Brown Podzolics over shale and slate bedrock and peat, with inclusions of Humic Rendzinas and Brown Earths on bedrock |
| 0843e | Glenary | Podzols and Brown Podzolics on drift with siliceous stones and peat |
| 0843f | Glenary | Blanket Peat and Podzols in mountainous areas, with outcropping rock and Humic Lithosols (on sandstones bedrock); interspersed with Stagno-Podzols and Surface-water Gleys, on drift with siliceous stones. |
| 0900a | Cooga | Brown Podzolic soils with Groundwater Gleys on drift with siliceous stones an inclusions of Podzols and Brown Earths |
| 0900b | Kiltealy | Brown Podzolics and Brown Earths predominate with altitudinal sequence of upland Peat, Lithosols and Podzols on drift with igneous and metamorphic stones |
| 0900e | Ross Carbery | Brown Podzolics and Brown Earths mainly on drift with siliceous stones, Surface-water Gleys and Groundwater Gleys in lowland areas |
| 0900f | Clonin | Shallow peat soils beside Lithosols, Podzols over sandstone bedrock and Brown Podzolics in upland on drift with siliceous stones |
| 0900g | Cupidstownhill | Brown Ppodzolics and Brown earth on undulating shale/slate bedrock and on drift with siliceous stones |
| 0900h | NBP4 | Predominantly Brown Podzolic and Brown Earths and Rendzinas on gneiss and shist bedrock and on drift with igneous and metamorphic stones, with inclusions of Surface-water Gleys and Groundwater Gleys |
| 0920a | Clonegall | Gleyic Brown Podzolics, Podzols and Brown Earths on drift with siliceous stones and inclusions of Groundwater Gleys |
| 0960c | Borrisoleigh | Humic Brown Podzolics, gleyic and humic Brown Earths on a wet undulating on shale bedrock and on drift siliceous with inclusions of Groundwater Gleys and Humic Lithosols |
| 0960d | Knockaceol | Altitudinal sequence of Humic Brown Podzolics, Podzols on sandstone bedrock and on drift siliceous and peat with inclusions of Surface-water Gleys and Rendzinas |
| 0960e | Knockboy | Brown Podzolics with Podzols on upper slopes and Surface-water Gleys in depressions, on drift with siliceous stones |
| 1000a | Elton | Luvisols associated with Surface-water Gleys, Stagnic Brown Earths and Calcareous Brown Earths, on drift with limestones |
| 1000c | Elton | Luvisols associated to histic and humic Groundwater Gleys and Calcareous Brown Earths, on drift with limestones and Basin Peat |
| 1000g | Elton | Heavier textures in the soils of this association. Association with Luvisols, Groundwater Gleys and Calcareous Brown Earths, on drift with limestones |
| 1000x | Elton | Luvisols and Surfacewater Gleys on drift with mixed of limestones and siliceous stones |
| 1030a | Crosstown | Luvisols, Surface-water Gleys and Stagnic Brown Earths on drift with siliceous stones, with inclusions of Groundwater Gleys |
| 1030b | Rathowen | Luvisols, Surface-water Gleys, Groundwater Gleys on drift with limestones and peat |
| 1100a | Clonroche | Well drained Brown Earths on drift with siliceous stones in an undulating land with some Brown Podzolics on upper slopes. Surface-water Gleys and Groundwater Gleys found in depressions |
| 1100c | Clashmore | Brown Earths and Luvisols on upper slopes; Surface-water Gleys and Grounwater Gleys in depressions |
| 1100d | Ballyvorheen | Brown Earths, Brown Podzolics and Podzols, soils related to coarse textures on drift with siliceous stones |

| Soil Association | Series leader | Description |
|---|---|---|
| 1100e | Ballylanders | Brown Earths on lower slopes, Podzols on steeper slopes, Luvisols and Surface-water Gleys in depressions, related to fine soil textures on shale bedrock and on drift with siliceous stones. |
| 1100h | Borris | Brown Earths and Brown Podzolics on slope on drift with igneous and metamorphic stones, inclusions of Surface-water Gleys |
| 1100l | Kennycourt | Brown Earths, Luvisols and Growndwater Gleys on drift with limestones |
| 1100m | Kill | Brown Earths, Brown Podzolics and Podzols on an undulating land with igneous and metamorphic stones, inclusions of Surface-water Gleys in depressions. |
| 1100n | Clashmore | Brown Earths, Luvisols and Surface-water Gleys on drift with siliceous stones |
| 1100q | Mullabane | Mostly Brown Earths and Calcareous Brown Eaths on drift with limestones, associated with Luvisols and some inclusions of Rendzinas and peat |
| 1100s | Broomhill | Brown Earths and Brown Podzolics mainly on sandstones bedrock and some occurs on drift with siliceous stones, with inclusions of Podzols and Surface-water Gleys |
| 1130a | Moord | Brown Earths and Surface-water Gleys associated to humic and gleyic diagnostic features on drift with siliceous stones and inclusions of Luvisols in a drumlin area. |
| 1130b | Duarrigle | Brown Earths, Surface-water Gleys and Lithosols on shale/sandstone bedrock in an undulating area |
| 1150a | Baggotstown | Calcareous Brown Eaths, Brown Earths and Luvisols on calcareous gravels and on drift limestones, inclusions of Rendzinas |
| 1150b | Ballincurra | Calcareous Brown Eaths and Luvisols associated with Rendzinas and decalcified Lithosols, on limestones bedrock |
| 1150c | Faoldroim | Calcareous Brown Eaths, Brown Earths and Luvisols on drift with limestones, associated with Rendzinas and decalcified Lithosols on limestones bedrock and peat |
| 1160a | Ashgrove | Humic and gleyic Brown Eaths and Surface-water Gleys, on drift with siliceous stones |
| 1160c | Schull | Brown Eaths, Brown Podzolics, Podzols and Surface-water Gleys associated to humic and gleyic diagnostic features on drift with siliceous stones |

# Appendix 4 Abstracts of Papers Published

## (1) Askari, M.S., O'Rourke, S.M. and Holden, N.M. (2014). Evaluation of soil quality using VIS-NIR spectra under agricultural management. In preparation and review.

In order for soil spectroscopy to progress to become a routine technique for soil carbon monitoring the following question needs to be addressed: does the choice of instrument influence the result obtained for the prediction of soil organic carbon (SOC)? Technology has advanced with the development of laboratory spectral imaging that allows a greater amount of spectral information to be collected from the soil sample compared to standard spectroscopy. This study evaluated both the newer spectral imaging technology and standard point spectroscopy, and examined how instrument choice and pre-processing impacts on analytical accuracy. A total 375 representative Irish soils were scanned by two point spectrometers (S-1; Foss NIR Systems 6500 and S-2; Varian FT-IR 3100) and two imaging spectrometers (SI-1; DV Optics Spectral Scanner push broom line-scanning hyperspectral system and SI-2; Spectral Imaging Lt ImSpector N17E push broom hyperspectral system). Assessment of the prediction accuracy by partial least square cross validation for each instrument was carried out. This involved assessment of models generated using raw spectra, spectral transformation, common wavelength range and resolution and spectral type (reflectance or absorbance), followed by evaluation and comparison of independently predicted accuracy by analysis of errors. In general, the SOC calibration models produced by point spectroscopy were more accurate than by imaging systems. Overall, the S-1 instrument achieved the highest accuracy across all spectral ranges and did not degrade with data reduction. The S-1 instrument was the only one with no significant difference between variance of measured and predicted SOC. The best fit regression line between laboratory measured and predicted SOC and the deviation from the best fit line (RMSE) ranked the instruments as S-1 (2.63) < S-2 (2.94) < SI-1 (3.43) < SI-2 (4.11). However, at equal spectral range and resolution, and with pre-processing (although different for each instrument) S1-1 resulted in almost equal accuracy to S-1. This demonstrated that spectral imaging has the ability to be as accurate as point spectroscopy. Future decisions on which instrument to employ for SOC will depend on the operator's decision to spend more time on sample preparation for point spectroscopy or more time on chemometric analysis for spectral imaging.

## (2) O'Rourke, S.M., Menesatti, P., Giorgi, S., Canal, E. and Holden, N.M. (2014). A non-selective modeling approach to predict soil organic carbon from spectral images. In preparation and review.

There is wide interest in developing visible near-infrared spectroscopy (VNIRS) for the measurement of carbon in carbon stock monitoring. Technology has advanced with the development of laboratory spectral imaging, which allows a greater amount of spectral information to be collected. Various multivariate statistical and spectral pre-processing techniques are reported in the literature but no single approach for soil spectral analysis emerges. The objective of this study is to test an automated 'non-selective' protocol to investigate all possible predictive combinations for a range of partition methods, partition ratios and spectral pre-processing transformations in a PLSR model in order

to determine the optimum predictive (i) performance and (ii) robustness of soil organic carbon by VNIRS. Here the protocol was tested on a diverse dataset of soils which varied in parent material, soil type and vegetation and spectral data obtained from soil spectral images. Results demonstrated that optimum predictive performance and robustness were similar in terms of accuracy (R = 0.93, 0.91 and RPD = 2.56, 2.24 in independent validation) but were obtained with different model inputs. The concentration of SOC was mapped in a test spectral image of 10 soils using both best performing and best robustness model parameters. Results show a higher correlation with measured concentrations using the best robustness model ($R^2$ = 0.88 v's $R^2$ = 0.83). Therefore, this protocol can assist the user to evaluate the loss of accuracy, if any, in selecting the prediction ranked to be most robust over the prediction ranked to be most accurate.

### (3) O'Rourke, S.M. and Holden, N.M. (2012). Determination of soil organic matter and carbon fractions in forest topsoils using VIS-NIR hyperspectral imaging. Soil Science Society of America Journal, 76: 586–596.

Adequately quantifying C sequestration in soil, post 2012, can be used to offset C losses in national greenhouse gas inventory but requires very large sample numbers and rapid analytical methods. Wet and dry combustion methods are analytically accurate but expensive and slow while optical techniques have the potential to provide rapid, cost-effective alternatives. This study examined the potential of spectral data acquired from laboratory hyperspectral imaging (HSI) systems and chemometric analysis to predict soil organic matter (OM), total carbon (TC), inorganic carbon (IC), and organic carbon (OC) fractions in forest top soils from Avondale Forest Park, Rathdrum, County Wicklow, Ireland. The spectral range of hyperspectral instruments operating in the visible (VIS; 400–1000 nm), near infrared (NIR; 880–1720 nm) and combined VIS–NIR regions (400–1720 nm) were investigated for each soil property. Validations using a randomly selected 25% partition of the dataset indicated that the best soil TC and OC predictions were achieved in the VIS region, a ratio of predicted deviation (RPD) indicated excellent predictions for both TC (3.39) and OC (3.39). The best OM and IC prediction was achieved in the VIS–NIR region, OM ranked as excellent (3.06) but IC produced models with very poor predictive ability (1.26) due to a limited range of concentrations. Model robustness was tested using alternative methods of partitioning the dataset (n = 152). Partitioning following stratifi cation by TC or OC concentration improved accuracy by 1.4-fold, while soil OM accuracy was improved 1.2-fold after stratifying by sampling site. When independent validations were tested on "new sites" by holding each sampling site out of model calibration in turn, OC predicted with reasonable root mean square error (RMSE) for most sites but produced RPD values indicating poor predictive performance. A certain degree of uniqueness associated with soils at new sites caused model accuracy to deteriorate. Overall results indicate that there is much potential to develop hyperspectral imaging as a methodology for soil C and OM analyses, but soils from the intended target site must be included in the model calibration to maintain model prediction accuracy.

### (4) O'Rourke, S.M. and Holden, N.M. (2011). Optical sensing and chemometric analysis of soil organic carbon – a cost effective alternative to conventional laboratory methods? Soil Use and Management 27: 143–55.

Soil organic carbon (SOC) is frequently determined by the Walkley-Black (WB) method. A limitation of the test is incomplete oxidation of the carbon fraction and underestimation of SOC. Automated dry combustion methods are expensive and slow. Optical sensing and chemometric analysis offer the potential of an economical method capable of quantifying SOC fractions. The aim of this study was to identify the best SOC analysis method to facilitate maximum sampling resolution based on the cost per sample, analytical accuracy and time. A comparative evaluation was made of five techniques; (1) the WB method, (2) total combustion by total organic C analyser, (3) infrared (IR) diffuse reflectance spectroscopy, (4) a portable spectroradiometer and (5) laboratory hyperspectral imaging. This involved assessing equipment costs, consumables and time to derive total analytical cost. The benefits were sample throughput and analytical accuracy. Instrumentation represented the largest input to analytical cost and for optical methods was governed by the spectral range. In contrast to dry combustion, this cost is offset by high sample throughput and minimal consumable requirements for IR spectroscopy and hyperspectral imaging. Hyperspectral imaging is identified as the most rapid technique with potential to scan about 720 samples per day at 90% less cost than the WB method. The opportunity cost of hyperspectral imaging is to forfeit some analytical accuracy associated with the dry combustion method. Dry combustion, despite its high cost per sample, incurs no further costs associated with updating prediction models or developing site or soil specific correction factors.

### (5) O'Rourke, S.M., Argentati, I. and Holden, N.M. (2011). The effect of Region of Interest size on model calibration for soil organic carbon prediction from hyperspectral images of prepared soils. Journal of Near Infrared Spectroscopy 19: 161–70.

Hyperspectral imaging is an attractive technique for soil analysis that provides both spectral and spatial information in a three-dimensional image. Scanning a large sample area than that permitted in soil spectroscopy allows a larger spatial area to be selected to represent the "average spectra" by means of an interactive region of interest (ROI) tool. The objective of this study was to assess the effect of ROI size on the prediction accuracy of soil organic carbon (SOC) for homogenised soils from a diverse dataset collected on a national scale. Five ROI sizes, 72x72 pixels, 54x54 pixels, 36x36 pixels, 18x18 pixels and 7x7 pixels were selected in the near infrared (NIR) region and partial least square calibrations were developed for each ROI size and compared. Cross-validation results demonstrated that increasing the area of sample considered for partial least square regression modelling improved SOC accuracy. Increasing the dimensions of a ROI size by 100-fold reduced root mean square error of cross-validation from 4.60% to 3.88% SOC, a 16% improvement, while $R^2$ increased from 0.62 to 0.75. Independently validated models showed further improved accuracy whereby root mean square error of prediction was reduced to 3.49% SOC overall, comparable to that reported elsewhere for geographically diverse samples. The spectral variables contributing to the SOC prediction ($P<0.05$) compared for each ROI size showed that the 7x7 pixels ROI could not differentiate between important and unimportant variables indicating loss of information at this spatial scale.

# An Ghníomhaireacht um Chaomhnú Comhshaoil

Is í an Gníomhaireacht um Chaomhnú Comhshaoil (EPA) comhlachta reachtúil a chosnaíonn an comhshaol do mhuintir na tíre go léir. Rialaímid agus déanaimid maoirsiú ar ghníomhaíochtaí a d'fhéadfadh truailliú a chruthú murach sin. Cinntímid go bhfuil eolas cruinn ann ar threochtaí comhshaoil ionas go nglactar aon chéim is gá. Is iad na príomh-nithe a bhfuilimid gníomhach leo ná comhshaol na hÉireann a chosaint agus cinntiú go bhfuil forbairt inbhuanaithe.

Is comhlacht poiblí neamhspleách í an Ghníomhaireacht um Chaomhnú Comhshaoil (EPA) a bunaíodh i mí Iúil 1993 faoin Acht fán nGníomhaireacht um Chaomhnú Comhshaoil 1992. Ó thaobh an Rialtais, is í an Roinn Comhshaoil, Pobal agus Rialtais Áitiúil.

## ÁR bhFREAGRACHTAÍ

### CEADÚNÚ

Bíonn ceadúnais á n-eisiúint againn i gcomhair na nithe seo a leanas chun a chinntiú nach mbíonn astuithe uathu ag cur sláinte an phobail ná an comhshaol i mbaol:

- áiseanna dramhaíola (m.sh., líonadh talún, loisceoirí, stáisiúin aistrithe dramhaíola);
- gníomhaíochtaí tionsclaíocha ar scála mór (m.sh., déantúsaíocht cógaisíochta, déantúsaíocht stroighne, stáisiúin chumhachta);
- diantalmhaíocht;
- úsáid faoi shrian agus scaoileadh smachtaithe Orgánach Géinathraithe (GMO);
- mór-áiseanna stórais peitreail;
- scardadh dramhuisce;
- dumpáil mara.

### FEIDHMIÚ COMHSHAOIL NÁISIÚNTA

- Stiúradh os cionn 2,000 iniúchadh agus cigireacht de áiseanna a fuair ceadúnas ón nGníomhaireacht gach bliain
- Maoirsiú freagrachtaí cosanta comhshaoil údarás áitiúla thar sé earnáil - aer, fuaim, dramhaíl, dramhuisce agus caighdeán uisce
- Obair le húdaráis áitiúla agus leis na Gardaí chun stop a chur le gníomhaíocht mhídhleathach dramhaíola trí comhordú a dhéanamh ar líonra forfheidhmithe náisiúnta, díriú isteach ar chiontóirí, stiúradh fiosrúcháin agus maoirsiú leigheas na bhfadhbanna.
- An dlí a chur orthu siúd a bhriseann dlí comhshaoil agus a dhéanann dochar don chomhshaol mar thoradh ar a ngníomhaíochtaí.

### MONATÓIREACHT, ANAILÍS AGUS TUAIRISCIÚ AR AN GCOMHSHAOL

- Monatóireacht ar chaighdeán aeir agus caighdeáin aibhneacha, locha, uiscí taoide agus uiscí talaimh; leibhéil agus sruth aibhneacha a thomhas.
- Tuairisciú neamhspleách chun cabhrú le rialtais náisiúnta agus áitiúla cinntí a dhéanamh.

### RIALÚ ASTUITHE GÁIS CEAPTHA TEASA NA HÉIREANN

- Cainníochtú astuithe gáis ceaptha teasa na hÉireann i gcomhthéacs ár dtiomantas Kyoto.
- Cur i bhfeidhm na Treorach um Thrádáil Astuithe, a bhfuil baint aige le hos cionn 100 cuideachta atá ina mór-ghineadóirí dé-ocsaíd charbóin in Éirinn.

### TAIGHDE AGUS FORBAIRT COMHSHAOIL

- Taighde ar shaincheisteanna comhshaoil a chomhordú (cosúil le caighdéan aeir agus uisce, athrú aeráide, bithéagsúlacht, teicneolaíochtaí comhshaoil).

### MEASÚNÚ STRAITÉISEACH COMHSHAOIL

- Ag déanamh measúnú ar thionchar phleananna agus chláracha ar chomhshaol na hÉireann (cosúil le pleananna bainistíochta dramhaíola agus forbartha).

### PLEANÁIL, OIDEACHAS AGUS TREOIR CHOMHSHAOIL

- Treoir a thabhairt don phobal agus do thionscal ar cheisteanna comhshaoil éagsúla (m.sh., iarratais ar cheadúnais, seachaint dramhaíola agus rialacháin chomhshaoil).
- Eolas níos fearr ar an gcomhshaol a scaipeadh (trí cláracha teilifíse comhshaoil agus pacáistí acmhainne do bhunscoileanna agus do mheánscoileanna).

### BAINISTÍOCHT DRAMHAÍOLA FHORGHNÍOMHACH

- Cur chun cinn seachaint agus laghdú dramhaíola trí chomhordú An Chláir Náisiúnta um Chosc Dramhaíola, lena n-áirítear cur i bhfeidhm na dTionscnamh Freagrachta Táirgeoirí.
- Cur i bhfeidhm Rialachán ar nós na treoracha maidir le Trealamh Leictreach agus Leictreonach Caite agus le Srianadh Substaintí Guaiseacha agus substaintí a dhéanann ídiú ar an gcrios ózóin.
- Plean Náisiúnta Bainistíochta um Dramhaíl Ghuaiseach a fhorbairt chun dramhaíl ghuaiseach a sheachaint agus a bhainistiú.

### STRUCHTÚR NA GNÍOMHAIREACHTA

Bunaíodh an Ghníomhaireacht i 1993 chun comhshaol na hÉireann a chosaint. Tá an eagraíocht á bhainistiú ag Bord lánaimseartha, ar a bhfuil Príomhstiúrthóir agus ceithre Stiúrthóir.

Tá obair na Gníomhaireachta ar siúl trí ceithre Oifig:

- An Oifig Aeráide, Ceadúnaithe agus Úsáide Acmhainní
- An Oifig um Fhorfheidhmiúchán Comhshaoil
- An Oifig um Measúnacht Comhshaoil
- An Oifig Cumarsáide agus Seirbhísí Corparáide

Tá Coiste Comhairleach ag an nGníomhaireacht le cabhrú léi. Tá dáréag ball air agus tagann siad le chéile cúpla uair in aghaidh na bliana le plé a dhéanamh ar cheisteanna ar ábhar imní iad agus le comhairle a thabhairt don Bhord.

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# Irish Soil Information System

epaResearch
Climate - Water - Sustainability
*Identifying pressures • Informing policy • Developing solutions*

Synthesis Report

## Identifying Pressures

Ireland, like all other EU Member States, faces the contemporary challenge of meeting a range of agri-environmental objectives in the context of the increasing food production in a post-quota environment. Examples include the need to obtain 'good quality' status for all waterbodies, as specified by the Water Framework Directive, the need to protect biodiversity under the Habitat and Birds Directives, the potential for offsetting agricultural GHG emissions through carbon sequestration and the need for sustainable recycling of nutrients under the Nitrates and Sewage Sludge Directives. It has been well documented that the capacity of land to deliver on each of these requirements depends primarily on soil properties and hence soil type. Therefore, meeting all targets simultaneously requires optimisation of the suite of soil functions delivered by each soil.

## Informing Policy

ISIS will be an invaluable tool in developing policies on sustainable land management and the agrienvironment. Practical examples of the utility of the ISIS map for policy and practice include:

(i) The facilitation of a migration from Tier 1 to Tier 3 greenhouse gas reporting to the UNFCCC

(ii) The attribute maps derived from the ISIS maps are being used by DAFM for the new delineation of the Areas of Natural Constraints

(iii) The facilitation of the development of soil-specific nutrient advice (by subgroup)

(iv) The facilitation of the development of targeted and context-specific agri-environmental schemes

(v) The identification of priority areas and more targeted actions in the ongoing development and review of the River Basin District Management Plan.

## Developing Solutions

The ISIS team has developed the concept of Functional Land Management to facilitate this approach, and has received an additional €1m funding from DAFM to further explore this concept. This approach will help with local scale farm management decisions, national scale legislation and reporting requirements as outlined above and European scale delivery of data and trends.


Comhshaol, Pobal agus Rialtas Áitiúil
Environment, Community and Local Government



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