Environmental RTDI Programme 2000–2006

Digital Soil Information System for Ireland – Scoping Study (2005-S-DS-22-M1)

Final Report

Prepared for the Environmental Protection Agency

by

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SOILS

The Soils Section of the Environmental RTDI Programme addresses the need for research in Ireland to inform policymakers and other stakeholders on a range of questions in this area. The reports in this series are intended as contributions to the necessary debate on soils and the environment.

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Executive Summary

Soil is a multifunctional and complex medium providing ecosystem services such as the production of food, fibre and fuel, provision of habitat, nutrient cycling, contaminant transformation, water cycling and climate regulation. A number of policy and legislative developments at European level (Thematic Strategy on Soil Protection (COM(2006)231), proposed Soil Framework Directive (COM(2006)232)) have led to the requirement for harmonisation and co-ordination of soil data across Europe. In light of the demands for soil protection on a regional basis, there is a need to support policy with a harmonised soil information system in order to maintain a sustainable agro–environmental economy and fulfil policy requirements at national and European levels.

In Ireland, soil data exist in variable forms and complete coverage at 1:250,000 – the target scale identified at European level – does not exist. The terms of reference for this scoping study were to investigate the feasibility of producing a 1:250,000 digital soil map and to consider a specification for a digital soil information system which would serve as the framework technology underpinning the 1:250,000 map.

The approach included reviewing procedures and mapping methods proposed at European level, a review of soil information systems from around the world, a review of existing Irish soil data, and an expert consultation exercise with national and international soil experts.

An inventory of Irish soil data was compiled to assess their utility and application. This survey of scientists and users of soil data confirmed that most soil data are held by Teagasc. The National Soil Survey (NSS) was based in An Foras Talúntais (forerunner organisation to Teagasc) from which the main outputs were: mapping at a 1:127,560 scale for 44% of the country, *General Soil Map of Ireland* and *National Peatland Map*, both at a 1:575,000 scale. More recently, Teagasc has produced Indicative Soil and Subsoil mapping with national coverage and the *National Soil Database* comprising 1,310 soil samples of the upper 10 cm based on a sampling grid of 10 x 10 km.

The inventory highlighted that soil data coverage of Ireland is incomplete in both detail and extent. This has created difficulties for users of Irish soil information and has often led to inappropriate use of soil data. While soil data users would like to see the completion of mapping at 1:127,560 for Ireland, this is unlikely at this point in time due to potential costs. It is on this basis that a methodology for the development of a soil map of Ireland at a 1:250,000 scale and an associated Soil Information System (SIS) for Ireland is developed and presented in this report.

The methodology proposed is based primarily on procedures developed by the European Soil Bureau Network (Finke *et al*., 1998)[1]. Methodology development was also guided by an expert consultation exercise which assessed the appropriate methodology for a 1:250,000 map for Ireland given the data required and the current state of soil data that exist in Ireland.

The methodology is proposed in two phases which address (a) surveyed areas, and (b) unsurveyed areas. A list of key tasks and an estimate of costs, resources and time needed to complete the production of a 1:250,000 map is provided in addition to any risks and recommendations identified.

At the predetermined scale of 1:250,000 soilscapes will be delineated, which are defined as groups of soil bodies having former or present functional relationships, and that can be represented at 1:250,000. Soilscapes will be delineated based on the integration of parent material and various topographic indices. A programme of systematic field survey and sample analysis will be required to complete soil body description and soilscape delineation.

The proposed SIS will provide a technical infrastructure to organise soil information in Ireland and will underpin the 1:250,000 soil map development. A number of existing SISs have been reviewed and a technology platform is

1. Finke, P.A., Hartwich, R., Dudal, R., Ibàñez, J.J., Jamagne, M., King, D., Montanarella, L. and Yassoglou, N., 1998. *Georeferenced Soil Database for Europe, Manual of Procedures*, Version 1.0. European Soil Bureau Research Report No. 5, Office for Official Publications of the EC (EUR 18092 EN), Luxembourg.

recommended along with core component data, and a cost estimate for construction of the Irish SIS is included. The development of the SIS for Ireland should proceed in a manner that is fully consistent with the INSPIRE Directive (COM(2004)516) principles.

The estimated timescale for the completion of all phases of the work, including time allocated to training staff is approximately 5–6 years. A future proposal should include a Review Committee comprising an interdisciplinary group of soil experts whose membership should be agreed among project participants and funding agencies. It is recommended that the project create a 1:250,000 map and that the SIS becomes part of a broader soil research platform. Such a platform will establish a dialogue on the applicability of existing and future maps and establish the ongoing soil data needs of the scientific community in a coherent manner.

This scoping study concludes that the production of a 1:250,000 digital soil map and SIS for Ireland is both desirable in the context of developments at European level and achievable, given the extent of existing Irish data and the technologies and methodologies available.

1 Introduction

Soil is our life support system, crucial for the production of food and biomass and critical for the sustainability of an agro–environmental economy. The authors suggest that it is axiomatic that Ireland should have ready access to its soil information through the benefits of modern information technology. Soil is a multifunctional and complex natural medium that provides ecosystem services such as the production of food, fibre and fuel, the provision of habitat, nutrient cycling, contaminant transformation, water cycling and climate regulation. Reports from the European Commission indicate that many of these functions and services are under threat and soil protection is now placed on the same level as that of water and air. The recently adopted *Thematic Strategy for Soil Protection* (COM(2006)231) has identified soil protection as the basis for the forthcoming Soil Framework Directive (SFD) (COM(2006)232), the proposal for which lists eight threats to soil:

1. Erosion
2. Loss of organic matter (OM)
3. Compaction
4. Salinisation
5. Landslides and flooding
6. Sealing
7. Loss of biodiversity
8. Contamination.

At national level, the Single Farm Payment lists soil protection as a requirement to maintain lands in good agricultural and environmental condition with special reference to soil quality. Thus, knowledge of our soils would seem to be an obvious prerequisite for maintaining a sustainable agro–environmental economy and fulfilling our policy requirements at national and European levels.

Comparison of soil information at European scale has led to the requirement for the harmonisation and co-ordination 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 (SIS). The first attempt at soil data harmonisation was seen during the development of the 1:1,000,000 geographical database of Europe under the MARS project (Monitoring Agriculture with Remote Sensing) initiated by the European Commission for the EU Directorate-General (DG) (Agriculture). The purpose of a soil database at this scale was to assess the information needed for sustainable land use. However, this scale is seen as too general for assessing soil quality and functions at regional level and expert groups have called for a mapping programme at a more detailed scale. The EU Technical Working Group dealing with Soil Monitoring and Harmonisation has recommended a soil map of Europe at 1:250,000 as an economically feasible intermediate scale that can identify specific problems at regional scale. The structure of the proposed map at a 1:250,000 scale and the database is such that information on soil functions and quality is held within physiographic landscape units and the proposed methodology takes into consideration existing methodologies, e.g. the SOTER project (Dobos *et al.*, 2005), and directives, e.g. the INSPIRE Directive, (COM(2004)516). A DG XI Task Force commissioned a feasibility study on the creation of a soil map of Europe at 1:250,000 (Dudal *et al.*, 1993) and concluded that a map at this scale, supported by an appropriate database, would provide the necessary resolution for a number of applications at regional level. Harmonised soil data across Europe within a 1:250,000 georeferenced soil database will allow for exchange of data across Member States and provide the information needed by the European Commission and the European Environment Agency for reporting on issues relating to soil quality under the forthcoming SFD.

In Ireland, soil data exist in many variable and disparate forms and complete coverage of soils at 1:250,000 within a centralised SIS does not exist. The principal objective of this scoping study as specified by the EPA was to examine the feasibility of producing a 1:250,000 digital soil map of Ireland and to design a specification for a digital SIS. Other Member States have produced soil coverage at this scale using existing soil data at detailed scale but the situation in Ireland is somewhat different in that detailed soil mapping exists for only 44% of the country. The applicability of existing soil data and working with unsurveyed areas provided the central challenge in the proposed development of a national map that uses a standardised methodology and classification system and allows for effective communication of Ireland's soil data internally and across Europe. In addition, the creation of a centralised SIS for the storage and dissemination of all soil data in Ireland is a desirable objective at both national and European levels.

For soil data that are held digitally in Ireland at present, whether as text or in map format, no harmonised system is currently available whereby all existing data can be interrogated electronically, or whereby the output of any interrogation can be displayed within a modern, publicly accessible, integrated IT framework.

Ireland needs a coherent framework for the presentation and updating of its soil information so that such data can be made readily available to all those concerned with the soil environment (and its varied interactions with air and water), including scientists, engineers, planners, policy makers and the general public. Such a system allows for the integration and presentation of data, the rearrangement and reclassification 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 system (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 understanding of a little understood but highly important component of our natural environment.

The work reported here was based around three agreed main objectives which incorporate the core tasks of the original EPA call for research proposals (2005):

1. Build an inventory of existing soil information in Ireland

2. Develop a methodology for the production of a digital soil map at a 1:250,000 scale for Ireland

3. Propose a specification for an SIS for Ireland that would underpin the digital map and encompass all existing soil data for Ireland.

Table 1.1 outlines in summary the proposed tasks in the original project call documentation and highlights which of the three main project objectives (as numbered above) addresses these tasks.

The methodology used in this work included reviewing procedures and mapping methods proposed at European level, a review of SISs from around the world, a review of existing Irish soil data, training in standardised classification systems, and an expert consultation exercise with national and international soil experts in the form of a project workshop. The findings of the scoping study are provided in the following chapters that outline the proposed methodologies and specifications with risks, recommendations and costs arising included. Finally, a list of general conclusions and recommendations relevant to the proposed work are provided.

Table 1.1. Tasks and their relationship to agreed project objectives.

Suggested tasks in EPA call documentation	Relevant main project objective
Inventory of all existing digital soil information in Ireland	1
Assess availability of soils information for characterising soils susceptible to degradation	1
Identify effort and costs of collation and digitising paper information	2, 3
Issues of copyright and intellectual property rights should be noted	1, 2, 3
Identification of sources of information that will be used to construct the final product map and information system	1,2,3
Assessment of risks of failure to receive access to relevant data to project completion	2, 3
Full description of SIS	3
Management issues for the SIS should be identified	2, 3

2 Inventory of Soil Information in Ireland

2.1 Introduction

The current state of soil data in Ireland was compiled to assess its use and application in the development of a national soil map and SIS for Ireland. The inventory sought information based on soil survey, field and point data and on maps derived from original soil data. A survey of scientists and users of soil data within state organisations and agencies, research institutes, universities and colleges was undertaken by way of a questionnaire that sought information on the type of soil data held within organisations and currently being developed. The questionnaire captured information on a variety of data types (survey, point or derived maps) and their spatial organisation and storage, quality control, access and distribution, and costs of acquisition. A summary of the soil map data is shown in Table 2.1 below and all the data compiled are described in the following chapters in the context of the state of soil information in Ireland to date. A Microsoft Excel file showing the questionnaire used to collect these data and a summary of all the data and their location are available to download as Excel files from the EPA Environmental Research Centre website (http://coe.epa.ie/safer/).

2.2 The National Soil Survey (1959–1985)

The National Soil Survey (NSS) established by An Foras Talúntais (AFT) in 1959 undertook a detailed reconnaissance survey of the soils of Ireland at a published scale of 1:126,720. The detailed reconnaissance survey characterised and identified the soils of Ireland on a county-by-county basis, completing approximately 44% of the country before being wound up in 1985. Surveyed areas are shown in Fig. 2.1 and include Clare, Carlow, West Cork, West Donegal, Kildare, Laois, Limerick, Leitrim, Meath, West Mayo, Offaly, Tipperary North Riding, Westmeath, Wexford and Waterford.

The remaining 56% of the country remains unsurveyed at this scale. Most of the maps for the areas listed are digitised and published with the exception of Co. Waterford. The information on the surveyed parts of the country is published in county maps and bulletins and the majority of this information is captured in GIS format. The published bulletins, which are out of print, have been made recently available in PDF format from Teagasc (http://www.teagasc.ie/publications/pricedpubsform.htm#pp_soil).

The soil map unit identified at detailed reconnaissance level is the soil series and includes phases and variants thereof. These county maps delineated individual soil series that were characterised and described by profile description and analytical data in the accompanying bulletins. Figure 2.2 provides an example of a detailed county survey delineating soils at the soil series level for Co. Wexford. Soil series in surveyed areas were named after locations in which they were first characterised and are best expressed. Figure 2.3 illustrates the extent of soil information captured in the soil profile description and analysis provided in the county bulletins.

The *General Soil Map of Ireland* (GSM) (second edition) was completed on a national scale and published at 1:575,000 (Gardiner and Radford, 1980a). This map identifies 44 soil associations grouped into broad

Table 2.1. Summary of soil map data in Ireland.

Map	Scale	Coverage	Minimum mapping unit (approx.)	Map unit type	Properties
General Soil Map	1:575,000	National	100 ha	Compound (Association)	Yes (principal soil only)
AFT county maps	1:127,560	Partial (44% of land area)	10 ha	Simple and compound	Yes
Teagasc/EPA indicative soils map	1:150,000 (nominal)	National	0.02 ha (specific classes only)	Simple to compound Simple classification	No
National Soil Database	n/a	National (sample only)	Point sample	n/a	Yes

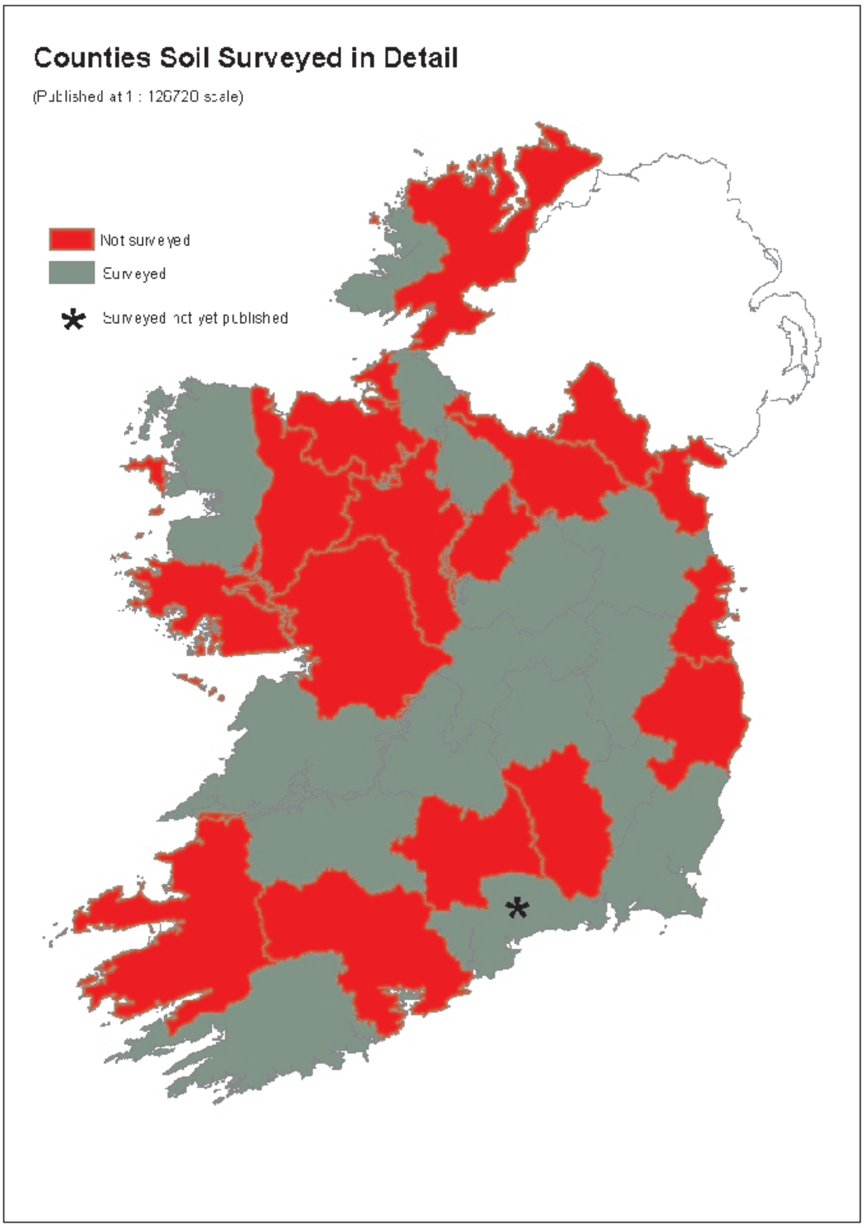

Figure 2.1. Map showing areas with soil surveys completed at detailed level.

physiographic divisions, namely Mountain and Hill, Hill, Rolling Lowland, Drumlin, and Flat to Undulating Lowland, and is illustrated in Fig. 2.4. The soils types occurring in repeatable patterns within these broad physiographic divisions are mapped and grouped as soil associations. The soil association does not delineate individual soil types, but serves as a mapping unit to illustrate a group of soils that are associated together on the landscape. The constituent soils within a soil association are presented at the Great Soil Group level (Brown Earths, Brown Podzolics, Gleys, etc.) and described with profile description and analysis of the major constituent in the bulletin accompanying the map (Gardiner and Radford, 1980b). While the GSM provides a general description of the soils of Ireland, the mapping unit used (the soil association) is a grouping of a number of soil types, none of which are delineated individually. Soil associations are therefore groupings of soil types that can encompass a wide range of properties. Specific application of the soil property information for the associations is inappropriate at the local scale and even at the regional scale may lead to imprecise estimation.

The *Peatlands of Ireland* bulletin (Hammond, 1981) described areas of peatland in Ireland and was written to

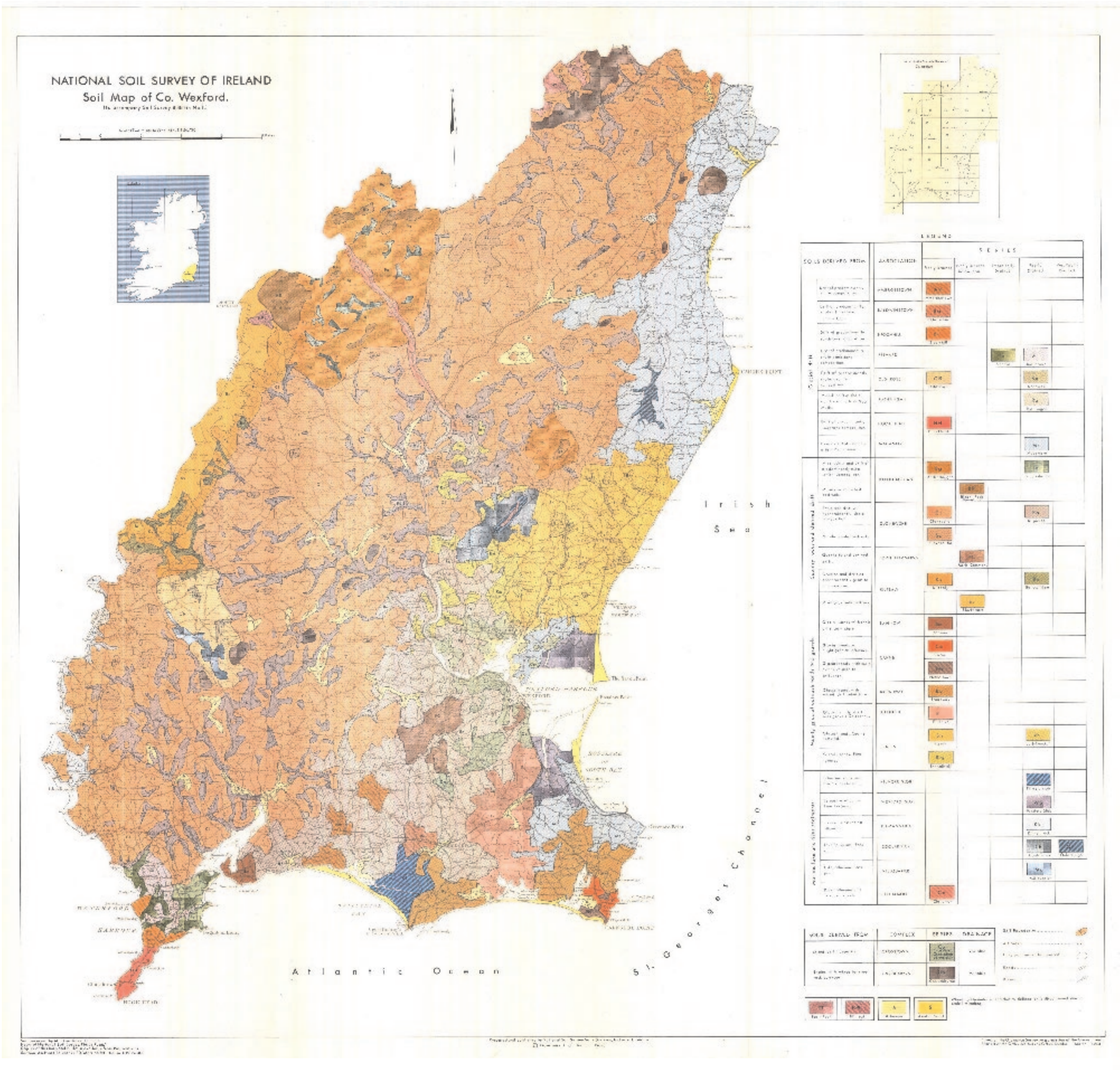

Figure 2.2. Soil survey map of County Wexford taken at detailed level delineating soil series.

accompany a national map of peatland (Hammond, 1978) published at the same scale as the GSM (1:575,000).

2.3 Special Soil Surveys

During the course of the NSS, a number of special surveys of Teagasc farms and local areas was carried out and published mostly at 1:2,500. Whilst the maps associated with these localised surveys are largely digitised, the bulletins remain out of print. Nine soil surveys of local areas were carried out by UCD and published at a scale 1:2,000 but the data remain largely undigitised and bulletins are currently out of print.

2.4 EPA/Teagasc Indicative Soils and Subsoils Maps

A recently completed indicative soils map of Ireland was produced and published in 2006 at a working scale of 1:150,000 by the Spatial Analysis Unit (SAU) within Teagasc as part of the *Subsoils, Land Cover, Habitat and Indicative Soil Mapping/Modelling Project* funded initially by the Forest Service and subsequently by the Department of Environment, Heritage and Local Government with project steering provided by the EPA. These data sets are currently available from the Office of Environmental Assessment, EPA. The project completed

Horizon	Depth (cm)	Description
A1	0-13	Loam; greyish brown (10YR5/2); moderate fine crumb structure; friable; abundant, diffuse roots; gradual, smooth boundary.
A2	13-23	Gravelly loam to sandy loam; light brownish grey (10YR6/2) with few, medium prominent, red (2.5YR4/6) mottles; weak fine crumb structure; friable but wet slightly sticky; plentiful roots; smooth boundary.
Btg1	23-35	Gravelly sandy clay loam to loam; dark brown (10YR4/3), brown (10YR5/3) and reddish brown (5YR5/4); with many medium, prominent, yellowish brown (10YR5/6) mottles; columnar breaking to weak, fine sub angular blocky structure, wet plastic; few roots; clear, smooth boundary.
Btg2	35-63	Gravelly sandy clay loam; brown (10YR5/4) and grey (10YR6/1) within a reddish brown (5YR5/4) matrix; common medium prominent yellowish brown (10YR5/6) mottles; grading towards columnar structure; wet slightly plastic; few roots; clear, smooth boundary.
C	63-122	Gravelly sandy clay loam; otherwise similar to above

Table 4.41: Profile Analyses – Gortaclareen Series

Horizon	A1	A2	Btg1	Btg2	C
Depth (cm)	0-13	13-23	23-35	35-63	63-122
Particle size distribution analysis (%)					
Coarse sand	25	28	24	27	24
Fine sand	25	24	24	21	23
Silt	32	29	28	21	23
Clay	18	19	24	25	25
pH	6.5	7.7	7.6	7.9	8.5
CEC, mEq/100 g	19.9	11.4	10.47	6.1	5.1
TEB, mEq/100 g	18.7	-	-	-	-
Base saturation, %	94	Sat	Sat	Sat	Sat
Carbon, %	4.8	1.3	0.9	0.3	0.2
Nitrogen, %	0.47	0.09	0.06	0.03	0.02
C/N ratio	10.0	14.4	15.0	10.0	10.0
Free iron, %	1.3	2.1	1.9	1.1	0.8
TNV, %	-	-	-	-	7.2

Figure 2.3. An example of the soil information captured in detailed county bulletins, that includes soil profile description and analytical data.

a large number of maps, with the indicative soils map being based on a modelling approach that infers soil type using parent material, land cover and other ancillary data. The soil map provides a simplified classification scheme devised as part of the original project specification and the classification system is outlined in Fig. 2.5. This classification scheme differs from traditional soil survey classifications and that used by the NSS in that soils are not characterised to soil series level but are inferred mainly from a set of soil-forming factors that are mapped and modelled using an expert rule base to predict soils occurring at locations on the landscape. Figure 2.6 shows an example output county map. The methodology is represented schematically in Fig. 2.7. The modelled soil classification system subdivides mineral and organic soils that are further categorised based on the nature of the subsoil (calcareous/non-calcareous), drainage (well drained/poorly drained) and depth (shallow/deep). Additionally, during the project in excess of 2,000 GPS-located field points were acquired to provide descriptions of soil and subsoil type and in-field assessments of soil properties such as texture and drainage status. This indicative soils map is based on a very simplified classification of soil type and does not contain soil property information which would require soil sampling and laboratory analysis. Initial accuracy assessment of the *Indicative Soils Map for County Monaghan* using field-collected data showed an overall accuracy of 70% (unpublished internal project documentation).

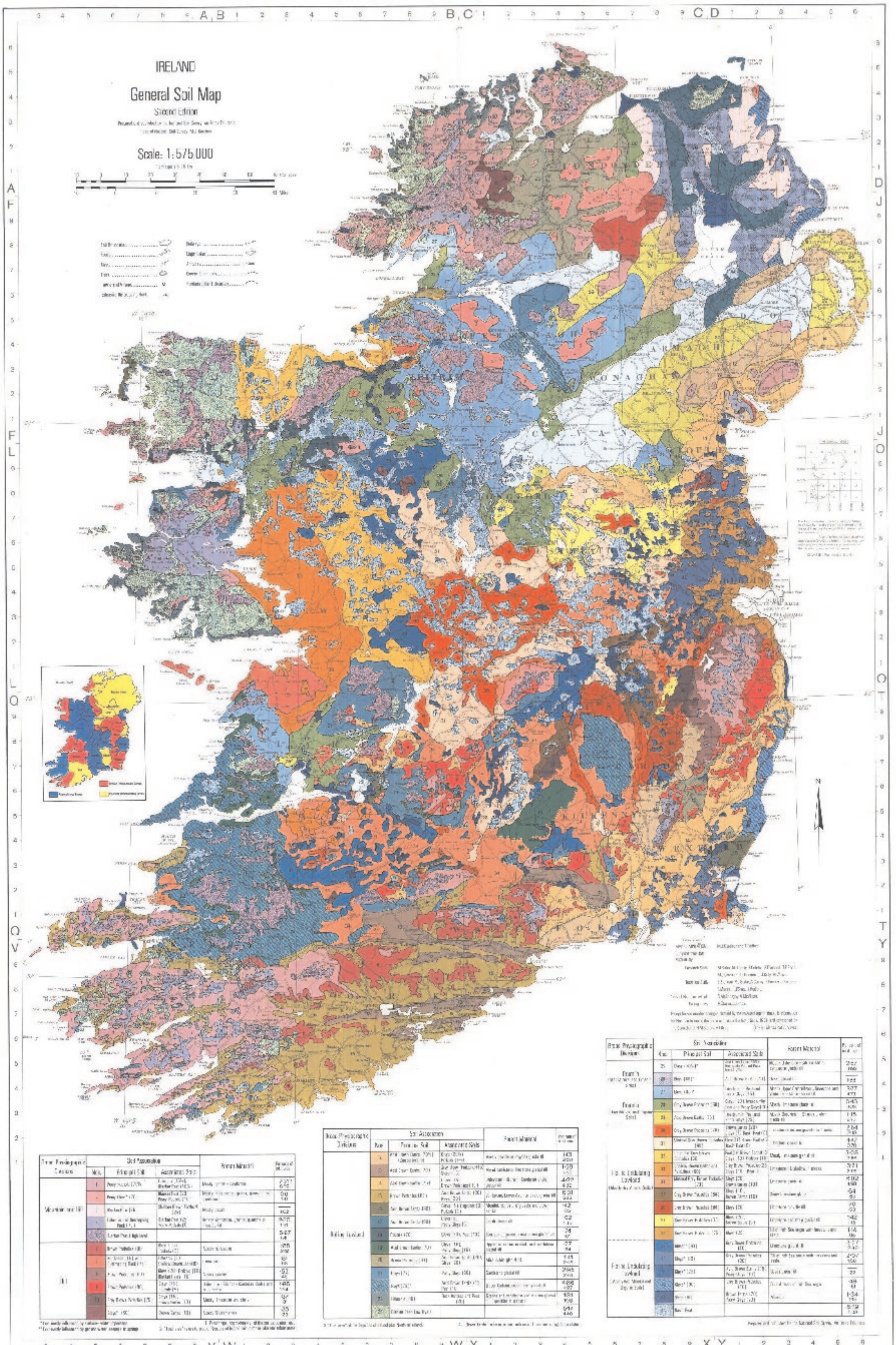

Figure 2.4. The *General Soil Map of Ireland*.

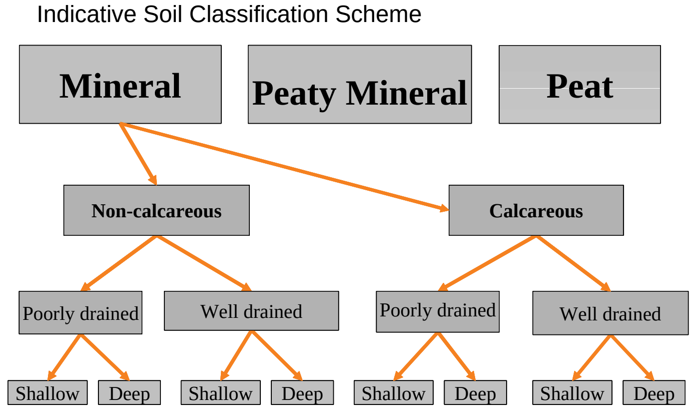

Figure 2.5. Classification scheme devised by the EPA/Teagasc *Subsoils, Land Cover, Habitat and Indicative Soil Mapping/Modelling Project* .

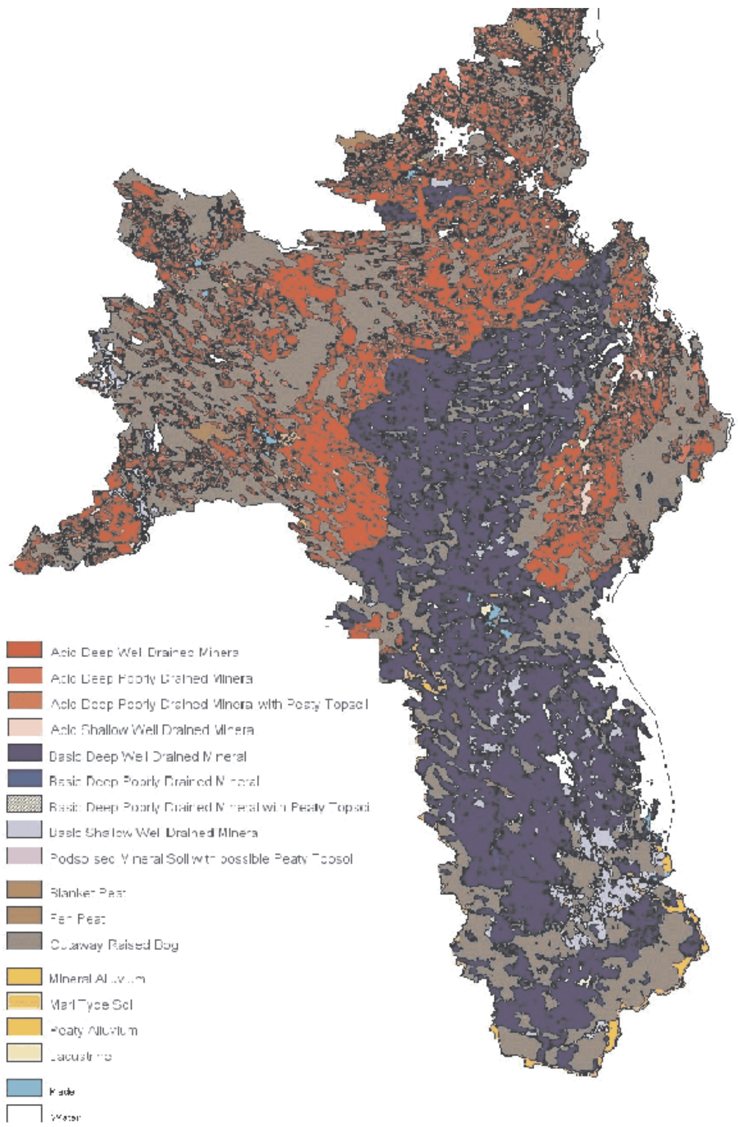

Figure 2.6. Example of individual county indicative soils map (County Roscommon) developed by the Teagasc/EPA *Subsoils, Land Cover, Habitat and Indicative Soil Mapping/Modelling Project.*

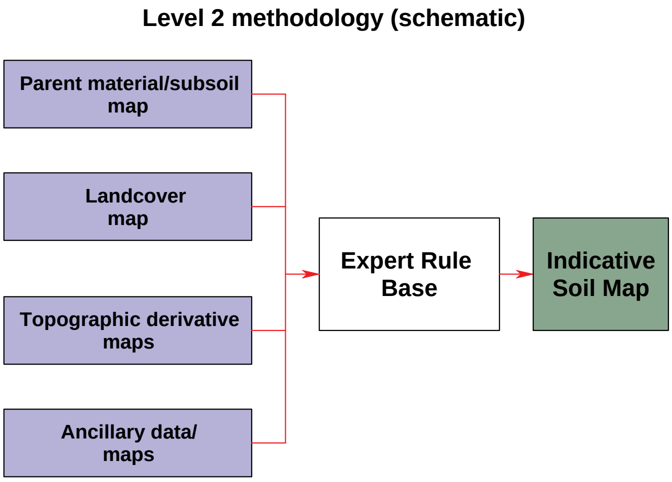

Figure 2.7. Modelling scheme used by the EPA/Teagasc *Subsoils, Land Cover, Habitat and Indicative Soil Mapping/Modelling Project* to infer indicative soil type.

2.5 Field and Point Data

The survey of government organisations, research institutes, colleges and universities highlighted a number of soil-related research studies that produced soil information at field and plot scales covering a wide range of research topics. These included nutrient cycling, OM turnover, hydrology, carbon flux in soil, diffuse pollution risk assessment and soil contamination.

On a national scale, a recently completed EPA/Teagasc project (Fay *et al*., 2007) has established a *National Soil Database* of soil chemical, biological and physical data from a sampling programme that provides baseline geochemical data for the whole country. A total of 1,310 soil samples were collected to a sample depth of 10 cm during two sampling periods, in 1995–1996 and 2003–2005. The samples were taken from defined positions on the national grid (10 x 10 km, two samples per grid) incorporating all land-use categories (pasture, arable land, forest and peatland). Soil chemical parameters investigated included pH and OM, as well as major elements, aluminium (Al), iron (Fe) and potassium (K), and trace elements arsenic (As), chromium (Cr), cobalt (Co), copper (Cu), cadmium (Cd), lead (Pb), mercury (Hg), selenium (Se), zinc (Zn), nickel (Ni), molybdenum (Mo), manganese (Mn), barium (Ba), strontium (Sr), titanium (Ti), and vanadium (V). Microbiological analyses included the development of a nucleic acid archive, representing all soil samples. The bacterial community structure and biodiversity of a range of soil samples was determined using molecular fingerprinting methods (T-RFLP and DGGE), while biomass was estimated based on DNA yields. While this information is extremely valuable, the *National Soil Database* is based on a sampling grid of 10 x 10 km, which presents challenges for detailed interpolation. The project did not aim at identifying soil types and only provides information on the upper 10 cm of the soil.

A *National Forest Inventory* (NFI) is currently being carried out by the Forest Service of the Department of Agriculture and Food to assess the current state and recent development of Ireland's forest resource. The first stage of this work identifies forest plots using aerial photographs and this is followed by a field survey of identified forest plots to describe soil type, texture and drainage class. The approach taken in this current work involves placing a 2 x 2 km systematic grid over the total land base of Ireland (6,976,112 ha) the density of which equates to 17,423 plots nationally, of which 10% or 1,742 are ground-survey plots classified as potential forest plots, each representing approximately 400 ha. The plots are 500 m^2 in size and one pit to a depth of 100 cm is dug for in-field assessment of soil type. Physiographic division, parent material and soil type are assigned based on the GSM (Gardiner and Radford, 1980a,b) at the level of Great Soil Group. In-field assessment includes recording of slope, relief form, surface topography, altitude and aspect. The litter layer is described and the type of humus noted where present. For each plot, soil/peat depth is recorded and texture described. Soil moisture status and drainage are also described and recorded in the field.

A number of projects on soil have incorporated soil sampling programmes to extract specific information on soils for research purposes. For example, pollution risk assessment requires information on soil nutrient status, soil OM content, Fe, Al concentrations and soil hydrological condition to estimate potential risk of nutrient loss from soil to water (Daly, 2006). Estimating carbon stocks in soils and CO_2 flux in soil requires specific information on soil bulk density, soil OM content and particle size (Byrne *et al*., 2005; Tomlinson, 2006). Estimating flood risk requires detailed hydrological information on soils in various areas (Dr M. Bruen, personal communication, Centre for Water Resources Research, UCD). An absolute link between soil series (the information carrier) and soil map unit (delineated areas) is often difficult to make with precision either on a map or on the ground, because of the scale at which the information is currently available. This leads to considerable uncertainties in the local, regional or national assessment of soil functions. Whilst research is frequently carried out at localised sites there is often a policy requirement to extrapolate results to other areas of the country with different soil types. In this regard, the research community has a requirement for specific information on soil over a wider area than is currently available and it is the soil series that remains the carrier of that information. Delineating soil series as an information carrier has been identified as a pressing need for many scientists and policy makers within the research community.

2.6 Soil-Derived Maps

A number of maps derived from Irish soil information have been produced as part of various research projects and surveys. The earliest soil-derived maps originated from the NSS interpretation of soil survey data to produce (approximately 13) soil suitability and grazing capacity maps from the detailed soil survey county maps.

More recently, the GSM has been used to derive maps illustrating the extent of soil- and land-related characteristics such as run-off risk, drainage class, diffuse pollution risk, carbon stocks in Irish soils, agro–meteorological conditions (opportunities for spreading slurry) and soil moisture deficit. An example of such application can be seen in the categorisation of run-off risk by Gleeson (1996). Since many of these characteristics are related to specific soil properties (drainage class, %OM, bulk density, etc.), the GSM is often not the most appropriate tool to extrapolate results into other areas using the soil association as the mapping unit. However, the map is used in this regard because it is the only complete map of the country that can be related in any way, however imprecisely, to a profile description and analysis of the principal soil types in each soil association. Arising from the survey of soil scientists and policy makers carried out as part of this study, there is a recognised desire for delineation of individual soil types (soil series) on a national scale so that research results with policy relevance can be extrapolated nationally.

2.7 Summary

As highlighted in the inventory and summarised in Table 2.1 at the beginning of this chapter, soil data coverage of Ireland is incomplete in either detail, extent or both. Whereas soil mapping at a scale of 1:127,560 is useable (with care) at a subregional level of application, data at this scale are only available for 44% of the country. The GSM maps the entirety of the land surface but the level of information is highly generalised and often inappropriate to the many applications to which it is put. The Teagasc/EPA indicative soils map also has national coverage and has a relatively small minimum mapping unit for some classes but the classification system used is highly simplified and the maps have no soil property information associated with the classes.

This situation has long created difficulties for all users of soil information in Ireland. In many cases, this has led to inappropriate use of soil data in Ireland for various research, consultancy or policy purposes. While the inventory exercise highlighted the fact that most soil users would like to see at the very least the completion of the county maps at 1:127,560 for all Ireland this is most likely not a viable alternative at this point in time due to potential costs. It is against the background of the European Commission's desire for the completion of a European soil database at 1:250,000 and the pressing need for unified soil map data which seek to meet the requirements of the SFD that the call was issued by the EPA for a scoping exercise to be carried out on the potential development of a 1:250,000 map and associated information system. It is on this basis that the methodology for the development of a soil map of Ireland at a 1:250,000 scale and an associated SIS for Ireland is developed and presented in the following sections of this report.

3 Proposed Methodology to Develop a Digital Soil Database at a 1:250,000 Scale for Ireland

3.1 Introduction

The methodology proposed in this chapter is based on procedures outlined by the scientific committee of the European Soil Bureau Network (ESBN) in *Georeferenced Soil Database for Europe, Manual of Procedures, Version 1.1* (Finke *et al.*, 1998) and referred to here as the Manual of Procedures (MoP). The process was also guided by an expert consultation exercise organised by the project team to assess the appropriate methodology for a 1:250,000 map for Ireland given the data required and the current state of soil and ancillary data that exist in Ireland to date. The expert consultation exercise recommended that the production of a 1:250,000 map should be viewed as primarily a compilation exercise utilising existing soil, parent material and topographic data in Ireland. The MoP was recommended as an appropriate tool from which to structure the development of a 1:250,000 map for Ireland by incorporating soil data from existing surveyed areas with predictive soil mapping for unsurveyed areas. A synopsis of the MoP is also provided in this chapter.

The methodology proposed here makes use of existing data on soils, parent material and topography and land use and is proposed in two phases, namely:

- Phase 1: The application of existing data, and
- Phase 2: Working with unsurveyed areas.

A list of key tasks and an estimate of costs, resources and time needed to complete the production of a 1:250,000 map is provided in addition to any risks and recommendations identified.

The proposed method is comprised of a number of stages, which although in the main distinct are based on a central notion of iteration. These stages are schematised in Fig. 3.1 and further elaborated in Sections

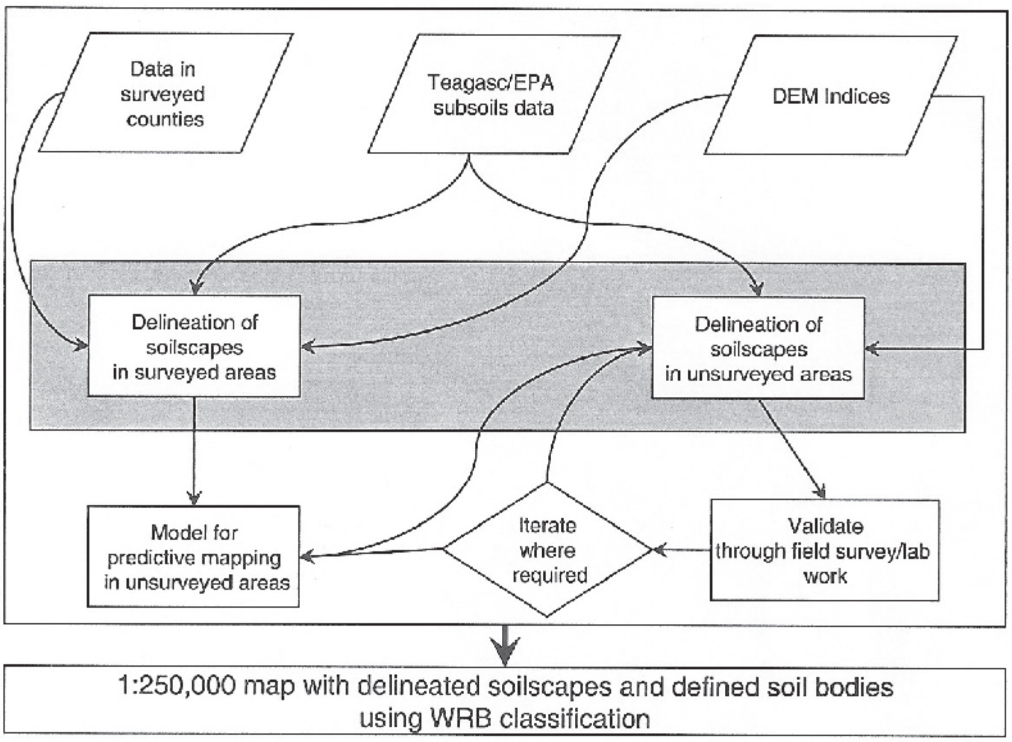

Figure 3.1. Schematisation of the recommended iterative procedure for producing a 1:250,000 map utilising the available data, complementary survey work and predictive modelling.

3.3 and 3.4. At the completion of any one step, application in subsequent steps provides verification of the process to that point. By iterating through the steps and including modifications where necessary, the overall quality and robustness of the approach is increased and knowledge of the soil's environment will be enhanced. The following list outlines in summary the recommended steps with each action described in detail in the sections following.

- Rationalisation of soil series
- Translation to WRB
- Development of geo-topological units (using geology/subsoil and DEM)
- Definition of soilscapes in surveyed areas and iterate where necessary
- Development of predictive rules for unsurveyed areas
- Fieldwork to test result of above (and iterate where necessary) and to provide samples for analysis for characterisation of soil bodies contained in soilscapes.

3.2 Synopsis of the MoP

The MoP was prepared by the scientific committee of the ESBN of the European Commission. The objectives of the MoP are to describe and define a structured methodology for regional mapping and sampling programmes, in conjunction with a prescribed format for data storage. The concept of the MoP was discussed with national and international soil experts at a workshop held in November 2006 (24/11/2006, Teagasc Research Centre, Johnstown Castle Co. Wexford) as part of an expert consultation exercise to assess the feasibility of creating a 1:250,000 map using existing Irish data and suitability of the MoP for doing so. Thus, procedures outlined in the MoP and the guidance on methodology that emerged from the workshop were considered by the project and form the direction of this current proposal.

The general concept of the MoP begins with the definition of a soil body as "*a portion of the soil cover with diagnostic characteristics resulting from similar processes of soil genesis*" and it is this entity that forms the focal point of the 1:250,000 database. The soil body is therefore described as the basic element defined by soil attributes and is composed of a number of soil horizons which may vary in thickness and properties. Its definition and classification depend on the diagnostic criteria that satisfy the World Reference Base for Soil Resources (WRB) (a modern soil classification scheme now widely adopted within the European Union and elsewhere), which in turn is based on the identification and properties of soil horizons within the soil body. Whilst the soil body is similar to a polypedon and often the smallest mappable unit, it can be used to classify soils into soil series, on the understanding that within a soil series lies a range of soil properties, represented by modal soil profiles. It is within this remit that the soil series maps of Ireland can be used to describe soil bodies for the creation of a 1:250,000 database. The criteria for determining a soil body according to the MoP are summarised in Table 3.1.

The predetermined scale of 1:250,000 means that soil bodies, delineated using the criteria above, cannot be represented at such a small scale. Thus, there is a requirement to create soil associations by combining different soil bodies into a single mapping unit. The MoP denotes these units as 'soilscapes' and defines them as that portion of soil cover which groups soil bodies having

Table 3.1. Summary criteria and guidelines for the definition of soil bodies.

Object	Criteria		Guidelines	Delineation
	For definition	For delineation		
Soil body	1 WRB classification*	Not applicable	1 One profile with estimated data	Only in small reference areas
	2 Parent material		2 Two or more profiles with measured data	
	3 Depth to obstacle for roots		3 More than 90% of soilscapes described by soil bodies***	
	4 Dominant texture and gravel content class (0–30 cm)**			

*Reference group plus two qualifiers.
**If an abrupt textural change occurs within the upper 30 cm, dominant texture and gravel content refer to the layers above the abrupt textural change.
***Including similar soils. Similar soils are soils that show a minor variation in a soil property that induces a different classification.

Table 3.2. Summary of criteria and guidelines for the definition and delineation of soilscapes.

Object	Criteria		Guidelines	Delineation
	For definition	For delineation		
Soilscape	*Minimally:* Characteristic association of physiography and parent material *Additionally:* Geomorphology and texture	*Minimally:* Physiography and parent material *Additionally:* Geomorphology and texture	1 Minimal size polygon: 1.5 km^2 2 Minimal distance on map of two arcs: 1 mm 3 Minimal size soilscape unit: 6 km^2 4 Soilscape = contiguous group of soil bodies	Using DEM, geologic and geomorphological maps, etc.

former or present functional relationships, and that can be represented at 1:250,000. However, whilst these become the information layers in the 1:250,000 database that map soil behaviour, the functional relationships between soil bodies and soilscape should be checked after mapping the soilscapes at 1:250,000. The MoP recommends delimiting soilscapes or landscape units based on the integration of physiography, parent material and additional geomorphology and surface texture. The main diagnostic criterion is topography, using attributes extracted from the digital elevation model (DEM). A summary of the criteria for the definition and delineation of soilscapes provided by the MoP is outlined in Table 3.2.

3.3 Proposed Methodology Phase 1: Application of Existing Data

3.3.1 Rationalisation of existing soil data

This work will essentially involve the organisation and compilation of existing soil series information into a format that permits the screening and aggregation of all soil series into a rationalised national list. Irish soil series were named according to the location in which they were first identified and characterised, and names are based on locations within the surveyed areas of the country, e.g. Clonroche Series, Elton Series, etc., a process that extended over approximately 20 years. There are approximately 300 soil series named within the surveyed counties although their descriptions and analytical data remain distributed among the published county bulletins that accompany the surveyed county maps. A compilation of all soil series and their attribute data (general description, modal profile description and analytical tables), in digital form, is required so that a screening or rationalisation of soil series can be carried out. Additionally, those soil series where no profile description or analytical data are available should be identified. Across the published county bulletins there are some inconsistencies in reporting of analytical data, for example some soil series contain a full suite of physical and chemical parameters whilst other have certain parameters missing, etc. Owing to these inconsistencies a compilation of the analytical parameters recorded and missing for each soil series should accompany the national list of soil series. The rationalisation process will involve screening and cross-checking soil data to ensure that soil series are not duplicated under different local names. The process will also involve combining and (probably) reducing the number of soil series based on common criteria so as to provide a rationalised or harmonised list of soil series in existing surveyed areas. Essentially, this process will be an iterative one and will include some consultation with original soil surveyors when necessary. Correlation of the national classification with a WRB classification should accompany this process to ensure that not only is the maximum amount of information captured from the soil series data but that soils with similar characteristics, identified by the WRB qualifiers, will assist the rationalisation process. This process of rationalisation and harmonisation is necessarily iterative.

3.3.2 Correlation of soil series classifications with WRB

The WRB, finalised and launched in 2006, provides a framework for an international classification of soils. As a comprehensive classification system it serves as a correlation and communication tool for naming and classifying soils in a language that allows soil scientists to communicate and compare soil information internationally. The main objective of the WRB is to provide an easy means to identify, characterise and name major soils. As such it is not meant to replace national classification systems but facilitate the correlation of national soil classes into a standardised international soil classification, fully endorsed by the global soil science community. The WRB is based on principles of the revised Food and Agriculture Organization (FAO) legend (FAO, 1988) and as such retains the fundamental rules of soil-forming factors and soil-forming processes, whilst incorporating new knowledge of soil ecology and pedology. The architecture of the WRB (shown in Appendix 1) consists of two tiers of categories: the Reference Soil Group (RSG) of which 32 are listed, and the qualifiers that deal with uniquely defined properties of the RSGs that allow very precise characterisation and classification of individual soils. Classification of soils into RSGs is based on diagnostic criteria defined by the WRB that reflect the dominant identifiers or soil-forming factors and processes within the soil. Further detail is provided by the qualifiers that accompany the RSG and are uniquely defined for that soil. At the qualifier level, further subdivision occurs into *prefix qualifiers,* based on typically associated diagnostic criteria (reflecting criteria of another RSG), and *suffix qualifiers*, based on unique characteristics (colour, drainage, base status, etc.), not linked to another RSG. For example, from the RSG, podzols may have the prefix *gleyic* and the suffix *turbic* and hence be classed as a Gleyic Podzol (Turbic).

Irish soil classification is based on a combination of United States Department of Agriculture (USDA) soil taxonomy (7th Approximation) with local names incorporated. In the USDA system, the higher category (Orders, Suborders and Great Soil Group) is based on the presence or absence of diagnostic characteristics and the lower category (Subgroups, Families and Series) represent the central concept of the category but provide further information on important features of plant growth and land use such as soil texture, mineralogy and depth. In Ireland, ten Great Soil Groups are identified and are represented on the GSM in the form of soil associations. The soil association provides a method of grouping Great Soil Groups as they occur on the landscape together. The GSM represents 44 soil associations mapped on a national scale (1:575,000).

The detailed soil survey carried out on a county basis for 44% of the country, identifies and characterises approximately 300 soil series, mapped individually and named locally after areas within a county in which they were first identified and classified. The soil series is the basic category in the Irish soil classification system and carries a lot of information about a uniquely defined soil type, characterised by profile character and arrangement of horizons.

Correlating Irish soil associations (from the GSM) and the soil series (detailed county maps) within the framework of the WRB will be a requirement in the development of a 1:250,000 map. The process of correlation itself demands familiarity with the WRB system and its terminology, and it is recommended here that this exercise should be done in collaboration with WRB experts (preferably a member of the WRB working group). Whilst a direct correlation of soil series into the WRB is feasible there are a number of inconsistencies in Irish soil data that will need special attention to ensure a robust and accurate classification. For example, some additional fieldwork and analysis on soil physical properties may be required to address some incompatibilities with procedures described in the WRB. In addition, there are a number of chemical parameters missing from some counties, such as % base saturation, dry-sample Munsell colour, etc., that are required as WRB diagnostic criteria. In this case, inferences will need to be made and fully recorded, in consultation with WRB experts on these issues. This correlation exercise should aim to capture as much information about Irish soil series as possible in a fully described and correlated WRB classification.

3.3.3 Delineation of soilscapes

The approach adopted here is based on a combination of guidance and advice following an expert consultation exercise and the procedures outlined in the ESBN document, the MoP. Given the incomplete nature of soil data at detailed scale in Ireland, a pragmatic approach is suggested. Whilst an ascending approach, starting at the smallest scale and working up, would be desirable, it is largely unfeasible since 56% of the country remains unsurveyed at a detailed enough level to provide the necessary information on soil bodies. A combination of both ascending and descending approaches, as detailed in the MoP, is proposed. An ascending approach will employ available data in surveyed areas to guide the development of soilscapes in these areas. In unsurveyed areas, soilscapes will be inferred in the first instance using predictive soil mapping techniques and subsequently assessing constituent soil bodies. This approach provides a tool for structuring the work and a firm basis for modelling in unsurveyed areas. A national DEM (at 20 m resolution) and parent material map (Teagasc/EPA Parent Material Subsoils Map) is proposed as the mechanism by which to delineate soilscapes in surveyed areas. Topographic features derived from the DEM, including degree of slope, degree of dissection, drainage density, etc., could be included with geographic features from a parent material map to produce landscape units at the required scale.

Further refinement of soilscapes is proposed by identifying and examining the soil bodies that occur within them and by doing so will provide natural regional units within which soil bodies and soilscapes are primarily related, thus satisfying the definition of a soilscape according to the MoP, i.e. as a portion of the soil cover which groups together soil bodies according to their functional relationships. It is within this process that a combination of the ascending and descending approach occurs, in that amalgamating soil bodies (or soil series) according to how they occur together in the landscape should be carried out in conjunction with the delineation of soilscapes at the required scale of 1:250,000.

Soilscapes delineated using topography and geology will require the use of the soil series maps at detailed scale (1:126,720) to identify the soil bodies (series) that occur in each of the mapped landscape units. Exploring the functional relationship between soil bodies (series) and soilscapes in these areas, will provide a basis on which inferences can be made about their mutual interdependence and assist the process of predicting the occurrence of difference soil types within these units in unsurveyed areas. Once identified, soil series or soil bodies occurring within delineated soilscapes should be amalgamated into soil associations. For the production of a 1:250,000 map, the legend should refer to soil associations using the WRB classification. Where a large number of soil bodies or series have been associated with a soilscape the WRB classification for each should be listed in the soil association number so as to avoid losing any information about the soils occurring within those areas. The actual delineation of soil bodies within each soilscape on a 1:250,000 map is not applicable due to restrictions of the scale employed (as detailed in the MoP) and referred to in Table 3.1. The proposed steps are fully explained in the next section.

3.4 Proposed Methodology Phase 2: Working with Unsurveyed Areas

3.4.1 Inferring soils in unsurveyed areas

The delineation of soilscapes using topography and geology on the national scale and the refinement of soilscape boundaries in existing surveyed areas using knowledge from previous surveys will provide a process for structuring work in unsurveyed areas. The examination of relationships between soil bodies and soilscapes in existing surveyed areas will provide the training data when moving into unsurveyed areas. An inferential model for the occurrence and pattern of soilscapes in unsurveyed areas will initially be developed using these training data. This model will be validated using fieldwork and refined as necessary in an iterative process.

In unsurveyed areas that are not proximal to previously surveyed areas, the soilscape will be largely unrefined at the outset since no adjacent soil series data exist to guide or train soilscape construction in these areas. As these soilscapes in unsurveyed areas will be delineated based on topography and geology alone, the GSM could initially be used to broadly indicate the potential range of Great Soil Groups that may occur in these areas.

A programme of systematic field survey and sample analysis that would include auguring and soil profiling will be required to complete soil body occurrence and soilscape mapping in all unsurveyed areas. The intensity of such a field survey will largely depend on the complexity of soils occurring in these areas. This field survey will be an iterative process; as more experience and ground-truthing is completed in unsurveyed areas, the inferential process will be refined and will lead to increased accuracy of mapping in these areas.

3.4.2 Field survey and laboratory soil analysis

There will be a need to undertake a field survey in currently unsurveyed areas, both to check on the accuracy of initial predictions and, by a process of refinement, to improve the accuracy of ongoing prediction (see above). Such fieldwork will allow further sampling of soils, both to check the correctness of their assignment to a particular class, and to provide further data by which predictions can be improved. The sampling programme should be guided by the initial step of predicting the type and location of soils occurring in unsurveyed areas. For complex areas where predicting soils proves difficult and/or the rationalisation exercise is problematic, a series of soil profiles should be excavated to provide clarity. Standard soil survey techniques for soil profile description (using FAO *Guidelines for Soil Description*, ESB report) should be used to provide general descriptions of the areas, profile description (arrangement of horizons, colour, texture, structure, extent of mottling, pH, effervescence, etc.) and samples from each horizon returned for physical and chemical analysis for additional diagnostic criteria for calibration and characterisation with respect to WRB classification at the qualifier level. In less complex areas, a system of field augering and profiling is recommended using field assessment techniques and sufficient laboratory analysis to satisfy the MoP classification of a soil body (WRB Reference Group (RG) plus two qualifiers). An approach to field surveying should be taken that starts in areas close to already surveyed counties and expands out to other areas and with a grid depending on the complexity of the soils in a given area. The soil inference model should be refined and revised as necessary, as the volume of data from previously unsurveyed areas increases.

3.4.3 Compiling a national legend

The final stage in the production of a national soil map at a 1:250,000 scale will include the compilation of soil associations from Phases 1 and 2 of the process outlined above. Soils identified in soilscapes within existing surveyed areas alongside soils predicted in unsurveyed areas should be compiled with their WRB classification intact. Whilst the MoP recommends that soil bodies should be defined by a WRB classification that includes an RG plus two qualifiers, the correlation exercise within existing surveyed areas may identify more than two qualifiers at the soil series level, that could be included in the legend. When working in unsurveyed areas, however, the MoP definition should be satisfied as specified (RG plus two qualifiers). Compiling a national legend will involve listing soil associations with the WRB names of all of the soil bodies individually listed within the soil association, so as to preserve the maximum amount of information on soil bodies incorporated in the WRB classification. It is also possible that new soil series will be encountered within the WRB classification that were not present in the old classification system.

3.5 Estimated Time and Cost

The estimated timescale for the completion of both phases of the work, including time allocated to training staff, is approximately 5–6 years. The cost of hiring staff, project co-ordination, equipment and data resources, training needs, consultation with experts, establishing a programme of field survey and laboratory analyses could be in the region €3.8 million (Table 3.3). However, given that this document is part of a scoping study and not a tender document with detailed costings, the estimated costs provided here are subject to change depending on issues such as training costs, Ordnance Survey of Ireland (OSI) licensing agreements, and the extent and intensity of a field survey programme. Therefore a more detailed costing would be required at tender document or proposal stage for the completion of this work.

3.6 Risks and Recommendations Arising

3.6.1 Dealing with unpublished surveyed areas

Whilst all of the counties surveyed at detailed reconnaissance level have been digitised and published, there is one exception, Co. Waterford. A comprehensive survey has been completed and is documented and mapped on paper only. These data have yet to be captured electronically. That includes digitising the surveyed area using modern techniques, and publishing the accompanying bulletin. This task should be completed during the development of the 1:250,000 map so that Co. Waterford can be included as part of the surveyed areas.

Other resource surveys (e.g. Co. Kerry) remain undigitised and should be included as part of this task.

3.6.2 Accessibility of existing soil data

Whilst the recently completed soils and subsoils maps produced by the EPA and Teagasc are freely available and accessible to all users (currently from the Office of Environmental Assessment, EPA) the same should apply to the existing surveyed data (detailed county maps and the GSM) held within Teagasc and needed for the production of the 1:250,000 map.

An OSI licence should be acquired during the lifetime of the project where a national DEM is required for delineation of soilscapes and any further licensing issues arising from the production of a national map of soilscapes and soil associations should be clarified with OSI prior to project initiation. Costs for OSI data licensing can be highly variable and these will largely depend on the existing licensed status of the project participants.

3.6.3 Project management

The overall project management of the work should be overseen by a project co-ordinator working full-time on managing all of the tasks listed and in conjunction with a GIS specialist whose function is to ensure high-quality output from the GIS tasks and development and integration with the SIS.

The soil series rationalisation should be carried out in conjunction with the correlation exercise, so as to optimise

Table 3.3. List of tasks and resource requirements.

	Estimated time	Estimated costs
Phase 1 tasks		
• Rationalisation of soil series and correlation with WRB	18 months	€165,000 (1 × soil scientist, expert consultation, training, workshop/meetings)
• Digitising unpublished surveyed areas	12 months	€80,000 (1 × GIS scientist, meetings)
• Extracting topographic indices from DEM for whole country • Extracting parent material ‘types’ on a national basis • Deriving ‘geo-topo' landscape units on a national level	18 months	€165,000 (1 × GIS scientist, expert consultation, meetings) Additional cost of OSI licence, if necessary, not included*
• Identifying soils (series) within soilscapes in surveyed areas • Preparing the training data: exploring the functional relationships between soil/soilscape	12 months	€150,000 (1 × soil scientist, expert consultation, training, meeting/workshop)
• Amalgamating soil series into soil associations within surveyed areas	6 months	€40,000 (staff)
	Phase 1 timescale: 2.5–3 years	Phase 1 estimated cost: €600,000 (OSI licence cost not included)
Phase 2 tasks		
• Inferring soils occurring in unsurveyed areas – using training data	12 months	€150,000 (1 × soil scientist/modeller, expert consultation, training, meetings)
• Validation with a programme of fieldwork to include sampling and laboratory analysis (additional information at qualifier level and calibration data)	24 months	€2.5 million (4 × field scientists, 1× analytical chemist, field survey training, meetings, expert consultation, field travel and subsistence, laboratory analysis (routine and special), equipment and data capture)**
• Delineation of boundaries of soil associations in soilscapes and completing a national legend with WRB classification	6 months	€50,000 (1 × soil scientist, expert consultation)
	Phase 2 timescale: 3 years	Phase 2 estimated cost: €2.7 million
• Project co-ordination and GIS supervision		€500,000
• **Summary**	**Approximate timescale: 5–6 years**	**Total estimated cost: €3.8 million**

*****OSI licence would be required for vector data (river and lake network, etc.), spot height and contour data. Although standard prices are available from OSI there is often large variability in applied costs depending on the pre-existing licensed status of applicants. This aspect of costs should be clarified and included in costing detail before a project begins.

**Based on 2 years of field survey with four field scientists and one laboratory analyst covering 56% of country; this may change depending on the predictive modelling process and the complexity of soils predicted in unsurveyed areas. Thus the cost estimated here will need to be revised at tender document stage.

the study of, and familiarity with, soil series properties. This should provide a more efficient approach to both rationalisation and correlation. The process of rationalisation will be an iterative one and may need some consultation with original soil surveyors where clarity is needed. The correlation exercise will need consultation with WRB experts to ensure accurate classification and appropriate inference where some soil series data are missing. Person(s) appointed to these tasks should work exclusively on this area and, depending on the level of expertise required, a training period in WRB classification and series rationalisation should be included that takes advantage of collaborative links forged with member states that have experience in this area. These tasks should be project managed to ensure that the process is both streamlined and that adequate progress is made.

Similarly for the delineation of soilscapes on a national level, the production of this database will require project management. The predictive element of the work (inferring soils within unsurveyed areas) will also require training and collaboration with other countries experienced in this area. Collaboration with predictive soil mapping experts who participated in the expert consultation exercise should be sought and training requested as part of this task. The programme of field surveys should also be carried out in consultation with other countries that have experience in the appropriate methodology for the map scale required. Training of field staff should be acquired, and a detailed timescale and cost should also be included before fieldwork is initiated. The project co-ordinator is also required to oversee and co-ordinate the work in unsurveyed areas.

3.6.4 Risk of inference

The risk associated with inferring both WRB classification and predicting soil bodies occurring in unsurveyed areas should be overcome by ensuring that collaborative links are made with experts in these areas during the proposal stage of the project. Experts should be identified and included as part of the project to provide guidance and advice on a consultancy basis. As the predictions are made and ground-truthed, experts can be consulted, thus making both the predictions and the predicting process more accurate.

3.6.5 Training and technology transfer

As already mentioned, there are a number of areas that will require some initial training of project participants before the production of the 1:250,000 map can be initiated. These are mainly in areas of WRB correlation, predictive soil mapping and field survey. However, technology transfer between original soil surveyors and project participants will also be required depending on the complexity of soils in any given area and the availability of the expertise at the time of the project. The establishment of a Review and Advisory Committee is discussed in the final chapter.

4 Proposed Specification for an SIS for Ireland

4.1 Introduction

This chapter of the scoping study reviews the design of an SIS for Ireland. The primary aim of the proposed SIS is to provide a technical platform to organise, store and distribute all relevant soil information in Ireland. In so doing, the SIS will underpin the most efficient development of the 1:250,000 soil map of Ireland. A range of options are examined that serve to provide fundamental design guidelines for the construction of such a system. These include aspects such as available data, available technology and emerging legislative considerations.

A number of key existing SISs are reviewed and an assessment of these is provided to serve as a basis for the discussion on the design and implementation of an SIS for Ireland. The systems examined provide examples of the range of options available for the provision of data within an SIS framework and will act to guide the future development of the SIS.

A technology platform is recommended along with core component data, and a cost estimate for construction of the Irish SIS is included. Key recommendations are made throughout and summarised at the end of the chapter.

4.2 Background

4.2.1 Definition of information system

The definitions of an information system often vary between those that use only a technology-based definition relating to networks, databases, hardware and software, etc., and those that include a human element in the definition. Amongst the latter, the following from the Alliance for Telecommunications Industry Solutions (ATIS) is one of the simplest while remaining comprehensive:

> *Information system: A system, whether automated or manual, that comprises people, machines, and/or methods organized to collect, process, transmit, and disseminate data that represent user information.*
>
> ATIS, http://www.atis.org/tg2k/

Almost all SISs are built on platforms, or utilise technology, provided by a GIS. GIS technology has been defined as:

> *GIS is a collection of computer hardware, software, and geographic data for capturing, managing, analysing, and displaying all forms of geographically referenced information*
>
> http://www.gis.com

Taking account of the human element required for the operation, maintenance and management of the system, a GIS ultimately combines technology, processes and people.

The concept underpinning an SIS is not new. Burrough (1991) traces the formalisation of the idea back to a proposal at the Tenth International Congress of the International Society of Soil Science, held in Moscow in 1974. At this congress, the Working Group on Soil Information Systems was formed under Commission V. The first international meeting, attended by 55 scientists from 18 countries was held the following year in Wageningen.

The issues addressed through the activities of the working group tended to focus on the potential utility of the SIS to organise the large data volumes associated with soil survey. Burrough reports that this focus inevitably led to a re-evaluation of the traditional modes of data collection and that one of the aims was to provide a practical alternative to the rigid, hierarchical soil classification systems that were in use.

Though innovative and arguably ahead of its time in the context of the unprecedented developments that would subsequently happen in the area of information technology, the particular focus of the SIS as envisaged tended not to address the issues of data distribution to the wider user community. In many respects, this may not only have been due to the lack of development in information technology but also due to the then small size of the soil data user community.

However, the nature of this community has undergone fundamental change in recent years. Mermut and Eswaran (2000) describe the dramatic increase in demand for soil information. Such demand for soil data has undoubtedly been driven by the expansion of environmentally focussed legislation. Skehan and Gonzalez (2006) discuss how implementation of the Strategic Environmental Assessment Directive (2001/42/EC) has seen a growth in demand for digital spatial data including soils data. Directives such as the Water Framework Directive (2006/60/EC) and the proposed Soil Framework Directive (COM(2006)232) are having a similar if not greater effect on the growth in demand, with the requirements of the Water Framework Directive placing a particular emphasis on the compilation, use and distribution of environmental data sets in digital format.

While the impact of such legislative initiatives is obvious, it should also be noted that the unprecedented expansion in the information technology underlying the distribution of data across network infrastructures has both facilitated and contributed to this increasing demand. Traditionally, digital soil data have been housed and maintained by mainly government agencies whose responsibility was the collection and archiving of these data. While simple queries on the available data may have been easily dealt with, access to the actual data held within these agencies has been often difficult, if not impossible.

This barrier to distribution, though sometimes due to institutional inertia, was also largely due to the technological difficulties in data handling. GIS technology was not widely available and where it was – largely in academia – users had to be comfortable with tools that were very powerful but equally very complex in their execution. Software was largely command-line driven and often scripted in proprietary languages. In many ways the example of soil data and their lack of demand, until recently, closely mirrors the effects that have been universally observed in the closely coupled relationship between IT capability, data demand and data supply. Lagacherie and McBratney (2006) have proposed an exponential growth term to describe the developments in digital soil mapping over time and related this growth to the commonly quoted Moore’s Law, which is used by the information technology industry to describe the effect of increased microchip processing power.

The rise in Internet GISs, where spatial data can be viewed in lightweight browser-based applications has, in many cases, reduced the need for expensive installed GIS software and facilitates access to spatial data by most users with rudimentary IT skills. While this has compounded issues in other areas such as the appropriate use and application of the delivered spatial data, it has without question completely changed the relationship between the data holders and the intended users and the expectation of those users of the services and data that should be provided to them.

Apart from individually providing drivers for change, these expectations and technological developments, and the obligations of various legislative initiatives, have, ultimately, come together in an EU directive which will probably have the most significant effect on the distribution of soils data in Ireland and the development of an information system to facilitate such distribution. Due to its anticipated impact and direct relevance to the terms of reference of this scoping study, this INSPIRE Directive is described in some detail below.

4.2.2 INSPIRE

The Directive of the European Parliament and of the Council establishing an Infrastructure for SPatial InfoRmation in the European Community (INSPIRE) (COM(2004)516) is undoubtedly the most significant piece of European legislation of relevance to the entire spatial data community, including both users and producers. Although the distribution (or lack thereof) of spatial data in Ireland has often been criticised, the data situation pertaining here is often not very different to that of other European countries.

It was due to the recognition of the lack of harmony in the development and supply of spatial data sets, mainly in support of environmental policy legislation, that the impetus for the development of the INSPIRE proposal came about. National data sets on various environmental parameters, such as soils, that are required to monitor both the implementation and success of European legislative initiatives are seen as fragmented and difficult to access. Efforts at production are often duplicated, as are storage and archival initiatives. There is a lack of consistency across Europe on appropriate charging and, combined with perhaps overly stringent interpretation of intellectually property rights concepts, the data-sharing environment has not traditionally been easy to access for potential data users. In many cases, even the simplest of tasks, such as establishing what data are available, let alone gaining access to such data, has proved extremely challenging in many European countries.

The problems existing with spatial data in Europe have been identified as:

- Lack of use of standards
  - incompatible information
  - incompatible information systems
  - fragmentation of information
  - overlap (of responsibility for supplied information)
- Lack of co-ordination
  - across borders
  - between levels of government that are the main data providers
- Lack of data
  - data policy restrictions
  - pricing
  - copyright
  - access rights
  - licensing policy.

The Commission sought to address these issues by adopting a proposal for the INSPIRE Directive in July 2004. The proposed Directive lays down rules for the creation of an infrastructure for spatial information in Europe, for the purposes of environmental policies or activities, which may have a direct or indirect impact on the environment. The Directive has at its core the development of a Community-wide spatial data infrastructure which seeks to reduce or remove altogether the barriers that have existed to date that have served to obstruct the rational and efficient creation, use and distribution of spatial data across Europe.

Underlying the development of this spatial data infrastructure is the idea that its associated services should allow the users to identify and access spatial or geographical information from a wide range of sources, from the local level to the global level, in an interoperable way for a variety of uses. A broad user community of such services is envisaged including policy makers, planners and managers at European, national and local levels and the citizens and their organisations.

Envisaged as a framework directive, the INSPIRE Directive requires Member States to implement various measures, some of which will require transposition by Member States. Other measures are framed as ‘Implementing Rules’. Ultimately, the INSPIRE initiative seeks to legislatively implement the vision put forward in its supporting consultative documentation. This vision can be summarised as:

Data should:

- be collected once
- combine seamlessly
- be easily shared between different levels
- have extensive use
- be easy to discover (catalogued)
- be properly documented (metadata).

Following adoption by the Council in January 2007 at the end of the conciliation procedure and the subsequent approval of the conciliation agreement by the European Parliament in February, the way was set for final approval and adoption of the Directive. The INSPIRE Directive was formally enacted into European law in May 2007. Under the current text of the Directive, Member States will have 2 years from adoption to transpose the terms of the Directive into national legislation. Implementation at national level is required during a subsequent 5-year period, with the specific timing determined by reference to the annexes appended to the terms of the Directive. These annexes classify data types according to their agreed priority. Soils and subsoils data are listed in Annex II of the Directive. At a minimum, metadata to the standard of the Directive will be required to be created no later than 2 years after the adoption of the specific implementing rules, which are currently being prepared in tandem with the co-decision and conciliation process.

In light of the significance of the INSPIRE initiative, the development of the SIS for Ireland should proceed in a manner that is fully consistent with the INSPIRE principles. INSPIRE not only represents best practice but will also become a legal obligation. On that basis, the SIS design and development phase should be informed by the future impact of INSPIRE implementation in Ireland. It is always cheaper to design-in proper procedures at the outset then having to retrofit new procedures subsequently.

Recommendations

- **The Irish SIS should be designed and built in full compliance with *anticipated legislative obligations* relevant to spatial soil data arising from the INSPIRE Directive.**
- **The Irish SIS should also be designed and constructed in a manner that is consistent, wherever possible, with the *underlying principles* of the INSPIRE initiative.**

4.3 Review of Key International Examples of SISs

4.3.1 Review of other SISs

A key part of the scoping process has been the review of a number of SISs from other countries. This process was undertaken to ensure that the design phase of the Irish SIS was fully informed by developments at an international level. Three of the systems reviewed have been chosen for presentation here. In choosing these systems for detailed assessment, account was taken of differences between systems in order to highlight the range of approaches that could be considered in developing the Irish SIS. The systems chosen were:

1. CanSIS — Canadian Soil Information System
2. NRCS-WSS — National Resources Conservation Service – Web Soil Survey (USA)
3. EUSIS — European Soil Information System.

The systems in question were examined under the following broad headings:

- Development costs
- Development time
- Data costs
- Associated/Supporting information
- Included functionality/interpretative data.

4.3.1.1 CanSIS

CanSIS was chosen due principally to its long established history and the fact that the emphasis in data distribution is not placed wholly on Internet channels via a web-browser GIS interface. This is in contrast to the other two systems chosen for review. While the notion of not using a technology layer that enhances data access may seem contrary to the notion of INSPIRE, a closer examination of CanSIS suggests otherwise.

CanSIS was initiated when it was first recommended in 1971 by the Canadian National Committee on Soil Survey that a computer system should be developed to organise and store the data derived from the NSS effort. Beginning in 1972, CanSIS was developed by the Land Resources Research Centre (LRRC) of the Research Branch of Agriculture Canada. Until 1986, the system ran on a proprietary platform coded by the centre's own computer scientists. In that year, the LRRC decided to move CanSIS to the ESRI ArcInfo platform. This move was made primarily due to the fact that information exchange was becoming increasingly difficult between the legacy CanSIS and other government agencies that were using GISs and had often deployed commercial off-the-shelf GIS solutions. Importantly, the transfer of the original CanSIS to the industry standard required a substantial revision of the structure of the system itself. This experience is considered important in deliberating on technology recommendations for the Irish SIS.

While CanSIS does provide data online, accessible via a web browser, the main thrust of CanSIS is towards the distribution of the core GIS files through traditional means, i.e. CD-ROM in ArcInfo coverage format. While initially this may seem somewhat restrictive at a time when web-browser technology would seem to have advanced sufficiently to replace this approach, the philosophy underlying CanSIS seems broadly to be one of open distribution. The stated data policy is

> *…(to) maximize the availability and benefit of the information in the National Soil Data Base to clients and users, with a minimum impingement on AAFC resources*
>
> http://sis.agr.gc.ca/cansis/interaction.html

Where an Internet GIS is deployed (in a limited fashion) to distribute data full Open Geospatial Web Services are applied.

> *The Open Geospatial Consortium, Inc. (OGC) is an international industry consortium of 337 companies, government agencies and universities participating in a consensus process to develop publicly available interface specifications. OpenGIS® Specifications support interoperable*

solutions that 'geo-enable' the web, wireless and location-based services, and mainstream IT.

http://www.opengeospatial.org/ogc

Of particular importance, however, is the degree of ancillary information provided in support of the CanSIS core data. In particular, the presentation of the soil landscapes of Canada with soil descriptions and supporting imagery is a very helpful support to the potential user of CanSIS. Interestingly, though the data presented are relatively simple, it is extremely effective in aiding the user to visualise Canadian landscapes and their associated soils. It could be argued that this information is at least as helpful to many users as the provision of the detailed soil attribute tables that accompany traditional soil survey bulletins. While such profile attribute tables are essential in providing detailed soil data to the more knowledgeable soil data users, the inclusion of more general soil-landscape descriptive information should be considered an extremely positive addition to an SIS.

Recommendation

- **A representation of soil landscapes, describing landscapes and their associated soils, similar to that provided as part of CanSIS, should be included as part of the Irish SIS.**

4.3.1.2 NRCS-WSS

The WSS was chosen due to the significance of the work done over many years in the USA in the discipline of soil survey and because it is a dedicated web-based tool for delivery of traditional soil survey data. The WSS is a web application that provides producers, agencies and others with electronic access to relevant soil and related information needed to make use and management decisions about the land. The purposes of the WSS are described as:

- Provision of alternative to traditional hard-copy publication
- Provision of means for quicker delivery of information
- Reduction of publication backlog
- Provision of electronic access to full soil survey report content
- Provision of access to most current data.

http://websoilsurvey.nrcs.usda.gov/app/Help/WSS_HomePage_HowTo.pdf

The WSS allows users to view or print soil and thematic maps and tabular soil data reports online for an interactively chosen geographic area of interest (AOI). Users are also able to download soil data for use in their local GIS application. It is planned that web map (WMS) and feature services (WFS) will be developed. WFS and WMS are implementation specifications devised by the Open GeoSpatial Consortium to facilitate the distribution of either spatial feature classes (WFS) or registered map representations (WMS) over the Internet.

Users are presented with a browser view that facilitates access to the application via three view tabs. The first tab accesses the AOI view through which the user must interactively define an area of interest using the graphic tools provided. On selection of the AOI, all available information for the area chosen either in map, tabular or document format is reported back to the user. This function – known as *geographic search* – is a very useful tool in the WSS. A similar tool would be particularly useful in the Irish SIS due to the somewhat fragmented nature of Irish soil data.

Recommendation

- **The Irish SIS at a minimum should include a geographic search function that returns a list of available soil data for any selected area. The returned list should both provide details of the availability of the data and provide a contact link to the appropriate source of the data. A link should also be provided to the metadata file for all data listed.**

The second tab brings users to a map view where digital soil survey data are presented for the AOI with an accompanying attribute table. Both the map and attributes are controlled by the AOI and only data within the AOI search box are represented. For the map data, the AOI frame is used to subset the original soil data and is then set as a bounding frame for the map data. While this method should lead to improved data delivery speeds this feature could prove cumbersome to a user intent on just browsing the soils data, as it would require revisiting the

AOI window and redrawing the AOI every time a new soil map view is required.

The final tab, termed Soil Data Explorer provides access to interpreted data from the soil survey reports such as soil suitability for development, septic tank installation, plant productivity, etc. These data are also provided on an AOI defined basis. This tool is extremely effective in its delivery of targeted user information. This success is chiefly due to the fact that many areas of the USA are surveyed at a significantly larger, more detailed, scale than in Ireland. Unsurprising though it is, it is worth noting that these interpretative reports, despite being derived from larger-scale soil surveys, still advise users that, due to soil variability, on-site testing should always be performed.

The WSS does have some drawbacks such as the lack of an immediate connection to industry-standard metadata presentation and perhaps a user interface that is not immediately intuitive to use. Despite these relatively minor issues the WSS is an excellent example of the application of browser-based GIS viewing and reporting capabilities to the distribution of traditional soil survey data in digital format.

4.3.1.3 EUSIS

Similar to CanSIS, EUSIS has been in development for quite a number of years. Le Bas *et al.* (1998) trace the development of an SIS for Europe from the digitisation of the EC Soil Map in 1986 under the CORINE programme. This development was the first 'spatialised' database and was named Version 1.0. Further development under the MARS (Monitoring Agriculture with Remote Sensing) programme led to the development of Version 2.0 and subsequent initiatives designed to meet the needs of the European Environment Agency have continued to enhance the data held in the information system.

At the heart of the SIS are a number of databases including the Soil Geographical Database of Eurasia (SGDBE), the Soil Profile Analytical Database of Europe (SPADE), the Hydraulic Properties of European Soils (HYPRES) and the Pedotransfer Rules Knowledge (PTR). The basic soil data are provided at a 1:1,000,000 scale. Current testing at a number of sites in Europe is assessing various methodologies for the production of a 1:250,000-scale soil map of Europe.

The EUSIS concept is based on the intention of the European Commission to have the broad range of soil data in the above soil databases integrated into a nested SIS for Europe. The planned EUSIS would be compatible with both the World Soil and Terrain database (SOTER) but should also link up with national and regional SISs providing a multi-scale information system from local (1:5–10,000) up to global scale (1:5,000,000 or smaller).

One of the key differentiators of the EUSIS concept from CanSIS and NRCS-WSS is its focus on the creation and provision of modelled, interpreted data based on the core soil data from the SGDBE. While the small map scale of the core soil data (and its consequent lower resolution) is probably a considerable driver behind this modelling effort, the requirement of monitoring and reporting at European level to meet various European legislative obligations is also fundamental to these efforts. To facilitate the development of these interpretative products, EUSIS seeks to incorporate pedotransfer rules that allow the preparation of derived products, such as soil erosion risk maps, soil organic carbon estimates, susceptibility to subsoil compaction, and water-holding capacity amongst others.

Access to the data is currently provided by a collection of applications designed to conform with the INSPIRE requirements. The applications are browser-viewable and are configured as WMS which allow appropriately configured client GIS software to connect with the data services and incorporate them with data held on a local machine or from other WMS servers. Applications include the Multiscale European Soil Information System (MEUSIS), the Eco-pedological Map of the Alps (ECALP), and Soil Profiles of Europe.

4.3.1.4 Comparison of reviewed systems

The three systems chosen for review represent different implementations of SISs. As such they represent suitable comparative cases for exploring the options on which to model the design and build of the Irish SIS. Ultimately the three systems have both attributes that are desirable for the Irish SIS but also those that could not, or perhaps should not, be included.

The following section examines the three systems in the context of the desirable aspects and functions of an Irish SIS. In this way, the review of the systems provides an illustrative basis for the consideration of the Irish SIS and avoids an abstract discussion on various design aspects. Importantly, this review and discussion can be used to inform future developments of an Irish SIS and in particular any discussions with prospective contractors can be guided by the examples provided by the three systems and the conclusions drawn here. Figure 4.1 gives a simplified representation of the relationship between selected aspects of the three 'model' systems.

CanSIS represents the simplest implementation but with its associated data it is perhaps the most useful to the non-specialist user of an SIS. The 'non-specialist user' in this context is not necessarily confined to members of the public with a passing interest in soils. In many of the more specialised disciplines including engineering, hydrology, etc., specific knowledge of soils is often lacking. In these cases, there is a necessity to provide educational material to the user, along with provision of the core data to help avoid misuse of the data.

The CanSIS model represents a simple but highly effective method to ensure that basic soil information is provided to assist any intending users. The Irish SIS should be required to include this function. It could be strongly argued that the inclusion of this function alone, using simple web pages and not necessarily employing browser GIS tools along with delivery of digital data via traditional routes such as CD-ROM, would instantly lead to a better understanding of the complexity of Irish soils and improved use of soil data. This enhanced understanding would lead to a more informed approach to the use of soils data, which surely must be a desirable function of any SIS. In fact the development of an Irish SIS without this function could arguably lead to a reduction in appropriate use of soil data. By facilitating improved access to data without this associated, supporting information there would be a greater capacity for naive and poor use of the data.

Development time and costs, if a minimal CanSIS-type implementation were chosen, would for the most part be small. In this case, the development of a soil-landscape website could be completed in a number of weeks based on using soil associations from the GSM without any further improvement. The only time delays envisaged would be in the collating and preparing of appropriate imagery to accompany soil landscape descriptions and in the processing of soil data to a suitable standard. The collation and preparation of associated imagery would be an important part of the production process and the effort should seek to maximise the appropriateness of the chosen imagery, the effectiveness of the accompanying text and the efficiency/speed of delivery of the information. With an image-heavy site, delivery speed will be an important consideration that could be overlooked.

The NRCS-WSS is in many ways an excellent implementation of the delivery of traditional soil survey derived data. The WSS benefits from the underpinning massive amount of core data from the USDA soil survey programme which has been operating over many years. This work has provided very detailed, larger-scale soil surveys for many areas, down to 1:12,000 in certain cases. The project also benefits from the application of a user-focussed approach to soil survey and soil survey data where a huge amount of effort has gone into interpreting the core survey data and presenting results in a targeted manner to a range of identified users. In Ireland, the vast bulk of soil survey data, where they exist, has been subject only to limited, agriculturally focussed interpretation. The operational scale of Irish soil survey data will always present a fundamental obstacle to the extensive provision of interpretive data. Arising from this, the Irish SIS should probably seek only to implement the best aspects of the soil map data provision with associated reporting of survey attribute information as seen in the WSS application. Along with the AOI information tool, this combination alone would provide a significant and very worthwhile advance on the current state of play.

Development time and costs for the WSS model would be significantly more than in the case of CanSIS. The principal software costs would include web-based GIS server technology to deliver the soil data. Hardware costs would include a storage server for the spatial data and web server to deliver the data via the internet. While transactional database technology may not necessarily be required, current GIS network architectures favour the implementation of server-side database storage to ensure enhanced delivery of spatial data over the web. Such technology is normally expensive. While these software and hardware costs will seem high in costings prepared for the Irish SIS design, it should be noted that the key stakeholders currently deploy or intend to deploy similar architectures, and opportunities for economies of scale could arise.

While the software and hardware costs will seem high the costs of data preparation will also be important. Such preparation as digitising, etc., can take the bulk of time allocated to a project and will more often than not greatly exceed the time required for software development. The

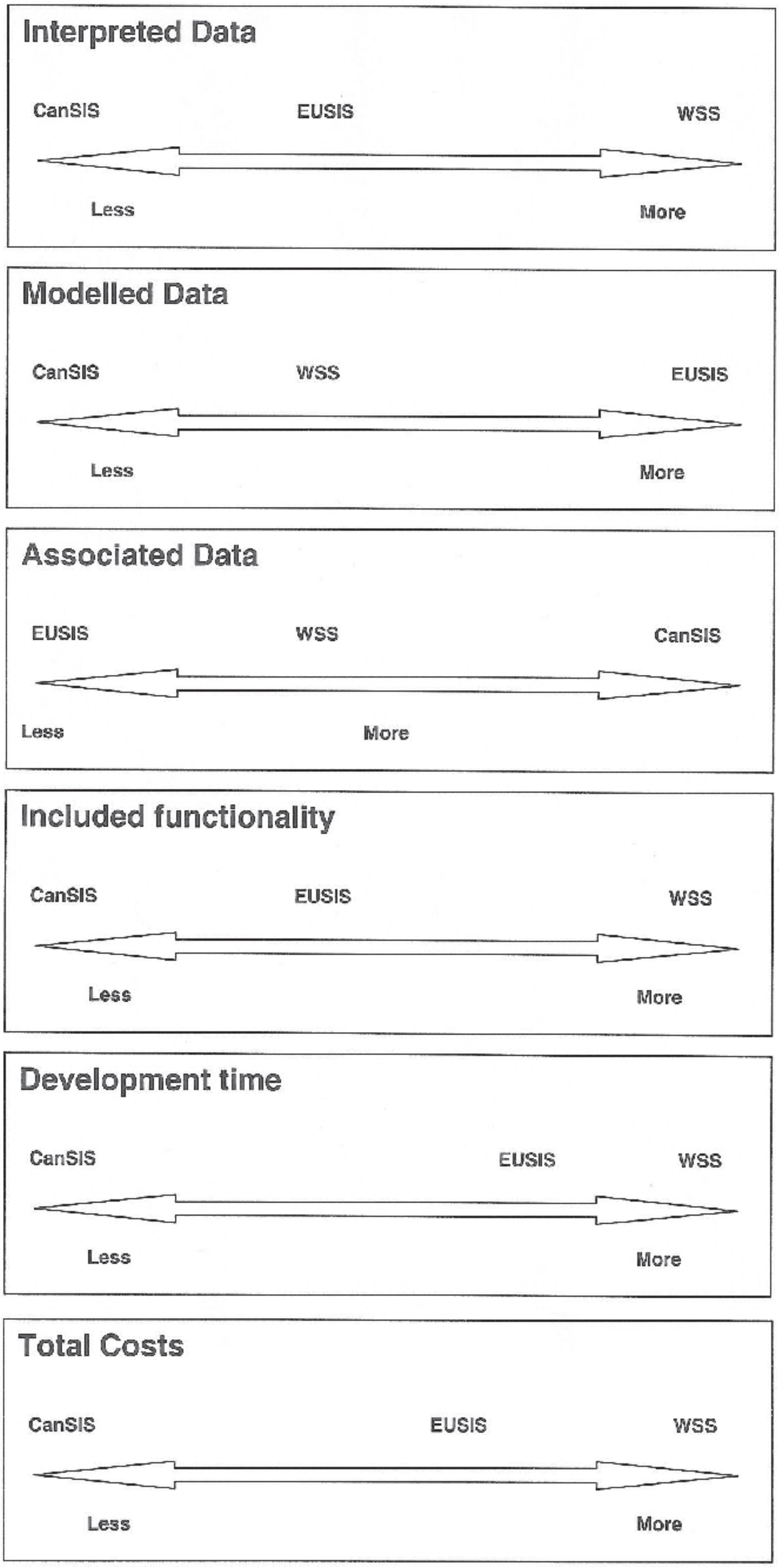

Figure 4.1. Simplified representation of the relationship between selected aspects of the three 'model' systems.

tasks involved in data digitising, editing and cleaning are labour intensive and subsequently costly. However, most of the proposed core data sets for the Irish SIS are already in digital format. Costs therefore will arise in any further formatting and standardisation requirements that may arise.

A further potential cost of the WSS model is the provision of background display mapping such as ortho-photography. These data are generally supplied by the Ordnance Survey of Ireland on an annual licence basis and would represent a significant cost. The increasing availability of high-resolution satellite imagery provides a potential alternative that could be investigated. There is a possibility that the data licences held by the key stakeholders (Teagasc and the EPA) would extend to this background mapping function and potential outlay would be significantly reduced.

In EUSIS, the development of a number of applications to view various and often complex derived and modelled soil data represents ongoing and interesting work in the area of predictive soil modelling. There is a potential difficulty in seeking to translate this model to the Irish SIS however. At pan-European scale, the extent of aggregation of results across large areas and the assessment of such results from aggregated areas will tend towards a smoothing of the output modelled data. If similar modelling efforts are to be applied at a national scale the aggregation effect would be lessened and gross errors would be more pronounced. This could result in not alone poor decisions being made from a policy perspective but also a reduction or removal of trust in the capabilities of an Irish SIS by intended users. In many ways EUSIS could be classified in capability terms as approaching the notion of a soil inference system which is further discussed in Section 4.3.2.

Development time and costs for the EUSIS model will for the most part mirror those of the WSS model. Where costs would diverge in the models as presented is in the separate development of applications as in the current implementation of EUSIS. However, it is currently envisaged that such applications would not be separate functions of the Irish SIS. Any derived maps, approved for publication to the system by the system managers should be made available from a standard interface and not comprise a separate application space.

4.3.2 Note on soil inference systems

There is a growing tendency towards the promotion of predictive soil mapping methods that seek to derive outputs such as those developed under the EUSIS pedotransfer initiative. Rossiter (2005) examines the growing demand for interpreted information from soil data users. He distinguishes between the traditional *supply-driven* approach where presented data products were of a form chosen by the data creators and the newer *demand-driven* approach where demand for soil data is being driven increasingly by environmental modellers, land-use planners, engineers and hydrologists.

McBratney *et el.* (2002) proposed the use of pedotransfer functions in developing a first approach to what they termed soil inference systems. They expanded on this theme and went further to propose a *scorpan-SSPF* approach which would "*replace the polygon-based soil maps of the past*" (McBratney *et el.*, 2003, p. 39). Lagacherie and McBratney (2006) have concluded that SISs must now extend their functionality and begin to not only reproduce static digital soil data but to begin creating new maps based on the suggested scorpan-SSPF approach.

While the proposed approaches offer an exciting view of the future of SISs, great care needs to be taken in the context of the proposed development of the Irish SIS. Lagacherie and McBratney (2006) themselves concede that there are important issues to be addressed before the suggested convergence in inferential soil mapping can take place. The input data required to drive such inference engines such as actual soil observations are often scarce and nearly always costly to acquire. Developing appropriate sampling strategies is therefore important but is not easily achieved. The choice of inference pathway requires optimising which is not straightforward. Ultimately the proposed soil inference systems will also face the same challenge of demand for interpretation by users that current, simpler SISs face.

While any proposed SIS for Ireland should be designed to the most modern standards and future-proofed to avoid becoming obsolete, care must equally be taken that the SIS development proposal is reasonable and achievable. In reality, it is probable that the area of soil inference systems will remain in the research domain for a number of years. This is probably especially the case in Ireland where we still lack an extensive core database of observed soil properties and are therefore missing a fundamental input into any inference system. The soils research community in Ireland should monitor developments in this area, and perhaps should be encouraged to do so by client agencies. Support for the collection of soil observations would greatly enhance the potential for inference system development. Downstream developments in this area should be connectable to any SIS developed for Ireland. In the interim however, the development of the Irish SIS should proceed on the basis that it will be constructed to deliver *available* digital soil data. In maintaining the focus as such it will prevent the project getting bogged down in aspirational development areas which will lead to further delays in distributing soil data to Irish users.

Recommendation

- **The focus of the Irish SIS should be on the delivery of existing digital soil data. While a soil inference system approach should not be part of the initial design focus, the final system should take account of the potential downstream adoption of such technology.**

4.4 System Outline and Technology Requirements

4.4.1 Options

Following from the above review of key international SISs, Sections 4.4.1.1–4.4.1.3 suggest options for the development of the Irish SIS and make recommendations on how the system development should progress. The use of the reviewed international systems as model options provides immediately accessible examples to facilitate detailed or formal design discussions concerning the system.

There is a tendency to reinvent the wheel in system development projects. Using these reviewed systems as benchmarks will aid in the avoidance of unnecessary duplicated development effort: the Irish system does not necessarily need to be – and should not be – designed in a vacuum.

‘Proofs-of-concept’ are already available in existing systems and this will help to rapidly accelerate the pace of development of the Irish system. This will not obviate totally the need for test phases in the development of an Irish system but should accelerate the design phase where working examples can be referenced in any detailed specification documentation.

Based on the review of the three operating SISs, three options for the Irish system emerge. Option 1 provides the fastest development interval with a basic data delivery mechanism but would arguably prove overly simplistic for requirements. The other options involve development of web applications of varying complexity and will entail higher costs. These costs may be mitigated however and this will be discussed below.

4.4.1.1 Option 1

Consideration of Options 1 and 2 as presented here arise primarily from discussions held at steering group level for this scoping study. An issue was raised concerning the potential misuse of data that can arise when digital data are made freely available. Users often have only a passing knowledge, if any, of scale issues and the complexity of soil variation on the ground. In the absence of this knowledge, soil data that are accessed over the Internet can be used to make site-level assessment or adjudications which could be prejudicial to various interested parties.

One of the options suggested by the steering group for consideration was that the SIS would act not as a delivery mechanism for online data delivery but solely as a 'discovery' tool for soil data. Under this design, option users would be able to specify a geographical area and the system would return a record of all the soil data that existed for that area. As well as giving a full report on the background context to the data and their creation, the returned information would allow the user to make direct contact with the suppliers named in the metadata supplied as part of the returned query.

This option would follow the CanSIS model with some modification. No specialist software is required and therefore the costs are low. The design would be based on a straightforward web page approach with no GIS requirements. Essentially the user could be provided with a search tool that could be presented as a series of dropdown lists of geographic administrative units of Ireland such as counties down to townlands. Alternatively, the search function could perform a simplified point-in-geometry select on a graphic of counties or any other geometry chosen to represent a chosen level of administrative detail. The search function would search a database containing lists of soil data available.

Construction of the database tables would be straightforward and would only require that appropriate location field(s) be completed to facilitate the user query. Requests for actual data could then be made to the listed data holders.

Construction and management costs for Option 1 would be minimal. It would still require a management plan to ensure that all new soil data created would be entered into the database but this management overhead would also be minimal. The advantages and disadvantages of Option 1 are described in Table 4.1.

4.4.1.2 Option 2

Following from the steering group's recommendation, Option 2 also takes the underlying principle of a soil data discovery tool as its lead. However, this approach to an SIS provides a more sophisticated mode of interaction with the available data.

Option 2 provides for web-based portal access to the metadata for selected soils data. The actual soil data are not held on the system but reside with the original data holders. Standardised metadata documents can be published to a metadata server. Potential users of the soil data can search for data and, if desired, can view the data using simple lightweight GIS tools or web services. Metadata documents should be published to best practise international standards. Currently, the ISO 19115 standard is probably the standard most likely to be adopted by the Irish Spatial Data Infrastructure (ISDI) initiative. In any case, the standard chosen should be aligned with the final ISDI recommendations.

Option 2 would allow users to search by various categories such as scale (digital data could be themed by scale, e.g. 1:50,000…1:127,560…, etc.), thematic type (soil series, soil group) or address. A geographic search by map function could easily be incorporated into the implementation of this option using a simple map viewer tool.

If fully implemented, Option 2 could provide an online delivery mechanism for spatial soils data. It is probable however that, in this system configuration, users wishing to incorporate soil data into an analytical framework would seek off-line access to the data which would be distributed through traditional channels (CD-ROM, etc.) The advantages and disadvantages of Option 2 are described in Table 4.2.

4.4.1.3 Option 3

Option 3 would involve the most comprehensive approach to establishing an Irish SIS. This option would incorporate the metadata search and discovery functionality of Option 2. However, the key feature of Option 3 is the

Table 4.1. The advantages and disadvantages of Option 1.

	Advantages	Disadvantages
Option 1	• Extremely cheap to build • Low overhead on maintenance and ongoing management • Rapid set-up time • No data management issues • Cost-effective • Complies with all INSPIRE data **discovery** principles	• Overly simple • Does not overcome poor data supply issues • Restricts data users to those who have GIS access • Does not encourage use of the data • Data provision by traditional means, e.g. CD-ROM • No reporting functionality

Table 4.2. The advantages and disadvantages of Option 2.

	Advantages	Disadvantages
Option 2	• International standards based system to store and access metadata on digital soils data in Ireland • Low overhead on maintenance and ongoing management • Relatively fast set-up time • Metadata documentation easily published using industry-standard desktop GIS tools • Users can view soil data • No data management issues with original data (data maintained by originator) • Complies with INSPIRE principles on data **discovery** and **documentation**	• Requires additional software and hardware (metadata Internet server) • More expensive to implement • Relies on data holders to publish web services to enable access • Requires data holders to maintain and update metadata to ensure currency • Limited reporting functionality • Could lead to misuse of data in the absence of appropriate 'training' documentation

construction of a unified database for all soil information in Ireland. The construction of this database could offer traditional database technology advantages such as versioning. Versioning allows multiple instances of a database to be stored, which facilitates tracking of all edits made to the data. Versioning may become more important in light of developments at European level which may lead to a reinvigoration of soil data collection/creation in Ireland. Although not currently planned, if such a campaign were to begin the management of versions would become increasingly critical to the management of soil data.

Current geographic database technology also provides for significant improvement in data delivery speed. This would be of particular relevance in the case of supplying grid or image files which have a high transport overhead on networks. Even in the simplest case of supplying background aerial imagery, such as the national orthophotographic data set, it is likely that Option 3 provides the only practical solution. It is probable that there will be an increased use of grid format files in the future. Many modern applications of soil data such as their use in modelling require grid-formatted data. Examples include applications developed as part of EUSIS such as PESERA (Pan-European Soil Erosion Estimates) (Kirkby *et al.*, 2004).

Option 3 would also provide a comprehensive reporting module. As seen by its application in the NRCS-WSS, the implementation of an Option 3 type solution provides a high level of control over the generation and display of reports based on area searches. The only limitation to report creation functionality of this implementation is the availability or otherwise of attribute or interpretative data to provide the reporting content. The technology is not limiting in this case unlike in the other options presented.

Of particular importance, Option 3 would also provide functional scalability. If desired, GIS services at server level could provide users with deeper analytical capability. Using these services, applications could be designed and served to users who could incorporate data from other sources and perform GIS analysis, such as overlay and intersect, summary functions, point-in-polygon analysis, etc. This option is obviously a very large step-up from providing just a viewing functionality for the data and it moves the envisaged Irish SIS away from the simpler discover-and-view type Internet GIS towards a more enterprise-style functionality level with Internet-served application functionality. As such, software licensing requirements would change depending on the functionality required. The advantages and disadvantages of Option 3 are described in Table 4.3.

Table 4.3. The advantages and disadvantages of Option 3.

	Advantages	Disadvantages
Option 3	• International standards based system to store and access digital soils data in Ireland • Metadata documentation easily published using industry-standard desktop GIS tools • Users can view and interact with soil data • Efficient data transfer • Extensive reporting functionality • Centralised data management (data maintained by system manager/organisation) • Complies with **all** INSPIRE principles	• Requires additional software and hardware (metadata Internet server) • High overhead on maintenance and ongoing management • Relatively slow set-up time • More expensive to implement • Could lead to misuse of data in the absence of appropriate 'training' documentation

4.4.2 Technology

The two key organisational stakeholders in the construction of an Irish SIS are clearly the EPA and Teagasc. Both organisations already have advanced in-house GIS capability. In both cases, considerable investment has been made in the GIS technology platform provided by the ESRI (Environmental Systems Research Institute). The GIS software provided by the ESRI is a robust, well-tested industry-standard platform. Software solutions are designed to be scaleable and interoperability is becoming an increasingly important focus. In light of this, it makes considerable sense that the software deployed to underpin the Irish SIS should be provided by the ESRI.

The technology offering from the ESRI has developed significantly in recent years. The most recent release of the ArcGIS product suite at level 9.2 represents a significant maturing of the technology. This is particularly the case with the ArcGIS Server which offers an integrated solution to the complex process of developing and managing network-GIS applications.

Recommendation

- **Due to the investment in GIS software already committed by the EPA and Teagasc, the Irish SIS should be developed using the GIS platform provided by the ESRI.**

As ESRI GIS technology has matured, the requirement to develop detailed specifications in a user requirement specification is redundant as most functions are available 'out of the box'. Previously, simple functionality at the interface level, such as the inclusion of user tools, e.g. panning, zooming area select, etc., would need detailed specification, particularly if proprietary software was envisaged, but this is no longer the case. In many ways, the model for software provision has changed and the focus is moving towards a mode of organic development. The capacity for software solutions to be scaleable in the sense that organisations can deploy solutions at a particular level of functionality and adjust their licensing structure subsequently if dictated by operational requirements means that solutions no longer need to be statically delivered.

In this sense, a solution can evolve as required where this requirement is based on operational monitoring or requests from the user base. The specification for a system should therefore be based on a conceptual base requirement. This base requirement should be specified following consultative-level interactions between the appropriate software provider and the key stakeholders. At this level of interaction, the model for data storage and provision of external access can be developed in tandem with the preferred supplier and detailed costing can be subsequently provided.

Prior to agreement of the conceptual model for data provision, it is strongly recommended that discussions should take place between the stakeholders on agreeing the appropriate management structure for the envisaged system. This is extremely important as the design and implementation of the system will vary according to how this structure is established. In the absence of this discussion and agreement, it is likely that duplication of effort could arise with an attendant increase in costs and a reduction in a clear rationale and operational environment for the system. It is highly advisable that the stakeholders commit time and personnel to the provision of management for the proposed SIS. Such a resource commitment would ensure as broad a user base as possible and would facilitate service delivery to users who may not be familiar with GIS.

Recommendation

- **Before proceeding with an Irish SIS development, agreement should be reached by the key stakeholder organisations (the EPA and Teagasc) on the management structure for the Irish SIS.**

A key step in the development process is the agreement of the conceptual requirements of the system. This part of the process can be based largely on these scoping study findings and by reference to the proposed options. It is clear from the comparison of options presented that implementation at Option 3 is the minimum required to satisfy the initial expression of desirable specifications as outlined in the supporting documentation for the scoping study. However, the contribution of the project steering group with regard to avoiding the potential misuse of soil data would favour implementation of an Option 2 type system. Clarification of the actual operational requirements by the stakeholders will facilitate a final decision on which conceptual implementation of the Irish SIS will be the most appropriate.

Recommendation

- **Following from agreement on a management structure, a decision should be made, guided by this document and the options provided, on the conceptual model of data provision for the Irish SIS.**

Subsequent to agreement on the conceptual model and management structure, the technical specification should then principally involve the GIS staff of the stakeholder organisation(s) working in tandem with the preferred software supplier. Following from this technical consultative stage, the output will be a detailed specification of software and services provision and costs from the supplier.

The system recommended in this document and its approximate costing are based on the presumption that the Irish SIS is built as a completely new system. Given that the key stakeholders involved already have GIS technology in place, this could potentially modify the system recommendation in order to incorporate it into a current technology platform.

As outlined above, the Irish SIS should be built on an ESRI ArcServer platform. The current release is at 9.2 and should be the technology level of choice for a new system implementation. ArcServer comes in a number of editions and levels. Implementation of an ArcServer-based solution will depend on the final system specification guided by the option choices. A key benefit of using ArcServer technology is the opportunity for scalability. If the functional requirements of the system increase, the implementation level of the software can be adjusted upwards and licensed accordingly. An ArcServer solution will enable current investment by the key stakeholders in GIS technology and training to be fully leveraged

At a minimum, the system will require implementation at **Standard edition** and **Workgroup level**. All of the functionality that would be required to implement Option 3 as described would be provided by the Standard edition. Workgroup level is restricted to a 4 GB data limit and the number of direct connect users is limited to ten. Enterprise level has no user or data limits. The decision on which level – Workgroup or Enterprise – will be dictated by the final functional requirements. Ultimately these functional specifications will need to be specified by the contracting agency. In this case, a functional specification will depend on whether the ultimate functionality of the Irish SIS is envisaged as bringing Irish soil geospatial data to a standard described by INSPIRE or whether the final use is as an internal reporting and analysis tool. In the latter scenario, internal transactional editing or user requirement could ultimately dictate implementation at Enterprise level.

4.4.3 Available data for inclusion

4.4.3.1 Map data

The range of available data to include in the system has been identified by the data inventory component of this scoping exercise. In essence, the majority of the data that should be included have been developed by Teagasc, either through its NSS agency or more recently through externally funded projects such as the EPA–Teagasc soils and subsoils project and the *National Soil Database* project. The Irish SIS should ideally include all the soil data that have been produced by Teagasc but at a minimum should include the following national data sets:

- 1:127,560 county (or parts thereof – often published as resource surveys) soil surveys
- *National Soil Database*
- EPA soils and subsoils project soil and subsoil county maps
- *General Soil Map of Ireland*
- *The Peatlands of Ireland Map.*

Additional data sets of value would include:

- An Foras Talúntais farm surveys
- Other farm surveys (Dept of Agriculture farms, etc.).

These data sets if in digital form are either point or polygon type data sets and will not conceptually cause major difficulties for system integration. However, digitising and processing of these data sets may not necessarily have been undertaken using standardised protocols across all products which might lead to further processing being required. This further processing would be minimal in the event that Option 2 was chosen or if viewing capability only was required from the system. In such cases, the alignment of boundary data sets would be less of an issue. These data sets if in digital form are either point or polygon type data sets and will not conceptually cause major difficulties for system integration. However, historically, digitising and processing of these data sets have been undertaken at different times and by different personnel. Consequently, standardised protocols have not been used across all products which will lead to further processing being required. This further processing would be minimal in the event that Option 2 were chosen or if viewing capability only were required from the system. In such cases, the alignment of boundary data sets would be less of an issue.

However, if the system is to be built in full anticipation of INSPIRE principles as recommended by this scoping study, then full processing of these data sets should take place to ensure that a national standardised suite of state soil data sets is finally developed and made available. This further processing of the data sets will add additional initial costs to the construction of the database but as envisaged by INSPIRE it will eventually lead to downstream efficiencies being achieved and ultimately to cost savings. In the event that an ArcGIS solution is implemented, the process of designing suitable schemata for data loading and the enforcement of topological rules will largely assist in this process.

Recommendation

- **Processing of the core input soil data sets should take place where necessary to guarantee a uniformity of standards across soil data sets. This may largely be achieved by suitable planning and design at the data-load stage in an ArcGIS-based solution.**

4.4.3.2 Attribute data

The primary attribute data that will be incorporated into the Irish SIS will be derived from the published attribute tables in the case of NSS data sets and accompanying attribute tables in the case of more recently developed data such as the EPA soils and subsoils map data. The NSS-published county maps have attribute data consisting of profile description tables that describe each individual soil series. Both the GSM and the *Peatlands Map of Ireland* have similar attributes where typical profile descriptions are included along with analytical data. Typically a similar model was used in publishing the resource surveys.

In these cases, the profile data refer to a modal profile. It would be beneficial to the SIS if these data could be geo-referenced. This would allocate each profile record with geographic co-ordinates which would facilitate display with other spatial data in the system. A reference system was used for some counties using a location grid for the 1:10,560 map series. Where this information is recorded accurately geo-referencing the profile data is relatively straightforward. However, in cases where these data are absent, the task will be far from easy and will probably require interaction with ex-members of the NSS.

Recommendation

- **In so far as is possible, the geographic co-ordinates of the modal profiles described in the published soil survey bulletins should be determined and incorporated into the system.**

In the case of data sets more recently produced, including the EPA soils and subsoils map data, the attribute tables supplied consist of an indicative soil or subsoil class. In these cases, the only associated data of relevance are the textual description of the particular soil/subsoil types. The *National Soil Database* is composed of two data types: the original point data and geostatistically derived raster maps. The point data have associated field-collected attributes with subsequent analytical results for the various geochemical properties. The geostatistically derived data sets are composed of individual raster layers representing modelled geochemical property values.

4.4.3.3 Metadata

As directed by INSPIRE and legally required 2 years after transposition into national law, metadata on all state-produced soils data will need to be created. Although this transposition could take some time, the development of metadata should proceed anyway. Ultimately the appropriate standards for metadata creation will be the subject of Implementing Rules under the Directive. In the meantime, the process of creating formal metadata documentation should proceed, guided by standards emerging from Europe. As standards are tending towards convergence, any metadata created prior to formal publication of the Implementing Rules will be modifiable subsequently with relatively little effort. Any costs arising from the necessity for such conversion should be largely offset by the gains made in making search and discovery of data more efficient which is fully complaint with the goals of INSPIRE.

Recommendation

- **Creation of formal metadata for core data sets should proceed, if necessary prior to finalisation of the Implementing Rules under the INSPIRE initiative. However, this creation stage should be fully informed by developments at INSPIRE level.**

4.4.3.4 Documents

A number of key documents are available that support the core data sets. These are the accompanying bulletins to the NSS maps and the project final reports accompanying recent projects. These documents should be made available in electronic format and made accessible via the Irish SIS.

> **Recommendation**
>
> - **Taking consideration of any copyright issues, the key documents that support the core data sets should be made electronically available through the SIS interface.**

Consideration should be made of developing and including a linked bibliography of academic papers or reports concerning Irish soils. Although not extensive, this inclusion of such an option would be very beneficial from both an archiving perspective and for guiding and educating potential users of soil data.

4.4.4 *Outline data structure*

The final design of the database structure for the Irish SIS will be dictated by the outcomes of the consultations between the stakeholders as recommended above. It is possible at this stage to outline a schematic representation of the table relationships that should be constructed in the database.

In the case of the polygon data from the NSS, the relationships are described in Fig. 4.2 and Table 4.4 as an entity relationship diagram and explanatory tables, respectively.

The table relationships are provided as an indicative model to guide the construction of the final database. Ultimately the table design should be configured by the system supplier to maximise efficiencies within the supplied software. The model table design presented here would apply to the published NSS data, including resource surveys. The table design for the GSM, the *Peatlands of Ireland Map*, EPA soil and subsoils maps and *National Soil Database* maps would be significantly more straightforward as the attributes associated with these data sets are relatively simple.

In most cases, a two-table design will suffice with a code for the unique soil type linked to a descriptor table in the case of the former three data sets. In the case of the *National Soil Database*, a unique identifier for each point could link with one or two tables (e.g. splitting field and laboratory data), depending on preference and performance issues.

4.5 Estimate of Costs

Table 4.5 contains estimated costs for the construction of the Irish SIS. Costs are assessed on the basis of whether external input is required and a presumption is made that internal costs arise where personnel from the key stakeholders – the EPA and/or Teagasc – can perform the functions listed.

4.6 Summary of Key Recommendations

- The Irish Soil Information System should be designed and built in full compliance with **anticipated legislative obligations** relevant to spatial soil data arising from the INSPIRE Directive.

- The Irish SIS should also be designed and constructed in a manner that is consistent, wherever possible, with the **underlying principles** of the INSPIRE initiative.

- A representation of soil landscapes, describing landscapes and their associated soils, similar to that provided as part of CanSIS, should be included as part of the Irish SIS.

- The Irish SIS should at a minimum include a geographic search function that returns a list of available soil data for any selected area. The returned list should provide both detail of the availability of the data and a contact link to the appropriate source of the data. A link should also be provided to the metadata file for all data listed.

- The focus of the Irish SIS should be on the delivery of existing digital soil data. While a soil inference system approach should not be part of the initial design focus, the final system should take account of the potential downstream adoption of such technology.

- Due to the investment in GIS software already committed by the EPA and Teagasc, the Irish SIS should be developed using the GIS platform provided by the ESRI.

- Before proceeding with an Irish SIS development, agreement should be reached by the key stakeholder organisations (the EPA and Teagasc) on the management structure for the Irish SIS.

- Following from agreement on a management structure a decision should be made, guided by this

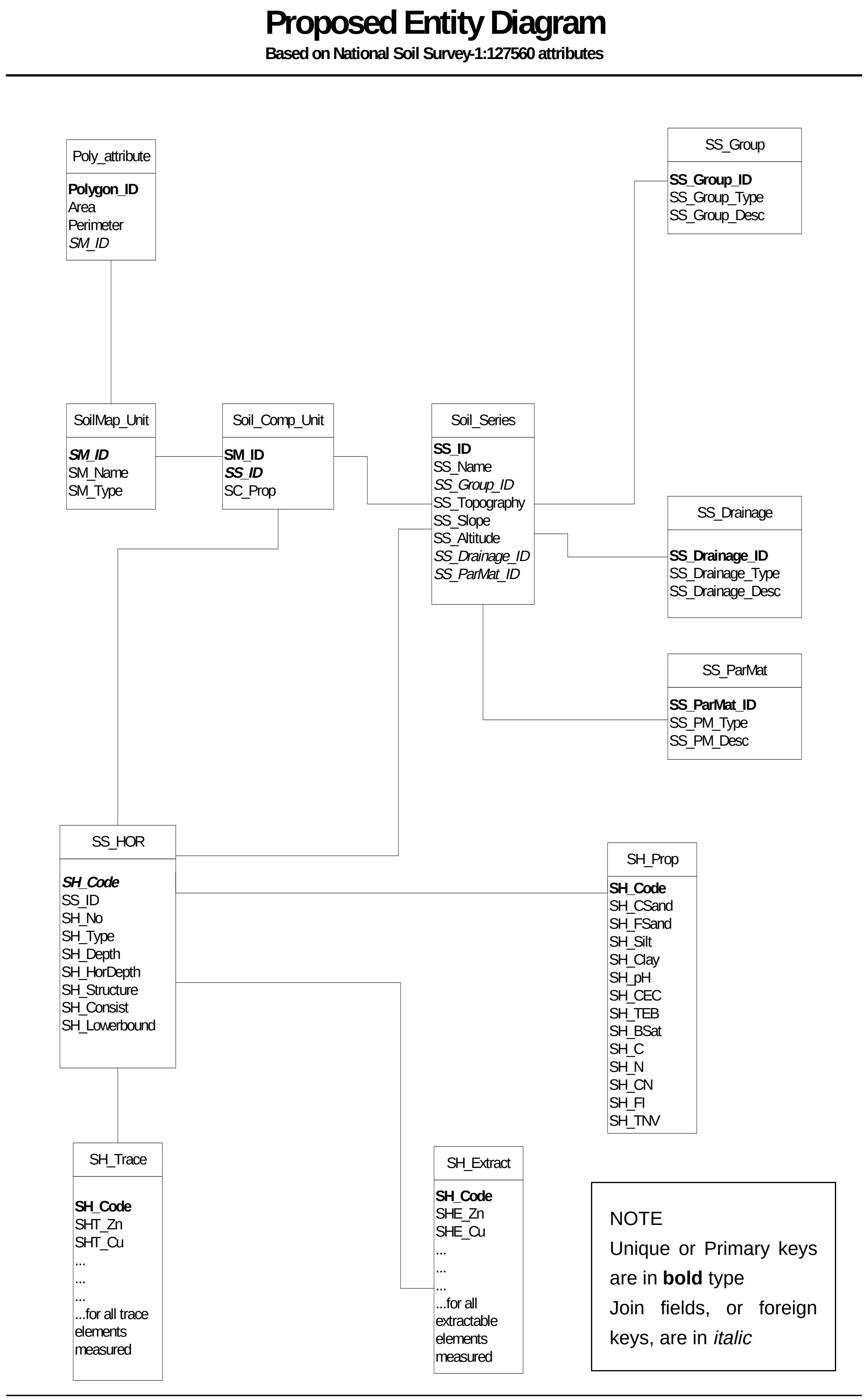

Figure 4.2. Proposed entity relationship diagram.

Table 4.4. Further description of the attributes shown in Fig. 4.2.

Field	Linked table	Comment
Table: Poly_attribute		
Polygon_ID		Unique ID
Area		
Perimeter		
SM_ID	SoilMap_unit	Map unit name
Table: SoilMap_Unit		
SM_ID	Soil_Comp_Unit	
SM_Name		Soil series name
SM_Type		Consociation, complex, association
Table: Soil_Comp_Unit		
SM_ID		
SS_ID	Soil_Series	For each SM_ID comprised of more than one soil, the SC_ID field links to the Soil_Series table where a detailed description of each member is described
SC_Prop		Proportionate membership of each SC_ID in SM_ID
Table: Soil_Series		
SS_ID		Soil series code
SS_Name		Soil series name
SS_Group_ID	SS_Group	Great Soil Group ID
SS_Topography		
SS_Slope		
SS_Altitude		
SS_Drainage_ID	SS_Drainage	Drainage code
SS_ParMat_ID	SS_ParMat	Parent material code
Table: SS_Group		
SS_Group_ID		
SS_Group_Type		Great Soil Group
SS_Group_Desc		Description of groups
Table: SS_Drainage		
SS_Drainage_ID		
SS_Drainage_Type		Excessive, Poorly, etc.
SS_Drainage_Desc		Description of types
Table: SS_ParMat		
SS_ParMat_ID		
SS_PM_Type		Parent material name
SS_PM_Desc		Parent material description
Table: SS_HOR		
SH_Code	SH_Prop, SH_Trace, SH_Extract	Unique identifier
SS_ID		
SH_No		Horizon number
SH_Type		Horizon A, B, C
SH _Depth		Depth to top of horizon
SH_HorDepth		Thickness of horizon
SH_Structure		Structure
SH_Consist		Consistency
SH_Lowerbound		Type of boundary to next horizon

Table 4.4. ***Contd.***

Field	Linked table	Comment
Table: SH_Prop		
SH_Code		
SH_CSand		% coarse sand
SH_FSand		% coarse sand
SH_Silt		% silt
SH_Clay		% clay
SH_pH		pH
SH_CEC		Cation exchange capacity
SH_TEB		Total exchangeable bases
SH_Bsat		% Base saturation
SH_C		% Carbon
SH_N		% Nitrogen
SH_CN		Carbon/Nitrogen ratio
SH_FI		% Free iron
SH_TNV		Total neutralising value
Table:SH_Trace		
SH_Code		
SHT_Zn		Total zinc ppm
SHT_Cu		Total copper ppm
Etc.		…and so on for all total trace elements recorded
Table:SH_Extract		
SH_code		
SHE_Zn		Extractable zinc ppm
SHE_Cu		Extractable copper ppm
Etc.		…and so on for all extractable trace elements recorded

document and the options provided, on the conceptual model of data provision for the Irish SIS.

- Processing of the core input soil data sets should take place where necessary to guarantee a uniformity of standards across soil data sets. This may largely be achieved by suitable planning and design at the data-load stage in an ArcGIS-based solution.
- In so far as is possible, the geographic co-ordinates of the modal profiles described in the published soil survey bulletins should be determined and incorporated into the system.
- Creation of formal metadata for core data sets should proceed, if necessary prior to finalisation of the Implementing Rules under the INSPIRE initiative. However, this creation stage should be fully informed by developments at INSPIRE level.
- Taking consideration of any copyright issues, the key documents that support the core data sets should be made electronically available through the SIS interface.
- Formal agreements, in the form of memoranda of understanding (MOU) should be considered as a means of securing the provision of data, metadata, documentation and support from the data providers.

Table 4.5. System costings are based on an Option 3 solution using the listed core Teagasc data sets.

Description	Item	Item amount	€ Cost[4]	€ Subtotal
EXTERNAL COST[1]				
Software[2]	ArcServer 9.2 (Standard edition-Workgroup level)	1	22,000	22,000
Hardware[2,3]	DellQUAD CORE Intel® Xeon® 8 GB FB 533 MHz memory 292 GB storage	1	5,000	5,000
Subtotal				27,000
Consultancy days[5]	Consultation and design	6	6,000	
	Schema design and test	10	10,000	
	Data load and test	10	10,000	
	Interface	6	6,000	
	Reporting module	10	10,000	
	Deliver, test, tune	6	6,000	
Subtotal				48,000
External cost subtotal				**75,000**
INTERNAL COST[7,8]				
Data processing days				
NSS county data[9]	Geometry edit	60	14,400	
	Attribute table digitising	60	14,400	
	QA/QC	10	2,400	31,200
Farm surveys	Geometry digitising	40	9,600	15,360
	Attribute table digitising	20	4,800	
	QA/QC	5	960	
EPA soils and subsoils	Geometry edit	20	4,800	4,800
NSDA	Attributes edit	10	2,400	2,400
GSM	Geometry edit	10	2,400	2,880
	Attribute entry	2	480	
Peatlands of Ireland Map	Geometry edit	10	2,400	2,880
	Attribute entry	2	480	
Modal profile	Georeferencing[10]	40	9,600	9,600
GIS specialist supervision[8]	All aspects	80	27360	27,360
Internal cost subtotal				**96,480**
Total				**171,480[11]**

Notes:

1 ***External*** relates to consultancy work, i.e. non-Teagasc/EPA.

2 Software and hardware included on basis of complete set-up of system. These costs could be reduced or removed depending on state of in-house capability at time of system development. Back-up system not included.

3 Server model shown is included as a guide. Final configuration will vary depending on system specification. The inclusion of raster grid data from the *National Soil Database* will increase storage requirements.

4 All costs shown exclude VAT.

5 Estimate of required consultancy days is based on work being undertaken in tandem with internal staff. This figure will increase accordingly if a total solution is required to be supplied exclusively by external consultancy.

6 Consultancy days costed at €1000 per day.

7 ***Internal*** relates to staffing by Teagasc/EPA personnel. These are functions that are deemed to be optimally performed by internal staff familiar with the data products.

8 Costs for processing based on Teagasc ENT Technical Grade. Supervisory costs based on Teagasc Research Officer Grade. Superannuation and overheads included in *per diem* costs. Costs based on 2006 research contract cost conventions. A 5% annual inflator will also apply (not included).

9 Cost based on presumption that NSS data currently digitised are to a sufficiently high standard. This means no additional digitising required except for minor edits. The costs for digitising non-digitised surveyed counties are referred to in Chapter 3 of this report.

10 Based on geographic coding presumed availability.

11 While a certain amount of contingency has been built in to the processing days, an overall additive contingency inflator has not been applied to the total budget. This should be considered in assessing final costs.

5 Conclusions and Overarching Recommendations

The results from this scoping study indicate that the production of a 1:250,000 digital soil database and SIS for Ireland is both desirable in the context of developments at European level and achievable, given the extent of existing Irish data and the technologies and methodologies available to build such a valuable national resource. Whilst recommendations arising from the proposed methodology and specification have already been identified in the previous chapters, there are a number of overarching recommendations that are considered here.

5.1 Project Management Structure

The production of the 1:250,000 database should be overseen by a project co-ordinator and GIS specialist whose functions are to ensure that both phases of the work scoped out in Chapter 3 are executed to achieve the best results. Tasks scoped out within Phases 1 and 2 will also need project co-ordination of staff hired exclusively for this work and to ensure that their training needs are met and the direction of the work is in accordance with the overall aim of the project. The project co-ordinator and GIS specialist should ensure that the project connects with experts from Member States with experience in this area and that links with the European Commission are made so that events in Europe on soil issues are highlighted.

5.2 Review and Advisory Committee

It is strongly recommended that a future project proposal should include a Review and Advisory Committee made up of an interdisciplinary group of soil experts and whose functions should include:

- To peer review an inception report such that timescales, costs and the direction of the work are accurately established. Accurate costings should be provided within a tender document.

- To provide expert consultation through a series of project workshops and meetings on issues that may arise during the course of the work – intensity of field survey and sampling programme, etc.

- To review progress and interim deliverables at allocated points in the project.

- To peer review and assess the final product.

Members of the Review and Advisory Committee should be agreed among project participants and funding agencies (utilising the contact made with experts invited to the SIS workshop). The Review and Advisory Committee should be chaired by the project co-ordinator overseeing the development of the 1:250,000 map and the SIS and meetings should be arranged in consultation with project leaders and participants at appropriate intervals – project initiation, when interim deliverables are due, and at any other times during the lifetime of the project where matters arising need the attention of the Review and Advisory Committee.

5.3 Funding and Collaboration

Since a national soil map and SIS have applications across many research disciplines and policy issues, it is recommended that inter-agency or inter-departmental funding is sought to complete this work by seeking co-funding opportunities between the EPA and the Department of Agriculture and Food. There could also be an opportunity to create a cross-border project with the Agri-Food and Biosciences Institute (AFBI) in Northern Ireland which has indicated the need to update the existing 1:250,000 map of Northern Irish soils to include WRB classification, etc. A collaborative project with soil scientists in Northern Ireland would significantly enhance the project development and extend the field of expertise and collaboration.

The survey of soil scientists and policy makers carried out to establish an inventory of soil data in Ireland revealed many common issues and data needs among the scientific community. Amongst scientists in areas such as climate change, pollution risk assessment, water quality and quantity, etc., there remains a pressing need for soil information from unsurveyed areas at the level of soil series. The soil series is the carrier of measured parameters of interest, such as carbon content, bulk density, drainage class, particle size analysis, pH, and other information carried within the suite of description and analysis provided. Whilst the scale of soil research ranges from field to catchment to regional, the need for delineation of soil series as the carrier of information still remains. It is recommended that a project to build a national soil database at a 1:250,000 scale and an SIS becomes part of, or helps to, establish a Soil Research Platform. Including a mapping element within a Soil Research Platform would establish a dialogue and discussion on the applicability of existing and future maps and establish the resource and research needs of the scientific community in a coherent manner.

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Acronyms and Notation

AFBI	Agri-Food and Biosciences Institute
AFT	An Foras Talúntais
AOI	Area of Interest
ATIS	Alliance for Telecommunications Industry Solutions
CanSIS	Canadian Soil Information System
DEM	Digital Elevation Model
DG	Directorate General
DGGE	Denaturing gradient gel electrophoresis
ECALP	Eco-pedological Map of the Alps
ESBN	European Soil Bureau Network
ESRI	Environmental Systems Research Institute
EU	European Union
EUSIS	European Soil Information System.
FAO	Food and Agriculture Organization
GIS	Geographic Information System
HYPRES	Hydraulic Properties of European Soils
INSPIRE	The INfrastructure for SPatial InfoRmation in Europe
ISDI	Irish Spatial Data Infrastructure
LRRC	Land Resources Research Centre
MARS	Monitoring Agriculture with Remote Sensing
MEUSIS	Multiscale European Soil Information System
MoP	Manual of Procedures
MOU	Memoranda of Understanding
NFI	National Forest Inventory
NRCS-WSS	National Resources Conservation Service – Web Soil Survey (USA)
NSS	National Soil Survey
OM	Organic Matter
OSI	Ordnance Survey of Ireland
PESERA	Pan-European Soil Erosion Estimates
PTR	Pedotransfer Rules Knowledge
RG	Reference Group
RSG	Reference Soil Group
SAU	Spatial Analysis Unit
SFD	Soil Framework Directive
SGDBE	Soil Geographical Database of Eurasia
SIS	Soil Information System
SOTER	World SOil and TERrain Digital Database
SPADE	Soil Profile Analytical Database of Europe
T-RFLP	Terminal-Restriction Fragment Length Polymorphism
UCD	University College Dublin
USDA	United States Department of Agriculture
WFS	Web Feature Services
WMS	Web Map Services
WRB	World Reference Base for Soil Resources

Appendix 1

Table A1. WRB reference soil groups, qualifiers and specifiers with recommended codes.

Reference soil groups							
Acrisol	AC	Albeluvisol	AB	Alisol	AL	Andosol	AN
Anthrosol	AT	Arenosol	AR	Calcisol	CL	Cambisol	CM
Chernozem	CH	Cryosol	CR	Durisol	DU	Ferralsol	FR
Fluvisol	FL	Gleysol	GL	Gypsisol	GY	Histosol	HS
Kastanozem	KS	Leptosol	LP	Lixisol	LX	Luvisol	LV
Nitisol	NT	Phaeozem	PH	Planosol	PL	Plinthosol	PT
Podzol	PZ	Regosol	RG	Solonchak	SC	Solonetz	SN
Stagnosol	ST	Technosol	TC	Umbrisol	UM	Vertisol	VR
Qualifiers							
Abruptic	ap	Aceric	ae	Acric	ac	Acroxic	ao
Albic	ab	Alcalic	ax	Alic	al	Aluandic	aa
Alumic	au	Andic	an	Anthraquic	aq	Anthric	am
Arenic	ar	Aric	ai	Aridic	ad	Arzic	az
Brunic	br	Calcaric	ca	Calcic	cc	Cambic	cm
Carbic	cb	Carbonatic	cn	Chloridic	cl	Chromic	cr
Clayic	ce	Colluvic	co	Cryic	cy	Cutanic	ct
Densic	dn	Drainic	dr	Duric	du	Dystric	dy
Ekranic	ek	Endoduric	nd	Endodystric	ny	Endoeutric	ne
Endofluvic	nf	Endogleyic	ng	Endoleptic	nl	Endosalic	ns
Entic	et	Epidystric	ed	Epieutric	ee	Epileptic	el
Episalic	ea	Escalic	ec	Eutric	eu	Eutrosilic	es
Ferralic	fl	Ferric	fr	Fibric	fi	Floatic	ft
Fluvic	fv	Folic	fo	Fractipetric	fp	Fractiplinthic	fa
Fragic	fg	Fulvic	fu	Garbic	ga	Gelic	ge
Gelistagnic	gt	Geric	gr	Gibbsic	gi	Glacic	gc
Gleyic	gl	Glossalbic	gb	Glossic	gs	Greyic	gz
Grumic	gm	Gypsic	gy	Gypsiric	gp	Haplic	ha
Hemic	hm	Histic	hi	Hortic	ht	Humic	hu
Hydragric	hg	Hydric	hy	Hydrophobic	hf	Hyperalbic	ha
Hyperalic	hl	Hypercalcic	hc	Hyperdystric	hd	Hypereutric	he
Hypergypsic	hp	Hyperochric	ho	Hypersalic	hs	Hyperskeletic	hk
Hypocalcic	wc	Hypogypsic	wg	Hypoluvic	wl	Hyposalic	ws
Hyposodic	wn	Irragric	ir	Lamellic	ll	Laxic	la
Leptic	le	Lignic	lg	Limnic	lm	Linic	lc
Lithic	li	Lixic	lx	Luvic	lv	Magnesic	mg
Manganiferric	mf	Mazic	mz	Melanic	ml	Mesotrophic	ms
Mollic	mo	Molliglossic	mi	Natric	na	Nitic	ni
Novic	nv	Nudilithic	nt	Ombric	om	Ornithic	oc
Ortsteinic	os	Oxyaquic	oa	Pachic	ph	Pellic	pe
Petric	pt	Petrocalcic	pc	Petroduric	pd	Petrogleyic	py
Petrogypsic	pg	Petroplinthic	pp	Petrosalic	ps	Pisoplinthic	px

Table A1 *contd.*

Placic	pi	Plaggic	pa	Plinthic	pl	Posic	po
Profondic	pf	Protic	pr	Puffic	pu	Reductaquic	ra
Reductic	rd	Regic	rg	Rendzic	rz	Rheic	rh
Rhodic	ro	Rubic	ru	Ruptic	rp	Rustic	rs
Salic	sz	Sapric	sa	Silandic	sn	Siltic	sl
Skeletic	sk	Sodic	so	Solodic	sc	Sombric	sm
Spodic	sd	Spolic	sp	Stagnic	st	Subaquatic	sq
Sulphatic	su	Takyric	ty	Technic	te	Tephric	tf
Terric	tr	Thaptandic	ba	Thaptovitric	bv	Thionic	ti
Thixotropic	tp	Tidalic	td	Toxic	tx	Transportic	tn
Turbic	tu	Umbric	um	Umbriglossic	ug	Urbic	ub
Vermic	vm	Vertic	vr	Vetic	vt	Vitric	vi
Voronic	vo	Xanthic	xa	Yermic	ye		
Specifiers							
Bathy	..d	Cumuli	..c	Endo	..n	Epi	..p
Hyper	..h	Hypo	..w	Ortho	..o	Para	..r
Proto	..t	Thapto	..b				