Soil Profile Analytical Database for the European Union

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In 1985 the European Communities now the European Union published a soil map covering all the Community countries. This map has been digitized, but for modelling purposes it was necessary to compile a Soil Profile Analytical Database connected to the European Communities Soil Map. This compilation commenced in 1992 following a decade of expert group meetings concerning European soil and land data. This account describes the events that led to the decision to develop this database, and how it was compiled.

Key words: *Soil database, European Union.*

Introduction

During this century, national or regional soil surveys have been established in most of the European Union (EU) member states. Today national soil maps at large scales exist in full in many member states such as the Netherlands, Belgium and Denmark; in other countries like Spain, France and Ireland only minor parts have been mapped and published (Hodgson 1991). The map scale and survey methodology used differ from one country to another, and it is not possible simply to combine the national maps to cover the whole of the EU. Today national soil mapping within the EU has almost ceased, only in a few countries like Greece (Aggelides & Theocharopoulos 1991) a nationwide mapping of soils is still taking place. During the last two decades, some of the national soil maps have been computerized and in the following years it must be expected that most of the other national soil survey maps will be digitized. Furthermore, national soil profile and analytical databases have been established in some of the member states. In most cases these databases are not compatible with each other because different analytical methods have been used in order to determine the soil properties.

Because the different national soil classification systems around the world are not compatible, an international soil classification system was developed in the 1960s and at the beginning of the 1970s world soil maps at scale 1:5,000,000 were elaborated (FAO-Unesco 1974). Based on the FAO-concept, the Commission of the European Communities decided to make a soil map of the entire European Communities at scale 1:1,000,000. This soil map was called the European Communities Soil Map or the EC Soil Map until 1992 when the European Communities became the European Union. The name of the soil map then changed to the European Union Soil Map or EU Soil Map. In the following sections EC and EU are used synonymously, but normally EC is used for events happening before 1992 and EU for events happening after 1992.

For an optimal use of the EC Soil Map, for example by transforming it into different thematic maps using pedotransfer functions, it is necessary to establish a soil profile analytical database connected to the EC Soil Map. Very few international soil databases have been compiled, these include the USDA-SCS database, the ISRIC-ISIS database and the FAO-SDB database. Proposals for a systematic collection of soil and terrain data have been developed at the International Soil Reference and Information Centre (ISRIC) (Van Engelen & Wen 1993), also published simultaneously as World Soil Resource Report 74 (FAO 1993). A global soil database has been compiled at ISRIC for the geographical quantification of soil factors and processes that control fluxes of greenhouse gases under the title of World Inventory of Soil Emission Potentials (WISE) (Batjes & Bridges 1994). However, it was not possible to use these data sets in the compilation of the soil analytical database connected to the EC Soil Map.

This paper describes the methodology used for compilation of a soil profile analytical database connected to the EC or EU Soil Map.

European Communities (EC) Soil Map.

In 1978, a working group on land use and rural resources of the European Communities proposed that a soil map of the member states should be prepared using the FAO legend and data already collected by FAO. In 1985, the soil map covering the entire European Communities was published, at a scale of 1:1,000,000, in seven map sheets and two legend sheets (Commission of the European Communities 1985). This EC Soil Map portrays the distribution of more than 120 different soil types, most of them defined in FAO-Unesco (1974), but about 40 new soil types were defined, for example, Plaggensols and Stagno-Eutric Gleysols. Combinations of the various soil types are used to define more the 300 different map units in the legend which relates to more than 16,000 soil polygons on the map.

Each map unit, an association of soil units occurring within the limits of a discrete physiographic entity, is given a number and a colour on the printed map. Each association is composed of a dominant soil unit and of subdominant associated soils, each of the latter covering at least 10% but less than 50% of the area. Important soils which cover less than 10% of the area are noted as inclusions. The percentage share of the dominant soil type, the associated soil types and the inclusions are generally indicated. The texture class of the dominant soil and a slope class are given for each association. Phases are used where indurated layers of hard rock occur at shallow depth and to indicate stoniness, salinity, alkalinity, a high content of stones or concretions.

As a part of the CORINE Project (Briggs & Martin 1988), the EC Soil Map was digitized in 1986 in order to establish a comprehensive geographical database to assist environmental protection in the European Communities. The digitization of the soil map was carried out by the Ministry of Agriculture, Bureau of Land Data (ADK) in Denmark (Platou et al. 1989) in cooperation with Birkbeck College, London University, a main contractor in the CORINE Project maintaining the GIS development (Wiggins et al. 1985).

The computerization of the EC Soil Map has several advantages. It is relatively easy to make area calculations and to reproduce maps at different scales, and it is possible to make interpretations of the soil map on various themes, for example land suitability and environmental risk assessment (Lee 1984, Briggs et al. 1989, Jones & Biagi 1989, King & Daroussin 1989, Madsen et. al 1989, Proctor et al. 1989, van Lanen et al 1989, Verheye 1989). Furthermore it is possible to update the soil map relatively easily when new knowledge becomes available. For example, in Denmark new EC Soil Map units have been constructed (Madsen & Jensen 1995), in Germany a new soil map including the former German Democratic Republic (East Germany) has been elaborated (Eckelmann & Adler 1994, Hartwich et al. 1995), and King et al. (1995) has expanded the soil attributes based on archive studies and data from national representatives. The printed soil maps therefore are outdated as a means of communication for today's needs.

Proposal for an EC Soil Profile and Soil Analytical Database

In order to collate soil and land data for the EC and in particular to improve the utilization of the computerized EC Soil Map, a Computerization of Land Data Group was set up. This comprised technical experts from the member states and a series of meetings was held in the 1980s to discuss the general availability of land data in computerized form throughout the European Communities. At the end of the 1980s, additional meetings of experts were convened to advise the Commission on the establishment of a soil profile and analytical database connected to the EC Soil Map. The participants at these additional meetings were Prof. H. Breuning-Madsen (DK) (chairman), Prof. W. Verheye (B), Prof. J. Bouma (NL), Dr. R.J.A. Jones (UK), Dr. B. Biagi (I), and Eng. J. Gil Pas (P). Dr. A.K. Bregt (NL) substituted Prof. J. Bouma (NL) at several meetings.

The meetings were held under the European Communities Exchange of Scientists Programme at the request of the Land and Water Use and Management Programme Committee of Directorate-General VI (Agriculture). The first meeting took place in Brussels in November 1986 and the second meeting was held in May 1987 during the Computerization of Land Data Group meeting in Pisa (Jones & Biagi 1989). Different methods for storing soil profile descriptions and soil analytical data were discussed, and at the third meeting in October 1988 in Brussels, a methodology was agreed upon for elaboration of an European Communities soil profile and analytical database. This is as follows:

I. The database should be compiled in phases, firstly at level 1, secondly at level 2 and so on.
II. The European Communities should be divided into several regions, in the first phase the member states. Within each region a soil profile and analytical database is elaborated. In later phases the member states might be subdivided into minor regions.
III. Within each region a typical soil profile description and soil analytical data should be identified for each soil type present. In the first phase data may be provided on the dominant soil types, but in later phases soil types present as associations and inclusions should also be described.
IV. The profile descriptions should be given according to the FAO-system and the soil analytical data according to international standards.

V. The construction of typical profiles including analytical data should be made by local experts, such as national soil survey bodies or local soil scientists.

The recommendations and the proposed methodology were then presented and further discussed at the following two meetings: the Computerization of Land Data Group meeting held in Wageningen in November 1988, with the theme Application of computerized EC Soil Map and climate data (Van Lanen & Bregt 1989), and the European Communities meeting for the European Heads of Soil Surveys held in Silsoe (UK) in December 1989 (Hodgson 1991). The final document for compiling an European Communities soil profile and analytical database described in detail the methodology, but no proformas and guidelines were elaborated (Madsen 1991).

Principles for Establishing a Soil Profile Analytical Database in Connection with the MARS Project

At the end of the 1980's a 10 year research project on the application of remote sensing in agriculture statistics was initiated. Called the MARS Project - Monitoring Agriculture with Remote Sensing - it has been and continues to be funded by the Commission of the European Communities Directorate-General for Science Research and Development. The main contractor is the Joint Research Centre (JRC), Ispra Establishment. The MARS Project is divided into different actions, one of these being a research and development activity on agrometeorological models aimed at establishing of a system for the forecasting of the yields of the principal crops in the Community countries.

This specific action is to be realised through internal studies and external study contracts, and scientific working groups to support the MARS Project were established. One of these, the Soil and Geographical Information Systems (GIS) Support Group, had the objective to study the pedological parameters that, when combined with other environmental data at a scale covering the 12 EC countries, will enable the yield forecasting models to operate.

The basic data for the project should be the EC Soil Map, but the Soil and GIS Support Group should evaluate the archives used in preparation of the EC Soil Map and propose a work plan for updating the description of the cartographic units of the 1:1,000,000 EC Soil Map. Furthermore, the group should propose a number of pedotransfer functions or rules for mapping the available water content in the root zone, to model the water balance and other soil attributes.

The Support Group was coordinated Dr. D. King of the Institute National Recherches Agronomique (INRA, France). Dr P. Vossen and A. Burrill represented The Joint Research Centre, Ispra. The other members of the group included: R.J.A. Jones (UK), A.J. Thomasson (UK), J. Daroussin (F), M. Jamagne (F), M.R.T. Bessa (P), A. Bregt (NL), E. van Ranst (B), W. Eckelmann (D), H. Breuning-Madsen (DK), D. Magaldi (I), J.J. Ibanez (E), J. Boixadera (E), F.O. Nachtergale (FAO, Rome)

The first meeting of the Soil and GIS Support Group was held at the Joint Research Centre in Ispra in autumn 1990, the second in Ghent in April 1991. At that meeting it was proposed to compile a soil profile analytical database exclusively connected to the EC Soil Map. Compared to the methodology proposed by the expert group at the end of the 1980s, soil profile descriptions were excluded, only the part concerning soil profile analyses should be included. A proposal for the establishment of such a database was made to the next meeting of the Support Group, which was held in at the Joint Research Centre, Ispra, in September 1991. The proposal was discussed and the types of analyses that should be present in the database were agreed in principle.

In June 1992, a contract was made with the Joint Research Centre, Ispra for the establishment of a soil profile analytical database connected to the EC Soil Map. Contractors were the authors of this paper, and the soil profile analytical database was to be established according to the following recommendations:

I. The database should exclusively be related to the EC Soil Map.
II. The database should be a first-level database only containing data from dominant soil types on the EC Soil Map. In a later phase data from soil types present only as associated soils or inclusions can be incorporated in the soil database.
III. If the land use type agriculture exists on at least some part of the dominant soil type, data for a farmland soil should be given
IV. Two soil analytical databases should be established, one containing estimated mean values for typical soil profiles (Proforma I) and one based on measured data from selected soil profiles (Proforma II).
V. The Proforma I database is proposed so that a data-

database for comparative use across the European Communities can be compiled for farmland. Therefore the experts are requested to complete Proforma I in full by transforming measured data according to a methodology given in the guidelines as well as on the basis of expert knowledge.

VI. The Proforma II database is proposed for recording measured data. It is accepted that data will be missing for some analyses or even for whole profiles.

VII. The collection and construction of the analytical data should be made by local experts, such as representatives of national soil survey bodies or local soil scientists.

During the second part of 1992, work concentrated on the establishment of guidelines and the development of suitable proformas for compiling the necessary data. The work was carried out in consultation with the following representatives from the member states: D. Magaldi (I), N. Yassoglou (GR), J.J. Ibanez (E), M.R.T. Bessa (P), M. Jamagne (F), E. van Ranst (B+L), A.K. Bregt (NL), W. Eckelmann (D), H. Breuning-Madsen (DK), R.J.A. Jones (UK), J. Lee (IRL).

The proformas were constructed as spreadsheets in Microsoft Excel. Together with the guidelines they were circulated in the summer 1992 and, by the autumn, some completed proformas were received from the member states as a test of the system. During the meeting of the Soil and GIS Support Group in Madrid in December 1992, a consensus was reached on the final form of the proformas and the associated guidelines. Following the meeting in Madrid minor revisions of the proformas and guidelines were circulated, and a final version was completed at the end of February 1993.

This finalized version was then circulated on paper and on diskette to the national representatives. Each representative was requested to complete the proformas over the next half year and return the completed proformas on diskette to the contractors. Some data were returned on paper only and subsequently had to be key punched before they could be stored in the computer, but most of the data were returned on diskette and easily stored directly in a simple database.

Results

An example of completed Proformas I and II is shown on the next page. The profomas show the data for an orthic podzol in Denmark. Proforma I is completed in full as it should be according to the recommendations. In Proforma II some data are missing as they have not been measured or recorded. Guidelines 1 and 2 show the guidelines for filling in the two proformas.

The collection of data took more than a year because difficulties were encounted by some member states in meeting the proposed timescale. The difficulties varied from one member state to another: for example in some cases, new information necessitated redrawing the soil map before establishing the soil profile analytical database, and in other cases national soil surveys no longer exist and it was difficult to find appropriate national experts who could respond to the requests for information. Furthermore, very limited funds were available for completing the proformas at national level and this made it impossible for some experts to reschedule national soil research programmes quickly enough to meet the proposed timescales.

Table 1 shows the number of proformas received by 1 January 1995. Information is still awaited from Greece, Portugal and Ireland. Greece has agreed to deliver the missing proformas in 1995; the national soil survey in Ireland no longer exists and the local soil scientists have suggested requesting information for Ireland previously submitted to the WISE Project, International Soil Reference and Information Centre (ISRIC) (Batjes & Bridges 1994). Data from Portugal are now being prepared. For some of the other

***Table 1:** National returns of soil profile data (as at 1 January, 1995)*

Country	*Proforma I*	*Proforma II*
UK	64	90
Denmark	9	8
Belgium	34	34
France	118	0
Germany	69	50
Italy	21	17
Netherlands	20	19
Spain	25	25
Luxembourg	13	13
Greece	0	19
Portugal	0	0
Ireland	0	0

Example of completed Proformas I and II:

Proforma I for Soil Analytical Data: Estimated
Soil name: Orthic Podzol
Country: Denmark
Groundwater level: **Highest:** 5 **Lowest:** 5 **Landuse:** Agriculture
Parent material: Outwash plain

Horizon	Depth (cm)	Texture µm <2	2-20	20-50	50-200	200-2000	Stones + Gravel	Structure	OM %	C N	CaC03 %	Active CaC03	CaS03 2H20	pH(H20)	EC dS/m	SAR	ESP
A	0-20	1	2	2	20	70	1	5	4.7	19	0	0	0	5.5	1	<4	<10
E	20-30	1	2	2	21	73	1	5	1.2	21	0	0	0	5.5	1	<4	<10
Bhs	30-50	2	1	4	34	57	1	1	1.9	25	0	0	0	5.1	1	<4	<10
C	50-200	1	1	1	39	58	1	1	0.2	20	0	0	0	5.0	1	<4	<10
Origin of Data		2	2	2	2	2	2	2	2	2	2	5	2	2	5		5

Depth (cm)	Exch. Bases cmol +/kg Ca	Mg	K	Na	CEC	BS%	Volumetric Water Content (%) Soil Water Retention (k Pa) 1	10	100	1500	FC	Total Porosity %	Bulk Density g/cm³
0-20	3.0	0.3	0.1	0.02	8.0	42	36	18	13	5	18	42	1.55
20-30	1.5	0.2	0.02	0.02	5.0	34	33	10	7	4	13	41	1.58
30-50	1.6	0.3	0.05	0.01	7.7	25	32	15	6	4	17	40	1.60
50-200	0.6	0.1	0.02	0.01	2.9	25	37	7	4	2	11	40	1.60
Origin of Data	2	2	2	2	2	2	2	2	2	2	2	2	2

Root Depth (cm)	Crops Winter-Sown Cereals	Spring-Sown Cereals	Short Grass	Beets	Olives	Maize	Cotton	A:
Mean Effective	50	50	50	50				
Mean Total	90	90	90	90				

Proforma II for Soil Analytical Data: Measured
Soil name: Po-1
Country: Denmark **Longitude:**
Groundwater level: **Highest:** 5 **Lowest:** 5 **Latitude:** **Landuse:** Agriculture
Parent material: Outwash plain **Altitude:**

Horizon	Depth (cm)	Texture_1 CLAY	esd	Texture_2 SILT	esd	Texture_3 SAND	esd	Texture_4 SAND	esd	Texture_5 SAND	esd	Stones GRAVEL	Struct COD	C VAL	COD	N VAL	COD	CaC03 VAL	COD	CaS04 VAL	COD	pH 3.9	COD	EC VAL	COD	SAR	ESP
Ap	0-27	6	2	2	20	2	63	8	200	80	2000	<10	-1	1.17	A2	0.8	A4	0	A6	-1		4.5	A13	-1		-1	-1
E	27-37	4	2	1	20	1	63	6	200	87	2000	<10	-1	0.53	A2	0.4	A4	0	A6	-1		5.1	A13	-1		-1	-1
Bs1	37-48	6	2	1	20	2	63	5	200	86	2000	<10	-1	0.76	A2	0.5	A4	0	A6	-1		5.3	A13	-1		-1	-1
Bs2	48-80	3	2	1	20	1	63	3	200	93	2000	<10	-1	0.12	A2			0	A6	-1		5.5	A13	-1		-1	-1
Bs3	80-120	3	2	1	20	2	63	5	200	90	2000	<10	-1	0.6	A2			0	A6	-1		5.5	A13	-1		-1	-1
Bs4	120-150	2	2	1	20	1	63	3	200	91	2000	<10	-1	-				0	A6	-1		5.5	A13	-1		-1	-1
C	150-	2	2	1	20	1	63	5	200	91	2000	<10	-1	-				0	A6	-1		5.1	A13	-1		-1	-1

Depth (cm)	Exch Ca 1.00	COD	Exch Mg VAL	COD	Exch K VAL	COD	Exch Na VAL	COD	CEC VAL	COD	BS VAL	COD	WC-1 VAL	COD	WC-2 VAL	COD	WC-3 VAL	COD	WC-4 VAL	COD	WC-FC VAL	COD	TOT VAL	POR COD	DB VAL	COD
0-27	1.00	A19	0.07	A19	0.14	A19	0.03	A19	7.54	A22	16	A24	33.5	1	14.8	10	10.3	100	4.4	1500			33.0	A26	1.74	A28
27-37	1.00	A19	0.06	A19	0.04	A19	0.02	A19	4.92	A22	23	A24	-1	-1	-1	-1	-1	-1	-1	-1						
37-48	2.00	A19	0.12	A19	0.05	A19	0.02	A19	7.99	A22	27	A24	-1	-1	-1	-1	-1	-1	-1							
48-80	0.42	A19	0.02	A19	0.03	A19	0.01	A19	2.48	A22	19	A24	35.6	1	4.4	10	2.7	100	1.5	1500			43.3	A26	1.50	A28
80-120	0.30	A19	0.02	A19	0.03	A19	0.01	A19	1.96	A22	18	A24	34.2	1	3.2	10	2.1	100	1.4	1500			41.4	A26	1.55	A28
120-150	0.32	A19	0.02	A19	0.02	A19	0.01	A19	1.37	A22	27	A24	-1	-1	-1	-1	-1	-1	-1							
150->	0.25	A19	0.02	A19	0.02	A19	0.01	A19	1.30	A22	23	A24	-1	-1	-1	-1	-1	-1	-1							

Root Depth (cm)	
D_Rock	
D_Oth_Obs	

Origin of Data e.g Code 1 or 2	

member states, there are still missing data on the Proformas I but efforts are under way to fill these gaps.

All data have been checked and minor errors have been corrected. The Proforma I data will be particularly important for modelling because most of the data are present and recorded for the same analytical methodology. However, the missing Proforma I data might give some minor problems, but the database is sufficiently complete to be useable. For the countries where Proforma I data are unavailable, it is suggested that appropriate data from neighbouring countries are used.

Future Work

In 1995-96, the EU soil profile analytical database will be expanded to include Eastern and Central Europe and the remaining part of Scandinavia. In doing this the database will be expanded from 12 to 29 countries.

For each of the EU member states a continuous updating of the database should be maintained. A completely revised soil map of Denmark is now available and a new soil profile analytical database has been constructed. Soil scientists in Germany have prepared a new version of their part of an EU Soil Map including Eastern Germany, and soil analytical data from Greece and Portugal will probably become available in 1995.

Guideline 1:

Guideline for Proforma I: Estimated Data

Give data for the profile representative of the dominant soil type in the mapping unit.

Soil Name

The name of the soil type is indicated inclusive of the texture lass. For example: Be-4, Lo-2. Some soil types do not have a texture class i.e. histosols.

Country

Use the international abbreviation of your country name, i.e. F, I, DK, D.

Groundwater Level

The mean highest and mean lowest permanent or perched groundwater table is indicated. That should be the mean of at least 10 years. Generally such information is lacking and so you will normally have to estimate or guess (guesstimate) the values. Please use the following classes:

1: groundwater table between: 0 - 50 cm
2: groundwater table between: 50 -100 cm
3: groundwater table between: 100 -150 cm
4: groundwater table between: 150 -200 cm
5: groundwater table below: 200 cm

For example, If you estimate the mean groundwater level in winter to be 70 cm and in summer 190 cm you record:

Highest: 2   Lowest: 4

Parent Material

Write in words what you believe is the parent material. For example: fluvial deposit, dune sand, boulder clay.

Landuse

This will be agriculture for dominantly agricultural units but record any non-agricultural use for units which are not used for agriculture.

Origin of Data for Description of Horizon Properties

The soil profile data available might be from actual profiles or modal ones. Furthermore, some data might be real analytical values, others might be estimates or even guesstimates - because of lack of information. The following categories are suggested:

1: average of a number of profiles;
2: from a single representative profile;
3: prediction derived from mathematical functions;
4: prediction derived from relationships between horizons and class functions (e.g. texture and density class);
5: expert judgement.

The codes 1, 2 3, 4 or 5 should be entered on Proforma I to identify the origin of the data.

Horizon

Name the different horizons according to the FAO system.

For example: The horizon sequence of a luvisol: Ap, E, Bt, C. Please choose or construct your benchmark soils, so they have as few horizons as possible.

Depth

Indicate the soil depth in cm.

For example: 0 - 30 or 30 - 50 or 50 - 120 cm. The deepest horizon stops at a depth of 2 metre, i.e. the last horizon may be 50 - 200 cm.

Texture

Estimate the % of different grain sizes (<2mm) to the nearest integer (or 'whole' number i.e. without giving decimals).

For example: clay 28%, not 27.8%. The contents of all the texture grades should add up to 100%

Stones + Gravel

Estimate the percentage stones and gravel in the soil.

Use the folowing codes to record the amount of stones + gravel for each horizon:

Code	*Class*
1:	very few *< 5% by volume*
2:	few *5 - 15% by volume*
3:	frequent or many *15 - 40% by volume*
4:	very frequent, *40 - 80% by volume*
5:	dominant or skeletal *> 80% by volume*

Do not describe the mineralogy, size or weathering status.

Structure

Describe the type of structure according to the following list FAO (1986). Do not describe size or stability but use the numeric code for the structure class.

Code	*Class*
1:	platy
2:	prismatic
3:	columnar
4:	angular blocky
5:	subangular blocky
6:	granular
7:	crumb
8:	massive
9:	single grain
10:	wedge shaped

Organic Matter (OM)

Estimate the organic matter content (%) {not the organic carbon content} in each horizon to one decimal place e.g. 3.8%.

Carbon/Nitrogen (C/N) Ratio

Record the C/N ratio to nearest whole number.

$CaCO_3$ and $CaSO_4.2H_2O$

The calcium carbonate equivalent ($CaCO_3$) and gypsum content ($CaSO4.2H_2O$) should be given to the nearest integer i.e. 36.

Active $CaCO_3$

The method of Druineau (1942) modified by Gehu-Frank (1959) is suggested. A 10g subsample or soil is shaken (for 2h) in 250ml of ammonium oxalate. A 20ml aliquot of filtrate is then treated with acidic potassium permanganate (60-70 deg C).

Active calcium carbonate is then determined from the following equation:

Active $CaCO_3$ (%) = (A - B) N 50 (0.125) where:
A = ml $KMnO_4$ in the blank (oxalate only)
B = ml $KMnO_4$ in sample
N = normality
50 = equivalent weight of $CaCO_3$

SAR and ESP

Sodium adsorption ratio (SAR) should be recorded to the nearest integer. In humid areas, SAR is usually less than 4. Unless data for these areas indicate otherwise, enter '<4'.

Exchangeable sodium percentage (ESP), the proportion of exchangeable sodium as a percentage of the cation exchange capacity, should be recorded to the nearest integer. In humid areas, ESP is normally less than 15% and should be recorded as '<10'.

Only one of these parameters, SAR or ESP, should be recorded.

pH (H_2O)

pH measured in water, soil: water ratio 1:2.5. If you do not have information on pH in water but in another medium estimate the pH(H_2O) from measured pH data. Based on several thousand analyses in Denmark i.e. the following algorithm can be used:

pH (H_2O) = pH (0.01 M $CaCl_2$) + 0.5 = pH (1 M KCl) + 0.9.

The pH - values should be given to one decimal place, i.e. 5.9.

Electrical Conductivity (EC)

EC measured in saturated paste extract; group the soil horizons into the following classes and record the numeric code. In non marine humid areas code 1 should be entered if analytical data are absent.

Code	*Range* *dS m-1 at 25 deg C*	*Class*
1:	0 - 4	free
2:	4 - 8	slightly affected
3:	8 - 15	moderately affected
4:	> 15	strongly affected

Exchangeable Bases

The exchangeable bases should be given for an extraction with 1M NH_4AOc at pH 7.0. The values should be given to one decimal place only except when the values are lower than 0.1 cmol+/kg.

Cation Exchange Capacity (CEC) and Base Saturation (BS)

CEC is given to one decimal place for each horizon as the sum of exchangeable bases and the exchangeable acidity at pH 8.1. Base saturation is calculated as the percentage of the CEC taken up by exchangeable bases.

BS = (TEB/CEC)100
TEB - total exchangeable bases
BS is expressed as an integer (mass) (or whole number)

Soil Water Retention

The volume percent of water in the soil horizons at 1, 10, 100, 1500 kPa and field capacity (FC) are estimated to the nearest integer value eg 38, 32, 20, 10. Indicate the most appropriate value for field capacity.

Porosity and Bulk Density

The porosity (%) is given to the nearest integer; the bulk density to two decimal places.

Root Depth

Two root depths are indicated for selected crops. The effective root depth is defined as the depth of soil in which the plant available water (field capacity - permanent wilting point) is equal to the amount of soil water utilized by the plants until wilting occurs due to lack of water. The mean total root depth is self evident. Depths are given for the different types of vegetation (indicated on the scheme) which may grow on the soil type. If no crop is growing enter '-1'. In arid areas, where there is usually little or no leaching, effective rooting depth has no significance and should not be recorded.

Guideline 2:

Guideline for Proforma II: Measured Data (existing soil profiles only)

The structure of this proforma is similar to that proposed for estimated data except for the introduction of a second column to record a code defining the type, method and/or units of measurement.

In general, under 'VAL', abbreviation for value, record the result of the measurement and under 'COD', abbreviation for code, list details, units or a code defining the measurement, eg under CEC, '1' under 'COD' could be the measurement in an extract from 1N NH_4AOc at pH 7.0. If it is self-evident that the measured value would be zero but no analysis has been carried out, record '0' in the 'VAL' column and 'NA' under 'COD'. Record missing values as '-1'

Longitude, Latitude and Altitude

Longitude and latitude should be recorded in the traditional way using degrees and minutes in relation to the Greenwich Meridian and the Equator. Altitude should be recorded in metres above Mean Sea Level.

Soil name, Country, Groundwater Level, Parent Material and Land Use

These should be recorded as on the proforma for estimated data (described above). Horizon notation should be recorded according to FAO system. Record the lower depth, in cm (to nearest integer value), for each horizon in the soil.

Texture

Record measurements for 5 fractions - clay, silt, and 3 sand fractions to one place of decimals. Under 'esd', an abbreviation for equivalent spherical diameter, record the upper limit (to the nearest integer), eg 2um for clay, 50 or 60 um for silt, 200, 600, 2000um or other (eg 200, 500 um) relevant limits for sand.

Stones and Gravel, and Structure

Record these using the same codes as for the estimated proforma.

Organic Carbon (OC)

Record measurement of organic carbon (not humus) to one decimal place under 'VAL' and one of the following codes under 'COD':

A1 Method of Walkley and Black
A2 Leco Method Tabatabai and Bremner (1970)
A3 Other (specify on separate sheet)

Total Nitrogen (N)

Record measurement to one decimal place under 'VAL' and one of the following codes under 'COD':

A4 Wet digestion (Kjeldahl method) (%)
A5 Other

Calcium Carbonate ($CaCO_3$)

Record measurement of total $CaCO_3$ to nearest integer under 'VAL' and one of the following codes under 'COD':

A6 Calcimeter method (%) [measures CO_2 emitted]
A7 Other

Gypsum ($CaSO_4.2H_20$)

Record measurement to nearest integer under 'VAL' and one of the following codes under 'COD':

A8 For soils with small quantities of gypsum: By water extraction: USDA Handbook No 60, Diagnosis and Improvement of Saline and Alkaline Soils (1954).
A9 For highly gypsiferous soils: By loss of crystallisation water between 40 & 110 deg C.
A10 Other

Acidity pH

Record measurement to one decimal place under 'VAL' and one of the following codes under 'COD':

A11 1:1 water (H_2O)
A12 1:2.5 water (H_2O)
A13 1:2.5 0.01 M Calcium Chloride ($CaCl_2$)
A14 1:2.5 1M Potassium Chloride (KCl)
A15 Other

Electrical Conductivity (EC)

Record the measured EC value in dS m^{-1}.

A17 In extract from sample saturated in water
A18 Other

Exchangeable Calcium, Magnesium, Potassium and Sodium

Record measurement to one place of decimals under 'VAL' and one of the following codes under 'COD':

A19 Neutral Ammonium Acetate (NH_4AOc) extract, cmol+/kg
A20 Other

Cation Exchange Capacity (CEC)

Record measurement to one place of decimals under 'VAL' and one of the following codes under 'COD':

A21 Distillation method (cmol+/kg)
A22 Total Exchangeable Bases (TEB) + Exchange Acidity
A23 Other

Base Saturation (BS)

Record measurement to nearest integer under 'VAL' and one of the following codes under 'COD':

A24 TEB/CEC (%)
A25 Other

Soil Water Retention (WC_1, WC_2, WC_3, WC_4, WC_4, WC_FC)

Because many different suctions are used for measuring soil water retention, national correspondents are requested to enter measurements for water contents (WC_..), as percent by volume, at 5 suctions one (WC_FC) of which should be field capacity (FC).

Record measurement to the nearest integer under 'VAL' and under 'COD' record the suction in kPa at which the measurement was made eg : 5, 10, 40, 200, 1500 kPa. With at least five measurements, a soil water suction curve can be constructed from which estimates at intermediate suctions can be made.

Total Pore Space (TOT_POR)

Record the result of the measurement under 'VAL' and method under 'COD':

A26 (1-DB/DP), % {DP is particle density, 2.55 - 2.65g/cm^3
A27 Other

Bulk Density (DB)

Record the result of the measurement to two decimal places under 'VAL' and method under 'COD':

A28 Soil core in lab, g/cm^3
A29 Wet measurement in the field, g/cm^3
A30 Other

Root Depth

The depth of soil available for rooting should be recorded to 2 m (200 cm); the depth in cm (to nearest integer) to rock should recorded under D_Rock and the depth (cm) to any other obstruction, such as a compact layer, under D_Oth_Obs.

Analytical Codes

Any additional codes for analytical methods can be introduced coding from A30 onwards. It will not matter if these codes appear to be out of numerical sequence as they will be setup as a relational table which can be added to easily in the future.

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