UNIVERSITY OF COPENHAGEN

FINAL REPORT ON THE ESTABLISHMENT OF A SPADE 14 SOIL PROFILE ANALYTICAL DATABASE CONNECTED TO THE EU SOIL MAP AT SCALE 1:1.000.000

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Introduction

The European soil map at scale 1:1.000.000

During the last century national soil maps have been established in many countries. In most cases, the maps are not compatible because specific national soil classification systems were used. Thus, an international soil classification system was developed during the 1960's, and in the early 1970's, world-wide soil maps at scale 1:5.000.000 were constructed (FAO-UNESCO 1974). The soil maps were made by national stakeholders who compiled one map for each individual country. They separated the country into mapping units with a distinct set of soil types. The soil types were divided into three categories: dominant soil types; associated soil types and inclusions. The dominant soil type covers the greatest area of the mapping unit; while associated soils cover between 20% and 50% of the area and the inclusions less than 20%. The maps were published with an explanatory text describing the geology, geomorphology, land use and a map showing the level of knowledge behind the map.

In the beginning of the 1980's, the 10 member states of the European Communities (EC) developed the concept from FAO-UNESCO further and made an expanded version of FAO-UNESCO (1974) for the soil types present in their countries. Based on this system, the EC published seven soil maps at scale 1:1.000.000, two legend sheets and an explanatory text in 1985 (Commission of the European Communities 1985). The soil map was digitized as a part of the EC financed CORINE programme in the end of the 1980's. The digitized EC soil map has been widely used, e.g. for mapping carbon stocks, erosion risks, traficability and similar agriculture/environmental problems. In 1990, FAO launched a new extended version of FAO 1974, and this FAO 1990 (FAO 1990) was the system used by the Central and Eastern European countries when they upgraded their FAO 1974 map at 1:5,000,000 to 1:1,000,000.

Soil profile analytical database 1 (SPADE 1)

After the construction of the EC soil map at scale 1:1,000,000 it became obvious that a soil profile analytical database would improve the value of the soil map substantially for modelling purposes. A working group of soil specialists was formed to advise the European Commission on the establishment of a soil profile and analytical database. In the end of the 1980's, it was decided that the soil profile analytical database connected to the EC soil map should be based on the concept presented at a meeting in Wageningen, 1988 (Breuning-Madsen 1989). The database contains four levels of soil analytical data:

- Level 1 only includes analytical data from one typical soil profile for the dominant soil type, if possible on arable land,
- Level 2 includes a dataset for all soil types, also the ones present as association or inclusion,
- Level 3 includes soil analytical data distinguished by land use
- Level 4 also allows for different soil analytical data for different sub-regions, e.g. based on geology or geomorphology.

The advisory board decided that the Soil Profile Analytical Database of Europe (SPADE 1) should be a level 1 database, which should be developed later into a level 2, 3 and 4 database. The database should be created at a national level. Therefore, national stakeholders should be selected being responsible for the national data in SPADE 1. Two soil analytical databases should be established: One containing estimated mean values for typical soil profiles according to fixed soil analytical procedures (proforma I), and another one containing soil profiles with measured data (proforma II). The proforma I database would contain data comparable across country borders while this would not always be the case for the proforma II database. Each country should mandatorily deliver one full covered set of proforma I analytical data for each dominant soil type on the EC soil map at scale 1:1,000,000. This was not necessary for the proforma II database. The data should be provided for agriculture land when applicable.

In the beginning of 1993, proforma I and II schemes (including guidelines) were sent to the stakeholders that should deliver the dataset for the individual countries within half a year. The datasets were stored in Excel spreadsheets in order to have it in a universal format compatible with most Geographical Information Systems (GIS). For detailed guidelines for the SPADE 1 dataset, see Breuning-Madsen & Jones (1995).

Later, the SPADE 1 database was expanded to include data from new EU member states but also from other European nations like Albania, Norway and Switzerland.

By the end of the 1990's, the SPADE 1 database was scrutinized for missing and obviously questionable data, and the result was presented to the stakeholders at an European Soil Bureau Network (ESBN) meeting in Vienna in 1999. The stakeholders were asked to update their national input according to the recommendations from the meeting. However, only few responses were received.

Soil profile analytical database 8 (SPADE 8)

The scrutiny of the SPADE 1 database showed that less than 20% of the total dominant Soil Typological Units (STU) in the 1:1 Million geographical database could be linked to data contained in the original SPADE-1 database.

The low linkage rate between the soil map and the SPADE 1 database and the missing response from the stakeholders on the questionable and missing data in the SPADE 1 database made it necessary to consider alternative methods for the completion of the database. Thus, a small specialist group from Denmark (Prof. Henrik Breuning-Madsen, Prof. Thomas Balstroem and Cand. Scient. Mads Koue) from the Institute of Geography, University of Copenhagen scrutinized the national datasets using error finding equations, expert judgements and pedotransfer functions. First, a quality check was conducted on all data from all countries. This process generally consisted of:

i) checking the interdependent variables against each other, e.g. pH vs. base saturation (BS) or porosity (POR) vs. water content (WC1),

ii) checking all numbers according to theoretical values, e.g. for bulk density (BD) or C/N-values.

An example of questionable data is water content by volume larger than 100%, C/N values of 1, base saturations of 90% when pH is 4,3 and a water content at 1 kPa (WC1) larger than the porosity. Moreover, free calcium carbonate of >10 % was found in horizons with acidic pH and in quite a few cases, the sum of clay, silt and sand fractions was >100%. Based on this examination, improbable values were either corrected (green, yellow) or marked as too high (red) or too low (turquoise) based on predefined criteria, Figure 1.

	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y
1	HOR_NAME	DEPTHSTART	DEPTHEND	AR_NA	BD	BS	C_N	CACO3_ACT	CACO3_TOT	CASO4	CEC	EC	EXCH_CA	EXCH_K	EXCH_MG	EXCH_NA	EXCH_NA_P	GRAVEL	OM	PH	POR	STRUCT	TEXT_2
20	Bw	20	100	-999	1.60	17	-999	-999	0	-999	4.6	1	0.40	0.00	0.40	0.00	-10	4	0.0	4.6	38	9	3
21	C	100	-999	-999	1.60	30	-999	-999	0	-999	4.6	1	0.60	0.10	0.70	0.00	-10	5	0.0	4.6	37	9	2
22	Ah	0	5	-999	1.40	6	20	-999	0	-999	35.0	1	2.00	0.10	0.10	0.00	-10	3	15.0	3.3	65	6	20
23	AB	5	15	-999	1.55	6	18	-999	0	-999	16.5	1	0.80	0.10	0.10	0.00	-10	4	8.0	3.7	54	8	20
24	BA	15	30	-999	1.65	7	-999	-999	0	-999	11.5	1	0.60	0.10	0.10	0.00	-10	4	2.0	3.9	50	8	20
25	Bw	30	60	-999	1.75	10	-999	-999	0	-999	3.1	1	0.20	0.00	0.10	0.00	-10	4	0.0	4.3	41	5	20
26	Cw	60	90	-999	1.65	7	-999	-999	0	-999	4.3	1	0.20	0.00	0.10	0.00	-10	4	0.0	4.4	42	8	15
27	Ah	0	5	-999	1.40	3	15	-999	0	-999	33.5	1	0.80	0.00	0.20	0.00	-10	3	10.0	3.8	60	7	20
28	Bw1	5	40	-999	1.75	1	-999	-999	0	-999	16.0	1	0.10	0.00	0.00	0.00	-10	3	4.0	4.4	41	5	20
29	Bw2	40	100	-999	1.60	10	-999	-999	0	-999	7.9	1	0.70	0.00	0.10	0.00	-10	4	4.0	5.0	43	5	8
30	C	100	-999	-999	1.60	83	-999	-999	13	-999	8.3	1	5.80	0.00	1.10	0.00	-10	4	0.0	7.7	44	5	10
31	AEh	0	10	-999	1.30	5	25	-999	0	-999	16.1	1	0.60	0.00	0.20	0.00	-10	2	8.0	3.5	58	5	10
32	AE	10	25	-999	1.40	44	30	-999	0	-999	8.6	1	3.50	0.10	0.20	0.00	-10	2	3.5	3.8	48	5	10
33	Bsw	25	35	-999	1.50	53	-999	-999	0	-999	8.0	1	3.30	0.20	0.60	0.10	-10	3	1.5	3.9	42	5	14
34	Bw	35	60	-999	1.55	49	-999	-999	0	-999	8.8	1	3.00	0.30	0.90	0.10	-10	3	0.0	4.0	43	4	20
35	Cw	60	110	-999	1.65	48	-999	-999	0	-999	9.2	1	2.90	0.10	1.30	0.10	-10	4	0.0	4.3	43	4	25
36	Ap	0	20	-999	1.30	88	13	-999	0	-999	11.3	1	6.20	0.20	3.20	0.30	-10	2	2.0	6.8	50	5	17
37	Bw	20	50	-999	1.55	52	-999	-999	0	-999	12.8	1	4.30	0.20	2.00	0.10	-10	2	0.5	4.8	45	5	25
38	Cw	50	85	-999	1.50	44	-999	-999	0	-999	12.2	1	3.60	0.20	1.50	0.10	-10	3	0.0	4.7	44	8	15
39	2C	85	120	-999	1.60	71	-999	-999	0	-999	10.8	1	5.40	0.20	1.90	0.20	-10	4	0.0	5.6	42	5	10
40	Ah	0	5	-999	1.35	61	6	-999	0	-999	19.8	1	8.90	0.30	2.70	0.20	-10	1	3.0	4.1	49	7	15
41	Ba	5	40	-999	1.60	78	-999	-999	0	-999	17.6	1	8.60	0.40	4.50	0.30	-10	2	0.5	4.6	43	7	20
42	2C	40	-999	-999	-999.00	-999	-999	-999	-999	-999	-999.0	1	-999.00	-999.00	-999.00	-999.00	-10	-999	0.0	4.3	-999	-999	-999
43	Ap	0	20	-999	1.40	75	15	-999	1	-999	15.7	1	7.80	1.60	2.00	0.40	-10	1	2.5	7.6	49	7	20
44	Bw	20	45	-999	1.65	77	-999	-999	1	-999	13.2	1	7.30	0.60	1.80	0.40	-10	1	0.0	7.9	43	5	20
45	2Bw	45	75	-999	1.70	100	-999	-999	2	-999	18.0	1	12.40	0.40	4.80	0.40	-10	4	0.0	8.1	46	4	30
46	2C	75	-999	-999	1.60	100	-999	-999	10	-999	[illegible]	1	10.10	0.00	0.60	0.00	-10	5	0.0	8.4	36	9	2
47	Ah	0	3	-999	1.30	19	8	-999	0	-999	46.9	1	5.60	0.40	2.80	0.10	-10	1	2.5	4.9	52	7	15
48	Bw	3	40	-999	1.60	36	-999	-999	0	-999	29.8	1	6.70	0.20	3.50	0.20	-10	2	0.5	4.4	43	7	20
49	2Bw	40	75	-999	1.65	70	-999	-999	0	-999	28.4	1	12.20	0.30	7.10	0.40	-10	1	0.0	4.3	46	4	35
50	3Cw	75	-999	-999	1.65	77	-999	-999	0	-999	25.0	1	14.00	0.40	4.60	0.20	-10	4	0.0	4.8	41	4	20
51	Ap	0	30	-999	1.30	75	5	-999	0	-999	3.2	1	2.00	0.20	0.20	0.00	-10	1	3.5	6.4	50	9	5
52	Bw	30	80	-999	1.50	90	-999	-999	0	-999	2.0	1	1.40	0.10	0.20	0.10	-10	1	0.0	7.3	41	9	5
53	C	80	140	-999	1.50	92	-999	-999	0	-999	1.3	1	0.90	0.10	0.20	0.00	-10	1	0.0	7.3	36	9	1
54	Ap	0	25	-999	1.30	57	8	-999	0	-999	12.4	1	6.20	0.20	0.60	0.10	-10	2	3.0	4.2	52	5	15
55	Bsw	25	35	-999	1.50	37	-999	-999	0	-999	6.2	1	2.00	0.10	0.20	0.00	-10	2	1.0	4.4	42	5	10
56	Bw	35	90	-999	1.70	69	-999	-999	0	-999	8.8	1	4.20	0.30	0.60	0.10	-10	2	0.0	5.1	41	5	20
57	Cck	90	120	-999	1.70	96	-999	-999	8	-999	9.0	1	7.30	0.20	0.70	0.40	-10	2	0.0	6.2	41	5	20
58	Ah	0	10	-999	1.40	2	18	-999	0	-999	31.3	1	0.20	0.20	0.20	0.10	-10	1	10.0	4.1	60	7	30
59	BA	10	40	-999	1.60	2	18	-999	0	-999	37.2	1	0.20	0.30	0.20	0.10	-10	1	5.0	4.4	50	7	30
60	Bw	40	45	-999	1.70	4	-999	-999	0	-999	12.6	1	0.10	0.20	0.10	0.10	-10	1	0.0	4.4	46	7	30
61	Bwg	45	60	-999	1.75	7	-999	-999	0	-999	7.4	1	0.10	0.20	0.10	0.10	-10	3	0.0	4.4	41	8	20

DE-EST_HOR-01 | DE-EST_HOR-08 | DE-EST_HOR-11 | DE-EST_HOR-14 | Sheet1

Figure 1: Sheet from SPADE 8 with colour codes

The resulting SPADE 8 database (Koue et al. 2008) was presented at an ESBN meeting in Paris in December 2008. It was discussed how the SPADE 8 database could be developed to cover all dominant soil types in the different countries. The outcome was that the national evaluation reports and the country specific databases should be sent to the individual stakeholders in order for them to i) review and correct the existing data and ii) estimate new datasets for the dominant soil types without soil profile analytical data, based on their local knowledge. This was done immediately after by the Danish specialist group. Stakeholders had the full authority to reject or adjust the corrections suggested expecting that the stakeholder took action on the values in the coloured cells (Figure 1) and corrected them to fit common knowledge. Again, only few stakeholders responded.

As a result of that study, a significant number of errors were identified and the linkage between profiles and dominant STUs were increased to 68% if specific edits were made to the original SPADE data. In an effort to involve the original contributors, a report was sent to each Member

State having contributed to the original SPADE database with highlights of the specific data issues they had provided and indicating proposed solutions.

Only a limited number of countries provided the JRC with updated values or datasets. Most countries indicated that the JRC should implement the corrections in the database highlighted in the report. In addition, requests for the voluntary provision of data for the remaining dominant STUs (approximately 32% of the database) did not generate any new data.

Soil profile analytical database 2 (SPADE 2)

SPADE-2 was developed to provide sufficient soil property data supporting higher tier modelling of pesticide fate at the European level (Hollis et al., 2006).

The SPADE 2 database is based on existing measured and the primary soil properties required for each STU are:

i) Horizon nomenclature (upper and lower depth in cm),
ii) Particle-size fractions: clay, silt, and content of at least 3 sand fractions (fine, medium, coarse),
iii) pH in water (1:2.5) ,
iv) Organic carbon content (%) and v: Dry bulk Density (g cm^{-3}).

Data supplied by each country were based on the national data archives and for some parameters, particularly particle-size distribution, the analytical techniques used varied slightly from country to country. The raw data supplied by national data providers has thus been harmonized and validated to provide a single data file (SPADE_2.dbf) that can be easily used in conjunction with the SGDBE.

Acquisition of soil property data was achieved through the European Soil Bureau Network. The first acquisition phase resulted in data sets from Belgium and Luxembourg, Denmark, England and Wales, Finland, Germany, Italy, Netherlands, Portugal and Scotland (Hollis et al., 2006). In a second acquisition phase providers from Bulgaria, Croatia, Czech Republic, Estonia, Greece, France, Hungary, Republic of Ireland, Latvia, Lithuania, Poland, Romania, Slovakia, Slovenia, Spain and Switzerland were contacted about participation. There was a negative response from Latvia and no replies from Croatia, Czech Republic and Poland. During subsequent negotiations of contracts, it was decided that the specified data could not be supplied for Greece, Lithuania and Slovenia within the project time-scale. Bulgaria, Estonia, France, Hungary, Ireland, Romania, Slovakia and Switzerland supplied complete data sets by December 2008. Spain provided an interim dataset to be completed in summer 2009. The datasets from France and Ireland were developed from existing SPADE 1 data and literature using expert judgment.

Soil profile analytical database 14 (SPADE 14)

In order to generate a full covered soil profile analytical database connected to the 1:1.000.000 European soil map it was decided to construct a SPADE 14 database based on the concept used in SPADE 1 and 8. The update of the SPADE 8 database to a full covered database was carried out from December 2013 to June 2015 by a group of Danish scientists, Prof. Henrik Breuning-Madsen, Prof. Thomas Balstrøm and M.Sc. Jeppe Aagaard Kristensen in cooperation with the stakeholder of the respective countries (Appendix 1). The full covered SPADE 14 database is available in Appendix 2.

Project goal

The project aimed at developing a revised and complete SPADE database for the dominant STUs. This is referred as SPADE 14. Specifically, this study has three key goals:

1. To implement the corrections of the original SPADE database as identified in the 2008 study.
2. To update the original SPADE database with revised data sent by Member States;
3. To populate the missing estimated profile data of SPADE (approximately, 32% of the dominant STU) through matches in neighbouring countries, the use of SPADE 2 or any other reference data sources.

Specific tasks

In order to produce SPADE 14, the following tasks were foreseen:

1. Implementation of the corrections of all potential errors within the current version of the SPADE dataset (EST_PROF and EST_HOR files) that currently limit the use of the product as specified in the 2008 study.
2. Quality control of revised information received from stakeholders during the period 2008-2012 taking into consideration classical pedological relationships and conditions (e.g. texture sum, pH vs carbonate content vs base saturation, CEC and clay content, distribution of SOC with depth, matching of horizon limits, etc. – this list is not definitive).
3. Update the SPADE database with controlled data from task 2.
4. Where estimated profile data are missing for dominant STU, attribute values will be produced from similar soils in same or neighbouring countries and/or from relevant data from the SPADE2 database (EUR 22127).
5. Production of a draft database for checking by Member States. Three months will be allowed for feedback from Member States.
6. Quality control of any revised information received from stakeholders taking into consideration issues outlined in task 2.

7. Incorporate feedback from Member States into revised database.

8. Flag all records of the database in such a manner that source of new data information can be traced.

9. Produce a report on the eventual modifications, highlighting any specific issues or possible future data acquisition routes for sub-dominant STUs.

10. Production of metadata records for inclusion in the ESDAC catalogue (template to be provided by JRC).

The transformation of the SPADE 8 database into the SPADE 14 database

In September-October 2014, the SPADE-8 database was evaluated in order to correct implausible data as well as suggest estimated values for the properties for which no data was estimated by the stakeholders.

1	PROF_NUM	HOR_NUM	HOR_NAME	)EPTHSTAR	DEPTHEND	BD	BS	C_N	CACO3_TOT	CASO4	CEC	EC	EXCH_CA	EXCH_K	EXCH_MG	EXCH_NA	EXCH_NA_P	GRAVEL	OM
2	DK1	1	A	0	2	1.50	32	15	0	0	3.9	1	1.00	0.02	0.20	0.01	0	1	2.0
3	DK1	2	C	2	200	1.60	28	15	0	0	1.0	1	0.20	0.02	0.05	0.01	1	1	0.1
4	DK2	1	Op	0	20	0.2	8	30	0	0	160.8	1	10.20	0.60	1.20	0.10	0	1.00	80.5
5	DK2	2	Oe	20	55	0.21	4	30	0	0	152.5	1	5.30	0.20	0.80	0.05	0	1	78.5
6	DK2	3	A	55	65	1.10	14	15	0	0	31.8	1	4.00	0.10	0.20	0.04	0	1	14.7
7	DK2	4	Cg	65	200	1.60	13	15	0	0	5.8	1	0.60	0.03	0.10	0.01	0	1	0.8
8	DK3	1	Ap	0	40	1.40	65	11	0	0	14.0	1	8.5	0.2	0.3	0.0	0	1	3.7
9	DK3	2	Cnor	40	200	1.50	29	15	0	0	1.4	1	0.3	0.0	0.0	0.0	1	1	0.1
10	DK4	1	A	0	20	1.55	43	19	0	0	8.0	1	3.0	0.1	0.3	0.0	0	1	4.7
11	DK4	2	E	20	30	1.58	35	21	0	0	5.0	1	1.5	0.0	0.2	0.0	0	1	1.2
12	DK4	3	Bhs	30	50	1.60	25	25	0	0	7.7	1	1.6	0.1	0.3	0.0	0	1	1.9
13	DK4	4	C	50	200	1.60	25	20	0	0	2.0	1	0.6	0.0	0.1	0.0	0	1	0.2
14	DK5	1	Ap	0	20	1.50	70	12	0	0	15.7	1	10.2	0.3	0.4	0.1	1	1	2.5
15	DK5	2	Btg	20	130	1.55	62	12	0	0	18.7	1	9.5	0.3	1.7	0.1	1	1	0.3
16	DK5	3	Cg	130	200	1.60	75	7	0	0	16.7	1	9.5	0.3	2.6	0.1	1	1	0.1
17	DK6	1	Ap	0	20	1.34	75	15	0	0	17.2	1	11.1	0.2	1.4	0.2	1	0	3.2
18	DK6	2	Bg	20	50	1.21	78	13	0	0	10.2	1	6.6	0.2	1.1	0.1	1	0	1.4
19	DK6	3	Cg	50	200	1.10	79	14	0	0	28.2	2	17.6	0.8	3.2	0.6	2	0	2.0
20	DK7	1	A	0	20	1.50	74	12	0	0	6.5	1	4.2	0.1	0.5	0.0	0	1	2.0
21	DK7	2	Bw	20	60	1.55	59	12	0	0	4.0	1	1.9	0.1	0.4	0.0	0	1	1.0
22	DK7	3	C	60	200	1.60	57	8	0	0	2.0	1	0.9	0.0	0.2	0.0	0	2	0.2
23	DK8	1	Ap	0	25	1.50	68	12	0	0	13.5	1	9.0	0.1	0.1	0.0	0	1	2.1
24	DK8	2	Bw	25	65	1.60	86	12	0	0	9.2	1	7.4	0.1	0.4	0.0	0	1	1.4
25	DK8	3	C	65	200	1.65	100	8	10	0	7.2	1	6.8	0.1	0.3	0.0	0	1	0.3

Figure 1. Screenshot of the Estimated Horizon Database (EST_HOR) for Denmark (DK). The white fields contain values estimated or approved by the stakeholders. Brown fields contain suggested values estimated by the current SPADE-14 evaluation team, and should be the primary concern of the stakeholders during the current evaluation.

The soil profile (EST_PROF) and horizon (EST_HOR) databases from SPADE-8 for each country formed the starting point for the SPADE-14 databases. The values identified as improper during the SPADE-8 evaluation were corrected according to theoretical or empirical values, if the individual stakeholders had not made the corrections themselves (brown cells, Figure 2). As a main principle, the values suggested by the stakeholders were maintained if they had been re-evaluated according to the SPADE-8 evaluation or if they did not differ significantly from theoretical or empirical values. Corrections to values suggested by the evaluation team or the stakeholders during the SPADE-8 evaluation were accepted with no further objections. In order to estimate missing water retention data (WC_X), a multiple regression equation was derived based on bulk density (BD), organic matter content (OM) and texture (TEXT_X) data from Belgium (BE) and Great Britain (GB), who had complete sets of WC data.

A number of stakeholders had provided very few or no estimated values for some or all of the Soil Typological Units (STU). In these cases, the dominating STU's were constructed based on profiles with the same SOIL and TEXT_1 codes in adjacent countries, i.e. a profile with the codes SOIL=Bc and TEXT_1=2 (Bc-2) in Austria (AT) could be replaced by a Bc-2 from Germany (DE). In cases where the dominating STU profiles did not exist in the bordering countries, they were imported from other countries covered by the database (yellow first column only, Figure 3). See Part 2 below for further information.

1	PROF_NUM	COUNTRY	SOIL	SOIL90	TEXT1	TEXT2	PM	SMU	STU	LU	GWL_HI	GWL_LO	DR_EFF_/	DR_EFF_E	DR_EFF_CO	DR_EFF_I	DR_EFF_OL	DR_EFF_S	DR_EFF_S	DR_EFF
39	GB38	GB	Ql	-999	1	1	Secondary	0	0	Arable	5	5	-999	80	-999	50	-999	50	50	5
40	GB39	GB	Rc	-999	1	1	Dune sand	0	0	Natural du	4	5	-999	80	-999	50	-999	50	50	5
41	GB40	GB	Rd	-999	1	1	Dune sand	0	0	Lowland h	4	5	-999	80	-999	50	-999	50	50	5
42	GB41	GB	U	-999	9	1	Clayey sar	0	0	Moor	5	5	-999	80	-999	50	-999	50	50	5
43	GB42	GB	Bc	-999	1	0	River terra	0	0	Arable lan	5	5	-999	-999	-999	-999	-999	-999	-999	-9
44	GB43	GB	Bd	-999	1	0	acid igneo	-999	-999	forest	5	5	-999	-999	-999	-999	-999	-999	50	-9
45	GB44	GB	Bd	-999	3	0	Glacial Till	0	0	Pasture	4	5	-999	-999	-999	-999	-999	-999	-999	-9
46	GB45	GB	Ges	-999	2	0	Glacial drif	0	0	Pasture	1	2	-999	-999	-999	-999	-999	-999	-999	-9
47	GB46	GB	Id	-999	1	0	Granite	0	0	Pasture	1	1	-999	-999	-999	-999	-999	-999	-999	-9
48	GB47	GB	Jcg	-999	1	0	marine sar	310029	310128	horticulture	1	2	-999	40	-999	50	-999	40	20	4
49	GB48	GB	Jd	-999	1	1	Fluvial dep	0	0	Agriculture	4	5	-999	-999	-999	-999	-999	-999	-999	-9
50	GB49	GB	Jeg	FLe	2	0	Fluvial dep	0	0	Agriculture	1	2	-999	-999	-999	-999	-999	45	-999	-9
51	GB50	GB	Lc	-999	1	1	Terraces	0	0	Vineyards	-999	-999	-999	-999	-999	-999	-999	-999	-999	-9
52	GB51	GB	Lo	-999	1	0	Calcareou	0	0	Pasture	5	5	-999	-999	-999	-999	-999	-999	-999	-9
53	GB52	GB	Po	-999	2	0	Weatherin	-999	-999	Forests	5	5	-999	-999	-999	-999	-999	-999	-999	-9
54	GB53	GB	Qc	ARb	1	0	Late glacia	0	0	Agriculture	2	5	-999	-999	-999	-999	-999	-999	-999	-9
55	GB54	GB	U	-999	1	2	Gneiss	0	0	Forest	-999	-999	-999	-999	-999	-999	-999	-999	-999	-9
56	GB55	GB	U	-999	2	2	Granite	0	0	Wasteland	-999	-999	-999	-999	-999	-999	-999	-999	-999	-9
57	GB56	GB	Ic	-999	2	4	dolomite d	-999	-999	pasture lar	5	5	-999	-999	-999	-999	-999	-999	-999	-9
58	GB57	GB	Bec	-999	1	2	Secondary	0	0	Arable	5	5	-999	80	-999	50	-999	50	50	5
59	GB58	GB	Gds	-999	1	0	Eolian san	-999	-999	Pasture	1	2	-999	40	-999	40	-999	40	40	4
60	GB59	GB	Ges	GLe	1	0	Post galci	0	0	Agriculture	1	3	-999	-999	-999	-999	-999	-999	-999	-9

Figure 3. Screenshot of the Estimated Profile Database (EST_PROF) for Great Britain (GB). Profiles GB38-41 are the original profiles estimated by the stakeholder (Part 1); data for profile GB42-56 is imported from other profiles with their existing (though quality checked) data (Part 2); and data for profile GB57-59 is pasted in a modified version (Part 3).

In more than 100 cases, the SOIL/TEXT_1 code for the dominating STU did not exist anywhere in the database. These profiles were constructed based preferably on adjacent profiles from the same country or countries in the vicinity (all columns yellow, Figure 3). See part 3 below for further information. The choice of profiles for modification was based on geographical proximity and the smallest possible modification necessary to meet the characteristics for the missing STU. As some parameters are interdependent, several values had to be adjusted when one value was modified. For instance, a Le-3 could be constructed from an Ld-3, with minor corrections of base saturation (BS) in the B-horizon. As the BS depends on pH and the exchangeable bases (EXCH_X) depend on BS, these values had to be adjusted accordingly. When the texture (TEXT_X) had to be modified, the water retention (WC_X) was estimated based on the multiple regression equations presented in part 1 below.

Finally, a quality check based on an extended set of the equations used in the SPADE-8 evaluation was conducted (see part 4 below). Generally, the profiles fit quite well after the initial modification in part 1, but few necessary corrections were made.

PART 1: Correction of the improbable values identified in the SPADE-8 evaluation

The following values are presented in the same sequence as they were corrected. For elaboration of the individual corrections, please consult the country specific SPADE-8 evaluation. For the original guidelines to the stakeholders, we refer to Breuning-Madsen and Jones (1995).

Estimated profile database (EST_PROF)

<u>*Soil classification (SOIL; SOIL90)*</u>

The corrections of soil classification were accepted without further notice.

<u>*Topsoil texture (TEXT_1)*</u>

The corrections of topsoil texture class were accepted without further notice.

No further corrections were suggested for the EST_PROF database.

Estimated horizon database (EST_HOR)

The corrections made in the EST_HOR database were based on the same guidelines as presented in SPADE-8. A few extra rules were added.

<u>*Metadata (PROF_NUM; HOR_NUM; HOR_NAME)*</u>

The corrections of horizon metadata were accepted without further notice. In a few cases, H-horizons referred to mor layers and O-horizons referred to peat layers. This was corrected according to EST_PROF under the convention that the upper horizon in soils with no sign of poor drainage and often with LU=forest and PH<5 were mor layers, while organic layers due to poor drainage conditions (e.g. GW=1-2 or SOIL/HOR_NAME with suffix "g") were assumed to be of peaty origin (H). The landuse (LU) of such soils were often referred to as "wetland" or "peaty" in the EST-PROF database.

<u>*Depth (DEPTHSTART; DEPTHEND)*</u>

The corrections of horizon depths were accepted with no further notice. Furthermore, the depth of the lowest horizon was corrected to 200 cm if no lower depth was specified (Breuning-Madsen and Jones, 1995). When shallow soils, i.e. Lithosols (FAO74=I)/Leptosols (FAO90=LP), were not underlain by a rock horizon (R) this horizon was added underneath the lowermost horizon. Rock horizons have no lower limit (DEPTHEND=-998; -999).

All O-horizons were adjusted to negative depths, so the mineral soil underneath the litter layer starts at 0 cm depth. Underlying horizons were adjusted accordingly.

<u>*Sodium adsorption ratio (AR_NA)*</u>

AR_NA was deleted due to its reference to irrigation water suitability rather than soil properties.

Bulk density (BD)

The bulk densities were adjusted according to the average empirical bulk densities in the SPADE-2 database. The BD for the soils with an organic matter content (OM)>10% were averaged over OM intervals of 10%. In soils with OM<5% the BDs were averaged over medium depth intervals of 25 cm (medium depth=[DEPTHSTART+DEPTHEND]/2). When 5%<OM<10% the BD was assigned a value of 1.1-1.2 g cm^{-3}.

The BD values are summarised in Table 1. The values were only corrected when no or very implausible values were provided by the stakeholder.

Table 1 Average bulk densities calculated from the SPADE-2 database. One standard deviation and the number of observations (n) are shown.

OM	**Bulk Density**	**Std dev**	**n**
%	**g cm^{-3}**		
90-100	0.1	0.13	165
80-90	0.1	0.05	81
70-80	0.2	0.11	64
60-70	0.2	0.13	36
50-60	0.3	0.13	25
40-50	0.4	0.08	28
30-40	0.4	0.17	19
20-30	0.8	0.31	35
10-20	1.0	0.72	176
5-10	1,1-1,2	n/a	n/a
<5	1.3	0.18	400
	1.4	0.18	726
	1.4	0.17	719
	1.5	0.14	468
	1.5	0.18	714

Carbon-nitrogen ratio (C_N)

The C/N ratio was corrected as an expert judgement according to the general guidelines presented in Table 2. These numbers should be perceived more as judgement guidelines than strict rules, as e.g. gleyic conditions could inhibit the turnover of the organic matter in an agricultural soil causing a higher C/N ratio than expected.

Table 2: Typical C-N ratios serving as reference for the expert judgement. Based on Brady and Weil, 2007.

Soil environment/horizon	**C/N**

Forest/A(h)	20-25
Mor/O	40-50
Agricultural topsoil/Ap	10-15
Subsoil/B-C	7-11
Peat/H, low pH (OM>40%)	40-50
Peat/H, high pH (OM=20-40%)	15-20

C_N<7 were corrected to 7, as C/N values below 7 are very unlikely.

Active calcium carbonate content (CACO3_ACT)

CACO3_ACT was deleted due to insufficient data provided.

Base saturation and pH (BS; PH)

First, the base saturation (BS) and the pH were corrected according to the total calcium carbonate content (CACO3_TOT) in the following manner:
If CACO3_TOT>10 %, the BS was adjusted to 100 % and the pH to 8.0-8.3.
If 0%<CACO3_TOT<10%, the BS was corrected to 97-99% and pH was adjusted to 7.8-8.1.

If CACO3_TOT=0, BS was corrected with respect to PH according to Equation 1:

$$BS = \frac{pH(1{:}2.5H_2O)-4}{0.041} \qquad \text{(eq. 1)}$$

Cation exchange capacity (CEC)

If the CEC value was missing, it was adjusted with respect to clay content (TEXT_2) and organic matter content (OM) according to Equation 2:

$$CEC = 50\ cmol^{+}kg^{-1} \times [TEXT\_2] + 200\ cmol^{+}kg^{-1} \times [OM] \text{ (eq. 2)}$$

Otherwise, the suggested values were accepted.

Exchangeable bases (EXCH_CA; EXCH_K; EXCH_MG; EXCH_NA)

The exchangeable bases were adjusted according to Equation 3:

$$TEB = CEC \times \frac{BS}{100\%} \qquad \text{(eq. 3),}$$

where TEB=total exchangeable bases (EXCH_CA+EXCH_K+EXCH_MG+EXCH_NA)

If values for exchangeable bases were provided by stakeholders, but the requirement in Equation 3 were not met, the exchangeable bases were adjusted proportionally until the equation was true.

If no data was applicable, the exchangeable bases (in "normal" soils where Ca^{2+} is expected to be the dominant base cation) were assigned according to equation 4-7:

$$EXCH\_CA = 0.90 \times TEB \quad \text{(eq. 4)}$$

$$EXCH\_K = 0.03 \times TEB \quad \text{(eq. 5)}$$

$$EXCH\_MG = 0.05 \times TEB \quad \text{(eq. 6)}$$

$$EXCH\_NA = 0.02 \times TEB \quad \text{(eq. 7)}$$

Organic matter content (OM)

The organic matter content was generally left untouched. However, adjustments were necessary in a few cases where for instance OM content in an H-horizon was <20%.

Structure (STRUCT)

Generally, no changes were made to structure but in some cases, data was missing. Then the structure was copied from the horizon immediately above or below, depending on the similarity of the other characteristics (primarily texture) with one or the other.

Texture (GRAVEL; TEXT_2; TEXT_20; TEXT_50; TEXT_200; TEXT_2000)

Very few changes were made to the texture except the ones suggested after the SPADE-8 evaluation. The changes made in the present evaluation were primarily assignment of data when it was missing or deletion of data in a few cases where it did not make sense. The former was done by copying the texture from the horizon in the same profile with the most similar characteristics. The latter was done by replacing the texture with -998 (nonsense data) if for instance <<50% of the volume was occupied by silicates (when OM+CACO3_TOT>>50% or GRAVEL≥4). The latter was not done consistently, as we decided to preserve certain values provided by the stakeholder, despite their questionable applicability.

Porosity (POR)

The most frequent correction made to the porosity was a downscaling of values as they relatively often were estimated significantly higher than suggested by Equation 8, where PD is the particle density:

:

$$POR = 1 - \left(\frac{BD}{PD}\right) \times 100\% \qquad \text{(eq. 8),}$$

The particle density was estimated according to Equation 9, where specific gravity is as follows: Silicates = 2.65 g cm^{-3}, Organic matter (OM) = 1.30 g cm^{-3} and $CaCO_3$ = 2.80 g cm^{-3}. Silicates, OM and $CaCO_3$ contents are entered as fractions.

$$PD(g\ cm^{-3}) = \frac{1.30g\ cm^{-3} \times 2.65g\ cm^{-3} \times 2.80g\ cm^{-3}}{(2.65g\ cm^{-3} \times 2.80g\ cm^{-3} \times OM) + (1.30g\ cm^{-3} \times 2.80g\ cm^{-3} \times silicates) + (1.30g\ cm^{-3} \times 2.65g\ cm^{-3} \times CaCO_3)}$$

(eq. 9),

Water retention capacity (WC_1; WC_10; WC_100; WC_1500)

If the soil water content at -1 kPa was higher than the porosity (WC_1>POR), all soil water retention contents for the given horizon were downscaled proportionally until POR=WC_1. In this way, the shape of the retention curve was preserved.

In cases where the texture or the organic matter content had to be modified significantly or the data was missing, the water retention data was estimated with Equation 10-13.

$$WC_1 = (-27.653 \times BD + 1.463 \times OM + 0.208 \times TEXT_2 + 0.017 \times TEXT_{20} + 0.154 \times TEXT_{50} + 0.013 \times TEXT_{200} + 0.003 \times TEXT_{2000} + 57.783) \times BD \quad \text{(eq. 10)}$$

$$WC_{10} = (-20.231 \times BD + 1.110 \times OM + 0.262 \times TEXT_2 + 0.029 \times TEXT_{20} + 0.193 \times TEXT_{50} - 0.026 \times TEXT_{200} - 0.072 \times TEXT_{2000} + 41.072) \times BD \quad \text{(eq. 11)}$$

$$WC_{100} = (-4.246 \times BD + 1.356 \times OM + 0.335 \times TEXT_2 + 0.071 \times TEXT_{20} + 0.105 \times TEXT_{50} - 0.002 \times TEXT_{200} - 0.015 \times TEXT_{2000} + 8.380) \times BD \quad \text{(eq. 12)}$$

$$WC_{1500} = (-0.330 \times BD + 1.088 \times OM + 0.358 \times TEXT_2 + 0.125 \times TEXT_{20} + 0.072 \times TEXT_{50} + 0.056 \times TEXT_{200} + 0.053 \times TEXT_{2000} - 4.719) \times BD \quad \text{(eq. 13)}$$

These equations are derived as multiple regressions on data from Belgium (BE) and Great Britain (GB), with water retention content as the dependent variable and bulk density, organic matter content and texture as independent variables. The dataset was validated on the dataset from Denmark (DK). A maximum of 8 observations out of 39 (21%) diverted more than 10 vol% WC from the 1:1 line between observed and calculated values. However, the majority of the diverting observations were found in Fluvisols (J/FL), which are often found to have rather unpredictable soil physical characteristics. Excluding the Fluvisol the match was very good.

Exchangeable sodium percentage (EXCH_NA_P)

The original classification was replaced by the actual percentage calculated from Equation 14.

$$EXCH\_NA\_P = \frac{EXCH\_NA}{CEC} \times 100\% \quad \text{(eq. 14)}$$

PART 2: Import of analytical data from neighbouring countries

In order to create as many profiles as possible with data estimated by stakeholders, profiles missing analytical data were assigned the complete dataset from a profile with a corresponding SOIL/TEXT_1 code, preferably from a neighbouring country. For instance, if a Be-2 was missing in The Netherlands (NL), the data from a Be-2 profile in Belgium (BE) or Germany (DE) was assigned to the Be-2 profile from The Netherlands – both in the EST_PROF and the EST_HOR databases. The only modification made was the profile name, which was corrected to the name of the original profile missing data. For example, if NL6 was a Be-2 with no analytical data and BE21 was a Be-2 with a complete dataset, all data for BE21 from BE_EST_PROF and BE_EST_HOR would be copied and pasted into NL_EST_PROF and NL_EST_HOR, and the profile name (PROF_NAME) would be changed to NL6. Such profiles are marked with yellow in the PROF_NAME column, Figure 3.

In cases where the country itself or neighbouring countries could not provide the profiles needed, the profile in question was replaced with data from a corresponding profile elsewhere in the database. In a few cases where very poor or no data was available, entire countries were created exclusively based on complete profile datasets from other countries (e.g. AT, LT, SI, SE, PL).

When the profiles where unavailable in the entire database, they were created by adjustment of existing profiles (see Part 3).

To see the entire list of the total exchange of analytical data between profiles, please see Appendix 3.

PART 3: Modification of existing soil profiles to create missing profiles

Several profiles did not exist anywhere in the database; hence, they could not be completed by a simple transfer of data from one profile to another, as described in Part 2. In such cases, similar profiles were modified before pasting them into the relevant database.

For example, if Norway (NO) lacked data for a Dystric Podzoluvisol with topsoil texture class 2 (Dd-2) and Finland (FI) had a complete analytical dataset for an Eutric Podzoluvisol with topsoil texture class 2 (De-2), the latter would have the base saturation (BS), pH (PH) and exchangeable bases (EXCH_X) downscaled in the subsoil to match the requirements for a Dystric Podzoluvisol (BS<50%). Subsequently, it would be pasted into the Norwegian databases. In the EST_PROF database, the soil name (SOIL) would be corrected from De to Dd, and in the EST_HOR database the necessary data would be adjusted as described. Finally, the profile name (PROF_NAME) would be adjusted accordingly in both the Norwegian horizon and profile databases (e.g. from FI4 to NO10).

The most radical modification was when texture had to be adjusted significantly, as it affects multiple other characteristics, e.g. water retention capacity and cation exchange capacity. Therefore, texture adjustments were avoided as much as possible. When necessary the texture was adjusted just enough to change the topsoil texture class adequately. For example, if a Lo-4 was missing data, a Lo-3 with 29 % clay could be modified to 36 % clay. The other grain size fractions were adjusted accordingly making sure the sum remained 100%. Subsequently, the water retention data was evaluated based on the new texture and corrected according to Equation 10-13, if major discrepancies were found.

If significant adjustments were made to the clay fraction (TEXT_2), the CEC was also adjusted; hence also the exchangeable bases to match the base saturation.

The full list of modified profiles and the main parameters adjusted can be found in Appendix 3.

PART 4: Quality control of the complete estimated database

Quality control was carried out on all datasets from all countries. It was done by creating an Excel spreadsheet built on the equations mentioned in Part 1, the thresholds defined in the SPADE-8 evaluation and a few additional criteria described below. When data was outside the threshold it was adjusted to the nearest limit. Below the QC is briefly presented. Again, the parameters are presented in the same chronology as they were evaluated.

Estimated horizon database (EST_HOR)

Lower depth of horizon (DEPTH_END)

The lowermost horizon must end in 200 cm unless it is a rock horizon (R).

Bulk density (BD) vs. organic matter (OM)

The bulk density must decrease with increasing organic matter content, when OM>5%. This relationship was only qualitatively evaluated based on XY-plots of the two parameters against each other. Furthermore, BD>2.0 g cm^{-3} were corrected to a value below 2.0, typically around 1.8 g cm^{-3}.

Total calcium carbonate (CACO3_TOT) vs. base saturation (BS) and pH (PH)

If CACO3_TOT>10 % the BS was adjusted to 100 % and the pH to 8.1-8.3.
If 0%<CACO3_TOT<10% BS was corrected to 97-99% and pH was adjusted to 7.8-8.1.

pH (PH) vs. base saturation (BS)

The BS was adjusted according to Equation 1. A divergence of ±1 pH unit was allowed. For pH<4 an arbitrary base saturation of 1-7 % was assigned. pH>8.4 was only allowed in saline soils, i.e. if the exchangeable sodium content (EXCH_NA) was considerable and EC was high (Solonchak, SOIL=Z).

Cation exchange capacity (CEC)

The CEC had to be within the limits specified in SPADE-8 based on mineralogy and OM-content (±5 %). When this requirement was not fulfilled the CEC was adjusted to the nearest limit.

Base saturation (BS) vs. total exchangeable bases (TEB)

Total exchangeable bases were adjusted proportionally according to Equation 3. 5 % exceedance was allowed.

Exchangeable bases (EXCH_X)

For ordinary soils the exchangeable calcium content should exceed the sum of the exchangeable content of the other three base cations (EXCH_CA>EXCH_K+EXCH_MG+EXCH_NA). In certain cases, where the parent material is dolomitic (high EXCH_MG) or on saline soils (high EXCH_NA), this requirement was ignored.

Organic matter (OM)

Organic matter contents were not allowed to be 0 in horizons starting within the upper meter of the soil profile. They were modified to a small arbitrary number like 0.1-0.3 % depending on the depth and the OM content of the overlying horizon.

pH (PH)

pH values below 3 where only allowed for in very few special cases where a soil profile looked like an acid sulphide soil. This would typically be drained wetland soils (SOIL=H, J or G).

Structure (STRUCT)

All horizons missing structure values were assigned one based on the overlying or underlying horizon. -999 values were accepted for organic horizons (H, O), rock horizons (R) or horizons with OM+CACO3_TOT>50 % or GRAVEL≥4.

Porosity (POR)

A theoretical porosity was calculated based on Equation 8. If the stated porosity deviated more than 25 % from the calculated porosity it was adjusted to be within the limits.

Water content (WC_X)

The water content was checked in order to make sure the following requirements were fulfilled:

POR≥WC_1≥WC_10≥WC_100≥WC_1500

If WC_1>POR, all the WC values for the horizon in question were adjusted proportionally, i.e. multiplied by POR/WC_1.

If WC_1≥WC_10≥WC_100≥WC_1500 was not fulfilled, the individual WC_X was adjusted based on an expert judgement.

Finally, it was checked whether WC_FC deviated more than 25 % from WC_10. Where it did the individual cases were evaluated. In very clayey or extremely sandy horizons, WC_FC was allowed to deviate slightly more than 25 %.

Texture (TEXT_X)

The texture had to sum up to 100 %.

Estimated profile database (EST_PROF)

Topsoil texture class (TEXT_1)

The texture in the uppermost horizon of each profile (horizons with DEPTH_START=0) in the EST_HOR database was checked against the topsoil texture class (TEXT_1) in the EST_PROF database. When they did not match, the texture of the top-horizon in the EST_HOR database was adjusted as little as possible to fit the texture class in the EST_PROF database. If the changes were considerable the CEC and the WC were checked to make sure they still complied with the rules mentioned above.

In a few cases, the topsoil texture class “0” was stated. This does not exist in the guidelines (Breuning-Madsen and Jones, 1995), but in most cases it referred to the texture class “9” (no texture), as it was typically stated for horizons with high contents (>50 %) of organic matter, calcium carbonate or gravel.

Topsoil texture classes (TEXT_1) occasionally referred to the horizon below a histic horizon (H). Thus, it was in fact a texture class 9 but held a texture class between 1 and 5. Vice versa, some profiles with O-horizons had the topsoil texture class 9 (or 0), although they should have been classified based on the underlying mineral horizon. This was not corrected as it would have corrupted the link to the SMUs, but it was noted in the quality control files.

Method for value estimation

In the EST_PROF database, the values indicating how the numbers in the horizon database were estimated were adjusted according to the modifications made in the EST_HOR database (see Breuning-Madsen and Jones (1995) for details). For instance, if the texture (TEXT_X) was altered in the EST_HOR, the corresponding values in the EST_PROF (TEXT_X_O) were changed to 5 (expert judgement). As texture modification most often implies changes in the water retention capacity (WC_X) in the EST_HOR, these would be calculated using the regression equation presented earlier. Therefore, the corresponding values in the EST_PROF (WC_X_O), stating how the values were estimated, would be corrected to 3 (calculated using a mathematical equation).

Response on the SPADE 14 database

On February 20th 2015 the SPADE 14 database was sent to the stakeholders for approval or suggestions for changes. The SPADE database contains 1045 profiles, and Table 3 shows how many profiles that was available from SPADE 1 and 8, how many profiles from other countries that has been used to update the different national dataset and how many profiles that have been constructed to complete the national datasets.

Table 3: The origin of the data in SPADE 14 at national level.

Country	Original SPADE 8	Profile from other country	New profiles	Total
AL	14 (AL 1-14)	13 (AL 15-27)	3 (AL 28-30)	30
AT	0	23 (AT 1-23)	4 (AT 24-27)	27
BE	42 (BE 1-42)	14 (BE 43-56)	0	56
BG	0	16 (BG 1-16)	7 (BG 17-23)	23
CH	28 (CH 1-28)	2 (CH 29-30)	7 (CH 31-37)	37
CZ	0	19 (CZ 1-19)	7 (CZ 20-26)	26
DE	60 (DE 1-60)	15 (DE 61-75)	2 (DE 76-77)	77
DK	13 (DK 1-13)	0	0	13
EE	11 (EE 1-11)	2 (EE 12-13)	4 (EE 14-17)	17
ES	26 (ES 1-26)	15 (ES 27-41)	8 (ES 42-49)	49
FI	6 (FI 1-6)	1 (FI 7)	0	7

FR	118 (FR 1-118)	35 (FR 119-153)	22 (FR 154-175)	175
GB	41 (GB 1-41)	15 (GB 42-56)	6 (GB 56-62)	62
GR	10 (GR 1-10)	15 (GR 11-25)	4 (GR 26-29)	29
HU	40 (HU 1-40)	10 (HU 41-50)	11 (HU 51-61)	61
IE	18 (IE 1-18)	4 (IE 19-22)	3 (IE 23-25)	25
IT	21 (IT 1-21)	11 (IT 22-32)	9 (IT 33-41)	41
LT	0	20 (LT 1-20)	8 (LT 21-28)	28
LU	0	10 (LU 1-10)	2 (LU 11-12)	12
LV	25 (LV 1-25)	0	0	25
NL	20 (NL1-20)	12 (NL21-32)	0	32
NO	15 (NO1-15)	0	1 (NO16)	16
PL	0	28 (PL1-28)	12 (PL29-40)	40
PT	18 (PT 1-18)	10 (PT 19-28)	4 (PT 29-32)	32
RO	28 (RO 1-28)	29 (RO 29-57)	21 (RO 58-78)	78
SE	0	9 (SE 1-9)	3 (SE 10-12)	12
SI	0	15 (SI 1-15)	9 (SI 16-24)	24
SK	17 (SK 1-17)	6 (SK 18-23)	1 (SK 24)	24
Total	**571**	**349**	**158**	**1078**
% of total	**53.0%**	**32.4%**	**14.6%**	**100%**

Table 3 shows that the SPADE 14 database contains soil analytical data from 1078 profiles which is almost the double of what is present in the SPADE 1 and 8 database. Most of the missing data could be allocated to the national dataset from other countries but 15% of the profile was not present in the SPADE 1 and 8 and had to be constructed from other profiles by changing some of the analytical data so the dataset fits the soil classification. 8 countries had not delivered data to the SPADE 1 and 8 and their dataset is exclusively based on imported data from the neighbouring countries or on constructed data if the soil type was not present in the database.

On February 20th 2015 the SPADE 14 data was sent to the respective stakeholders for acceptance or suggestions for changes. Deadline for response was April 17th 2015 but it was subsequently extended to be June 1st. We got response from LV, PT, FI, BE by whom we sorted some problems or mistakes and HU, DE and GB have asked for more time to scrutinize the dataset. Information from these countries will later be stored in the database.

Appendix 4 shows a paper using the SPADE 14 database for mapping the wheel load caring capacity in Europe, see Fig 9. The signature no data shows areas with soil types like Leptosol and Histosols where calculations have not been made. Fig. 9 shows that the SPADE 14 is a full covered level 1 database for 28 European countries.

Future work

We can in the future expect updates of the existing SPADE 14 database due to increasing knowledge about soils in the 28 countries that have delivered data to the SPADE 14 database.

The SPADE 14 database covers most of the European countries, but Iceland, Croatia, Bosnia-Herzegovina, Macedonia (FYROM), and Montenegro, Malta and Cyprus are still missing. EU soil-related research would benefit if these countries could construct a soil profile and analytical database to match the specifications of SPADE 14.

The SPADE 14 database is a Level 1 database - this means that the dominant soil type in a SMU cover the entire SMU although it might only cover 40% of the SMU the other 60% is soil types present as associations (20-50% coverage) or inclusions (<20% coverage). For agricultural and environmental problems this might not be sufficient as the problem within a SMU might be linked to one of the soils present as an association or inclusion. Thus a level 2 database should be established as fast as possible in order to overcome this problem. A full coverage level 2 database can be made for 35 European countries within a 3 year period using the methods for the construction of the SPADE 14 database.

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