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# European HYdropedological Data Inventory (EU-HYDI)

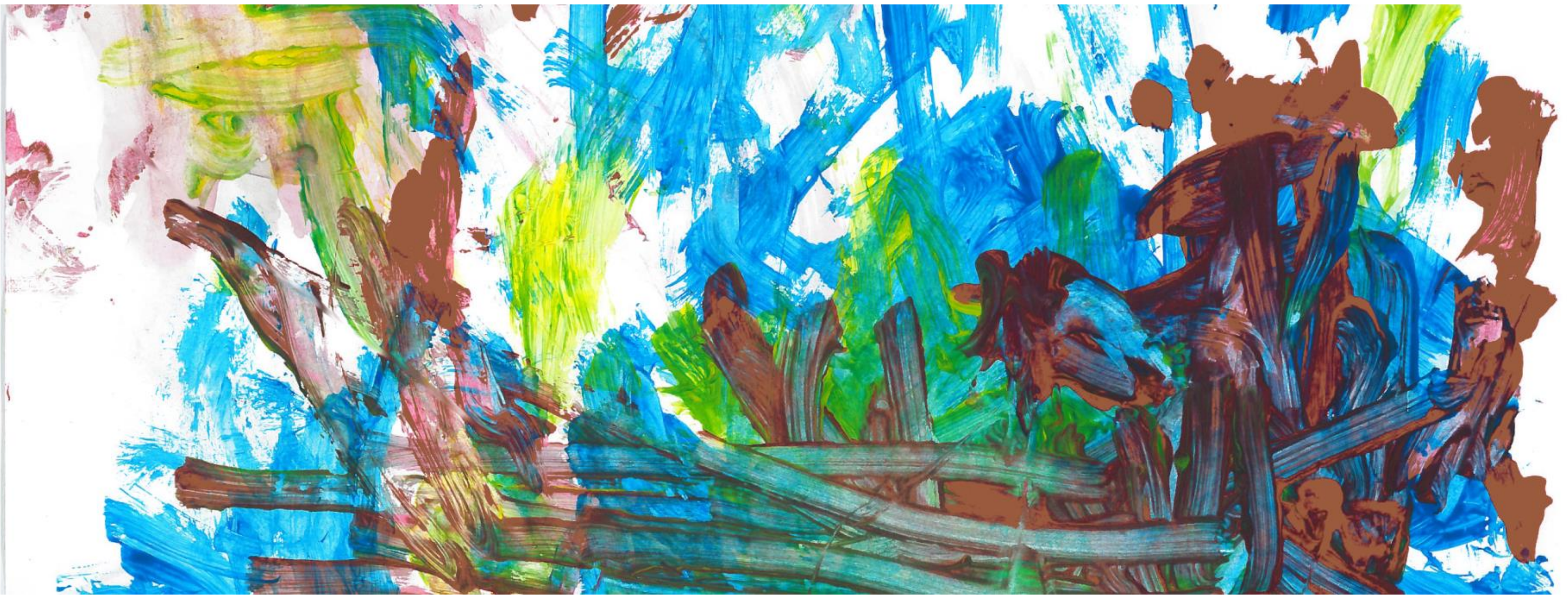

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Table of contents

# 1 Introduction

*Luca Montanarella and Gergely Tóth*

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The European Commission has been involved since 1995 in the development of pedotransfer functions and rules for soil hydrology in Europe. Starting with the Human Capital and Mobility Programme (CHRX-CT94-0639) “Using existing soil data to derive hydraulic parameters for simulation modelling in environmental studies and in land use planning” it has been developing a database of HYdraulic PRoperties of European Soils (HYPRES). Institutions from 10 EU member states co-operated in the development of this database of soil hydraulic properties, covering mostly north western part of Europe and some areas in the Mediterranean (Wösten et al. 1999).

In contrast to this, activities to prepare an integral ’Soil Geographical Database of Europe 1: 1.000.000’ and connecting database (soil profile database (Hiederer et al. 2006)) have been extended to Central and Eastern Europe in the 1990s (EC 2003). Many institutions in Central and Eastern Europe have expressed their keen interest and willingness in contributing to such a database of soil hydraulic properties and much data exist in these countries. In the last decades a number of new continental and regional scale databases became available to support soil water modelling in Europe. Besides the European Soil Database and data from the BioSoil forest soil monitoring (Lacarce et al. 2009), a new set of soil data was collected through the LUCAS Soil survey (Tóth et al. 2013), including particle size distribution, organic carbon and other chemical properties of about 22.000 sampling points over the EU.

Parallel with the extension of spatial soil datasets and development of new modelling tools there has been an increasing demand towards purpose specific new pedortansfer functions and rules which are applicable from catchment scale to continental scale assessments. MyWater, a recent European collaborative project, sets the aim to obtain reliable information on water quantity, quality and usage for appropriate water management, by joining three scientific research areas: earth observation, catchment modelling and meteorology (Araújo 2011). As far as soil water information is concerned, the ultimate goal of the European Commission with this and related projects is to implement a multiscale thematic soil water database through the European Soil Data Centre (http://esdac.jrc.ec.europa.eu/).

While there is an increasing need for reliably information on soil water, this information is often combined with other soil data under the umbrella of the emerging discipline of hydropedology.

In November 2011, leading European soil hydrologists, including members of the European Soil Bureau Network were invited to discuss the possibilities to assemble a comprehensive European Hydropedological Data Inventory (EU-HYDI). Scientists from institutions from across Europe expressed their interest in participating in this initiative and assembled in Ispra, Italy on the 12 April 2012 and again on 4-5 March 2013 with the goal to establish the scientific principles, database structure and the implementation of the EU-HYDI.

The participants shared the common interest to establish a joint database (the EU-HYDI) with equal access rights for the advancement of hydropedological research and applications in Europe.

The database holds soil properties with a special but not exclusive focus on hydrological properties; it also holds various other soil properties associated to the same samples. The comprehensive joint European Hydropedological Data inventory thus can serve multiple purposes, including scientific research, modelling and application of models on different geographical scales.

The EU-HYDI, being the most comprehensive dataset of its kind, is foreseen to yield a series of new research results, including accurate and reliable inputs for soil water models in the coming years.

This report first presents an overview of the EU-HYDI (Chapter 3), then details the contributed datasets (Chapters 4 to 26) and finally describes how these datasets were assembled and harmonized (Chapter 27).

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# 2 Notice on data access

All raw data contained in the EU-HYDI database are accessible only to the contributing participants and the EU-HYDI coordinators at the JRC. Thus, authorised users of the raw data are limited exclusively to the authors of this report. Authors are listed on page 4 of this report and at the headings of each chapter.

The EU-HYDI database is not distributed outside the participating institutions. External partners can access only derivatives for joint publications.

However, scientists from any institution are welcome to contact any author of this report for cooperative research. In such research projects handling and analysis of raw data has to be done by the EU-HYDI contributing participant without giving access to the raw data to the external partner. Results of the analysis and derived information can be published together with external partners.

For uses of data originating from three or less institutions, the original data providers should be approached for offering co-authorship.

The intellectual property rights related to the data remain with the data providers.

When data are used and derived product is published, data contributors are cited through a reference to this report, or its chapters, in case if only a subset of data from three or less institutions are involved in the research.

# 3 Database overview

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The European HYdropedological Data Inventory collects data from European soils focusing on soil physical, chemical and hydrological properties. It also contains information on geographical location, soil classification and land use/cover at the time of sampling. It was assembled with the aim of encompassing the soil variability in Europe.

We based the structure of the database on various soil databases: HYPRES (Wösten et al., 1999), the European Soil Database (ESDB) (EC, 2003), the Land Use/Cover Area frame Statistical Survey (LUCAS) (Eurostat, 2013), the Hungarian Detailed Soil Hydrophysical Database (Hungarian acronym: MARTHA) (Makó et al., 2010), the Portuguese soil database PROPSOLO (Gonçalves *et al.*, 2011) and the AUTh database (Tóth, et al., 2011). The final database structure (Annex 2) was decided based on suggestions of the EU-HYDI team (Annex 1).

The database consists of ten tables: the first nine hold original data while the last contains harmonized data (Table 3.1). Each profile from table GENERAL has a unique identifier of 8 digits. In tables BASIC, CHEMICAL, PSIZE, RET and COND, each sample is uniquely identified by its sample identifier: the profile identifier (8 digits) to which 2 digits are added for the sample. Tables can be linked through these two keys. The EU-HYDI structure makes room for time series data, but none of the contributors provided such data.

Table 3.1 List of tables in EU-HYDI database

| | **Description** |
|---|---|
| GENERAL | **General profile properties** |
| BASIC | **Basic and physical data at the sampling layer level** |
| CHEMICAL | **Chemical data at the sampling layer level** |
| PSIZE | **Measured particle size distribution data at the sampling layer level** |
| RET | **Measured soil water retention data at the sampling layer level** |
| COND | **Measured soil hydraulic conductivity data at the sampling layer level** |
| METHOD | **Measurement methods** |
| TSERMETA | **Time series metadata** |
| TSERDATA | **Time series data** |
| PSD_EST | **Harmonized particle size distribution** |

## 3.1 Number of samples and geographical distribution

Soil samples of the EU-HYDI originate from 18 European countries and were contributed by 29 institutes. In total, the database contains information on 18682 soil samples from 6014 profiles.

76% of the data contain information about soil water retention with 43% of samples having at least five measured water retention values, 34% have measured soil hydraulic conductivity although 19% have only saturated hydraulic conductivity. There is information about particle size distribution for 89% of the samples included in the dataset (84 % summing to 100%).

11138 samples (62 %) have measured bulk density, organic carbon, particle size distribution and at least one measured water retention value.

Table 3.2 shows the list of participants who contributed to the EU-HYDI and the number of samples and soil profiles per country. Figure 3.1 shows the geographical distribution of soil profiles contained in EU-HYDI.

Table 3.2 Number of samples and profiles provided by participants per country (without replicates) included in EU-HYDI database

| Country | Institution | Number of profiles | Number of samples |
|---|---|---|---|
| Austria | Federal Agency for Water Management | 68 | 204 |
| Belgium | Ghent University<br>Earth and Life Institute, Université catholique de Louvain | 131 | 285 |
| Czech Republic | Czech University of Life Science in Prague | 72 | 174 |
| France | INRA, Orléans | 123 | 352 |
| Germany | ZALF Müncheberg, Institute of Landscape Hydrology<br>Federal Institute for Geosciences and Natural Resources (BGR) | 616 | 2310 |
|  | University of Naples Federico II |  |  |
| Greece | Aristotle University of Thessaloniki | 883 | 2588 |
| Hungary | University of Pannonia | 308 | 900 |
| Italy | University of Palermo<br>University of Naples Federico II<br>University of Padova | 962 | 1242 |
| Netherlands | Alterra, Wageningen University | 102 | 358 |
| Norway | Bioforsk Soil and Environment<br>Norwegian Forest and Landscape Institute<br>Norwegian University of Life Sciences<br>Norwegian Water Resources and Energy Directorate | 504 | 2033 |
| Poland | Institute of Agrophysics, Polish Academy of Sciences, Lublin | 281 | 447 |
| Portugal | Instituto Nacional de Investigaçao Agrária e Veterinária | 330 | 697 |
| Russian Federation | Moscow State University | 65 | 304 |
| Slovakia | Soil Fertility Research Institute<br>Soil Science and Conservation Research Institute | 36 | 155 |
| Spain | Evenor-Tech | 1091 | 3801 |
| Sweden | Swedish University of Agricultural Sciences | 185 | 1744 |
| Ukraine | National Scientific Center, Institute for Soil Science and Agrochemistry Research named after ON Sokolovskiy , Kharkiv | 95 | 529 |
| United Kingdom | James Hutton Institute<br>Cranfield University | 162 | 559 |
| Total |  | 6014 | 18682 |

Table 3.3 shows the proportion of soil profiles containing general site or profile description. At least one third of the profiles have data about land cover and land use information. Description of soil surface is avaialable only for minor part of the data (0 to 16 % of profiles). Soil type according to national classification systems is given for 40% of the data, but harmonized WRB (WRB1998 or WRB2006) names are only available for 16% of the data.

Table 3.4 shows the list and descriptive statistics of basic and chemical soil properties included in the EU-HYDI.

Figure 3.1 Geographical distribution of the soil profiles of EU-HYDI (some data are not included because the provided coordinates could not be transformed in WGS84 or because they lack coordinates)

Table 3.3 Proportion of soil profiles, having information about properties related to site or profile description

| General information (N=6186) | | | | | |
|---|---|---|---|---|---|
| Geographical coordinates | 96% | SRF_ERO_COV | 10% | WRB1998_RSG | 7% |
| ELEV | 41% | SRF_ERO_DEG | 10% | WRB1998_ADJSPE1 | 7% |
| ISO_COUNTRY | 100% | SRF_ERO_ACT | 2% | WRB1998_ADJSPE2 | 3% |
| RC_L1 | 86% | SRF_SEAL_THIC | 6% | WRB1998_ADJSPE3 | 1% |
| RC_L2 | 85% | SRF_SEAL_CON | 0% | WRB1998_ADJSPE4 | 0% |
| LC_L1 | 36% | SRF_CRAC_WID | 0% | WRB1998_ADJSPE5 | 0% |
| LC_L2 | 31% | SRF_CRAC_DEP | 0% | WRB1998_ADJSPE6 | 0% |
| LC_L3 | 21% | SRF_CRAC_DIS | 0% | NAT_CLAS | 46% |
| LU_L1 | 39% | SRF_SAL_COV | 6% | NAT_CLAS_REF | 46% |
| LU_L2 | 29% | SRF_SAL_THIC | 6% | YEAR | 68% |
| SITE_LANDFORM | 12% | PAR_MAT | 25% | MONTH | 45% |
| SITE_SLOP_POS | 4% | AGE | 8% | DAY | 41% |
| SITE_SLOP_FORM | 3% | WRB2006_RSG | 20% | SURVEYOR_P | 13% |
| SITE_SLOP_GRAD | 36% | WRB2006_PQ1 | 16% | PUBL_REF | 19% |
| SRF_ROCK_COV | 8% | WRB2006_PQ2 | 4% | CONTACT_P | 100% |
| SRF_ROCK_DIS | 0% | WRB2006_PQ3 | 0% | CONTACT_A | 100% |
| SRF_COAR_COV | 15% | WRB2006_SQ1 | 9% | EMAIL | 100% |
| SRF_COAR_SIZ | 1% | WRB2006_SQ2 | 3% | | |
| SRF_ERO_CAT | 10% | WRB2006_SQ3 | 1% | | |

## 3.2 Measurement methods

Measurement methods of soil physical, chemical and hydrological properties vary according to countries as it appears from the following chapters. The METHOD table was harmonized (see Section 27.3, page 123) and the principal measurement techniques encountered in the database are overviewed in the following paragraphs.

### 3.2.1 Porosity

Where available (39 % of samples), porosity was generally calculated from bulk density and particle density. In most cases, the latter was assumed equal to 2.65 g/cm3. Some contributors corrected this value for topsoils with large organic carbon contents. In some cases particle density was measured (pycnometer). In the remaining cases, porosity is assumed equal to the saturated volumetric water content.

### 3.2.2 Bulk density

Where available (80 % of samples), bulk density was almost always measured by the gravimetric core method. Only some French samples were submitted to the clod method instead. However, the volumes of the sample differ among contributors. Also, although the samples are usually left in the oven at 105°C for 48 hours, samples form the Greek dataset were dried for only 24 hours.

In total, ten method codes are kept for describing bulk density.

Table 3.4 Descriptive statistics of measured basic and chemical properties

| Sample attribute | Min. | 1stQu. | Median | Mean | 3rdQu. | Max. | Number of samples |
|---|---|---|---|---|---|---|---|
| **Basic properties (N=18682)** | | | | | | | |
| | Min. | 1st Qu. | Median | Mean | 3rd Qu. | Max. | N |
| SAMPLE_DEP_TOP | 0 | 10 | 30 | 37.63 | 60 | 396 | 15589 |
| SAMPLE_DEP_BOT | 1 | 20 | 45 | 52.68 | 75 | 400 | 14884 |
| HOR1_TOP | -10 | 0 | 30 | 33.59 | 58 | 500 | 6766 |
| HOR1_BOT | -6 | 30 | 59 | 66.43 | 90 | 999 | 6696 |
| POR | 17.33 | 41.8 | 46.8 | 47.69 | 52.8 | 93.3 | 7221 |
| BD | 0.09 | 1.29 | 1.44 | 1.408 | 1.572 | 2.65 | 14908 |
| COARSE | 0 | 0 | 2.6 | 8.092 | 11.5 | 90.4 | 4177 |
| **Chemical properties (N=18605)** | | | | | | | |
| | Min. | 1st Qu. | Median | Mean | 3rd Qu. | Max. | N |
| LOI | 0 | 2 | 3 | 7.419 | 5.8 | 97.8 | 3253 |
| OC | 0 | 0.31 | 0.61 | 1.111 | 1.1 | 59.02 | 9623 |
| TC | 0 | 0.28 | 0.99 | 1.954 | 2.17 | 47.45 | 1111 |
| HOC | 0 | 0.43 | 0.964 | 1.982 | 1.631 | 87.01 | 13563 |
| CACO3 | 0 | 0 | 0.92 | 9.036 | 12.76 | 93.6 | 7831 |
| PH_H2O | 3.5 | 6.55 | 7.5 | 7.189 | 7.9 | 10.62 | 8786 |
| PH_KCL | 2.7 | 6.3 | 7.13 | 6.911 | 7.8 | 9.66 | 466 |
| PH_CACL2 | 0 | 4.9 | 5.5 | 5.528 | 6.1 | 8.5 | 625 |
| EC | 0 | 0.34 | 0.53 | 1.087 | 0.898 | 50.7 | 3442 |
| SALT | 0 | 0 | 0.01 | 0.133 | 0.05 | 26.96 | 1108 |
| CEC | 0 | 9.4 | 15.9 | 19.36 | 24.7 | 176.75 | 3690 |
| EX_NA | 0 | 0.06 | 0.17 | 0.616 | 0.4 | 50.4 | 2576 |
| EX_MG | 0 | 0.56 | 1.6 | 2.804 | 3.66 | 27.7 | 2341 |
| EX_K | 0 | 0.09 | 0.2 | 0.367 | 0.4 | 7 | 2512 |
| EX_CA | 0 | 3 | 7 | 10.18 | 12.9 | 125 | 2367 |
| BASE_CATIONS | 0.06 | 4.3 | 10 | 13.6 | 18 | 143.4 | 2259 |
| POT_AC | 0 | 2.54 | 4.6 | 7.734 | 8.135 | 140 | 1055 |

### 3.2.3 Coarse fragments content

Most samples do not have coarse fragments content, but where available (22 % of samples), this property was mostly measured by sieving at 1 or 2 mm, depending on the standard in force in the respective country. For the samples from Scotland however, coarse framgents content were determined in the field.

### 3.2.4 Organic carbon content

As described in section 27.4 (page 123), the initially contributed methods were split into loss on ignition (LOI), total carbon (TC) and organic carbon (OC) contents, and a harmonized value (HOC) was computed (Table 3.4). In few cases, values were given for more than one method. Where available, loss on ignition was obtained after burning the sample for 2 or 3 hours. The organic carbon content is usually the results of some so-called wet combustion, with varying temperature controls. In the remaining cases, it was obtained by dry combustion at 900°C after destruction of the carbonates or by correcting the measure for the carbonates content. In somes cases however, doubt remains whether organic carbon content can be assumed equal to total carbon content for lack on information on carbonate content and/or soil pH.

The harmonized organic carbon content (HOC) was obtained by applying correction factors specific to the previously described methods (see section 27.4 and Annex 3 for details).

### 3.2.5 Calcium carbonate content

Where available (42 % of samples), calcium carbonate content was almost exclusively measured by volumetric method using one of the following calcimeters: Schleiber, Bernard, Bascomb or Dietrich-Fruhling. The remaing values were obtained by titration method.

### 3.2.6 pH

Where available (47 % of samples), pH was measured in suspensions of soil in water, KCL or CaCl2 solutions in varying proportions.

### 3.2.7 Electrical conductivity (EC)

Where available (18 % of samples), electrical conductivity was measured by potentiometric method in a suspension of soil in water, mostly in proportion 1:1.

### 3.2.8 Salt content

Soil salinity was not assessed in most case, but where available (6 % of samples), it was either obtained by spectrophotometry or calculated based on the electrical conductivity of a saturated paste.

### 3.2.9 Cation exchange capacity (CEC)

Where available (20 % of samples), CEC was mostly obtained by the so-called Mehlich/Bascomb method or by extraction with ammonium acetate, followed by spectrometry, flame photometry or distillation. In other cases, it is the sum of all exchangeable cations (Na, Mg, K, Ca and H (and Al)).

### 3.2.10 Exchangeable base cations

Where available (14 % of samples), base cations were principally measured by the ammonium acetate method. In the remaining cases, the Bascomb or Mehlich or Tucker method were used.

### 3.2.11 Potential and exchangeable acidity

In few cases (6% of samples), potential or echangeable acidity was extracted by titration method in ammonium, calcium or barym acetate solutions or in potassium chlorite.

### 3.2.12 Particle size distribution

Particle size distribution was usually obtained by a combination of sieving and sedimention. The pretreatments applied to the samples diverge and are not always specified. The definition of fine earth varies between 1 and 2 mm. The fine fractions were mostly determined by the pipette method, then the hydrometer. Optical methods were used in few cases. For very few samples, fine clays (<0.2µm) were obtained by centrifugation.

### 3.2.13 Moisture retention curve

In most cases, the retention curve is the result of a combination of sand/kaolin box and pressure plate or pressure membrane measurements. Evaporation methods were also largely used. The volumes of the samples largely vary, but the most common is 100 $cm^3$.

### 3.2.14 Hydraulic conductivity

Only 33 % of samples have information on the hydraulic conductivity from which less than half have unsaturated hydraulic conductivity. Saturated hydraulic conductivity was generally measured in laboratory by constant or falling head method, but in some cases a field method was used. Unsaturated hydraulic conductivity is most often the result of evaporation methods, but crust methods and onestep or multistep outflow was also used. The sample volume largely vary.

## 3.3 References

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# 4 Soil data from Austria

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## 4.1 Introduction

Work of the Institute for Land and Water Management Research of the Federal Agency for Water Management (BAW) has a main focus on evaluation of the soil water relationship of the unsaturated zone. For this reason, soil physical analyses are carried out routinely as part of various project activities (research and consulting) around this issue. During the years BAW has obtained a large volume of results on soil physical properties for many Austrian regions. The results presented here however, constitute a selected portion of his data set. Selection was done in a way to represent as many Austrian landscapes and soil types as possible. Due to time span of the data collection methodological approaches for particular methods may have changed in some cases. This is especially true for the more time demanding methods of the determination of unsaturated hydraulic conductivity. They are undergoing a steady modification as new approaches for measurement and evaluation are being developed. All results have been performed by the technical staff of BAW.

## 4.2 Number of samples, geographical distribution and pedological variability

The distribution of sampling sites within Austria is given in Figure 4.1. The sample consists of 68 sampling sites with a total of 204 samples, taken from different soil depths. Results for undisturbed samples are already means of between 3 and 5 cylinders that were taken per sampling depth. On all samples the determination of dry bulk density, coarse fraction, determination of water retention characteristic, particle-size analysis and determination of organic carbon (respectively organic matter on few samples) was carried out. In addition, the determination of porosity and carbonate content was done on 140 samples and hydraulic conductivity was determined on 152 samples.

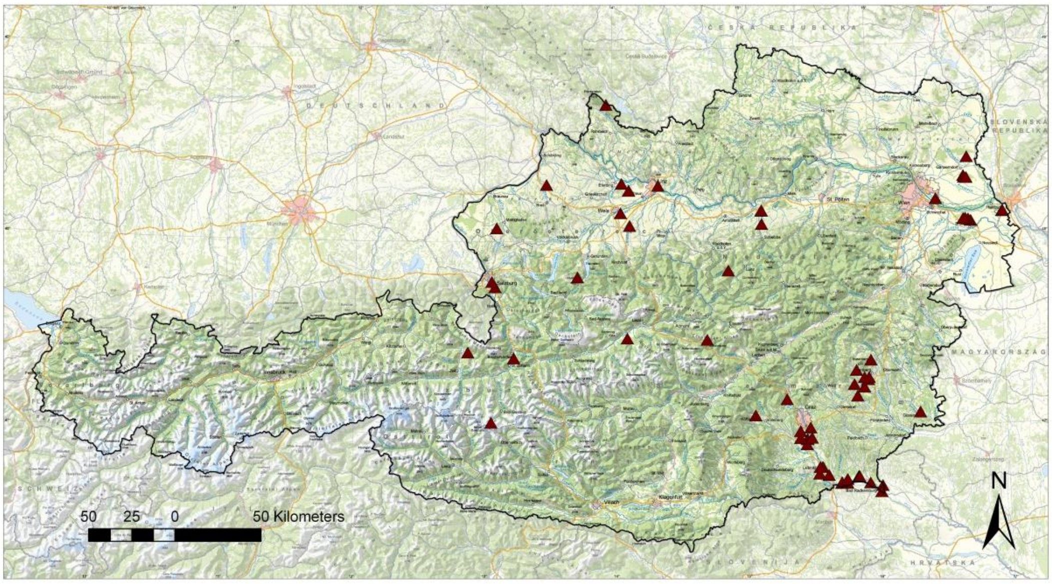

Figure 4.1 Location of sampling points across Austria

Table 4.1 gives an overview about the different soil types that are represented in the data base. The biggest group of data has been derived from Cambisols (n=32). This reflects the distribution of soil types in Austria with about 30% of all soils belonging to Cambisols.

Table 4.1. Number of soil types (WRB) represented in the database

| Pedological Unit | n |
|---|---|
| Eutric Fluvisols | 6 |
| Calcaric Fluvisols | 5 |
| Eutric Cambisols | 19 |
| Dystric Cambisols | 1 |
| Spodo-Dystric Cambisols | 4 |
| Stagno-Gleyic Cambisols | 8 |
| Dystric Histosols | 1 |
| Orthic Luvisols | 9 |
| Stagno-Gleyic Luvisols | 6 |
| Orthic Rendzinas | 3 |
| Haplic Chernozems | 4 |
| Dystric Lithosols | 1 |
| Haplic Phaeozems | 1 |

Table 4.2 gives an overview about the spread of some basic properties of the soil samples. Again it appears, that the sample covers a wide range of different physical and chemical properties with clay contents from between 1% and 51% and organic carbon contents from between 0.12% to 11.92%.

## 4.3 Measured soil properties and methods

### 4.3.1 Determination of dry bulk density (ÖNORM L 1068)

Core samples of known volume are taken with a sampling tool. The sample is dried in an oven (105°C), the dry material is weighed and considering the volume of the core the dry bulk density is calculated.

### 4.3.2 Determination of coarse fragments (ÖNORM L 1061-1)

Particles not passing a 2 mm sieve are weighed.

Table 4.2. Number available data, means, median values, minimum and maximum values for the data set

| Determination of | n | Min | Max | Mean | Median |
|---|---|---|---|---|---|
| Porosity [Vol.-%] | 140 | 34,4 | 68,7 | 47,2 | 46,7 |
| Dry bulk density [g/cm³] | 204 | 0,77 | 1,79 | 1,41 | 1,43 |
| Coarse fragments [Mass-%] | 204 | 0 | 55,9 | 4,8 | 0,2 |
| Organic carbon [Mass-%] | 204 | 0,12 | 11,92 | 1,05 | 0,76 |
| Carbonate content [Mass-%] | 140 | 0 | 43,0 | 6,8 | 0,1 |
| Clay content [Mass-%] | 204 | 1 | 51 | 19 | 20 |
| Saturated hydraulic conductivity [cm/d] | 140 | 0,3 | 27600 | 398 | 58,8 |

### 4.3.3 Determination of porosity (ÖNORM L 1068)

The porosity is calculated from dry bulk density and particle density.

### 4.3.4 Determination of organic carbon (ÖNORM L 1081)

This determination is done by wet oxidation. The sample is mixed with potassium dichromate and sulfuric acid and heated. After the addition of deionized water and phosphoric acid the sample is titrated with ferrous sulfate heptahydrate, using diphenylamine as an indicator.

### 4.3.5 Determination of soil organic matter (ÖNORM L 1079)

This determination is done by loss of ignition. The sample is ashed at 550 ° C in a muffle furnace, the residue is weighed and the content of organic matter is calculated.

### 4.3.6 Determination of carbonate content (ÖNORM L 1084)

The soil carbonates are destroyed by adding a 10% hydrochloric acid solution. The resulting carbon dioxide is determined volumetrically using the apparatus of "Scheibler".

### 4.3.7 Determination of particle size < 2 mm (ÖNORM L 1061-2)

Particle size distribution is determined by a combination of sieving and sedimentation, starting from air-dried soil. Particles passing a 2 mm sieve, but retained on a 0.063mm sieve, are determined by wet sieving. Particle size distribution of particles passing the latter sieve is determined by sedimentation by pipette method.

### 4.3.8 Determination of water retention characteristic (ÖNORM L 1063)

Soil cores are placed in contact with a porous ceramic plate contained within a pressure chamber. A gas pressure is applied to the air space above the samples and soil water moves through the plate and is collected in a burette. At equilibrium status, soil samples are weighed, oven dried and reweighed to determine the water content at the predetermined pressures.

### 4.3.9 Determination of saturated hydraulic conductivity (ÖNORM L 1065)

The volume of water filtrating through a soil cylinder in a defined period of time is measured. Considering the hydraulic potential and the water flux the hydraulic conductivity is calculated by Darcy`s law.

### 4.3.10 Determination of unsaturated hydraulic conductivity (ISO 11275)

Undisturbed soil samples are wetted in the laboratory and then evaporating from the top. Pressure heads are measured at different depths in the sample, using tensiometers. At known times the decrease of the mass of the sample and the pressure heads are recorded. The experiment ends when air enters the uppermost tensiometer. The water content of each compartment is estimated from the water content of the whole sample and the tensiometer readings. From these data the retention characteristic and the conductivity are calculated, using an adaptation (Halbertsma, 1994) of Wind`s evaporating method (Wind, 1966) or the approach of Schindler (1980).

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# 5 Soil data from Belgium

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## 5.1 Introduction

The dataset was compiled in the framework of some projects at Ghent University and KULeuven, Belgium. These projects aimed at evaluating pedotransfer functions (Cornelis et al., 2001), evaluating the effect of soil management on soil quality (e.g., D'haene et al., 2008, Arthur et al., 2010), assessing the predictive quality and usefulness of soil maps and historical soil profile data of forest soils (De Vos et al., 2005; Cornelis et al., 2005), among others.

## 5.2 Number of samples, geographical distribution and pedological variability

The dataset contains 241 samples taken from 120 soil profiles spread mostly over the Flemish Region, and to a small extent the Brussels-Capital Region and the Walloon Region of Belgium. The samples cover a wide variety of soil textures as depicted inFigure 5.1. They were collected from soils under different land uses including farmland, pasture and forests.

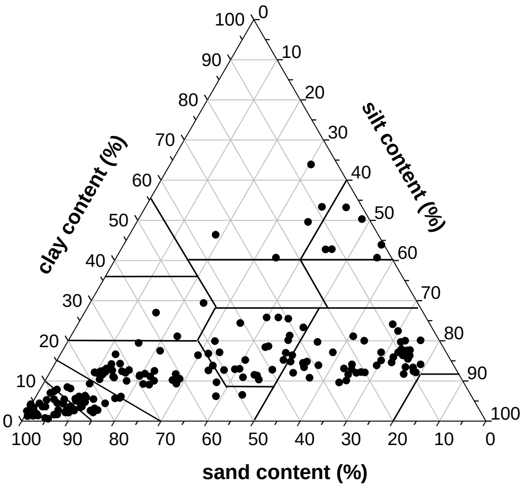

Figure 5.1 Clay (0–2 µm), silt (2–50 µm), and sand (50–2000 µm) content of the dataset

Table 5.1 shows the summary statistics of the dataset.

Table 5.1. Summary statistics of the dataset

| Soil property | N | Mean | SD | Min | Max |
|---|---|---|---|---|---|
| Sand content (%) | 241 | 52.8 | 29.6 | 0.6 | 96.9 |
| Silt content (%) | 241 | 33.0 | 23.8 | 0.0 | 79.0 |
| Clay content (%) | 241 | 14.2 | 10.6 | 0.5 | 63.8 |
| OC content (%) | 241 | 1.32 | 1.22 | 0.06 | 6.69 |
| Bulk density (g cm$^{-3}$) | 241 | 1.44 | 0.18 | 0.31 | 1.77 |

## 5.3 Measured soil properties and methods

### 5.3.1 Basic soil properties

All samples were analysed for at least bulk density, organic carbon content and particle size distribution. Additionally, $CaCO_3$ content, pH-$H_2O$, and pH-KCl was available for 66 samples, and CEC and EC for 31 samples.

Bulk density was determined with the core method on undisturbed soil samples contained in standard sharpened steel 100-$cm^3$ sized Kopecky rings (diameter 5.1 cm, height 5 cm). Cores were driven in the soil with a push ring (Dirksen, 1999), with a hammer head and guide cylinder (Eijkelkamp Agrisearch Equipment, Giesbeek, the Netherlands), or with an auger with closed ring holder after having prepared a flat sampling platform with a Riverside auger (Eijkelkamp Agrisearch Equipment). The samples were then brought to the laboratory in dedicated boxes to avoid disturbance during transport (Eijkelkamp Agrisearch Equipment).

Particle size distribution (PSD) was for most samples determined using the conventional pipette-sieve method (Gee and Bauder, 1986; ISO 11277) on disturbed pretreated air-dried samples (<2 mm). The pretreatment included removal of organic matter with $H_2O_2$ and of $CaCO_3$ with HCl, and dispersion with $Na_2CO_3$ and $(NaPO_3)_x$. PSD of part of the dataset (#48) was determined on air-dry samples, pretreated in a similar fashion as above, using a Coulter LS200 laser diffractometer, calibrated and validated using the above ISO 11277 procedures.

Organic carbon was measured according to Walkley and Black (1934; ISO 14235:1998), $CaCO_3$ with acid-base titration (Van Ranst el., 1999), pH-$H_2O$ and pH-KCl with a Model 420 pH meter (Thermo Orion Inc, USA) on respectively a 1:5 and 1:2 extract (ISO 10390:2005), EC on a saturation extract using an Orion conductivity meter (Orion Inc., USA; ISO 11265:1994) and CEC by using an ammonium acetate solution extract at pH 7 according to Van Ranst et al. (1999). All chemical analyses were performed on air-dried samples (<2 mm).

### 5.3.2 Soil hydraulic properties

Water retention curves (WRC) were constructed by measuring soil-water content at eight to nine soil-matric potentials using undisturbed soil samples contained in standard sharpened steel 100-$cm^3$ sized Kopecky rings (diameter 5.1 cm, height 5 cm), taken in a similar way as described above for determining bulk density. For the pressure potentials ranging from -1 kPa to -10 kPa, the sand box apparatus (Eijkelkamp Agrisearch Equipment) was used, whereas between -20 kPa and -1500 kPa pressure chambers (Soilmoisture Equipment, Santa Barbara, CA) were employed, following the procedures outlined in Cornelis et al. (2005) for samples from Ghent University, and Vereecken et al. (1989) for samples from KULeuven. After having obtained hydraulic equilibrium between the applied pressure and the water present in the sample, water content was determined gravimetrically and multiplied with bulk density to convert to volumetric water content.

In the current dataset, we did not include hydraulic conductivity K. However, in the course of 2013, on top of the basic properties and WRC, K data should become available from measurements with tension infiltrometers in the field and the constant water head method in the lab, at locations different from those considered here.

## 5.4 Acknowledgements

I would like to acknowledge all students, researchers and technicians of Ghent University who helped in collecting and analysing the samples over several years. I would further like to thank Jan Feyen and Lode Hubrechts from KULeuven, who provided me more than 10 years ago their dataset.

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# 6 Soil data from Belgium (Walloon Brabant)

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## 6.1 Introduction

The dataset was gathered in the framework of a PhD research project to study the effect of soil structure on hydraulic properties of silt loam soils (Weynants 2011).

## 6.2 Number of samples, geographical distribution and pedological variability

Eleven sampling locations under different land covers were selected near Louvain-la-Neuve (Belgium), where soils are principally formed in loess deposits over a sand bedrock. The depth of the loess deposit is very variable and, for some profiles, the sand bedrock is quite shallow (Figure 6.1).

The soil profiles were described and laboratory measurements were made on two to four samples from each horizon thicker than 8 cm. For the purposes of the EU-HYDI, measurements were averaged at the horizon scale, leading to a total of 44 samples from 11 soil profiles. Table 6.1 presents some summary statistics of the dataset.

## 6.3 Measured soil properties and methods

### 6.3.1 Particle size distribution

Soil texture analysis was performed on 10 grams subsamples. Organic matter and peds were destroyed before the soil was sieved and settled in a (NaPO3)6 solution, used as dispersing agent. Four textural classes were characterised: sand (50-2000 µm), coarse silt (20-50 µm), fine silt (2-20 µm) and clay (< 2 µm).

### 6.3.2 pH

pH was measured in 1:5 soil:water solution. 5gr of sieved air-dried soil were mixed with 25 grams of demineralized water. The mixture was shaked every 20 minutes for one hour, than the pH was measured with a pH-meter.

### 6.3.3 Organic carbon content

Total carbon content was measured by dry combustion at 900°C. Since pH values were small, carbonates were not destroyed and total carbon is assumed to be equal to organic carbon.

### 6.3.4 Water retention

Moisrure retention curves were measured on 100 cm$^3$ with sand-box apparatus and pressure chamber methods. From 0 to -70 cm of pressure head, we used the sand-box apparatus with undisturbed 100 cm$^3$ soil samples contained in steel rings (Kopecki). A fine suction-wise resolution was applied close to saturation (0, -0.5, -1, -2, -3, -4, -5, -6.5, -8, -10, -15, -20, -30, -40, -80 cm). The rings were then placed in a low pressure chamber for measurements at 0.3 and 1 bar (-300 and -1000 cm). Unfortunately, these measurements were not reliable for all samples due to failure of the pressure regulation system. The samples were then destroyed for measurements at 3 and 12 bar (-3000 and -12000 cm) in high pressure chambers. Bulk density was measured after drying the samples during at least 48 hours at 105°C.

Table 6.1. Summary statistics of sand, silt, clay, organic carbon contents (%) and bulk density (g/cm$^3$) in the analysed samples.

| | % Sand | % Silt | % Clay | % OC | BD |
|---|---|---|---|---|---|
| Minimum | 0.50 | 0.10 | 6.80 | 0.00 | 0.81 |
| 1$^{st}$. Quantile | 8.86 | 64.05 | 17.75 | 0.05 | 1.45 |
| Median | 11.73 | 67.06 | 21.14 | 0.22 | 1.51 |
| Mean | 19.21 | 60.27 | 20.51 | 0.63 | 1.47 |
| 3$^{rd}$ Quantile | 16.43 | 70.29 | 24.07 | 0.70 | 1.57 |
| Max | 89.92 | 76.40 | 32.97 | 5.48 | 1.69 |

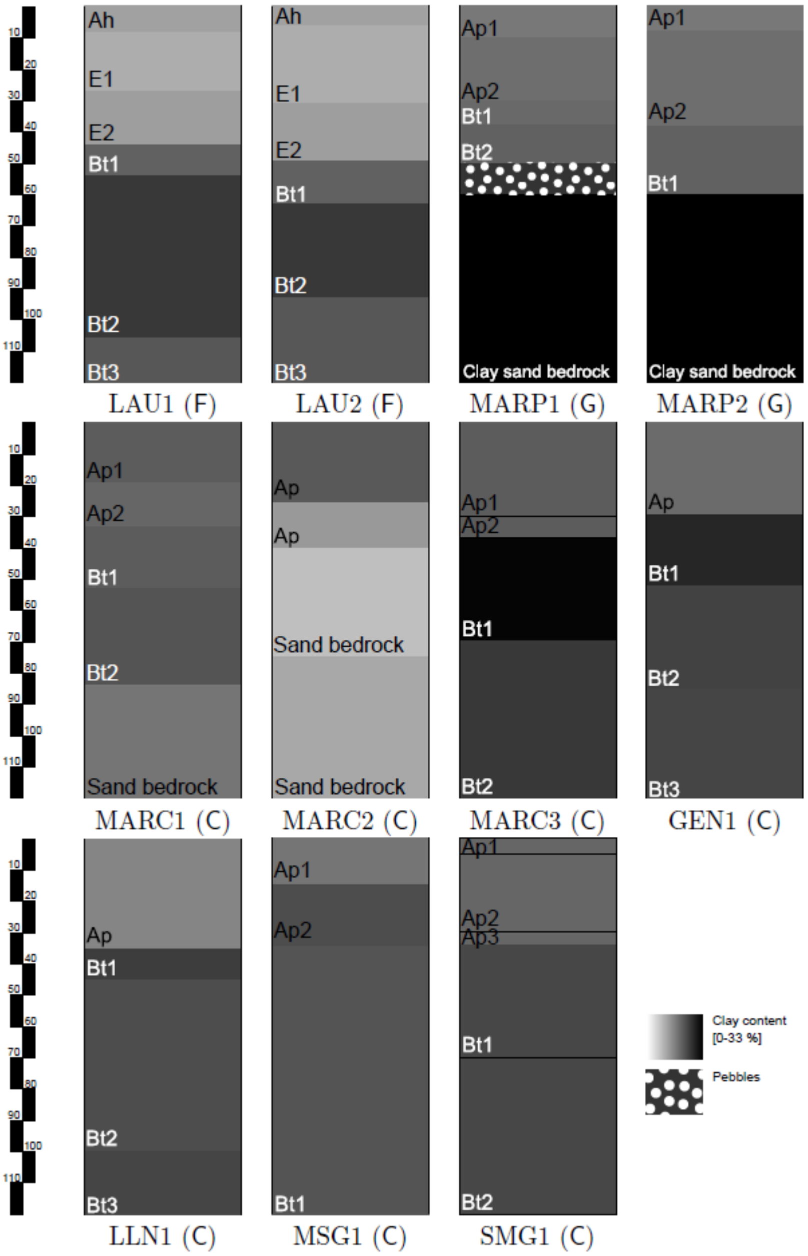

Figure 6.1 Schematic description of the soil profiles. All horizons thicker than 8 cm were sampled. Land cover in parentheses: F for forest, G for grassland, C for cropland.

### 6.3.5 Saturated hydraulic conductivity

Saturated hydraulic conductivity was measured with a constant head method on samples 10 cm high and 11.25 cm in diameter. Saturated samples placed atop porous plates in hermetic cells were subjected to a constant head with a Mariotte's bottle. The cumulative outflow was measured during two minutes. The test was repeated three times and the measurements were averaged. Saturated conductivity was calculated from Darcy's law.

### 6.3.6 Unsaturated hydraulic conductivity

Multistep outflow (MSO) experiments were carried out on undisturbed samples 10 cm high and 11.25 cm in diameter. Experiments combined a suction and a pressure modes. We applied low suctions (+10 to -80 cm of water column) during short periods of time (from one to eight hours) and then longer higher pressure steps (equivalent to -160 to -960 cm). The protocol was slightly modified from one experiment to another resulting in small discrepancies in the number of suction steps and their duration. Mini tensiometers (EcoTech, Bonn, Germany) were horizontally inserted at 5~cm depth. The outflow, the applied pressure and the suction inside the samples were monitored during the experiments. The water content at the end of the experiments was measured by gravimetric method.

The parameters of the Durner model (Durner 1994) were obtained for each sample by inverse modeling, using AMALGAM-SO global algorithm (Vrugt et al. 2009)

## 6.4 Acknowledgements

The PhD research project was funded by the Belgian Fonds pour la Formation à la Recherche dans l'Industrie et dans l'Agriculture (F.R.I.A.). The Multistep Outflow device was partly funded by the Belgian Fonds de la Recherche Scientique (F.R.S.-FNRS.).

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# 7 Soil data from the Czech Republic

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## 7.1 Introduction

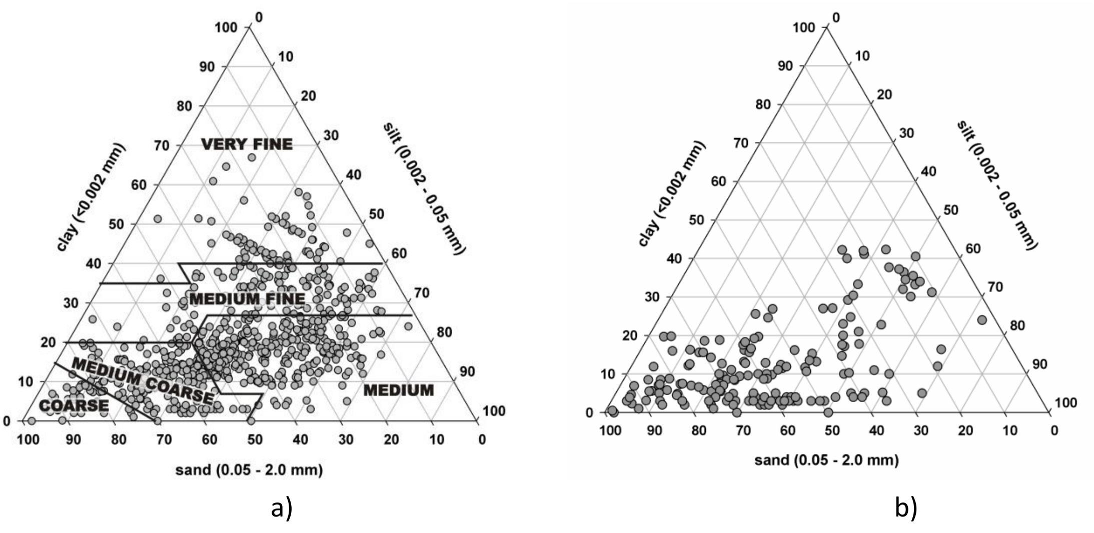
The database of soil hydrophysical properties in the Czech Republic called HYPRESCZ was created by the staff of the Department of Water Resources, Faculty of Agrobiology, Food and Natural Resources, CULS in Prague, CZ. The structure of this dabase is similar like the database HYPRES, HYdraulic PRoperties of European Soils (Wösten et al., 1999), and follows its structure with certain modifications. It gathers available data from the Czech Republic (Matula et al, 2010, Matula et al, 2011, Miháliková et al, 2013) needed for derivation of pedotransfer functions (PTFs) for estimation of soil hydrophysical properties from easily available soil properties .

## 7.2 Number of samples, geographical distribution and pedological variability

The total number of 2101 database entries was collected with different quality of data, from that number 707 entries were applicable to PTFs derivation for retention curves estimation. After reducing replicates, finally 159 unique soil horizons (arable land only) were used for PTFs derivation.

The data for this particularly report were selected from the HYPRESCZ database and due to the regulations of the former Project No. 1G58095 of the NAZV only some data might be used for the application in this work. From the database HYPRESCZ totally 174 individual retention curves were selected. These curves represent 72 soil profiles.

The soil samples were analysed for basic soil properties like particle size distribution, bulk density, organic carbon content and total porosity.



a) b)

Figure 7.1 Distribution of all available data in HYPRESCZ database (a) and selected data used in this work (b) in the textural triangles (texture in FAO/USDA categories: clay smaller than 0.002 mm, silt between 0.002 and 0.05 mm, sand between 0.05 and 2 mm).

Table 7.1 Summary statistics related to the selected data of the dataset.

| Characteristic | n | Min | Max | Mean | Median | SD |
|---|---|---|---|---|---|---|
| Porosity (Vol.-%)* | 66 | 35,9 | 61,2 | 45,4 | 45 | 6 |
| Dry bulk density (g/cm$^3$) | 174 | 0,21 | 1,88 | 1,4 | 1,5 | 0,3 |
| Organic carbon (Mass-%) | 171 | 0 | 31,79 | 2,3 | 1,2 | 4 |
| Clay (%) | 174 | 0 | 42,3 | 12,2 | 8,6 | 10,9 |
| Silt (%) | 174 | 1,5 | 73 | 31,2 | 31,8 | 16 |
| Sand (%) | 174 | 3 | 98 | 56,6 | 59,1 | 22 |

** Calculated only if soil particle density was determined, too.*

### 7.2.1 Determination of total porosity

The porosity is calculated from dry bulk density and particle density of soil solid particles using the classical density method (see for example Danielson and Sutherland, 1986.).

### 7.2.2 Determination of dry bulk density

Core samples taken from the field mostly into the Kopecky rings 100 cm$^3$ were transported to the lab and dried to 105°C in an oven. The dry soil material is weighed and considering the volume of the core sample the dry bulk density was calculated using commonly known procedure. This method is very well known as the core method (Blake, Hartge, 1986).

### 7.2.3 Determination of soil organic carbon

Different modifications of Walkley and Black methods (Walkley, Black, 1934) were used, very often modification called Tyurin method (titrametric). The exact method for particular samples was not registered.

### 7.2.4 Particle size analysis (particles < 2 mm)

Particle-size distribution curve was determined by the combination of sieving and sedimentation methods like hydrometer method or pipette method (Gee, Bauder, 1986).

### 7.2.5 Soil hydraulic properties

Soil water retention curves – primary drainage curves (SWRC) were determined creating a series of equilibria between water in the soil sample and body of water at known soil water potential expressed as pressure head (Klute, A. 1986). The hydraulic contact between the soil-water system and the body of water was managed by semi-porous membrane (sand or kaolin layer, ceramic plate). The data pair of soil water content by volume and related pressure head in cm forms the measured point of the SWRC. Usually, the undisturbed soil samples, again Kopecky rings 100cm$^3$ or bigger initially fully saturated in the laboratory were used. The pressure head steps ranging from –0.001 MPa to -1.5 MPa were applied using different devices. For the beginning of the SWRC the sand box apparatus was used, then kaolin box was employed followed by pressure chamber using the ceramic pressure plate (Soilmoisture Equipment, Santa Barbara, CA or similar). Some samples were tested by the application of new evaporation method (Schindler, Műller, 2006) instead of sand box and kaolin box. The water content was determined gravimetrically and multiplied with dry bulk density to convert water content by mass to water content by volume.

In the dataset of this work, we did not include data of saturated hydraulic conductivity K. Those which we have available need a significant elaboration and there is no financial support and time for it now.

## 7.3 Acknowledgements

The collecting data for the HYPRESCZ Database was supported by Ministry of Agriculture of the Czech Republic, National Agency of Agricultural Research, Project No. 1G58095, and by Ministry of Education, Youth and Sports of the Czech Republic, Project No. 6046070901. The authors are grateful to their project partners from Dept. of Soil Science and Soil Protection (CULS Prague) for cooperation within this study, namely to J. Janků, J. Kozák, J. Němeček and K. Němeček. The authors are grateful to their project partners from the Research Institute for Soil and Water Conservation in Prague, namely M. Vlčková, Z. Kulhavý and J. Vopravil. Furthermore, the authors thank to other colleagues for sharing their data and valuable comments, namely K. Báťková (CULS Prague, Dept. of Water Resources), V. Kuráž (Czech Technical University in Prague), M. Tesař (Academy of Sciences of the Czech Republic), A. Prax (Mendel University in Brno) and J. Haberle (Crop Research Institute Prague).

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# 8 Soil data from France

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*The Soil Science Research Unit (UR 0272) is located in Orléans in the Région Centre, France. It is part of the Department of Environment and Agronomy (E&A) of the French National Institute for Agricultural Research (INRA). The Soil Science Research Unit studies the organization, the evolution and the functioning of the soils at various space scales (soil profile, agricultural field, catchment, landscape) and time scales (rainfall event, cropping period, rotation, decade, and century). It analyses the variability of the characteristics and properties of soils (texture, mineralogy, porosity, aggregate stability, hydraulic properties, natural pedo-geochemical background, and geochemistry) according to their origin, their use and of the climate.*

## 8.1 Introduction

Many soil surveys and studies are carried out over the French territory at different times, locations and scales by all kinds of institutions, public as well as private, for research purposes as well as for applied needs. These studies collect soil profile, horizon, sample and analytical data in zones of various sizes and locations, at various densities and using various sampling and analytical methods. In order to capitalize such a data collection effort, a database called SOLHYDRO of hydro-geochemical properties has been set in several steps over the past 25 years (Bruand et al., 2004; Al Majou et al., Al Majou et al., 2007).

At this stage the database holds mainly data for studies in which the Soil Science Research Unit of INRA Orléans is involved. Current efforts to structure this database will lead to the construction of a new database called PepSol developed and maintained by both the Soil Science Research Unit and the InfoSol Unit of INRA Orléans. This new, extended database will aim at collecting data from all French soil studies.

The data provided to the EU-HYDI project was extracted from the SOLHYDRO database. The selection of profiles was made so as to fulfill at least the minimum requirements of the project.

## 8.2 Number of samples, geographical distribution and pedological variability

123 soil profile descriptions where extracted from the SOLHYDRO database and formatted to comply with the guidelines of the EU-HYDI dataset. The data were collected from 1985 to 2007 during various research projects. The soil properties were measured in the laboratories of the Soil Science Research Unit and of the Soil Analysis Laboratory of Arras (LAS: Laboratoire d'Analyses des Sols d'Arras).

Important warning:

As described in the introduction, it is important to understand that, due to both the data collection strategy of the originating SOLHYDRO database and to the extraction constrains imposed by the EU-HYDI guidelines, despite our effort to be as exhaustive as possible the dataset provided here is not representative of the French territory nor is it of the French soil types distribution. Although sampling strategies are applied at the scale of each study that provides data to the SOLHYDRO database, at the scale of the whole country no global sampling strategy can be drawn out. This should be clear to the users of the French part of the dataset when e.g. developing pedo-transfer functions or rules.

Soil profiles are mainly located in the center of France (NUTS2 region FR24), where the Soil Science Research Unit is located and has the majority of its studied areas (Figure 8.1).

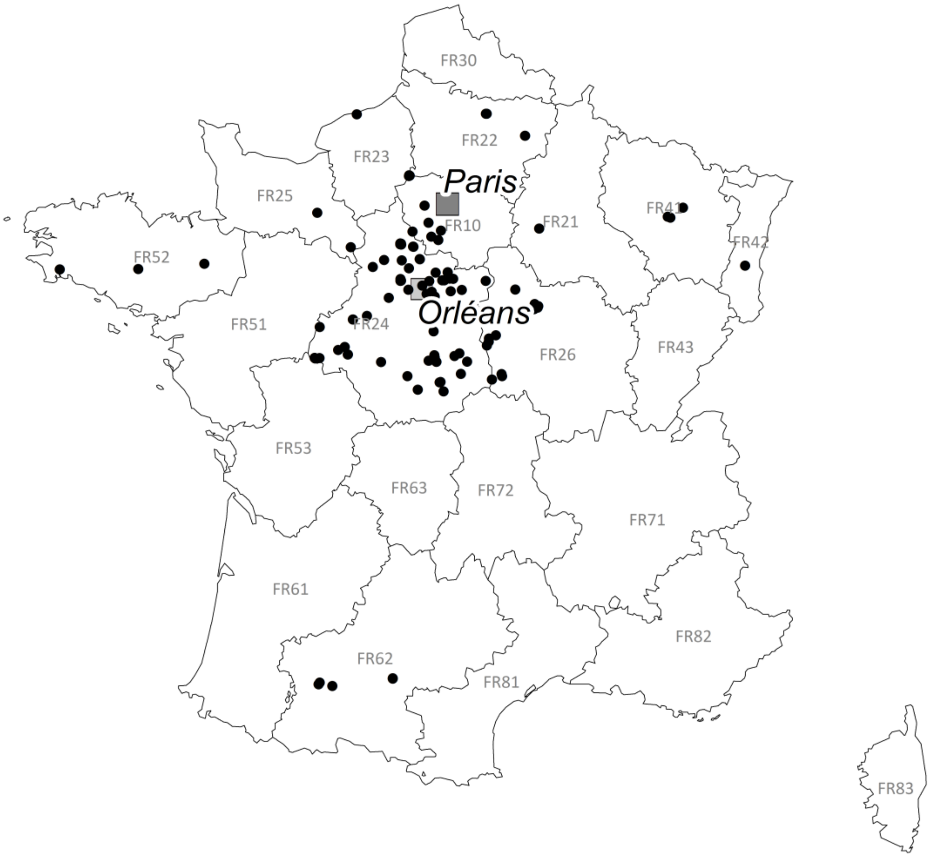

Figure 8.1 Geographical distribution of the French EU-HYDI soil profiles over the NUTS2 regions.

57% of the soil profiles are located in the NUTS2 FR24 (Région Centre), 17% are located in the NUTS2 FR26 (Région Bourgogne) and 7% are located in the NUTS2 FR10 (Région Ile de France) (Figure 8.2).

The soil profiles cover 8 different soil types from the World Reference Base for Soil Resources (WRB), most of which are Cambisols (Figure 8.3).

82% of the profiles were characterized down to at least 50 cm depth, and 32% down to at least 1 m. The maximum depth reaches 2.6 m. Soil samples were always taken from within one horizon considered homogeneous. However we do not hold the horizons' depths. Soil properties were thus measured from 352 soil samples. Figure 8.4 shows the number of samples per profile. For example 32 profiles were characterized by 4 samples each.

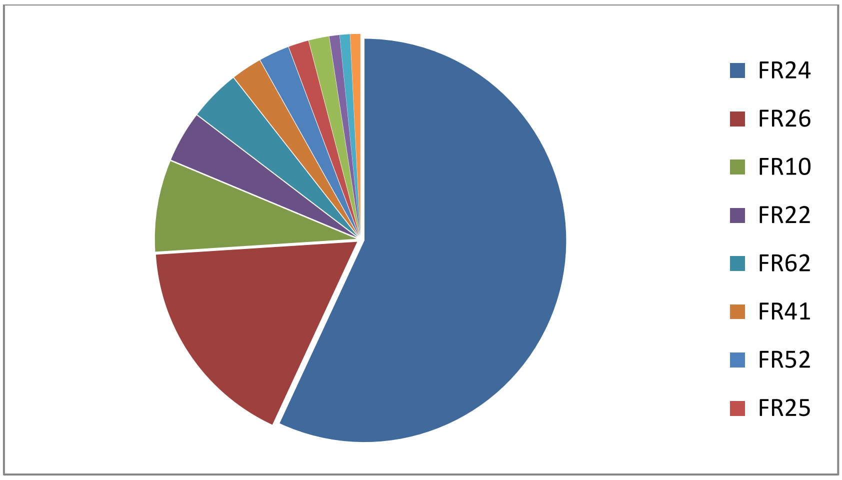

Figure 8.2 Repartition of French soil profiles in Code Eurostat/NUTS

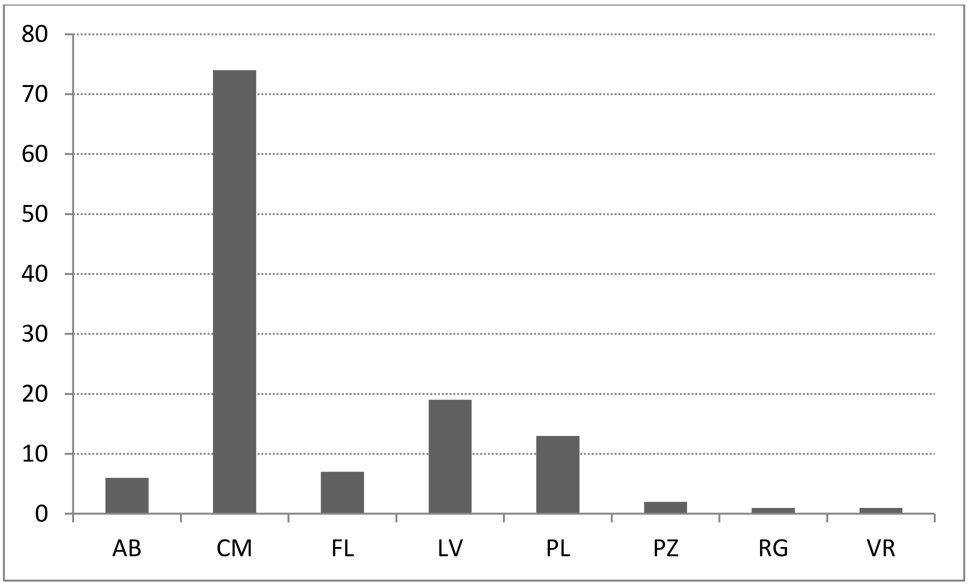

Figure 8.3 Distribution of soil profile in WRB 2006.

| | |
|---|---|
| AB: Albeluvisol | PL : Planosol |
| CM: Cambisol | PZ: Podzol |
| FL: Fluvisol | RG : Regosol |
| LV : Luvisol | VR: Vertisol |

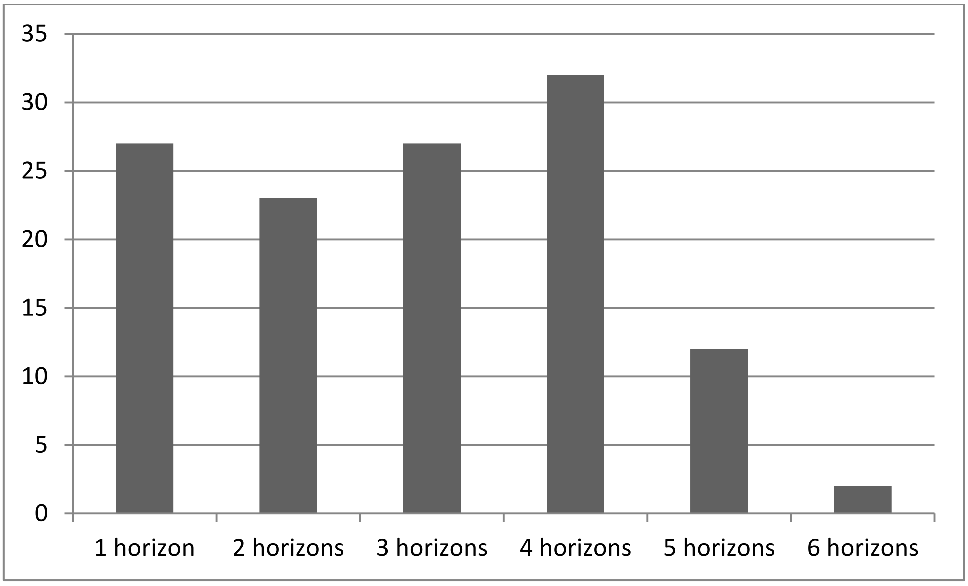

Figure 8.4 Number of soil samples by soil profile

| | | |
|---|---|---|
| 27 profiles have 1 horizon | 23 profiles have 2 horizons | 27 profiles have 3 horizons |
| 32 profiles have 4 horizons | 12 profiles have 5 horizons | 2 profiles have 6 horizons |

## 8.3 Measured soil properties and methods

### 8.3.1 Bulk density (BD)

To measure the soil bulk density on undisturbed soil we used the NF X31_501 and the NF X31_505 methods (NF: French norm).

- Measurement of the soil bulk density on undisturbed soil cylinders of 500 cm3.

The NF X31_501 method consists in determining the bulk density of an undisturbed soil sample using equation BD = P/Va. The volume (Va) is sampled with a cylinder directly pressed into the soil by hammer blows. Once the cylinder has been pressed in, the soil block is cut out with a spade and trimmed at both ends. Then the sample is dried at 105°C during 48 hours and weighed (P). Va = 500 cm3.

- Measurement of the soil bulk density on undisturbed soil clods of a few cm3.

The NF X31_505 method consists in determining the bulk density of soils in their natural state to avoid the use of large soil peds or clods. Clod volume is determined by coating with a water repellent substance, here kerosene in our experiments, then making use of the Archimède Principle which states that a mass immersed in water will displace its own volume (Monnier et al., 1973). Bulk density can then be calculated by weighing the coated clod suspended in water and then in the air.

### 8.3.2 Organic carbon content (OC)

Measurement of the carbon content is made by elementary analysis of dry combustion (ISO 10694) as a measurement of $CO_2$ gas emitted from the sample when heated to 900°C minimum.

The organic carbon content is calculated from this content after correcting for carbonates present in the sample. If carbonates are removed beforehand, the organic carbon content is measured directly. The method is applicable to all types of air-dried soil samples.

### 8.3.3 Carbonate content (CaCO3)

CaCO3 content is measured by volume analysis with the Scheibler apparatus after treatment by HCl (4mol/L) (ISO 10693): the soil is put in contact with a strong acid which dissolves the limestone in a closed environment. The attack of limestone (CaCO3) results in a CO2 gassing witch's volume is measured.

### 8.3.4 Cation exchange capacity (CEC)

To measure the cationic exchange capacity two methods were used:

- Measurement of CEC by analysis of N-NH4 distillation after preparation with a cobaltihexamin chlorure at 0,0166 mol/L (NF X31_130).

- Measurement of CEC by spectrometry after preparation with a cobaltihexamin chlorure at 0,0166 mol/L (NF X31_130 and NF X31_108).

### 8.3.5 Particle size and particle size content (PSIZE & P_PERCENT)

Granulometry was measured with the Pipet method (NF X31_107).

The pipet method utilizes Stoke's law by the extraction of subsamples of the soil suspension at a given depth after a predetermined settling time for each size fraction of interest. As time passes, larger particles pass by the sampling depth, and smaller and smaller size fractions can be sampled. After extracting the sample, it is dried and weighed, and a calculation can be done to determine the percentage of the total soil in suspension present in each sample.

$$V = (2gr^2)(d1-d2)/9\mu \text{ (Stokes Law)}$$

where
$V$ = velocity of fall (cm.sec$^{-1}$)
$g$ = acceleration of gravity (cm.sec$^{-2}$)
$r$ = "equivalent" radius of particle (cm)
dl = density of particle (g.cm$^{-3}$)
d2 = density of medium (g.cm$^{-3}$)
and $\mu$ = viscosity of medium (dyne.sec.cm$^{-2}$)

### 8.3.6 Matric potential and water content (HEAD & THETA)

The measurement of the volumetric water retention curve on undisturbed soil clods of few cm3 is realized by using the ISO 11274 and NF X31-505 or NF X31-501 protocols.

Briefly, the water retention curve is determined by using a pressure membrane or plate apparatus (Klute, 1986) on 10 to 15 undisturbed soil clods, at eight potentials (-10, -33, -100, -330, -1000, -3300, -10000, and -15400 cm). The clods are first gently separated by hand from larger undisturbed samples. After one week of saturation by capillarity, the clods are placed on a paste of saturated kaolinite (< 2 µm) to obtain sufficient hydraulic continuity between them and the pressure membrane. After one week of equilibrium in pressure cells, the gravimetric water content is measured.

The volumetric water content is then calculated from bulk density that can be determined following two methods:

- it can be determined on undisturbed soil cylinders of a known volume of 500 cm3 (see paragraph 1.3.1.1; NF X31-501)

- or it can be determined on clods at the -10 cm water potential by the Archimedes' displacement method using kerosene (Monnier et al., 1973; see paragraph 1.3.1.2; NF X31-505).

Depending on the samples, one or two values of bulk density are available in the database.

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# 9 Soil data from Germany (North East and Central Germany)

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## 9.1 Introduction

Knowledge of hydraulic functions is required for various hydrological and plant physiological studies. During the last decades numerous measurement procedures have been developed. Currently a broad array of methods exists for determination of soil hydraulic properties in the field or in the laboratory (Klute and Dirksen, 1986; Dane and Hopmans, 2002; Nimmo et al., 2002; Arya, 2002). The evaporation method is a frequently used procedure for measuring hydraulic functions of unsaturated soil samples in the laboratory (Wind 1966, Becher, 1970, Schindler, 1980, Wendroth et al., 1993, Halbertsma, 1996; Bertuzzi et al., 1999; Arya, 2002). The method allows an accurate characterization of the water retention properties of the porous system, from saturation to the measurement limit of tensiometers, and of the unsaturated hydraulic conductivity in the range where significant hydraulic gradients occur in the sample (Schindler and Müller, 2006; Peters and Durner, 2008). The method of Schindler (1980) is a simplified setup of the WIND procedure. Only the total soil sample weight and tensions at two height levels are recorded at several times as basis for quantifying the hydraulic functions. Peters and Durner (2008) showed that despite the larger spatial distance of the tensiometers, effects of spatial and temporal nonlinearity are negligible in the data evaluation and that the method leads to precise and unbiased results, provided the usual assumption of water flow according to Richards' equation, with local equilibrium between water content and matric pressure, is valid (Durner and Flühler, 2005).

In the period between 1995and 2009 soil hydrological properties- water retention curve and unsaturated hydraulic conductivity function- of 193 soil samples were measured with the evaporation method. The samples were collected from 32 sites located in North East and Central Germany. The data base includes the soil hydrological properties and additional information to the geo reference, the soil type and horizon, the particle size distribution, the dry bulk density and other parameters and is available at the ZALF homepage. Methodical information to methods and measurements techniques are given in the following.

## 9.2 Number of samples, geographical distribution and pedological variability

The data (raw data) are collected in the soil hydrological data base of the Institute of Landscape Hydrology of the ZALF Müncheberg. Table 9.1 gives an overview of the data base content.

Soil and site description was done according to WRB (2006).

Measurements of the water retention curve and the unsaturated hydraulic conductivity function were carried out in the laboratory with the evaporation method (Schindler, (1980, Schindler et al., 2010a, Schindler et al, 2010b). The 193 mineral soil samples cover a wide range of texture classes (FAO, 2006, Figure 9.1). The 104 organic soils contain peat samples of different degree of decomposition and mineralization, several muddy substrates, as well as clay and sand soils rich in humus. Additionally to the soil hydrological properties, the particle size distribution, the dry bulk density, the organic matter content and other parameters were measured.

Table 9.1 Content and structure of the ZALF Muencheberg (Germany) data base

| | | |
|---|---|---|
| **General properties table:** | Profile identification | |
| | Site name | |
| | Geo reference (ETRS89) | |
| | Country and region | |
| | Elevation | |
| | Land use and site land form | |
| | Soil type acc. to WRB (2006) guidelines | |
| | Soil type acc. to KA5 (German guidelines) | |
| | Date of sampling | |
| | Contact person | |
| **Basic and physical data:** | Profile identification | |
| | Layer identification | |
| | Sampling depth | |
| | Horizon | |
| | Dry bulk density cm$^3$ cm$^{-3}$ | |
| | Methodological information | |
| **Chemical data table:** | Profile identification | |
| | Layer identification | |
| | Organic matter content (%) | |
| | Ash content (%) | |
| | Methodological information | |
| **Measured particle size data:** | Profile identification | |
| | Layer identification | |
| | Percentage of particle classes (mm) | |
| | Clay: | 0.002 |
| | Fine silt: | 0.0063 |
| | Medium silt: | 0.02 |
| | Coarse silt: | 0.063 |
| | Fine sand: | 0.2 |
| | Medium sand: | 0.63 |
| | Coarse sand: | 2 |
| | Methodological information | |
| **Measured SWR data:** | Profile identification | |
| | Layer identification | |
| | Pair of values of water content(cm$^3$cm$^{-3}$) and tension (hPa) | |
| **Measured conductivity data:** | Profile identification | |
| | Layer identification | |
| | Pair of values of tension (hPa) and hydraulic conductivity (cm d$^{-1}$) | |

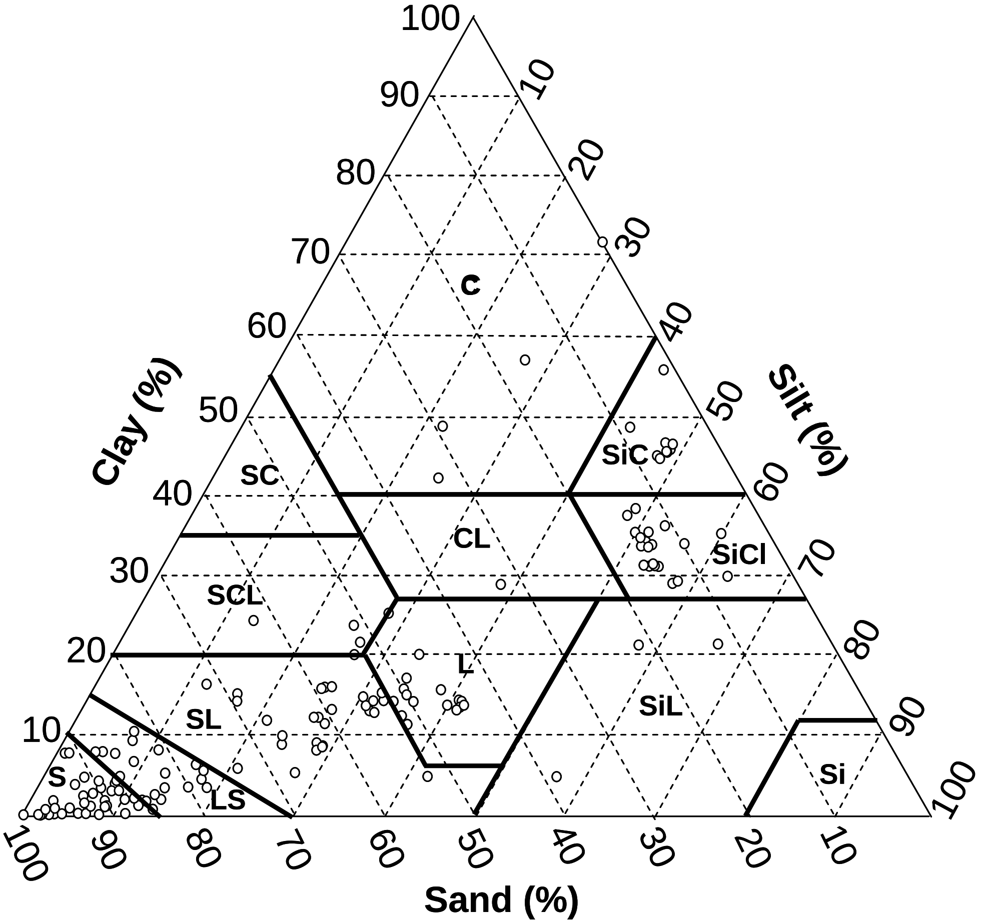

Figure 9.1 Distribution of texture classes of the investigated soils according to (FAO, 2006)

## 9.3 Measured soil properties and methods

### 9.3.1 Measurement of soil hydraulic properties with the evaporation method (Schindler, 1980)

Intact soil cores are taken in stainless steel cylinders (250 cm$^3$ volume, 6 cm height) with a sharpened leading edge to minimize soil disturbance during insertion. Two tensiometers are installed sidewise at depths of 1.5 and 4.5 cm above bottom, respectively. Cores are slowly saturated in the laboratory by placing them in a pan of water. After saturation, the sample is sealed at the bottom and placed on a balance. Its surface remains open to evaporation. Tensions ($\Psi$) and sample mass (m) are measured at time intervals. The measurement interval of both, sample mass and tension varied depending on soil material and evaporation rate between 10 minutes (clay soils and sand at the end of measurement, when the hydraulic gradient increased rapidly) and 4 hours (sand soils at the beginning of measurement, as long as the hydraulic gradient was small). The measurement was finished when the upper tensiometer reaches its tension limit. The mean hydraulic gradient ($i_m$) is calculated on the basis of the tension values in the interval. The flux (v) is derived from the soil water volume difference $\Delta V$ (1 cm$^3$ of water = 1 g) per surface area (A) and time unit ($\Delta t$). Single points of the water retention curve are calculated on the basis of the water loss per volume of the sample at time t and the mean tension at that time.

The hydraulic conductivity (K) is calculated according to Darcy-Buckingham's law.

$$K(\overline{\Psi}) = \frac{\Delta V}{2A * \Delta t * i_m} \qquad (1)$$

where $\overline{\Psi}$ is the mean tension averaged over the upper tensiometer at position $z_1$ (4.5 cm above bottom) and the lower tensiometer at position $z_2$ (1.5 cm above bottom), $\Delta t$ is the time interval, $\Delta V$ is the total evaporated water volume of the complete sample (equal to sample mass difference, $\Delta m$, in the interval), A is the cross sectional area of the sample, and $i_m$ is the mean hydraulic gradient in the time interval.

The assumptions for the validity of Eq. (1) are:

i) "quasi steady state" conditions, which means that flux and hydraulic gradient are approximately constant over the time interval.

ii) linear decreasing water content over the sample height in the measuring interval. Accordingly, the flux through the measured layer (half of the total flux) can be calculated from the soil water volume difference in the time interval. Results by Peters and Durner (2008) confirmed the validity of this assumption.

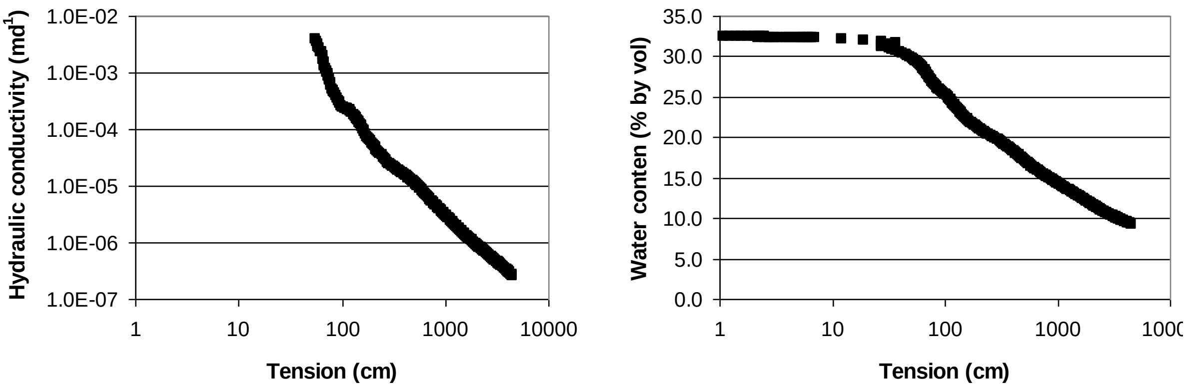

Figure 9.2 Hydraulic conductivity function (left) and water retention curve (right) of a sandy loam measured with the extended evaporation method (EEM) of Dedelow site (Uckermark, Germany), Ap horizon.

At the end of the measurement, the residual amount of storage water is derived from water loss upon oven drying (105°C). The initial water content is determined by total water loss (evaporation part plus residual amount) related to the core volume. Dry bulk density is derived from the dry soil mass divided by core volume. For this reason the volume of the tensiometer holes (1 $cm^3$) is subtracted from the core. The total measurement time depended on the evaporation rate and the soil water content in the measurement and varied between 1 day for clay soils and maximum 10 days for peat sand soils. Figure 9.2exemplarily presents hydraulic functions measured with the evaporation method.

Since 2008 the extended evaporation method (EEM, Schindler et a., 2010a,b) was applied. Measurements were carried out with the HYPROP device.

### 9.3.2 Particle size analyses

The particle size distribution is an important basic soil physical variable for characterizing and classifying soils. Its measurement occurred by gravitational sedimentation (pipette method) acc. to Gee and Or (2008). Sedimentation analysis relies on the relationship between settling velocity and particle diameter. The pipette method is a direct sampling procedure. It depends on taking a small subsample by a pipette at a depth, h (10 cm for our analysis), at time, t, in which all particles coarser than d have been eliminated. Settling times are calculated using Stokes' Law (Eq. 3)

$$d = \sqrt{\frac{18\eta * h}{g(\rho_s - \rho_l) * t}} \tag{3}$$

where η is the fluid viscosity, h is the sedimentation length, d is the particle diameter, $\rho_s$ is the particle density, $\rho_l$ is the liquid density, g is the gravitational acceleration, and t is the time.

Preconditions are disintegrated soil material and a solution free off organic carbon. Organic carbon was destroyed by cooking in hydrogen peroxide ($H_2O_2$). Dispersion occurred by shaking in sodium pyrophosphate ($Na_4P_2O_7$). Analyzed particle classes where: clay (<0.002mm), fine silt (0.002-0.0063mm), medium silt (0.0063-0.02), fine silt (0.02-0.063mm). The sand fraction (fine sand 0.063-0.2mm), medium sand (0.2-0.63mm) and coarse sand (0.63-2mm) was analyzed by sieving of the disperse solution.

### 9.3.3 Soil organic matter content and ash content

Soil organic matter : Dry combustion acc. to DIN ISO 10694 (1994),

Soil organic matter = organic C*1.724

Ash content: Combustion at 550 °C (DIN 19684 T3) related to the oven-dried soil sample (DIN ISO 11465).

## 9.4 Conclusions

The evaporation method allows the simultaneous measurement of soil hydraulic functions – SWR and K - with high resolution. Measurement time ranges between 1 day for clay soils, and maximum 10 days for peat and sand soils. The new extended evaporation method (EEM, Schindler et a., 2010a,b) with the commercial device HYPROP enables the measurement extension close to the wilting point. Additionally, the quantification of shrinkage and hysteresis is possible.

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# 10 Soil data from Germany (Lower Saxony)

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## 10.1 Introduction

The dataset described in this chapter is a common contribution of two institutions from Hannover / Germany, the Federal Institute for Geosciences and Natural Resources (BGR) and the State Authority for Mining, Energy and Geology (LBEG) which includes the Soil Survey of Lower Saxony. In Germany, the state soil surveys are responsible for soil mapping within their borders and for publishing large- and medium-scale soil maps, whereas BGR is responsible for nation-wide soil maps, and for issues at the EU and international levels. The dataset was provided within the framework of the HYPRES project and dates back to the mid-nineties. All data originate from sampling locations inside of Lower Saxony (see Figure 1.1). The database of the Lower Saxony Soil Information System (NIBIS) was described by Horn et al. 1991.

## 10.2 Number of samples, geographical distribution and pedological variability

The contribution from BGR and LBEG consists of 1527 data sets, distributed over 508 sampling locations. In some cases soil profiles are characterized by up to eight samples, in other cases a soil profile is represented by only one sample. Information on water retention characteristics is available for all data sets, information on saturated hydraulic conductivity is available in 1084 cases.

By translating horizon symbols from German taxonomy to FAO taxonomy 295 variants had to be reduced to 84 variants. This means an unavoidable loss of information. Especially three cases should be mentioned:

--- Different types of mottled horizons (Go, Sw, …) have been arranged under the FAO symbol “Bg”.

--- According to German taxonomy, covered Ah horizons are characterized by the small letter “f”. This additional symbol is missing after translation to FAO taxonomy.

--- In case of diagnostic horizons from Gleysols (Go, Gr, …) or Pseudogley soils (Sw, Sd, …) it is not clear whether they represent B…g… or C…g… horizons.

By translating soil types from German taxonomy to FAO taxonomy 69 variants had to be reduced to 37 variants. “FAO soil types” correspond to the 1985 version of the Soil Map of the European Community. Again this means an unavoidable loss of information, e.g. when “Gley” and “Pseudo-gley” soils have to be merged . Especially the following cases should be mentioned:

--- The FAO classification system does not allow to differentiate between “Gley” and “Pseudogley” soils.

--- In order to characterize “Pseudogley” soils, in some cases the adjective “stagno-…” has been added. Sometimes this aspect may be overemphasized.

--- German taxonomy often offers no possibility to distinguish between eutric and dystric soils, for example for “Braunerden” (“cambisols”).

--- Kolluvial soils from German taxonomy (“Kolluvium”, “Gley-Kolluvium”, “Pseudogley-Kolluvium”, “Flussmarsch”) often have been translated to fluvi-calcaric fluvisols (“Jcf”) even though they are not always calcaric.

--- According to German taxonomy, Marsh soils are segregated into “See-“, “Brack-“ and “Fluss-marsch”. The 1985 Soil Map of the European Community knows only gleyo-calcaric fluvisols (“Jcg”) and gleyo-eutric fluvisols (“Jeg”). Against this background, the translation process is no simple relabeling.

--- For “deep-ploughed marsh soils” (German symbol “UM”) no correct translation could be given.

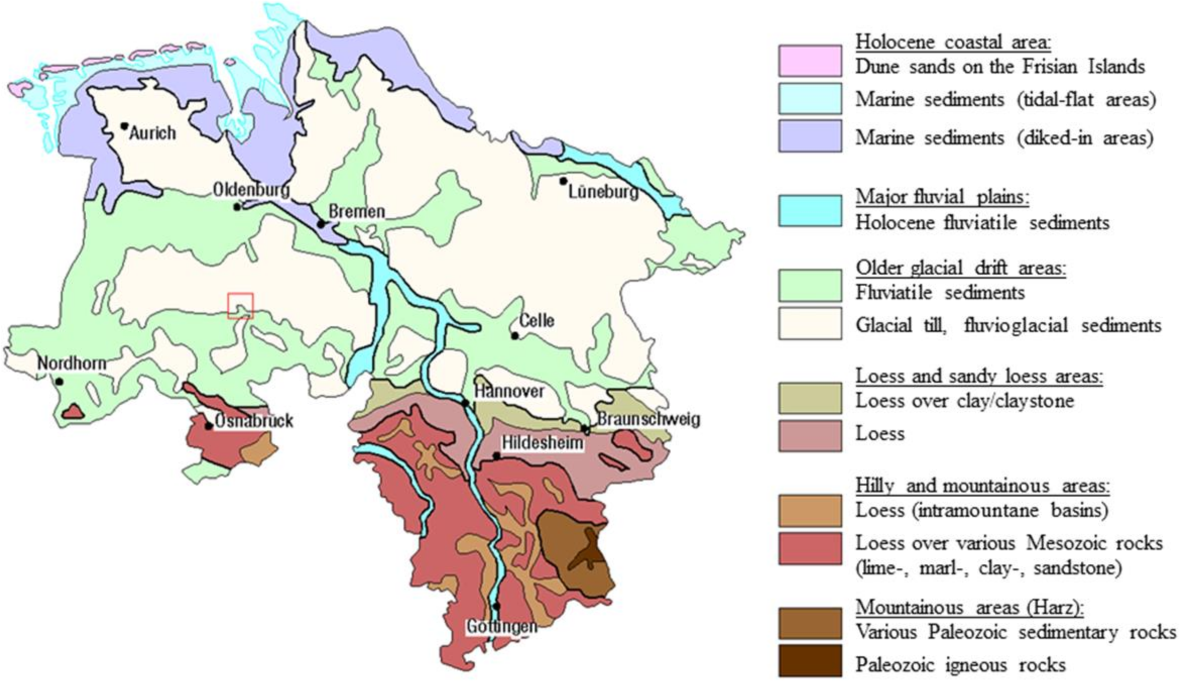

Figure 10.1 Parent materials of soils in Lower Saxony

As it can be seen from Table 1.1, 855 samples or 56 % of the inventory of the dataset represent Gleysols and Fluvisols. This means that soils from Holocene coastal areas, major fluvial plains and lower parts of older glacial drift areas (see Figure 1.1) were overrepresented in the NIBIS laboratory database in those times. On the other side, soils developed from glacial till and loess were underrepresented. Luvisols for example, usually developed on loess, cover only 14.3 % of the inventory of the dataset.

## 10.3 Measured soil properties and methods

### 10.3.1 Water retention characteristics

All measurements were carried out on undisturbed, horizontally oriented cores with a volume of 250 cm$^3$. Each water retention curve is defined by four points (pF = 0, 1.8, 2.5, 4.2). The measurement procedure can be described as the standardized pressure membrane technique (Hartge 1965).

Table 10.1. Soil type distribution of the dataset

| FAO Soil Type | No. of samples | FAO Soil Type | No. of samples |
|---|---|---|---|
| B | 22 | Cambisols | 145 |
| Bef | 4 | | |
| Beg | 4 | | |
| Bg | 52 | | |
| Bgg | 29 | | |
| Bv | 28 | | |
| Bvg | 6 | | |
| De | 9 | Podzoluvisols | 9 |
| E | 1 | Rendzinas | 13 |
| Ec | 10 | | |
| Eo | 2 | | |
| G | 74 | Gleysols | 441 |
| Gds | 213 | | |
| Ge | 21 | | |
| Ges | 133 | | |
| Hg | 24 | Phaeozems | 66 |
| Hh | 12 | | |
| Hl | 30 | | |
| J | 26 | Fluvisols | 414 |
| Jcf | 168 | | |
| Jcg | 70 | | |
| Jeg | 60 | | |
| Jg | 64 | | |
| Jgg | 26 | | |
| L | 10 | Luvisols | 219 |
| Lg | 96 | | |
| Lgs | 10 | | |
| Lo | 103 | | |
| O | 1 | Histosols | 9 |
| Oe | 8 | | |
| Pg | 72 | Podsols | 110 |
| Pgs | 13 | | |
| Pl | 6 | | |
| Po | 19 | | |
| U | 13 | Ranker | 13 |
| pL | 59 | Plaggensols | 59 |
| ?? | 29 | - unknown - | 29 |
| | Σ 1527 | | Σ 1527 |

### 10.3.2 Saturated hydraulic conductivity

The laboratory technique applied to measure saturated hydraulic conductivity can be described as a special type of the falling-head method (Hartge 1961, 1965). Again, results refer to horizontally oriented cores with a volume of 250 cm$^3$. The value given in the database is the geometric mean of seven replicate samples.

## 10.4 Existing studies based on this dataset

Data from the laboratory database of the Lower Saxony Soil Information System (NIBIS) were used for several studies on pedotransfer functions. Tietje and Hennings (1993) evaluated pedotransfer functions for estimating the water retention function. A similar investigation on pedotransfer functions to estimate the saturated hydraulic conductivity was undertaken by Tietje and Hennings (1996).

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# 11 Soil data from Greece (East Macedonia and Thrace)

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## 11.1 Introduction

The soil database of the Faculty o Agronomy of the Aristotle University of Thessaloniki (Misopolinos et al., 2010) includes thematic maps, 1:20000 in scale, of more than 20 soil properties (soil texture, SOC, soil depth, bulk density, calcium carbonate, pH, EC, CEC, SAR, macro and micro nutrients etc). Ground truthing activities for measuring actual soil water content were performed for calibrating and validating models and pedotransfer rules.

## 11.2 Number of samples, geographical distribution and pedological variability

The database consists of physical and chemical data collected on 883 soil profiles in East Macedonia. Data are assembled by administrative region.

Out of the 3000 soil horizons, 2588 have water content at field capacity and wilting point and 900 have saturated hydraulic conductivity. These profiles are associated with a soil map of East Macedonia, with a resolution of 1/20000. Soils are classified according the USDA Soil Taxonomy.

Figure 11.1 shows the soil classification derived from the soil profile data. The soil map of East Macedonia is sparse. It was generated from the profile and borehole descriptions. Each polygon is associated with at least one profile. The dominant soil gives its name to the mapping unit

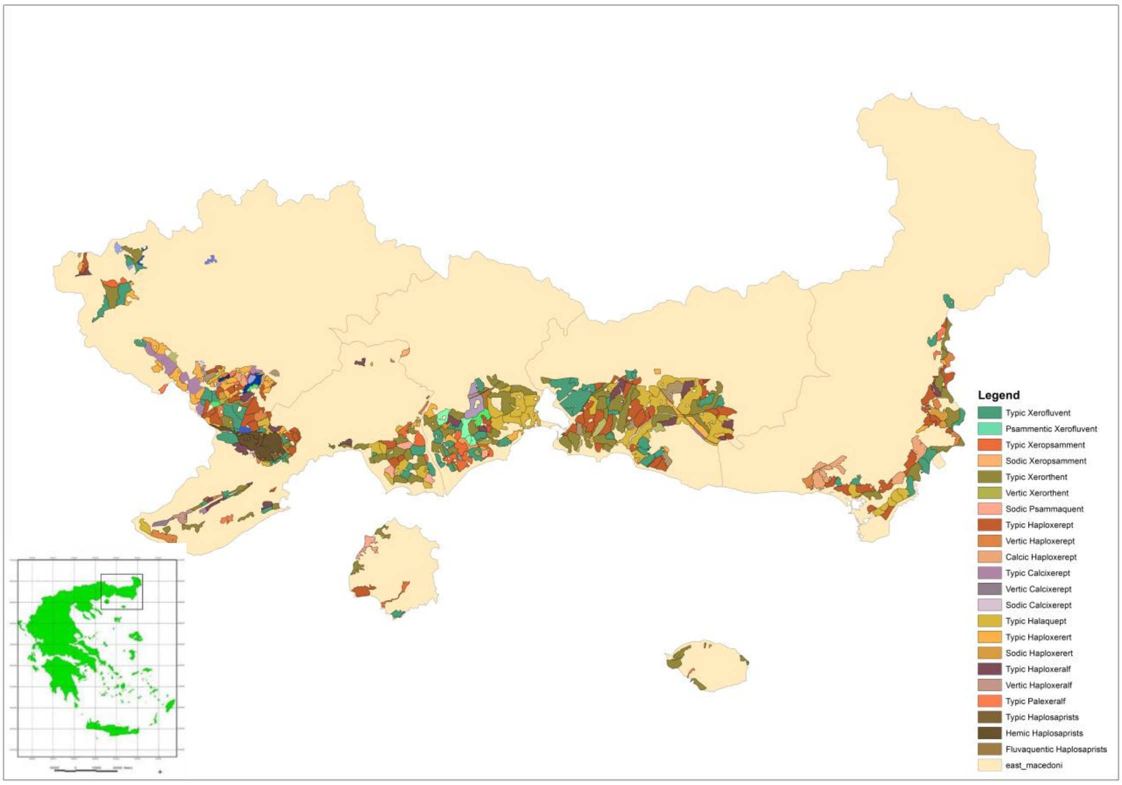

Figure 11.1 Soil map of East Macedonia

## 11.3 Measured soil properties and methods

### 11.3.1 Bulk density

Bulk density was measured in undisturbed soil cores (diameter 7cm, height 5cm) in the oven at 105°C for 24 hours (Grossman et al., 2002)

### 11.3.2 Organic carbon

Organic carbon (OC) was measured by wet combustion (Nelson and Sommers, 1996) without external heating and without applying any correction factor, assuming that the combustion was complete given the low levels of OC.

### 11.3.3 Calcium Carbonate content

CaCO3 content was measured by volumetric method using a Bernard calcimeter. The amount of CO2 produced when the sample is mixed with HCl in proportion 1:3 and water (Loeppart, 1996).

### 11.3.4 pH

Electrometric measurement of soil pH (1:1 soil:water solution) was used (Thomas, 1996).

### 11.3.5 Electrical conductivity

EC was measured in a 1:1 soil:water solution (Rhoades, 1996).

### 11.3.6 Particle size distribution

Sand silt and clay contents ( 50-2000 µm, 2-50 µm and <2µm) were measured with the hydrometer method (Gee and Or, 2002)

### 11.3.7 Water retention

Soil moisture retention were measured at pF 2.5 and 4.1 on undisturbed soil samples contained in cylinders (diameter 7cm, height 5cm) with a pressure plate extractor (Dane and Hopmans, 2002)

## 11.4 References

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# 12 Soil data from Hungary

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## 12.1 Introduction

Hungarian data included in the European Hydrophysical Data Inventory (EU-HYDI) was selected from the Hungarian Detailed Soil Hydrophysical Database, called MARTHA (acronym of the Hungarian name of the database) (Makó et al., 2010).

Hungarian hydrophysical datasets available in the past had information about only narrow groups of soils. Huge amount of hydrophysical information was measured as well for various soil assessments in the last 40 years but they were not organized into a single dataset. Therefore our aim was to collect all the measured soil hydrophysical data available in Hungary and harmonize them into one uniform database. With the National Scientific Research Fund (OTKA) under grant No. T048302 our university (University of Pannonia) had the opportunity to develop the Hungarian Detailed Soil Hydrophysical Database (MARTHA) with the collaborations of the County Offices of the Hungarian Plant and Soil Protection Service and Soil Protection Service and Institute for Soil Sciences and Agricultural Chemistry, Centre for Agricultural Research of Hungarian Academy of Sciences.

The MARTHA database includes existing smaller datasets: the Unsaturated Soil Hydraulic Database of Hungary (HUNSODA) (Nemes, 2002) (576 horizons) and the dataset of the Research Institute for Soil Science and Agricultural Chemistry of the Hungarian Academy of Science (RISSAC) (Rajkai et al., 1981) (270 soil samples). Further to these basic datasets, we included the data of the Hungarian Soil Information and Monitoring System (TIM) and data hold by the University of Pannonia (UP). The first (TIM) contains field and laboratory data for soils in Hungary, the soil-physical data on about 1023 profiles are ready for processing. Measured values of water retention curves are available for 3115 horizons (Várallyay, 1995). The second (UP) has information about 150 soil samples. These samples are originated mainly from county Zala and Somogy (South-west Hungary). The third main additional data source is from the Plant and Soil Protection Services of the Hungarian Counties, which produce various purpose soil assessments (e.g. for irrigation planning) and collect data for these needs. In addition to the above data sources, data were obtained from scientists as well through personal request. We received data about the agricultural areas from all over the country, therefore this database is representative for the Hungarian soils under cultivation.

## 12.2 Number of samples, geographical distribution and pedological variability

The MARTHA ver2.0 database contains the soil taxonomical, physical and chemical data of 15005 soil horizons belonging to 3937 soil profiles. In the EU-HYDI dataset we contributed with 900 horizons of 309 soil profiles. Figure 12.1 outlines the location of the selected soil profiles on the map of Hungary.

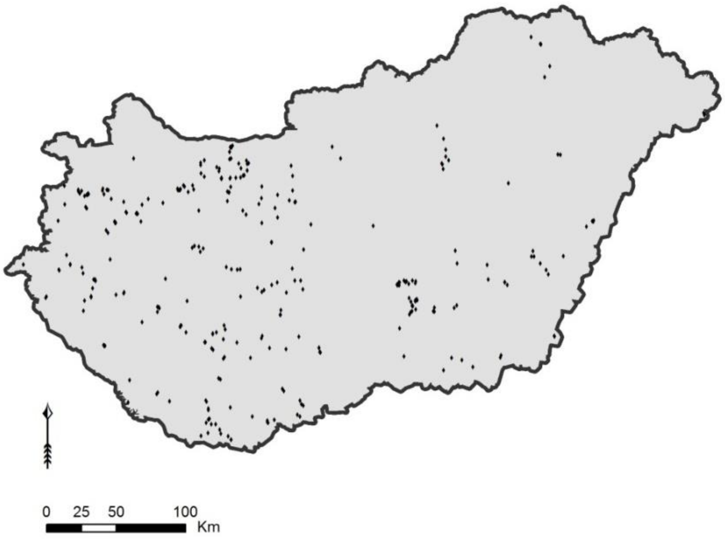

Figure 12.1 Location of selected MARTHA samples for the EU-HYDI contribution.

During selection of soil samples the main requirement was to meet the minimum criteria of the EU-HYDI database. Further considerations were having measured pH and calcium carbonate content and measured water content at least at five matric potential values. Finally we have chosen the 900 soil horizons based on the proportion of main soil types of Hungary (Figure 12.2)[1] with the aspect of selecting full soil profiles from as many counties as possible. In this way the selected profiles represent those Hungarian soil types, which are under cultivation. The MARTHA database is not representative for Histosols and shallow soils with unfavourable soil moisture regime therefore we could not chose soil samples from these soil types. We divided their proportion among the other six characteristic main soil types. Where we had the possibility we gave priority to those samples which have measured saturated hydraulic conductivity.

## 12.3 Measured soil properties and methods

The MARTHA database consists of general, physical and chemical properties of the soil profiles. The *general properties sheet* contains basic information about the soil profile (identifier; origin of the sample; name of the county, where the soil profile is; EOV coordinates; GPS coordinates; soil type and subtype), location of the selected soil profile on the map, horizons of the selected soil profile (name of the horizon, depth of the horizon). The p*hysical properties sheet* holds the following parameters: bulk density; particle size distribution (0.25-2 mm; 0.05-0.25 mm; 0.02-0.05 mm, 0.01-0.02 mm; 0.005-0.01 mm; 0.002-0.005 mm; < 0.002 mm); pF values (pF 0, pF0.4, pF1.0, pF1.5, pF2.0, pF2.3, pF 2.5, pF3.4, pF 4.2, pF 6.2); saturated hydraulic conductivity. The *chemical properties sheet* stores data about the organic carbon content (calculated from organic matter content), calcium-carbonate content, $pH_{H2O}$, $pH_{KCl}$, soluble salt content, cation exchange capacity, exchangeable Na content, Ca $(CH_3\text{-}COO)_2$ extractable acidity, KCl extractable acidity. Table 19.1 shows the descriptive statistics of selected physical and chemical soil properties of the 900 soil samples, indicating the number of samples containing measured data of the given soil property.

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[1] Hungarian soil classification is based on soil genesis and geography (Stefanovits et al., 1999). We described our main soil types with the WRB2006 reference soil groups' names.

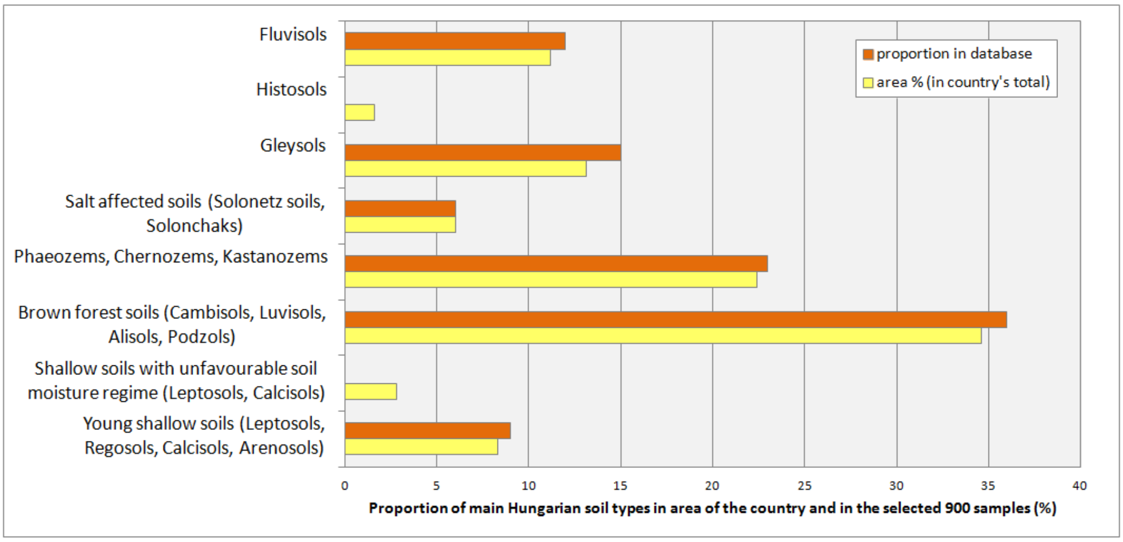

Figure 12.2 Proportion of area of Hungarian eight main soil types and proportion of main soil types in the selected 900 soil samples.

Table 12.1. Descriptive statistics of the selected Hungarian samples.

| **Measured soil property** | **N** | **Minimum** | **Maximum** | **Mean** | **Std. Deviation** | **Variance** |
|---|---|---|---|---|---|---|
| Bulk density (g cm$^{-3}$) | 900 | 1.05 | 1.87 | 1.47 | 0.14 | 0.02 |
| Sand content (2.0-0.05 mm) (weight %) | 900 | 0.80 | 94.76 | 37.71 | 24.25 | 588.23 |
| Silt content (0.05-0.002 mm) (weight %) | 900 | 3.06 | 80.04 | 39.10 | 17.57 | 308.73 |
| Clay content (< 0.002mm) (weight %) | 900 | 0.40 | 70.80 | 23.19 | 11.94 | 142.59 |
| Number of measured θ-h pairs | 900 | 5 | 10 | 5.90 | 1.14 | 1.30 |
| Water content at -0.1 kPa (pF0) (vol%) | 896 | 28.50 | 60.50 | 45.99 | 5.29 | 27.98 |
| Water content at -0.25 kPa (pF0.4) (vol%) | 60 | 34.20 | 53.30 | 43.33 | 4.48 | 20.10 |
| Water content at -1 kPa (pF1.0) (vol%) | 140 | 25.70 | 55.50 | 42.52 | 4.60 | 21.17 |
| Water content at -3 kPa (pF1.5) (vol%) | 497 | 28.10 | 54.80 | 39.37 | 4.38 | 19.16 |
| Water content at -10 kPa (pF2.0) (vol%) | 894 | 10.60 | 53.80 | 34.94 | 5.97 | 35.68 |
| Water content at -20 kPa (pF2.3) (vol%) | 39 | 19.36 | 38.60 | 32.07 | 5.77 | 33.27 |
| Water content at -33 kPa (pF2.5) (vol%) | 897 | 5.20 | 47.80 | 30.22 | 6.69 | 44.71 |
| Water content at -250 kPa (pF3.4) (vol%) | 127 | 3.42 | 43.50 | 23.02 | 8.04 | 64.71 |
| Water content at -1500 kPa (pF4.2) (vol%) | 900 | 0.27 | 35.30 | 15.18 | 6.57 | 43.22 |
| Water content at -1.5x10$^{5}$ kPa (pF6.2) (vol%) | 858 | 0.23 | 9.70 | 2.42 | 1.43 | 2.04 |
| Saturated hydraulic conductivity (cm day$^{-1}$) | 492 | 0.01 | 2467.00 | 141.83 | 302.42 | 91460.40 |
| Organic carbon content (weight %) | 900 | 0.03 | 4.21 | 0.73 | 0.54 | 0.29 |
| Calcium carbonate content (weight %) | 900 | 0.00 | 80.00 | 10.57 | 12.94 | 167.42 |
| pH in soil-water suspension | 900 | 4.98 | 10.62 | 7.79 | 0.86 | 0.73 |
| pH in soil-KCl suspension | 262 | 4.10 | 9.66 | 6.88 | 1.18 | 1.39 |
| Soluble salt content (weight %) | 876 | 0.00 | 0.45 | 0.03 | 0.05 | 0.00 |
| Cation exchange capacity (meq(100g)$^{-1}$) | 563 | 1.50 | 54.20 | 26.29 | 8.97 | 80.41 |
| Exchangeable Na$^{+}$ content (meq(100g)$^{-1}$) | 66 | 0.00 | 50.40 | 4.49 | 9.32 | 86.89 |
| Ca (CH$_3$-COO)$_2$ extractable acidity | 114 | 1,30 | 29,67 | 8,00 | 4,12 | 17,01 |
| KCl extractable acidity | 13 | 0,22 | 4,52 | 0,95 | 1,16 | 1,35 |

The measurements of the parameters were executed according to the Hungarian standardsTable 12.2 shows reference and short description of measurement methods used to determine chemical and physical properties of the soil samples.

Table 12.2 Methods used to determine soil chemical and physical properties.

| **Soil property** | **Short description of method** | **Reference for the method** |
|---|---|---|
| Bulk density | Oven drying 100 $cm^3$ sample at 105 $^oC$. | Buzás, 1993 |
| Particle size distribution | Conventional pipette method, dispersing agent: $Na_4P_2O_7$. | Gee and Bauder, 1986 |
| Water content at -0.1 KPa | Saturating the 100 $cm^3$ undisturbed sample and weighting them. | Várallyay, 1973 |
| Water content between -0.1 and -10 KPa | Sand-box with 100 $cm^3$ undisturbed sample (steel rings). | Várallyay, 1973 |
| Water content between -20 and -50 KPa | Kaoline-box with 100 $cm^3$ undisturbed sample (steel rings). | Várallyay, 1973 |
| Water content between -250 and -1500 KPa | Pressure membrane apparatus with cellophane membranes with 2 $cm^3$ disturbed sample. | Buzás, 1993 |
| Water content at $-1{,}5x10^5$ kPa | Water adsorption at 32.2 % relative humidity ($CaCl_2.6H_2O$) with 2 g undisturbed, air dried sample. | Buzás, 1993 |
| Saturated hydraulic conductivity | Falling head method with 100 $cm^3$ undisturbed sample. | Klute, 1965 |
| Organic matter content | Wet combustion with Tyurin titrimetric method: oxidation with chromic acid using boiling, $Cr_2O7^{-2}$ not used in oxidation is titrated with $Fe(NH_4)_2(SO_4)_2$. | Tyurin, 1931 |
| Calcium carbonate content | Scheibler calcimeter: 1-10 g sample + HCl, calculating the $CaCO_3$ from volume of released $CO_2$. | Nelson, 1982 |
| pH in soil-water suspension | Potentiometric method, soil : water = 1 : 2.5 | McLean, 1982 |
| pH in soil-KCl suspension | Potentiometric method, soil : KCl (1 mol/L) = 1 : 2.5 | McLean, 1982 |
| Soluble salt content | Calculated based on the EC of the saturated pasture and temperature. | MSZ 1978 |
| Cation exchange capacity | Mehlich method: sample + 0.1 mol/L $BaCl_2$ at pH 8.1; than replacement of the adsorbed cation with $CaCl_2$ at pH 7 . | Buzás, 1993 |
| Exchangeable $Na^+$ content | Mehlich method: sample + 0.1 mol/L $BaCl_2$ at pH 8.1; than replacement of the adsorbed cation with $CaCl_2$ at pH 7 . | Buzás, 1993 |
| Ca $(CH_3\text{-}COO)_2$ extractable acidity | 40g sample + 100 $cm^3$ $Ca(CH_3COO)2.H_2O$ solution, titration with NaOH (0.1 mol/L). | Buzás, 1993 |
| KCl extractable acidity | 40g sample + 100 $cm^3$ KCl (1 mol/L) solution, titration with NaOH (0.1 mol/L). | Buzás, 1993 |

## 12.4 Acknowledgements

We had the opportunity to develop the Hungarian Detailed Soil Hydrophysical Database (Hungarian acronym: MARTHA) in the framework of Grant No. T048302 provided by the National Scientific Research Fund (OTKA) with the collaboration of the County Offices of the Hungarian Plant and Soil Protection Service and Institute for Soil Sciences and Agricultural Chemistry, Centre for Agricultural Research of Hungarian Academy of Sciences. We would like to thank Csilla Farkas, Kálmán Rajkai, Hilda Hernádi, Péter Marth and Mihály Kocsis for their work during the database construction.

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# 13 Soil data from Italy (Veneto)

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## 13.1 Introduction

The dataset described in this document was provided by the Department of Agronomy Food Natural Resources Animals and Environment (DAFNAE), University of Padova, Italy. Soil analyses were carried out within the framework of agro-environmental projects a) evaluating the long-term effect of fertilization and/or rotation systems on soil quality b) monitoring the effectiveness of agro-environmental measures on water quality (e.g. Nitrate directive), particularly in areas characterized by shallow watertable (Borin et al. 2000; Morari et al., 2012); c) assessing the consequences of salt intrusion on soil productivity along the Venetian coastland

## 13.2 Number of samples, geographical distribution and pedological variability

The dataset contains 161 samples collected in the Po valley, within the Venice lagoon watershed or in the southern part of the Veneto Region (Figure 13.1). Alluvial fine-silty soils developed on the recent (Holocene) Venetian low plain are the most represented. A significant number of samples was also collected in a lagoon reclaimed area characterized by histosoils or soils with mollic horizons.

Surveys considered agrarian fields cultivated under conventional tillage. Maize was the main crop, as typical in the Region; it was subjected to different fertilizer input and management systems.

Figure 13.1 The Veneto region, NE Italy

Table 13.1. Summary statistics of the dataset

| Soil property | N | Mean | SD | Min | Max |
|---|---|---|---|---|---|
| Sand content (%) | 161 | 35.6 | 13.4 | 14.0 | 35.6 |
| Silt content (%) | 161 | 47.8 | 9.6 | 14.5 | 47.8 |
| Clay content (%) | 161 | 16.7 | 6.5 | 2.5 | 16.7 |
| pH (%) | 161 | 7.56 | 0.73 | 4.19 | 8.40 |
| OC content (%) | 160 | 5.61 | 5.80 | 0.20 | 22.19 |

## 13.3 Measured soil properties and methods

### 13.3.1 Basic soil properties

The minimum dataset included pH (ISO 10390), organic carbon content and particle size distribution. Data of CaCO3 (ISO 10963), CEC (ISO 11260) and EC 1:2 (ISO 11265) were also provided for several samples. Chemical analyses were performed on air-dried samples (<2 mm). Reference of the methods is given in Violante (2000).

Organic carbon was measured by dichromate oxidation according to Walkley and Black (1934) or dry combustion at 900°C (ISO 10694), previous removal of $CaCO_3$ by acid attack .

Bulk density was determined with the core method using standard sharpened 250-cm$^3$ sized Kopecky rings driven in the soil by a hammer head or a hydraulic sampler.

Particle size distribution was determined using the conventional pipette-sieve method (ISO 11277) on disturbed pretreated air-dried samples (<2 mm). The pretreatment included removal of organic matter with $H_2O_2$. For the costal soils, particle size was measured using the laser diffraction method (Mastersizer 2000, Malvern Instruments), dispersing the aggregates with sodium hexametaphosphate and sonication. Laser diffraction data were converted to the conventional pipette-sieve method according to a calibration equation developed on purpose.

### 13.3.2 Soil hydraulic properties

Water retention curves were measured at various soil-matric potentials, from three to eight according to the experiment. Water content at potentials > -330cm was determined on undisturbed cores, 250-cm$^3$ in size, while water contents at lower potentials (< -1000 cm) were determined on disturbed soil samples. For the latter, water content was determined gravimetrically and multiplied by bulk density to convert to volumetric water content. Sand box apparatus was used to measure the higher part of the water retention curve (up to -80 cm) whereas for lower potentials water retention was measured using the pressure chamber apparatus. In the most recent researches, potentials < -7000 cm were measured applying the dew point technique (Solone et al., 2012), using the temperature controlled dew point meter device WP4 (Decagon).

Saturated hydraulic conductivity was measured both in the lab and field. Lab analyses were carried out on 250 cm$^3$ cores applying the constant-head method or the falling-head method according to the sample conductivity. Field saturated hydraulic conductivity was measured with Guelph permeameter method (Reynolds et al., 2002).

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# 14 Soil data from Italy (Campania)

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## 14.1 Introduction

The Soil Hydrology Laboratory at University of Naples Federico II has been operating for more than 50 years. During these decades, consolidating certain techniques and developing new measurement methods have always been a target for us and represented an excellence in the field of soil hydrology. Many field campaigns have been undertaken during these years with the major aim of supporting the various research activities of the different groups of our Division. All of the data contained in the database that we provided have been measured in our laboratory.

## 14.2 Number of samples, geographical distribution and pedological variability

In addition to the data we already provided for the HYPRES soil database, our new set of soil data comprises 451 soil profiles, for which we have determined the physico-chemical and hydraulic characteristics of 623 soil horizons. This new database cover three Nations (Italy, Spain, and Germany; see Figure 14.1). The data collected in Italy pertain to a relatively wide variety of pedological and climatological conditions. However, because of the location of our university, it is worth noting that many soil samples show “andic” features since the investigated sites are affected by the presence of volcanos, like the Vesuvio or Vulture. A detailed list of sampling location is given in Table 14.1 .

Table 14.1. Sampling locations for the HYDI database.

| Location | Nation | Project | horizons |
|---|---|---|---|
| Barrax | Spain | ESA-*SEN2Flex* | 14 |
| Demmin | Germany | ESA-*AGRISAR* | 14 |
| Upper Alento River catchment | Italy | MiUR/PON-*AQUATEC* | 143 |
| Gromola-Paestum | Italy | Local project | 98 |
| Torre Lama – Battipaglia | Italy | Local project | 68 |
| Corleto Perticara | Italy | EU-*MEDALUS* ; MiUR/PRIN | 6 |
| Catania | Italy | Local project | 78 |
| Monteforte Irpino | Italy | MiUR/PON- *PetitOSA* | 9 |
| Acerra | Italy | Local project | 183 |
| Giugliano | Italy | Local project | 4 |
| Succivo | Italy | Local project | 3 |
| Lusciano | Italy | Local project | 3 |

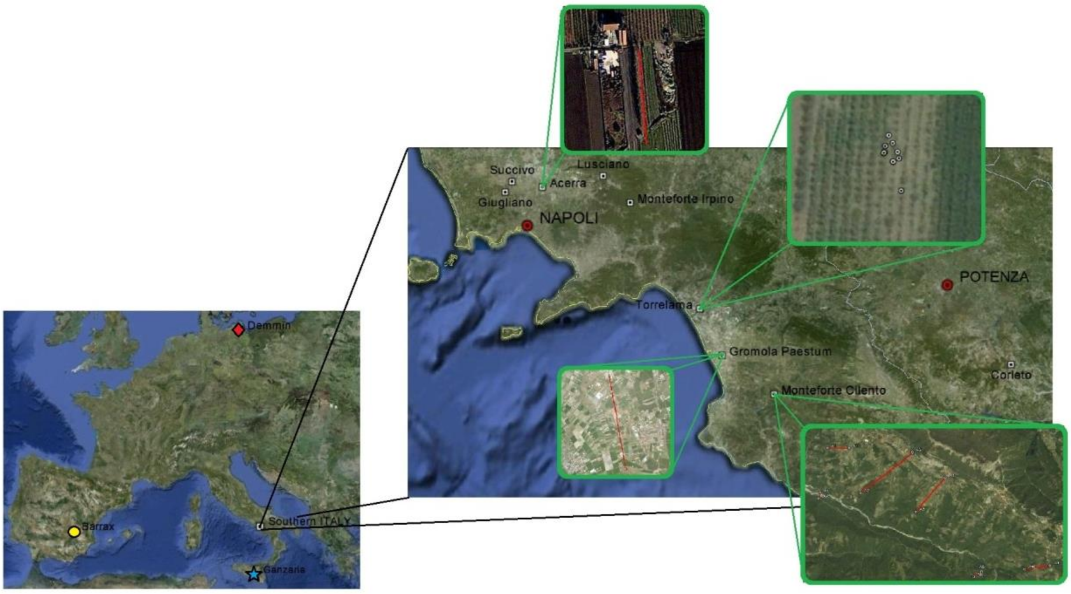

Figure 14.1 Map of sampling sites.

## 14.3 Measured soil properties and methods

All soil cores are obtained by driving a steel cylinder vertically into the soil using a hand-operated device and excavating the soil around the cylinder by hand to reduce disturbances during sampling. Usually and for most textural classes, soil cores are collected at the prescribed soil depths using steel cylinders having diameters of about 0.07-0.08 m. For structured clayey soils, cylinders with larger diameters are employed.

Before performing the hydraulic tests, the top of each undisturbed soil core (approximately 0.03 -0.04 m) is removed and put aside for the particle-size analysis and organic carbon content, and for measuring soil water retention data points in the dry range through the pressure plate apparatus.

### 14.3.1 Particle-size distribution

A portion of the disturbed sub-sample is used to determine the particle-size distribution by using standard laboratory techniques based on a set of sieves and the soil hydrometer (Gee and Or, 2002).

Our particle-size data are primarily grouped into sand (<2000-0.05 µm), silt (50-2 µm), and clay (<2 µm) fractions according to the USDA classification. Particle-size data are also grouped according to the ISSS classification. The grouped data (% sand, % silt, and % clay) are used to derive the textural class of each soil sample according to the USDA or ISSS textural triangles.

### 14.3.2 Organic carbon content

The organic carbon content is determined with the dichromate method (Mebius, 1960). As suggested by Schulze (1849) and Russel and Engle (1928), by convention measured organic carbon is multiplied by a factor of 1.724 to obtain organic matter.

### 14.3.3 Soil hydraulic parameters at full saturation ($\theta_{sat}$, $K_{sat}$)

The height of soil that remains in the core (which depends on the total length of the soil core collected) is slowly wetted from below, until saturated, using a de-aerated 0.005 M $CaSO_4$

solution. Firstly, the individual core, with its lower side covered by a voile held in place with an elastic band, is placed on a Perspex support perforated by a series of small holes. To obtain a complete saturation under laboratory conditions, we use the following procedure: (step *a*) the cores are placed in a container and water is slowly poured from below into the container until a head of water is set at 0.5 cm (with respect to the lower end of the core) and this head is maintained for 48 hours; (step *b*) 2.0 cm of water is then gradually raised in the container so that a head of 2.5 cm is set with respect to the bottom of the core and is maintained for additional 6 hours; (step *c*) finally the water level in the container is raised to submerge the cores, and this level is maintained for at least 4 hours.

Saturated water content, $\theta_{sat}$ , is measured by the gravimetric method (Topp and Ferré, 2002). Saturated hydraulic conductivity, $K_{sat}$, is usually measured in the laboratory by the falling-head method, but sometimes also by the constant-head method (Reynolds et al., 2002).

### 14.3.4 Soil water retention data points measured using the suction table and pressure plate extractor apparatus

After having measured $\theta_{sat}$ and $K_{sat}$, the soil core (usually of 0.04 m in height and 0.075 m in diameter) is placed on a suction table for measuring directly soil water retention points, usually considering various steps ranging from 0.01 m to about 2.50 m of suction head. The relevant equipment and procedures are fully described in the chapter by Romano et al. (2002).

Soil water contents at higher suction pressure values, usually ranging from 75 kPa to 1200 kPa, are determined using a pressure plate extractor apparatus (Dane and Hopmans, 2002).

### 14.3.5 Simultaneous determination of soil water retention and hydraulic conductivity functions using the evaporation method (direct and inverse methods)

Soil water retention and hydraulic conductivity data of a soil core are simultaneously determined from laboratory evaporation experiments by analyzing the measurements with a modified Wind's method (Wendroth et al., 1993; Peters and Durner, 2008) or using an optimization approach (Ciollaro and Romano, 1995; Romano and Santini, 1999).

The evaporation experiment starts from an initially saturated soil core of length L and involves the measurements with time of matric head profiles and soil core weights. Starting from a condition of hydrostatic equilibrium, with a nearly zero matric head at the bottom of the soil core, $h_L$ , the evaporation experiment is performed by draining the core with a small fan placed near the top and sealing completely the lower end of the core. In some cases, the small fan is removed and evaporation occurs at room temperature. During the transient flow event, the total weight of the soil sample, $P_j$ , (by a load cell) and the matric head, $h_{ij}$, (by horizontally inserted micro-tensiometers) at different soil depth $z_i$, where z=0 is the top of the soil sample, are measured at frequent but irregular time $t_j$. All data were recorded automatically and processed using a data-logger and a personal computer. The selection of the size of the soil sample as well as of the number and locations of the tensiometers were determined based on the works of Ciollaro and Romano (1995) and Romano and Santini (1999).

***Direct evaporation experiment***

In brief, the soil core subjected to the evaporation experiment is split into two (or more) sections centered around each micro-tensiometers. An iterative calculation is set up to determine the water retention function. First, an approximated water retention function is fitted by a polynomial regression on the basis of the average water contents measured for the entire core by the load cell, and the mean values of the measured matric heads. Then, a polynomial function is assigned to each section of the soil core to predict water contents at the measured matric heads. By comparing at fixed times the mean predicted water contents and the measured water contents, the iterations are updated until no improvement was detected from a statistical viewpoint. After determining the water retention function, the hydraulic conductivity function is computed using a modified instantaneous profile method. Readers wishing further details are directed to the works by Wendroth et al. (1993) and by Peters and Durner (2008).

***Inverse evaporation experiment***

The water flow in the soil core induced by the evaporation experiments is simulated by the Richards equation, while parametric relations (such as, for example, those of van Genuchten-Mualem, or of Brooks and Corey, or some more complex bimodal analytical relationships) are assumed to describe the soil hydraulic properties, i.e. the soil water retention and hydraulic conductivity functions. Estimation of the unknown hydraulic parameters and the associated uncertainty is carried out by employing a Maximum Likelihood (ML) approach. Additional details of this inversion technique and the minimization algorithm can be found in the paper by Romano and Santini (1999).

### 14.3.6 Bulk density and porosity

At the completion of the hydraulic tests, we measure the oven-dry bulk density. For most of the soil cores of our database, total porosity was calculated from the measured oven-dry bulk density assuming that soil particle density is 2.65 g cm$^3$. In some cases, however, soil particle density is measured using the pycnometer method.

## 14.4 Acknowledgements

The soil database established at the Laboratory of Soil Hydrology of University of Napoli Federico II is a contribution from all the Agricultural Hydraulics Group of this institution. Special thanks go to our technicians, Ms. Paola Di Fiore and Dr. Benedetto Sica.

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# 15 Soil data from Italy (Sicily)

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## 15.1 Introduction

Soil erosion and water deficit traditionally affect agriculture of Mediterranean areas. In Sicily, these issues are complicated by the very accentuated spatial and temporal variability of rainfall that concentrates in the northern coast and in the period from October to April. Modelling of the hydrological processes may help to prevent soil loss, predict the fate of agrochemicals in the soil profile, optimize dry agriculture and manage irrigation. However, agro-hydrological simulation models require the detailed knowledge of the soil hydraulic properties, i.e. the water retention curve and the hydraulic conductivity function. The Sicilian regional administration has recently published a new edition of the soil map of Siciliy (Perciabosco et al., 2012). Unfortunately, the very significant information contained in that map doesn’t include detailed hydrological data. Therefore, despite being largely studied, the Sicilian soils were never systematically sampled for determining their hydrological properties. The soil data included in the EU-HYDI database were collected during several projects conducted by the Hydraulic Section of the Department of Agricultural and Forestry Sciences (SAF) – University of Palermo and Funded by the Sicilian regional administration (Regione Siciliana, Assessorato delle Risorse Agricole ed Alimentari), and Environmental Protection Agency of Sicily (ARPA).

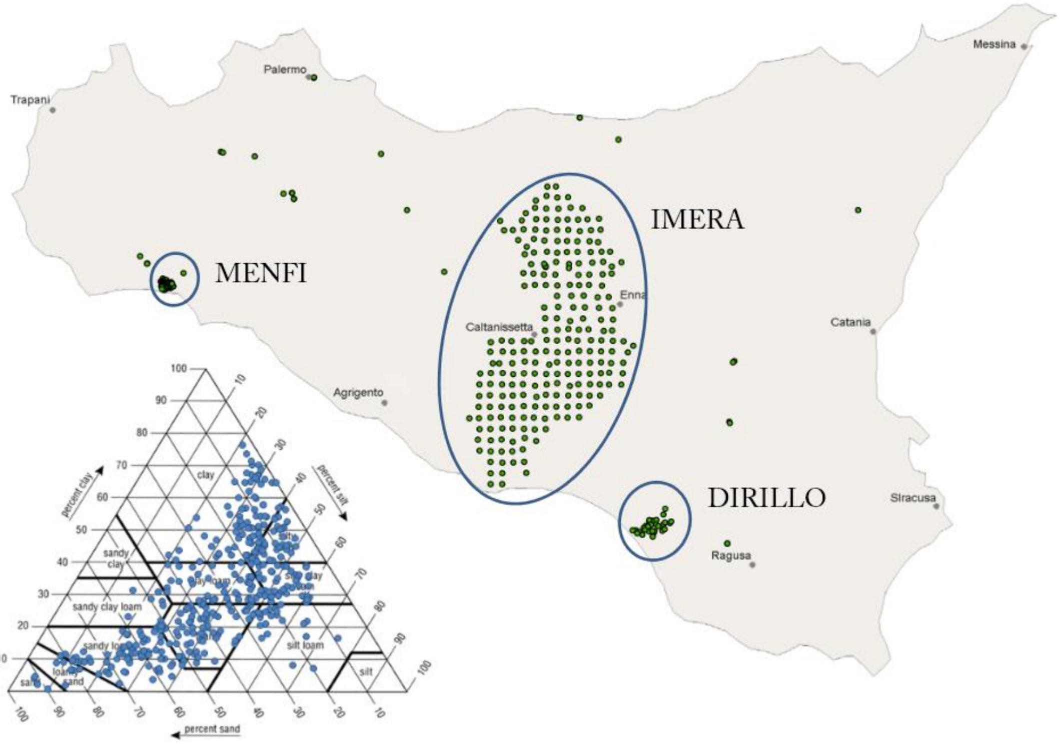

Figure 15.1 Distribution of sampled profiles

## 15.2 Number of samples, geographical distribution and pedological variability

Sicilian hydro-pedological inventory consist of 375 profiles and 417 samples. Basically, two irrigated areas (Menfi and Dirillo) and a large watershed (Imera Meridionale) were sampled (Figure 15.1). The irrigated areas are those of Menfi located in the south-west of Sicily, and the Dirillo valley in the south of Sicily. The watershed of Imera Meridionale is located in central Sicily and covers a surface of approximately 2000 km$^2$. The other data were collected in 32 soil profiles (41 soil samples) located across Sicily that were selected for the specific purposes of different researches conducted by SAF Department with grants from University of Palermo and Italian Ministry of University.

In the wine-specialized district of Menfi, 84 surface samples were collected in summer 2004 in an area of approximately 850 ha. The most common soils in this area are Typic Xerochrepts, Typic Xerofluvents, Typic Haploxeralfs and Typic Haploxererts.

The irrigated district of Dirillo valley (3000 ha) is mainly under citrus, vineyard and horticultural crops. The data set consists of 64 samples collected during spring 2006 in A, B and C horizons of 31 soil profiles. The typical soil of this part of Sicily are Fluventic Haploxerept, Typic Haploxerepts, Typic Xeronthent and Lithic Xerorthent.

The watershed of Imera Meridionale was systematically sampled during 2007 using a square grid of sampling points with sides of approximately 3 km for a total of 228 soil profiles. The prevalent soil coverages are durum wheat in rotation with leguminous crops, vineyards and olive trees. In the northern mountainous part of the watershed, natural woodlands and grasslands are common, whereas specialized horticultural crops (also in greenhouses) are widely practised in the south, near the coastline. Soil types are high variable with Lithic Xerorthens, Typic Xerochrepts, Typic Haploxeralfs, Vertic Xerochrepts and Typic Xerofluvents covering the most part of the watershed.

Table 15.1. Statistics of the measured soil properties

| | N | min | max | mean | median | dev. St. |
|---|---|---|---|---|---|---|
| Cl (%) | 417 | 0.5 | 76.3 | 30.7 | 28.8 | 16.8 |
| Si (%) | 417 | 4.4 | 75.0 | 37.6 | 37.8 | 12.6 |
| Sa (%) | 417 | 0.0 | 91.8 | 31.6 | 24.9 | 22.3 |
| $\rho_b$ (g cm$^{-3}$) | 417 | 0.82 | 1.76 | 1.24 | 1.25 | 0.16 |
| OC (%) | 414 | 0.02 | 7.18 | 1.40 | 1.00 | 1.08 |
| $\theta_{0.1}$ (cm$^3$ cm$^{-3}$) | 183 | 0.27 | 0.58 | 0.43 | 0.43 | 0.06 |
| $\theta_1$ (cm$^3$ cm$^{-3}$) | 402 | 0.08 | 0.74 | 0.43 | 0.44 | 0.11 |
| $\theta_{10}$ (cm$^3$ cm$^{-3}$) | 407 | 0.05 | 0.60 | 0.32 | 0.32 | 0.12 |
| $\theta_{150}$ (cm$^3$ cm$^{-3}$) | 409 | 0.02 | 0.50 | 0.19 | 0.19 | 0.08 |
| $K_{fs}$ (cm day$^{-1}$) | 59 | 13.5 | 10859 | 1254 | 378 | 2326 |

## 15.3 Measured soil properties and methods

### 15.3.1 Soil sampling

At each sampling site, at least two undisturbed soil cores were collected (inside diameter = 0.08 m, height = 0.05 m) to determine soil bulk density and water retention curve at high pressure heads ($h \geq -1.5$ m). Stainless steel cylinders were inserted into the soil by gently hand-hammering while removing the surrounding soil to reduce soil disturbance. The cores were wrapped in plastic immediately after collection to prevent evaporation and then stored at 4 °C to minimize chemical and biological changes before laboratory analysis. A disturbed soil sample was also collected to determine PSD, organic matter content and water retention curve at low pressure heads ($h \leq -3$ m).

### 15.3.2 Particle size distribution

The PSD was measured using conventional methods following $H_2O_2$ pre-treatment to eliminate organic matter and clay deflocculation using sodium hexametaphosphate and mechanical agitation. Fine size fractions were determined by the hydrometer method, whereas the coarse fractions were obtained by mechanical sieving (Gee and Or, 2002). A total of 14 particle size limits were considered for each sample. The clay, silt, and sand percentages were determined according to the USDA classification (Figure 15.1).

### 15.3.3 Soil bulk density and porosity

The core method (Grossman and Reinsch, 2002) was used to determine the soil bulk density, $\rho_b$, on the undisturbed soil cores previously used for water retention measurement. Soil porosity, $\phi$, was calculated from $\rho_b$ assuming a particle density of 2.65 g $cm^{-3}$.

### 15.3.4 Organic matter content

The organic carbon, OC, content was determined by the Walkley-Black method (Nelson and Sommers, 1996).

### 15.3.5 Soil water retention

Desorption water retention data were determined on undisturbed soil cores by a hanging water column apparatus (Burke et al., 1986) for h values ranging from -0.05 to -1.5 m. The cores were previously saturated by wetting from below and then equilibrated at established decreasing h values. The volumetric water content corresponding to the last equilibrium pressure head value was determined by oven drying the core. The volume of water drained from the sample was recorded and used to calculate the volumetric water content corresponding to the equilibrium pressure heads. The soil water content corresponding to h values ranging from -3.37 to -153.0 m was determined by a pressure plate apparatus (Dane and Hopmans, 2002) on soil samples (diameter = 0.05 m, height = 0.01 m) obtained by packing the sieved soil to the $\rho_b$ value of the undisturbed cores. For each applied h value of the sequence, the mean water content of at least two replicated cores was considered. Depending on the sample, six to 13 points of the water retention curve were experimentally determined.

### 15.3.6 Soil hydraulic conductivity

Field saturated hydraulic conductivity, Kfs, was determined by the Simplified Falling Head (SFH) technique (Bagarello et al., 2004) that is based on the Philip's analysis for one dimensional falling head infiltration. The SFH technique consists of quickly pouring a known volume of water on the soil confined by a ring (diameter 0,15 m) inserted for 0,12 m into the soil and in measuring the time the water completely infiltrates into the soil. Measurement of the field saturated and initial volumetric soil water contents and estimation of a soil texture/structure parameter are also required to calculate Kfs. For each sampling site a minimum of 5 replicate SFH runs were conducted.

Near saturated soil hydraulic conductivity was measured in the field by 0.22 m diam. base plate tension infiltrometer. Multipotential experiments were conducted in duplicate with ascending sequences of three or four pressure heads in the range from -120 to -10 mm. A thin (< 10 mm thick) layer of contact material was placed over the surface to fill small depressions and to improve the contact between the soil and the disk of the infiltrometer. Steady-state infiltration rates were used to estimate the unsaturated hydraulic conductivity of soil corresponding to each applied pressure head of the sequence by the Ankeny et al. (1991) solution.

For a limited number of samples, the Wind (1968) evaporation method was applied under controlled laboratory conditions on undisturbed soil cores (0.085 m diameter by 0.10 m height) to simultaneously determine the water retention curve and the hydraulic conductivity function. Starting from quasi-saturation, the soil core was sealed at the bottom and a small fan was used to facilitate evaporation. The water pressure head at four depths (12.5, 37.5, 62.5 and 87.5 mm) and the sample total weight were monitored and recorded during evaporation by an automated system. The code Metronia by Halbertsma (1996) was used to analyse evaporation data.

## 15.4 Acknowledgements

Soil data were collected in the frame of the Projects “Modellistica idrologica e telerilevamento satellitare a supporto delle informazioni agrometeorologiche della regione Sicilia” (head Prof. C. Agnese), “Studi e ricerche per la definizione ed applicazione dei modelli per la produzione di indicatori di qualità del suolo finalizzati al monitoraggio dei processi dei desertificazione nel bacino del fiume Imera Meridionale” (head Prof. V. Ferro), “Monitoraggio e modellizzazione della dinamica dei nitrati nel suolo” (head Prof. M. Iovino), “Digitalizzazione della filiera agroalimentare” (head Prof. V. Bagarello), “Metodologie innovative per la caratterizzazione idraulica e la valutazione della qualità fisica dei suoli siciliani” (head Prof. V. Bagarello). The database was developed thanks also to expert assistance of C. Antinoro, M. Castellini, A. De Santis, A. Giangrosso, M. Birtone, S. Pomilla, S. Sferlazza, A. Sgroi in collecting samples and conducting laboratory and field analyses.

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# 16 Soil data from the Netherlands

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## 16.1 Introduction

The soil data for the Netherlands were provided by both Alterra and Wageningen University. Data were collected during systematic measurement campaigns aiming at the soil physical characterization of the main Dutch texture classes distinguished on the soil map at a scale 1 : 50 000. The individual measurements per soil horizon were grouped in different texture classes and they were used to generate both class- and continuous pedotransfer functions. Results have been published in three updated versions of the Staring Series: 1987, 1994 and 2001 (Wösten et al. 1987, 1994 and 2001). At the European scale the HYPRES database has been established and its class- and continuous pedotransfer functions are being used in a range of studies at the European scale (Wösten et al. 1999). Recently a procedure has been developed in which the 315 soil mapping units of the soil map of the Netherlands, scale 1 : 50 000, are characterized in a soil physical sense. Next the 315 units were used as input in a hydrological model and based on the modeling results the 315 soil units were clustered in 72 soil hydrological response units (Wösten et al. 2013a). The resulting map of hydrological response units is a frequently used source of input data for modeling studies on for instance droughts, leaching of manure and nutrients, and pesticide behavior in the soil. A similar procedure has been developed to generate soil hydraulic information for river basin studies in semi-arid regions (Wösten et al. 2013b)

## 16.2 Number of samples, geographical distribution and pedological variability

Soil samples were extracted from the Soil Information System of the Netherlands and they are considered to be representative for the different soils occurring in the Netherlands. For the Netherlands the following particle-size limits are used: 2 – 16 – 5 - 105 – 150 – 210 – 300 – 2000 µm.

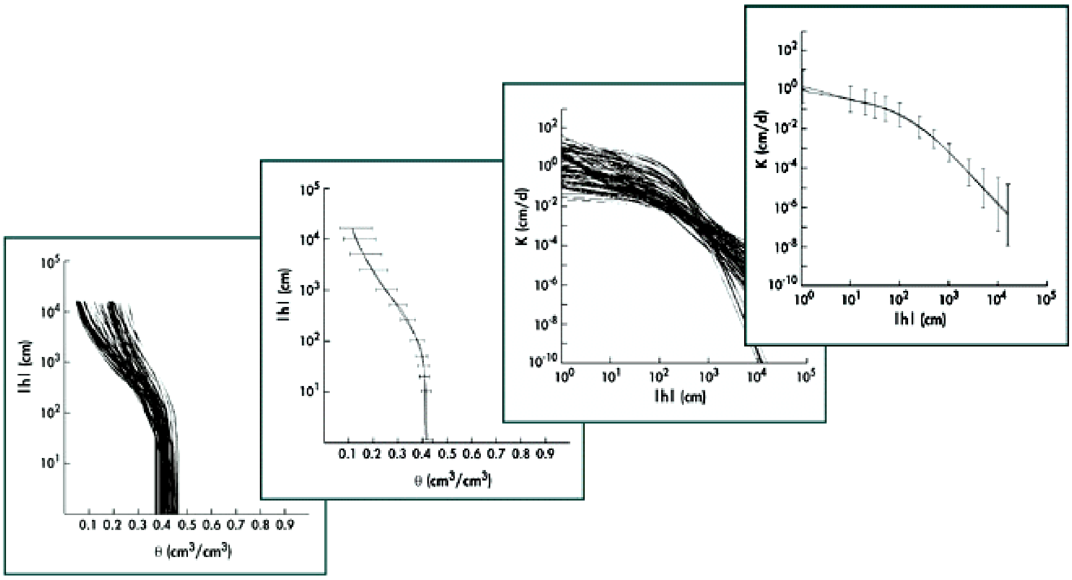

Figure 16.1 Individual and average water retention and hydraulic conductivity curves for a texture class

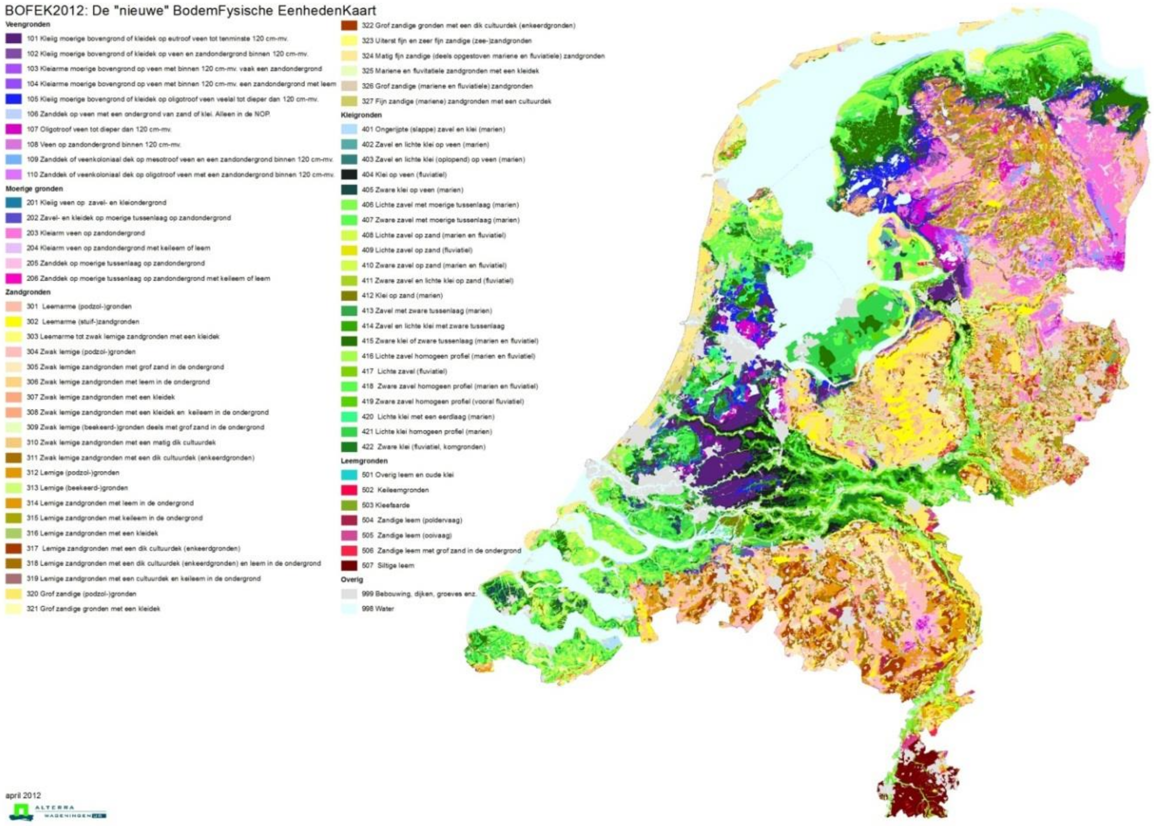

Figure 16.2 The 72 hydrological response units distinguished for the Netherlands

## 16.3 Measured soil properties and methods

### 16.3.1 Soil texture

Soil texture is determined in the laboratory using standard techniques such as sieving and pipette method.  The analysis allows distinguishing 7 particle size classes. Organic matter content is determined by loss of ignition.

### 16.3.2 Water retention and hydraulic conductivity

Special techniques are needed to measure both the water retention and hydraulic conductivity characteristics accurately and efficiently. Each technique covers a specific part of the pressure head range from saturated to very dry soil. Together, these techniques cover the full range. Measurements are made in the laboratory under controlled conditions on undisturbed soil samples, normally taken from the major soil horizons as distinguished by experienced soil surveyors.

Techniques used in the Netherlands are:

- Hanging water column

    This technique determines water retention in the pressure head range from -5 to -150 cm. A pressure head is induced by lowering a hanging water column connected with a porous plate on which the soil sample is placed. The amount of water outflow from the soil sample is measured. Measurements at successive pressure heads up to -150 cm will take one week for a sandy soil and three weeks for a clay soil. Not only can the drying curve be determined, but also the wetting curve. The differences between these curves indicate to what extent hysteresis occurs.

- Pressure cell

  This technique is used to measure water retention in the pressure head range from -900 to -16 000 cm. Air pressure are imposed on soil samples placed on saturated, very fine porous cellophane. After steady state is reached, soil water contents are determined by weighing. The measurements will take two weeks for a sandy soil at low air pressure up to a few months for a clay soil at high air pressure.
- Evaporation method

  This technique measures both water retention and hydraulic conductivity in the pressure head range from -50 to -900 cm. Water is allowed to evaporate from the top of an initially wet soil sample. Pressure heads and average water contents are measured. This method will take a few days for a clay soil and two weeks for a sandy soil. With a fully automated set-up, ten samples can be measured simultaneously and independently.
- Constant head

  The technique determines the saturated hydraulic conductivity (pressure head = 0). A constant wate4r-level of 1 cm is maintained on top of the saturated soil sample. The volume of water that percolates through the sample is measured.
- Drip infiltrometer

  This technique determines conductivity in the pressure head range from -1 to -100 cm. It measures pressure heads and flux density. One series will take a few days when an automated set-up is used.

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# 17 Soil data from Norway

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## 17.1 Introduction

The Norwegian dataset contributed to the EU-HYDI was collected by a joint effort by the major institutions working with soils in Norway: the Norwegian Institute for Agricultural and Environmental Research (Bioforsk), the Norwegian Forest and Landscape Institute (Skog & Landskap) and the Norwegian University of Life Sciences (UMB). A national soil survey database with basic soil chemical and physical data has already been established by Skog & Landskap, but so far soil hydraulic properties have not been included in this database. Neither has data from other sources and projects not related to the national soil survey. EU-HYDI was therefore an excellent starting point for collaboration between institutions to provide a more comprehensive national database based on all available sources. The data, collected since the 1970s until today, came from Masters theses (Holt & Samuelsen, 1978; Bjørdal & Tyldum, 1979; Reklev & Vikan, 1979; Berland & Brautli, 1980; Jonsen, 1981; Renolen & Sivertsen, 1981; Pedersen, 1983; Lorentzen, 1984; Nakken, 1984; Straume, 1993; Svendgård, 1996; Torberntsson, 2008), PhD theses (Børresen, 1987; Høstmark, 1994; Rosef, 2008), project reports (Hole & Solbakken, 1986; 1987; Hole, 1987; Solbakken, 1986;1987a,b; Haraldsen, 1991; Haraldsen et al., 1994; Sveistrup et al., 1994a,b; ), scientific publications (Sveistrup et al., 2005), and unpublished data from individual researchers (Haugen, unpubl.; Riley, unpubl.) and from the national soil survey database ("Jordprofildatabasen"). The data were assembled by all involved institutions, and further standardized and formatted to the required EU-HYDI format by Bioforsk.

## 17.2 Number of samples, geographical distribution and pedological variability

We assembled data from a total of 504 sites and 2033 soil layers, distributed by counties as shown in Figure 17.1 Distribution of sampling sites in counties in Norway (left), the figures within each county represents the number of sampling sites/profiles; Land use map (middle, modified from www.skogoglandskap.no); Simplified map showing superficial deposits/parent material (right, modified from www.ngu.no).Figure 17.1. The majority of sites are located in South-east Norway (Hedmark, Oppland and Akershus counties). The main land cover classes for the 504 sites are listed in Table 17.1. Arable land, including cropland, grassland and pasture, accounts for 71 % of the sites, while 9 % of the sites are under forest, marsh and heather. The land cover for the remaining 20 % of the sites is unknown, but most likely it is arable land for most of them. A land cover map for Norway is shown in Figure 17.1 Distribution of sampling sites in counties in Norway (left), the figures within each county represents the number of sampling sites/profiles; Land use map (middle, modified from www.skogoglandskap.no); Simplified map showing superficial deposits/parent material (right, modified from www.ngu.no).Figure 17.1.

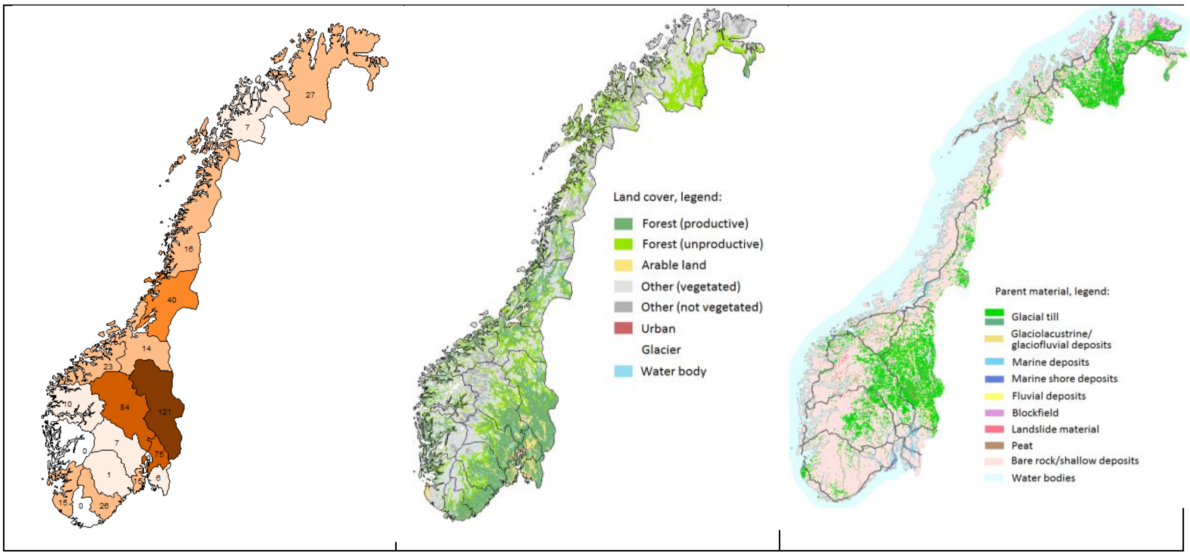

Figure 17.1 Distribution of sampling sites in counties in Norway (left), the figures within each county represents the number of sampling sites/profiles; Land use map (middle, modified from www.skogoglandskap.no); Simplified map showing superficial deposits/parent material (right, modified from www.ngu.no).

Information about landform and topography is sparse for the Norwegian data. Roughly 20 % of the sites fall into slope classes flat to very gently sloping (gradient 0-2 %), 15 % into classes gently sloping to sloping (2-10 %), and 5 % into classes strongly sloping to moderately steep (10-30 %). For the remaining 60 % of the sites the slope is unknown. Information about rock outcrops, coarse surface fragments, erosion, surface sealing and surface cracks is mostly missing from the Norwegian data sources.

The main parent material classes for the 504 sites are also listed in in Table 17.1. A large proportion of the sites is dominated by either marine clay deposits (22 % of the sites) or glacial till (28 %). On a national basis, these are the most important types of parent material, especially on arable land (see parent material map in Figure 17.1 Distribution of sampling sites in counties in Norway (left), the figures within each county represents the number of sampling sites/profiles; Land use map (middle, modified from www.skogoglandskap.no); Simplified map showing superficial deposits/parent material (right, modified from www.ngu.no).Figure 17.1). Fluvial deposits are also quite well represented (11 %). For 28 % of the sites the parent material is unknown. The superficial deposits of Norway were mostly formed during and after the last glaciation, i.e. the age of the parent material is less than about 10 000 years old.

Soil classification according to WRB is missing for 77 % of the sites. For roughly one fourth of these sites an alternative classification is available (Soil Taxonomy, Canadian classification system, FAO or local classification). Where WRB classification exists, the reference groups listed in Table 17.1 are represented, with the most frequent occurrence of Stagnosols, Gleysols and Albeluvisols. It can be noted that according to the Norwegian soil map, which covers about 50 % of arable land in Norway, the WRB reference groups with largest areal extent are Stagnosols, Cambisols and Albeluvisols, each of which represent cca. 20 % of the mapped area (Skog & Landskap, 2011).

The textural composition of the soil samples is shown in Figure 17.2 according to the Norwegian classification system as well as the classification system used by USDA (after particle-size interpolations as described in Chapter 27). Soils range from coarse sandy soils to clay soils with a clay content up to 70 %. The texture classes loam, loamy sand and silty clay loam are well represented in the dataset. The texture classes silt loam and sand are also decently well represented. Data are sparse for the classes with highest silt and clay content. Soils with more than 20 % clay combined with high sand content are quite uncommon in Norway, and are consequently sparsely represented in the dataset. Sandy loam and loam textures are typically associated with glacial till, silt loam, silty clay loam and clay with marine clay deposits, silt and silt loam with flood and fluvial deposits, and the sandy soils with glacial till, fluvial deposits and marine shore deposits. The gap seen in the high silt content zone of the USDA triangle in Figure 17.2 is produced by the artifact that when interpolating silt content from the 2-60 μm range to the 2-50 μm range, the silt content will necessarily be lesser than – or in some cases equal to – the originally determined silt content.

Table 17.1. Land cover, soil types and parent material for the 504 sampled sites in Norway. Percentage of sites is given for each category.

| **Land cover** | **%** | **Parent material** | **%** | **WRB reference group** | **%** |
|---|---|---|---|---|---|
| Cereals + oilseed | 33 | No information | 28 | No information | 77 |
| No information | 20 | Glacial till | 28 | Stagnosols | 4 |
| Grass ley | 18 | Marine deposits | 22 | Gleysols | 3 |
| Arable land, unspecified | 9 | Fluvial deposits | 11 | Albeluvisols | 3 |
| Forest, planted stands | 7 | Beach deposits | 4 | Phaeozems | 2 |
| Arable land, bare/tilled | 4 | Peat | 3 | Umbrisols | 2 |
| Vegetables | 4 | Glaciolacustrine deposits | 2 | Fluvisols | 2 |
| Pasture | 3 | Glaciofluvial deposits | 1 | Histosols | 2 |
| Marsh, heather, grassland | 2 | Flood deposits | 0.4 | Planosols | 1 |
| | | Anthropogenic material | 0.4 | Regosols | 1 |
| | | Lacustrine deposits | 0.2 | Cambisols | 1 |
| | | | | Arenosols | 1 |
| | | | | Podzols | 1 |

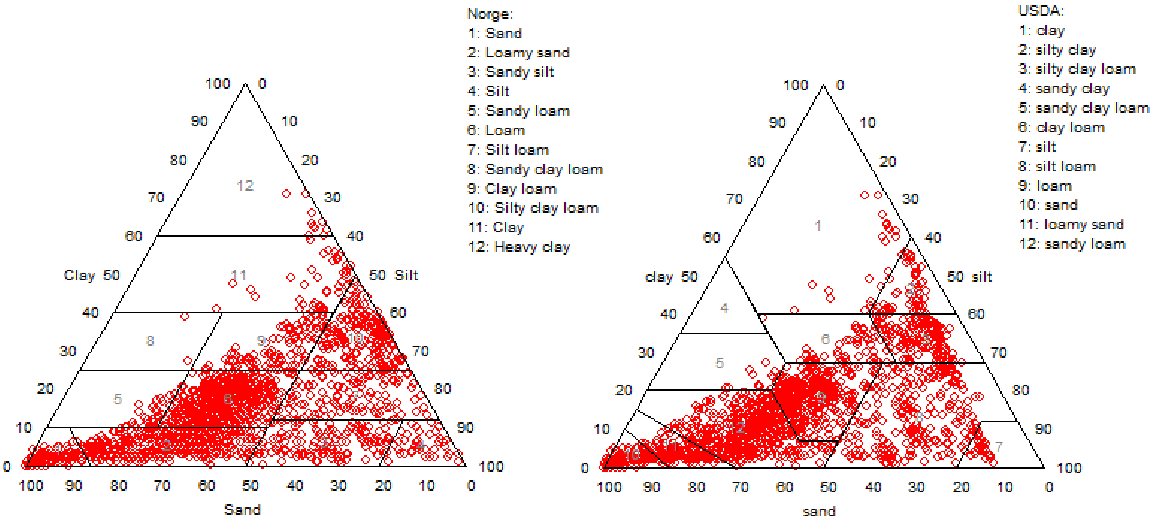

Figure 17.2 Textural composition and texture classes of the EU-HYDI soil samples from Norway, according to the Norwegian soil textural triangle with clay <2 μm, silt 2-60 μm, and sand 60-2000 μm (left) and the USDA triangle (right) with clay <2 μm, silt 2-50 μm, and sand 50-2000 μm. The 2-50 μm silt fraction was estimated using the procedure outlined in Chapter 25.

## 17.3 Measured soil properties and methods

### 17.3.1 Soil chemical properties

Soil chemical properties are available for 2012 out of 2033 soil layers. Carbon content is available for 847 layers. Carbon content is given as total or organic carbon content. Total carbon content was measured by dry combustion with subsequent determination of $CO_2$ content by gas chromatography or using an IR detector and calculation of carbon content from the $CO_2$ volume (ISO 10694; Øien, unpubl.; Nelson and Sommers, 1982). For many of the samples with data on organic carbon content, the method of determination is not known. In some cases the organic carbon content was measured by first removing carbonates from the sample, followed by combustion and determining $CO_2$ gas by IR-detector. For some sites a wet combustion method by Tinsley (1950) for determination of organic carbon was reported. Loss on ignition (LOI) is available for 1246 layers, of which 1011 layers lack data for total or organic carbon. LOI was determined by burning the soil sample at 500°C for 12 hours or at 550°C for 3-8 hours (time required depending on organic matter level).

The soil pH was mostly (835 layers) measured in a water solution, with a soil to water ratio of 1:2.5. In some samples pH was also (232) or alternatively (13) measured in a $CaCl_2$ solution.

Cations H+, Na+, Mg2+, K+ and Ca2+ were measured for 784 samples in 1M NH4OAc solution at pH 7 (Ogner et al., 1975). Na+ and K+ were determined by flame photometry, while Ca2+ and Mg2+ were determined by atomic absorption. H+ was determined by titration to pH 7 with NaOH or $NH_4OAc$. In rare cases for this dataset, the cations were determined using ICP (inductively coupled plasma). Exchangeable acidity (73 samples) was measured using a KCl extractant with subsequent titration with NaOH. Cation exchange capacity, equaling the sum of all cations, was available or could be calculated for 811 samples.

### 17.3.2 Particle size distribution and coarse fragments

Measured particle size distribution is available for 1812 samples, and coarse fragments for 1499 samples. The amount of coarse fragments (>2 mm) has been determined gravimetrically, by sieving the soil through a 2 mm mesh after destruction of aggregates. The amount of coarse fragments is given as a percentage of the total sample weight.

The particle size distribution (PSD) was determined on crushed and sieved soil with the hydrometer method (Njøs, 1967) or pipette method (Elonen, 1971; Njøs, 1967) for the fine fractions (clay <2 µm, fine silt 2-6, medium silt 6-20 and coarse silt 20-60 µm) and wet-sieving for the sand fractions (very fine sand 60-100, fine sand 60-200 or 100-200, medium sand 200-600 and coarse sand 600-2000 µm). For the fine fractions, we have not been able to identify the method for 413 out of 1812 samples, but we know that it has to be either the pipette or the hydrometer method. For the sand fractions the method is known for all samples except for the fraction 100-200 µm (59 samples). The fractions determined for the samples are summarized in Table 17.2. Most frequently, data for seven fractions are available.

### 17.3.3 Soil water retention, bulk density and porosity

Bulk density, porosity and water retention have usually been determined on the same sample. The samples were collected as undisturbed soil cores, using 100 $cm^3$ steel cylinders. The cylinders are either 5.1 cm high with a diameter of 2.5 cm, or 3.7 cm high with a diameter of 3.0 cm. The sampling has been performed in different ways, depending on the individual studies,

Table 17.2. Particle size distribution fractions – number of samples.

| Fractions measured (in µm) | Number of samples |
|---|---|
| <2, 2-60, 60-2000 | 35 |
| <2, 2-60, 60-200, 200-600, 600-2000 | 437 |
| <2, 2-6, 6-20, 20-60, 60-200, 200-600, 600-2000 | 1281 |
| <2, 2-6, 6-20, 20-60, 60-100, 100-200, 200-600, 600-2000 | 59 |

Table 17.3. Number of samples with measured water content at specified matric potentials (hPa), and number of samples with specified number of measured points per retention curve.

| Matric potential (hPa) | POR | 0 | 5 | 7.5 | 10 | 15 | 20 | 40 |
|---|---|---|---|---|---|---|---|---|
| Count | 526 | 1676 | 208 | 10 | 43 | 49 | 996 | 43 |
| Matric potential (hPa) | 50 | 70 | 100 | 500 | 1000 | 3000 | 15000 | 16000 |
| Count | 32 | 43 | 1779 | 79 | 1625 | 224 | 1710 | 35 |
| Number of points per curve | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Number of samples | 19 | 75 | 748 | 487 | 375 | 10 | 43 | 22 |

and includes sampling at specified depths, sampling at regular depth intervals (e.g. every 10 cm), sampling in mid-horizon, sampling within horizons while at the same time trying to sample at the same depths in different profiles, and sampling in the “most representative part” of a horizon or layer.

Data for bulk density is available for 1731 samples. The method is according to ISO 11272: Undisturbed soil is sampled in 100 $cm^3$ steel cylinders, oven dried at 105°C for 48 hours (24 hours has also occurred), and weighed.

Porosity was available for 526 samples, and was calculated as the sum of air and water volume at a matric potential of 100 hPa, or calculated from the measured particle density. Particle density was measured using either a method involving an isopropanol/ethanol mixture, or in a pycnometer using water as solvent, followed by an adjustment for loss on ignition ($PD=2.66-0.014\times LOI$; Riley, 1996).

Water retention, in this case water content at specific matric potentials, was available for 1779 samples. For most of these samples the water content was measured at matric potentials 0, 100, 1000 and 15000 hPa, and for nearly 1000 of the samples also at the matric potential of 20 hPa. Water content at a few other matric potentials was determined for only a limited number of samples. The number of samples with water retention data available at different matric potentialsis given in Table 17.3. The water content at saturation, i.e. 0 hPa matric potential, was determined gravimetrically after being saturated in water for 3-5 days, weighed, and then dried at 105°C to obtain the dry weight. Before drying, the samples were usually analysed for water content at other matric potentials and to obtain their porosity. Until the mid-1990s a pressure plate apparatus with ceramic plates was used for water retention measurements at all listed matric potentials, except 15000 (or 16000) hPa. From the mid-1990s, the UMB laboratory started using a sandbox apparatus for matric potentials below 100 hPa. For determination of water content at 15000 or 16000 hPa a pressure membrane apparatus has been used. For this analysis the samples are dried at 105°C and crushed through a 2 mm sieve. The sieved material is placed in a 15 $cm^3$ plastic ring on the membrane plate, wetted to saturation using a plant sprayer, and then left for equilibration under pressure. In all methods the samples remain in the pressure cell or the sandbox until no more outflow from the system is observed (equilibrium is reached), or for a maximum of two weeks.

### 17.3.4 Hydraulic conductivity

Hydraulic conductivity data are sparse in Norway. For the EU-HYDI database a total of 111 values for saturated hydraulic conductivity were included. Some additional data (in a few cases also near-saturated hydraulic conductivity) are available, but could not be included in the database due to lack of other crucial information. In 54 cases, the samples were analysed using the constant head permeameter (Eijkelkamp Agrisearch Equipment) on 100 $cm^3$ undisturbed soil cores. In 42 cases the falling head method was used to measure Ks in the laboratory on samples of unknown volume, but most likely 100 $cm^3$. In one case an in situ infiltration method by Jensen (1986) was used. This method involves excavating a pit in the soil, placing a sponge in the pit, and adding water by a mariotte bottle. Ks is assumed to equal the steady infiltration rate. In 15 cases a double ring infiltrometer (dimensions unknown) was used, and also here Ks is assumed to equal the steady infiltration rate. In Norway, air permeability has often been measured on the same samples for which the water retention curve has been measured, and such data have been used to estimate Ks by pedotransfer functions (Riley, 1996). Air permeability data are currently not included in the EU-HYDI database, but are available for many Norwegian samples.

## 17.4 Acknowledgements

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# 18 Soil data from Poland

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## 18.1 Introduction

Soil data submitted to the EU-HYDI database are a part of a Polish Mineral Soils Databank "BIGLEB". Creation of this soil database was a joint attempt of the Institute of Agrophysics PAS from Lublin and the Institute for Land Reclamation and Grassland Farming from Falenty.

The aims of the creation of the "BIGLEB" was to collect mineral soils representative for Poland, and to measure chemical, physical, hydrological and other properties of these soils. One of the aims of the "BIGLEB" creation, which makes it probably unique, was to collect in one place appropriate amounts of diverse, representative for Poland soil material which could be used by the scientific community for further studies without the constant need for taking the soil samples from the field. Undisturbed soil samples was collected in 100 ccm cylinders and in sacks each of 3 kg of soil material. Most of these soil material is still preserved in the Institute of Agrophysics PAS.

The collection of soils was done at years 1988-1989. There were 940 locations where soil samples were collected. For each profile samples were taken from three depths.

## 18.2 Soil dataset

Part of the soil data submitted to EU-HYDI consists of 447 soil samples taken from 280 profiles. Most of the data: 280 samples were taken from arable layer (horizon A), 95 from subsoil (horizon B) and 70 from the horizon C. The Figure 18.1 shows locations of the soil profiles from which samples with data submitted to EU-HYDI were collected.

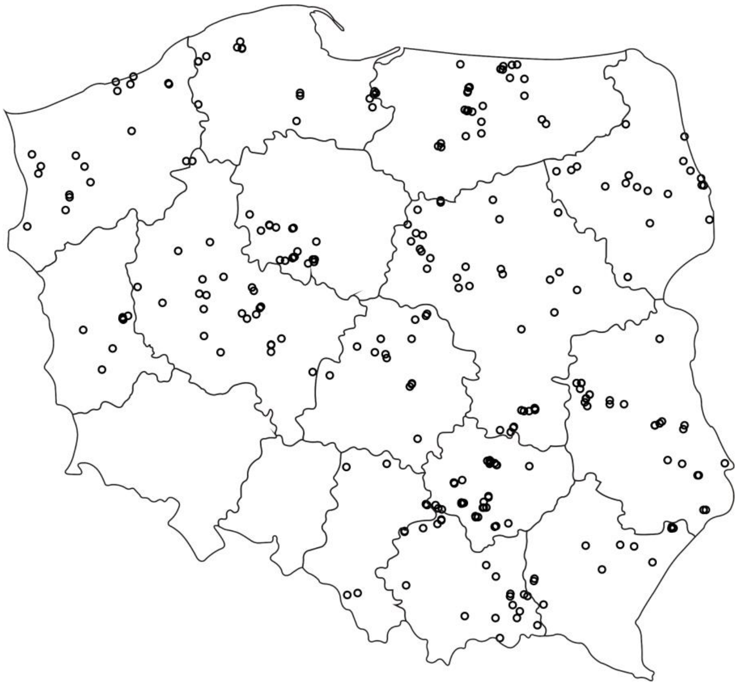

Figure 18.1 Locations of the soil profiles

## 18.3 Measured soil properties and methods

### 18.3.1 Particle size distribution

Before 2008, according to Polish Society of Soil Science (PSSS) as a soil fraction were considered material with diameter below 1 mm. According to this guidelines the particle size distribution of soils was determined with division into 6 fractions. Table 18.1 presents fractions for which PSD was determined and its average values for the dataset.

Table 18.1. Average for all soils values of the PSD fractions

| PSD fraction [µm] | Average [%] |
|---|---|
| <2 | 9.23 |
| 2-5 | 6.07 |
| 5-20 | 10.44 |
| 20-50 | 14.21 |
| 50-100 | 13.23 |
| 100-1000 | 46.83 |

Particle size distribution was measured using the Casagrande method modified by Prószyński. This method is a variant of the hydrometer method. It is based on Stoke's law, which describes sedimentation of soil particles (Ryżak *et al* ., 2009, Turski *et al* ., 1977).

The modification involves:

- construction of the hydrometer (the hydrometer is calibrated in the percentage of the mass in the total mass of suspension);
- elaboration of a time interval table of the measurements using the hydrometer.

The procedure included:

1. Air dry soil was sieved through a 1 mm sieve.
2. A 40 g sample of sieved soil was added to 0.5 dm3 of distilled water.
3. 25 cm$^3$ of Calgon (35.7 g of sodium hexametaphosphate and about 7.94 g of anhydrous sodium carbonate in 1 dm$^3$ of solution prepared in distilled water) was added to the soil suspension.
4. The suspension was shaken in a rotary shaker for 20 min.
5. The suspension was moved quantitatively into a 1 dm$^3$ cylinder and filled up with distilled water. The same cylinder with the Calgon solution was prepared as a correction solution.
6. A series of preliminary measurements allowed choosing the appropriate time interval tables of hydrometer readings.
7. The measurements were carried out in 20$^o$C. The time intervals were read from the proper time tables selected on the basis of the previous step.
8. After sedimentation, the suspensions were wet sieved through a 0.1 and 0.05 mm sieve

### 18.3.2 Soil water retention curve

SWRC was determined for 11 values of the soil water potential: -1, -10, -31.6, -100, -158.5, -316.2, -501.2, -1000, -1584.9, -5011.9 and -15849 kPa. Only the drying branch of the SWRC was determined. Three methods were used for that purpose. For the potentials -1 and -10 kPa sandbox method was used and the undisturbed samples had volumes 100 ccm. For the potentials -31.6, -100, -158.5, -316.2, -501.2, -1000 and -1584.9 kPa pressure plate apparatus was used with the undisturbed samples which volume was 100 ccm. For the other potentials: -5011.9 and -15849 also the pressure plate apparatus was used, for disturbed samples which volume was 20 ccm.

### 18.3.3 Organic matter content

The organic matter content of the samples was determined using Tjurin's method (Kosaka *et al* ., 1961).

### 18.3.4 Saturated water permeability

Constant head permeameter was used for the saturated water content permeability of the undisturbed samples of the volume 100 ccm.

## 18.4 References

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# 19 Soil data from Portugal

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## 19.1 Introduction

The Portuguese data included in the European Hydropedological Data Inventory (EU-HYDI) was extracted from the PROPSOLO soil database (Gonçalves *et al*., 2011). This database gathers the information on soil hydraulic and pedological properties from soil profiles obtained within the framework of research projects and academic studies carried out at the Portuguese National Institute of Agronomic and Veterinarian Research (former Estação Agronómica Nacional).

All soil profiles available in PROPSOLO are georeferenced and information on soil hydraulic properties is mandatory. This database gathers practically all the existing knowledge on soil hydraulic properties of Portuguese soils (with exception of a few specific retention points found in soil survey studies). The main purposes are the development and update of pedotransfer functions for indirect estimation of soil hydraulic properties and solute transport parameters (Gonçalves *et al*., 1997; Gonçalves *et al*., 2001) and the delivery of input data for modelling applications.

## 19.2 Number of samples, geographical distribution and pedological variability

The data included in EU-HYDI contains a set of 697 horizons/layers from 330 soil profiles analysed between 1977 and 2011.Figure 19.1 shows the location of the soil profiles in Portugal. These were mainly located in the Alentejo region in southern Portugal, where some of the most important irrigation areas in the country were established.

Land use was mainly associated to agriculture, namely, to annual summer (31.5%) and winter (9.4%) cereals, pastures (23.9%), olive groves (8.9%), horticultural crops (3.6%), fruit trees (1.5%), vineyards (0.9%), and rice fields (0.9%).

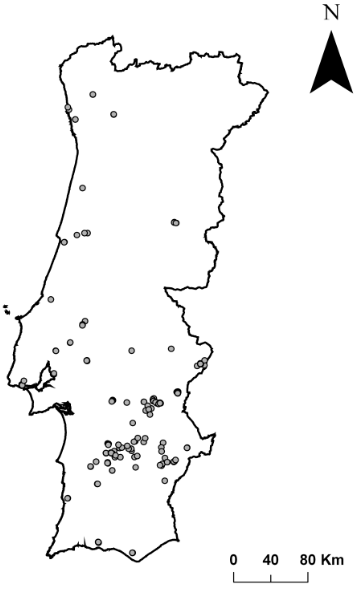

Figure 19.1 Location of the 330 soil profiles in Portugal.

Table 19.1. Main physical, chemical, and hydrological characteristics of the Portuguese dataset.

| Soil property | Nº samples | Minimum | Maximum | Average | St. deviation |
|---|---|---|---|---|---|
| Coarse fragments (%) | 205 | 0.00 | 69.70 | 7.49 | 9.74 |
| Texture (%): | | | | | |
| 2-0.2 mm | 697 | 0.05 | 94.60 | 20.72 | 17.60 |
| 0.2-0.02 mm | 697 | 0.66 | 73.60 | 34.23 | 15.42 |
| 0.02-0.002 mm | 697 | 0.90 | 68.07 | 21.43 | 12.17 |
| <0.002 mm | 697 | 0.10 | 63.30 | 23.62 | 14.78 |
| Organic carbon (%) | 627 | 0.00 | 2.51 | 0.82 | 0.50 |
| $CaCO_3$ (%) | 682 | 0.00 | 57.60 | 2.35 | 7.55 |
| pH (-) | 482 | 3.50 | 9.20 | 7.04 | 1.22 |
| EC (mS $cm^{-1}$) | 239 | 0.10 | 32.00 | 3.00 | 5.51 |
| Salt content (%) | 202 | 0.00 | 0.77 | 0.55 | 0.11 |
| CEC (meq $100g^{-1}$) | 372 | 1.00 | 50.41 | 19.05 | 12.24 |
| Ex. cations (meq $100g^{-1}$): | | | | | |
| $Ca^{2+}$ | 356 | 0.06 | 48.11 | 10.85 | 9.13 |
| $Mg^{2+}$ | 356 | 0.01 | 19.98 | 4.33 | 3.68 |
| $K^+$ | 359 | 0.01 | 3.55 | 0.48 | 0.73 |
| $Na^+$ | 372 | 0.01 | 14.95 | 1.22 | 2.47 |
| Bulk density (g $cm^{-3}$) | 697 | 0.91 | 1.90 | 1.50 | 0.18 |
| Total porosity (%) | 697 | 25.00 | 65.90 | 44.10 | 7.42 |
| Water retention ($cm^3$ $cm^{-3}$): | | | | | |
| at-10 cm | 691 | 0.192 | 0.624 | 0.399 | 0.076 |
| at -100 cm | 696 | 0.036 | 0.574 | 0.332 | 0.088 |
| at -330 cm | 661 | 0.029 | 0.536 | 0.286 | 0.090 |
| at -1000 cm | 301 | 0.008 | 0.474 | 0.239 | 0.086 |
| at -2500 cm | 331 | 0.009 | 0.449 | 0.210 | 0.083 |
| at -15848.9 cm | 697 | 0.006 | 0.407 | 0.162 | 0.080 |
| Ks (cm $d^{-1}$) | 288 | 0.5 | 2400.0 | 197.6 | 348.1 |

The slopes were relatively gentle with 43.9% of the soil profiles being studied in areas with slopes below 1% and only 3.3% presenting slopes above 5%.

The soil reference groups (FAO, 1998) represented in the dataset were Fluvisols (36.4%), Luvisols (29.4%), Vertisols (10.3%), Cambisols (8.5%), Calcisols (6.1%), Anthrosols (4.2%), Arenosols (1.5%), Podzols (0.9%), Regosols (0.9%), Ferralsols (0.6%), Leptosols (0.6%), and Planosols (0.6%).

The dataset contains 697 soil water retention curves θ(h) and 288 hydraulic conductivity curves K(h). Soil hydraulic properties were always measured on undisturbed soil samples. The dataset further contains the particle size distribution of all horizons/layers and chemical properties of most of them, namely organic carbon content (in 627 samples), $CaCO_3$ content (in 682 samples), and cation exchange capacity (in 372 samples). Table 19.1 shows the main statistical indicators of the physical, chemical, and hydrological characteristics of the soil horizons/layers included in EU-HYDI.

## 19.3 Measured soil properties and methods

### 19.3.1 Coarse fragments

The proportion of coarse fragments was obtained by sieving for particles having diameters >2 mm, after destruction of aggregates.

### 19.3.2 Particle size content

The weight percentage of the particle size content was obtained using the pipette method for particles having diameters <0.002 mm (clay) and between 0.02 and 0.002 mm (silt), and by sieving for particles between 0.2 and 0.02 mm (fine sand) and between 0.2 and 2 mm (coarse sand). These textural limits follow the Portuguese classification system (Gomes and Silva, 1962) and are based on the International Soil Science Society (ISSS) particle limits (Atterberg scale).

### 19.3.3 Bulk density

The bulk density was determined by drying volumetric soil samples (100 $cm^3$) at 105ºC for 48 hours.

### 19.3.4 Total porosity

Total porosity was determined from the maximum holding capacity of the 100 $cm^3$ undisturbed soil cores in volumetric basis.

### 19.3.5 Soil water retention

Soil water retention data was obtained using different methods, depending on the pressure head applied. Water retention data were determined in the laboratory on undisturbed samples of 100 $cm^3$. The suction tables with sand were used for pressure heads ≥ -100.0 cm, while suction tables with sand and kaolin were used for pressure heads between -199.5 and -501.2 cm (Romano *et al.*, 2002; ISO 11274:1998). A pressure plate apparatus was used for pressure heads between -330 and -15848.9 cm (Dane and Hopmans, 2002; ISO 11274:1998). A pressure-membrane extraction apparatus was used with undisturbed 25 $cm^3$ samples for pressure heads <-2500 cm (Richards, 1941; ISO 11274:1998). The evaporation method was further used between pressure heads of approximately -50 and -800 cm (Wind, 1968; Halbertsma and Veerman, 1994). Samples of 630 $cm^3$ (10 cm diameter by 8 cm high) were used for the evaporation method, with tensiometers placed at depths of 1, 3, 5, and 7 cm. The evaporation data were analyzed using procedures documented by Halbertsma and Veerman (1994). All the methods were not applied in every horizons/layers included in EU-HYDI.

### 19.3.6 Soil hydraulic conductivity

Soil hydraulic conductivity data was obtained using different methods, also depending on the pressure head applied. The saturated hydraulic conductivity (Ks) was determined on undisturbed 630-4700 $cm^3$ samples using a constant-head method (Stolte, 1997). The crust method was used for determining the unsaturated hydraulic conductivity on undisturbed 4700 $cm^3$ samples for pressure heads ≥ -50 cm (Bouma *et al.*, 1971). The evaporation method was used on undisturbed 630 $cm^3$ samples for pressure heads between -50 and -800 cm (Wind, 1968; Halbertsma and Veerman, 1994). The hot air method was used on undisturbed 200 $cm^3$ samples for pressure heads < -50 cm (Arya *et al.*, 1975). All the methods were not applied in every horizons/layers included in EU-HYDI.

### 19.3.7 Organic carbon content

The organic carbon content was determined by wet combustion of the organic matter with a mixture of potassium dichromate and sulphuric acid at 125ºC, i.e., the Walkley-Black method (Nelson and Sommers, 1982).

### 19.3.8 Calcium carbonate content ($CaCO_3$)

The calcium carbonate content ($CaCO_3$) was measured with a calcimeter (Bascomb, 1961).

### 19.3.9 pH in soil-water suspension

The pH in a 1:2.5 soil-water suspension was measured by potentiometry in samples studied until 2009 (Hissink, 1930). Since 2010, pH started being measured in a 1:5 soil-water suspension (ISO 10390:2005).

### 19.3.10 Electrical conductivity of the soil solution

The electrical conductivity (EC) of the saturation extract was determined by electrometry (US Salinity Laboratory Staff, 1954).

### 19.3.11 Soluble salt content

The soluble salt content was obtained from the sum of the soluble cations determined in the saturation extract using atomic absorption spectrophotometry (US Salinity Laboratory Staff, 1954).

### 19.3.12 Exchangeable cations and cation exchange capacity

Exchangeable cations ($Ca^{2+}$, $Mg^{2+}$, $K^+$, and $Na^+$) and cation exchange capacity (CEC) were determined with a ammonium acetate pH 7.0 method (Dewis and Freitas, 1970) and with a modified Melich method (Mehlich, 1948) using a solution of BaCl2+triethanolamine at pH 8.1 (ISO 13536:1995). The former method was used mostly in non-calcareous and non-saline soils, while the latter was used mainly in calcareous and saline soils.

## 19.4 Acknowledgements

T. B. Ramos was funded by the Fundação para a Ciência e Tecnologia grant SFRH/BD/60363/2009.

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# 20 Soil data from the Russian Federation

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## 20.1 Introduction

The data were collected on basis of the researches conducted in Moscow State University, Soil Science Faculty, Department of Soil Physics and Reclamation.

## 20.2 Number of samples, geographical distribution and pedological variability

Two experimental plots were included at present in the database. The first site (S1) is located in the Vladimirskaya oblast', natural region - Vladimir Opol'e. Second site (S2) - Voronezhskaya oblast', natural region – Chernozemic Black Earth area of steppe zone (Figure 20.1).

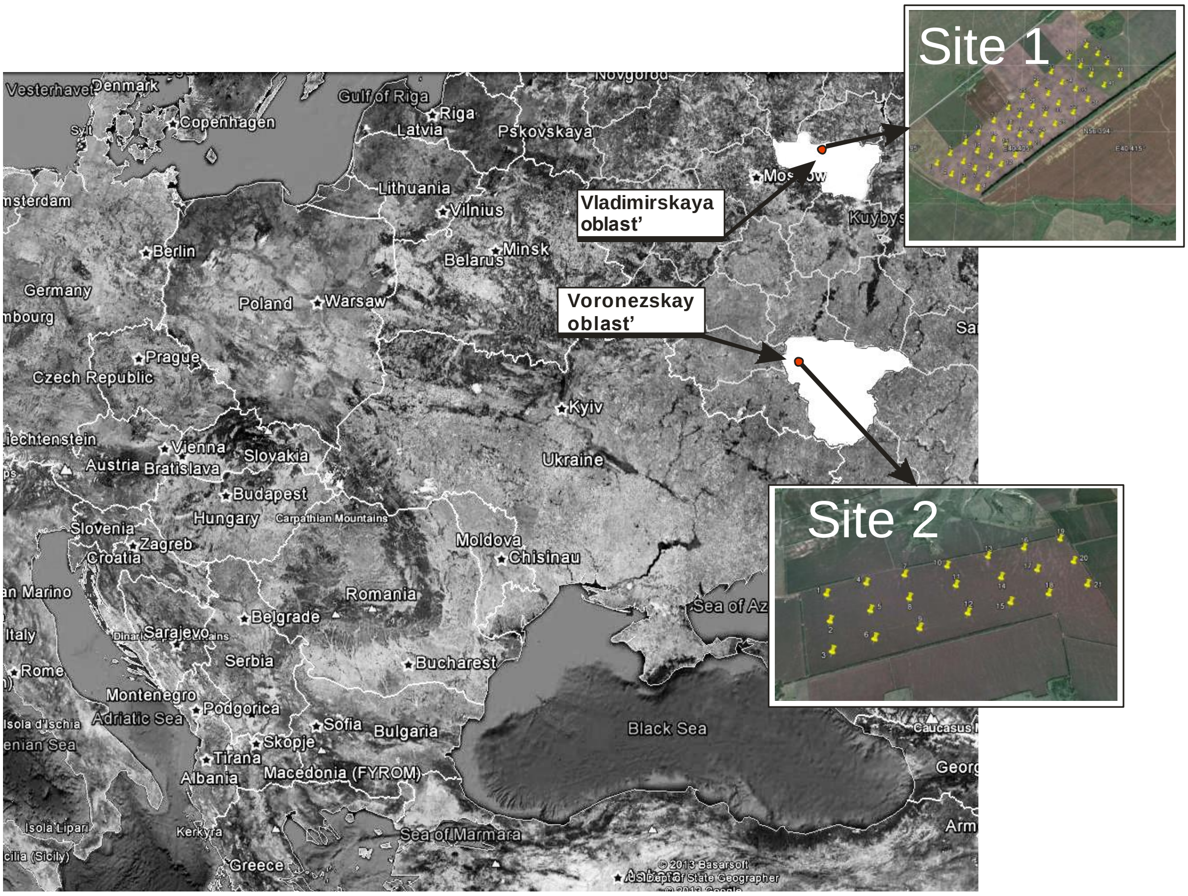

Figure 20.1 . Geographical distribution of experimental fields. Site 1 (S1) – Vladimirskaya oblast'; Site (S2) - Voronezhskaya oblast'

### 20.2.1 First experimental site (S1)

The objects of the study were an agricultural field of grey soil complex of the Vladimir Opol'e region (Vladimirskaya oblast). The major soilscape components are represented by Grey forest (Greyic Phaeozems Albic, WRB, 2006) soils ; Grey forest with the second humic horizon (Greyic Phaeozems Albic) of different level podzolized; and Grey forest residual-calcareous (Greyic

Phaeozems Albic ), and Grey forest low and medium podzolized (Greyic Phaeozems Albic) (Figure 20.2). It is widely believed that the soil cover complexity of Vladimir Opol'e is due to the paleocryogenic microrelief. Grey soils with the second humus horizon occurring at a depth of 25–40 (60) cm as a grayish black humus enriched material developed in microdepressions of the old cryogenic relief. This horizon is usually less dense with an elevated content of humus and better aggregated compared to the underlying humus horizon.

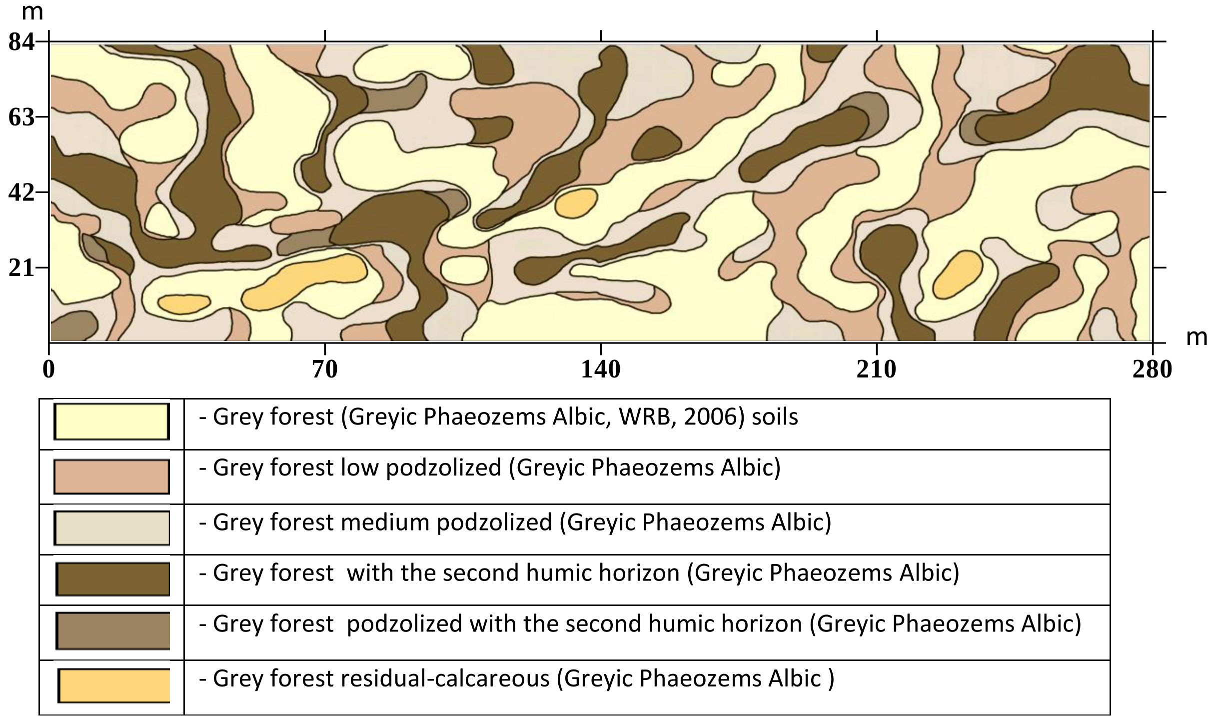

Figure 20.2 soil map of S1

Complex soil cover of Vladimir opol'e landscapes has peculiarities of paleocryogenic soilscape such as areas with high organic matter content (loose zones) and compacted soil. Typically soil density varies from 0.73 g/cm$^3$ to 1.54 g/cm$^3$ in the arable layer and from 1.0 g/cm$^3$ to 1.68 g/cm$^3$ at the depth of 35-40 cm. Organic carbon content varies from 1.36% to 2.98% and from 0.23% to 4.65% in the arable layer and 35-40 cm layer, respectively. Agricultural practice altered soil physical properties and resulted in formation of compacted subsoil layers, spatially distributed differently from soil subtypes. Figure 20.3 shows the spatial distribution of the soil density on experimental plot S1. Spatial patterns of the compact and loose zones create a specific structure in water and temperature distribution.

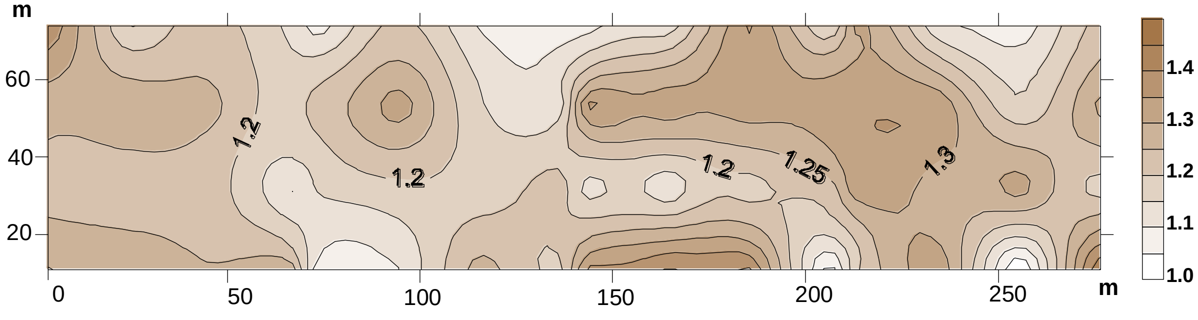

Figure 20.3 Spatial distribution of the soil density on experimental plot S1 for the depth 35-40 cm

Second experimental site (S2). Central Chernozemic Region of Russia, Voronejskaya oblast', Khokholskiy rayon. The database shows the typical chernozem (Voronic Chernozems pachic, WRB, 2006) on the territory of the agricultural field, which is located 16 kilometers south-west of Voronezh on the right bank of the Don River. The relief is rather flat. Annual average temperature is 8-10 ° C, in January -1,5 ... -5 ° C, July 20-23 ° C. Annual precipitation is 400-650 mm. Soil cover is rather homogenious, agricultural field. In Table 20.1 some morphological and physical properties are presented.

Table 20.1 Some morphological and basic properties of chernozem typical (Voronic Chernozems pachic, WRB, 2006)

| Horizon | Depth, cm | Morphological description | Soil density, g/cm3 | Granulometric composition | Organic carbon content, % |
|---|---|---|---|---|---|
| Ap | 0-25 | Black, soft, shiny individual grains of sand, fine-grained structure, medium moisture, the presence of roots, the boundary is smooth, gradual transition in density and color | 0.82 – 1.47 | Silty clay | 2.7-4.81 |
| A1 | 25-58 | Dark gray, dense, coarse texture is lumpy, not expressly aggregate structure, expressed individual faces, some sand, the presence of roots, gradual transition of color (the presence of brownish tint), the border is irregular, gradual transition of grain size and color | 1.00-1.56 | Silty clay loam | 2.9-3.88 |
| AB | 58-86 | Dark gray with brownish tint, nonuniform color, dense, moistened, traces shrews filled material underlying horizon, heavy loam, aggregate structure, the presence of roots, smooth border, the transition marked by the dominance of the gray-brown color and density | 1.11-1.34 | Silty clay loam | 0.77-1.5 |
| B1 | 86- 97 | Brown, dark gray spots on a uniform brownish background, dense, moistened loess clay loam | 1.17-1.29 | Silty clay loam | 0.42-0.68 |

## 20.3 Measured soil properties and methods

### 20.3.1 Granulometric composition.

The particle size distribution analysis was performed by the method of laser diffractometry using an Analysette 22 (FRITSCH) laser particle size after preliminary ultrasonic dispersion in water with the use of a BRANSON 250 sonifier (20 kHz, 40% power, 4 min)

### 20.3.2 Carbon content.

The content of organic carbon was determined by dry combustion in an oxygen flow using an AN_8012 rapid response carbon analyzer.

### 20.3.3 Soil hydrological properties: Water retention curve.

1. Method of sand-kaolinic boxes, which is traditional for many soil physical laboratories in many countries (tensostat method) for pF 1-2.7.

2. The water retention curves in the pF range 4.5-6.5, were determined by the method of vapor-soil water equilibrium above saturated solutions of different salts.

3. Field method. Method of synchronous profiles of soil water content and water pressure. Volumetric moisture content was determined by the neutron moisture meter, soil water pressure – by tensiometers. Using this field method in any cases we had the different moisture content at the same soil water pressure. The reasons of this phenomenon may be different. But we decided to present all the field data in Data base, because it is difficult to remove any data without good reasons.

# 21 Soil data from Slovakia

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## 21.1 Introduction

Data source is database of Soil Science and Conservation Research Institute, SSCRI Bratislava, Gagarinova 10, Slovakia. Data have been collected in scope of the monitoring of soil and hydropedological properties of soils in Danubian lowland where the broad variety of soils is present.

## 21.2 Number of samples, geographical distribution and pedological variability

In total the dataset comprises 36 entries represented by 2 to 5 layers. This dataset represents soils of Slovakian lowlands where the agricultural production is very intensive and the need for accurate data of soil properties is high. The pedological variability is lower in comparison with mountains areas, anyhow are here several soil types from the most fertile Chernozems and Mollic Fluvisols to Haplic and Eutric Fluvisols.

## 21.3 Measured soil properties and methods

### 21.3.1 Bulk density

Bulk density is measured from undisturbed samples taken to the steel cylinders with volume 100 $cm^3$ according to the Core method (ISO 11272) where samples are oven-dried at 105°C for 48 hours.

### 21.3.2 Porosity

Porosity is expressed as total porosity and is determined from bulk density and particle density according to the ISO 11272 and pycnometric method.

### 21.3.3 pH

We measured pH in H2O and pH in KCl according to the ISO standard – ISO 10390: ISO 10390:2005. It requires using a glass electrode in a 1:5 (volume fraction) suspension of soil in water (pH in H2O), in 1 mol/l potassium chloride solution (pH in KCl) or in 0,01 mol/l calcium chloride solution (pH in CaCl2).

### 21.3.4 $CaCO_3$

$CACO_3$ is measured according to ISO 10693: Soil quality. Determination of carbonate content - Volumetric method.

### 21.3.5 Total organic carbon

Total carbon (TC) is determined according to the ISO 10694: Soil quality. Determination of organic and total carbon after dry combustion (elementary analysis). Total organic carbon is obtained by correcting TC for the presence of inorganic carbon by substracting the carbonates content:

$$\mathrm{TOC}[\%] = \mathrm{TC}[\%] - 0.12 \times \mathrm{CaCO3}[\%]$$

### 21.3.6 Electrical conductivity

Electrical conductivity of soils is measured as content of water-soluble electrolytes in a soil water extract according to the ISO 11265:1994, Soil quality -- Determination of the specific electrical conductivity.

### 21.3.7 Cation exchange capacity

CEC is determined according to the ISO 13536:1995 Soil quality -- Determination of the potential cations exchange capacity and exchangeable cations using barium chloride solution buffered at pH = 8.1.

### 21.3.8 Basic cations

Basic cations: Na, Mg, K and Ca are determined as Mehlich III method according to the Mehlich, A. 1953. Determination of P, Ca, Mg, K, Na, and NH4. North Carolina Soil Test Division (Mimeo, 1953).

### 21.3.9 Particle size distribution

Soil texture is determined by pipette method according to the ISO 11277:2009. Preparation of the sample: air drying of soil sample, crushing and sieving through the mesh <2mm, i.e. preparation of fine soil. Than boiling in the solution of sodium hexametaphosphate and sedimentation of 10 grams of fine treated soil in cylinders with distilled water in the lab with stable temperature. The particle size determined is: 2 000; 250; 50; 20; 10; 5 and 1 µm.

### 21.3.10 Retention of soil

Soil retention properties are determined at different water heads ranging from 1,0; 10,0, 33,0; 330,0; 3300,0 and 15000,0 mm of water by use of pressure plate apparatus with 100 $cm^3$ steel rings of undisturbed samples volume.

### 21.3.11 Conductivity

Soil conductivity is determined as saturated hydraulic conductivity in laboratory conditions measured on undisturbed soil samples in apparatus with constant water table and water flow.

## 21.4 Acknowledgements

The database was created with help of colleagues from Soil Science and Conservation Research Institute, Bratislava, Slovakia.

## 21.5 Reference

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# 22 Soil data from Spain (Andalusia)

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## 22.1 Introduction

The EU-HYDI database of Andalusia region was obtained from the SEIS.net database (www.evenor-tech.com) which stores soil information from more than 1000 soil profiles. Soil data harmonization was previously stored and performed with the SDBm Plus (De la Rosa et al., 2002), component of MicroLEIS DSS. This soil database is a multilingual soil profile database that stores and retrieves geo-referenced soil attribute data collected in soil surveys and laboratories.

The SDBmPlus database is considered an essential part of any support system for the exploration in decision-making for sustainable agriculture development. However, this sophisticated database can be useful for independent storage of primary soils information assembled at regional or national level, or for temporary storage of data accumulated during a particular soil survey or monitoring exercise at local level.

The FAO-CSIC Multilingual Soil Profile Database (SDBmPlus) was developed by the Consejo Superior de Investigaciones Cientifícas (CSIC)/Instituto de Recursos Naturales y Agrobiología de Sevilla (IRNAS) and coordinated by D. de la Rosa. Its development is funded mainly by the Spanish Ministry of Environment through the programme SEIS.net.

The CSIC is the legal owner of the SEIS.net database registered under application number 200899900514357 in the Delegate Office of the Intellectual Property Registry in Seville, Spain. On the 2nd of February, 2009, CSIC and Evenor-Tech signed a License Contract by which CSIC grants Evenor-Tech exclusive rights to exploit the MicroLEIS System.

## 22.2 Number of samples, geographical distribution and pedological variability

The Soil Data Bank, SEISnet, it is integrated by a wide range of information (alpha-numeric, spatial and photographic) useful for public and private-sector agencies involved in land use planning and environmental management. The data bank comprises:

- A first approach to Spanish soils, digital atlas of soil regions (S 1:1.000.000) containing cartography of: types of soil, slope, geology, topography and land use.
- An on-line soil data base of Andalusia region containing physico-chemical and environmental data of 1.043 profiles and 15.048 soil tests. This information is also integrated in the SDBm Plus soil data base.
- A semidetailed soil cartography (S 1:400.000) of Andalusia region, containing cartography of: Lithology, Organic Matter, pH, clay content, slime content, sand content, soil porosity, bulk density and field capacity.
- A collection of 124 photos: 62 soil profiles and 62 landscapes, together with the corresponding morphological description and analytical characterization. These soils are representative of the main pedological traits in the various nature areas of Andalusia and were selected from the global soil data base of SEISnet.

The information of soil profiles collected for the EU-HYDI database was referred to Andalusia region (Figure 22.1). This region is located in Southern Spain and covers an area of approximately 87.600 km2. Its orography is rather complex and elevation varies between 0 and 3479 masl (Mulhacen Peak). Climate is typically Mediterranean semiarid with an average annual precipitation between 300 and 2000 mm and average annual temperatures between <10 and 18 C. Approximately 44,1% of the region is occupied by agricultural areas and 49,8% by natural areas. Both urban and water spaces cover 3%, 3.1% of the area respectively (Bermejo et al., 2011). Most of natural vegetation is Mediterranean forest, mainly evergreen trees such as oaks, pines and firs, with dense riparian forests, and Mediterranean shrubland. Agriculture in Andalusia has usually been based on wheat crops, olive trees and vineyards.

There is a great diversity of soil orders (Table 22.1), and the main order is Inceptisol (26,9%), Entisol (21.2%), Alfisol (19.8%), Vertisol (17.9%), Mollisol (7.2%), Ultisol (4.3%) and Aridisol (2.8%).

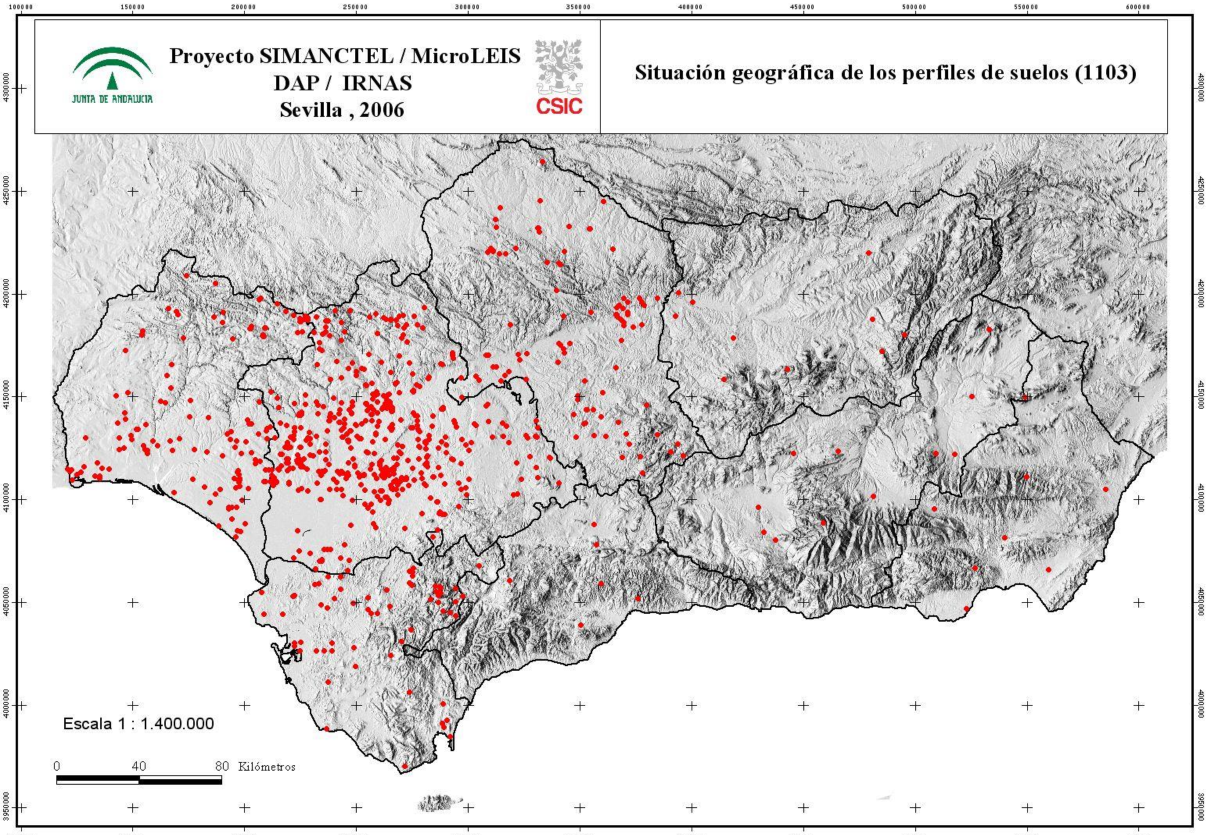

Figure 22.1 Localization of soil profiles across Andalusia region

Table 22.1 Soil taxonomy Classification (USDA, 1975) of representative soil profile of Andalusia

| Order | Sub-order | Great-group | Sub-group | Code of representative soil profile* | Area, km$^2$ |
|---|---|---|---|---|---|
| ALFISOLS | Xeralfs | Haploxeralfs | Aquic Haploxeralfs | SE08 | 627 |
| | | | Calcic Haploxeralfs | SE01 | 217 |
| | | | Typic Haploxeralfs | CO06, CO05 | 3.115 |
| | | | Xerochrecptic Haploxeralfs | JA07 | 2.366 |
| | | Palexeralfs | Aquic Palexeralfs | HU05 | 821 |
| | | | Typic Palexeralfs | CA04 | 1.645 |
| | | | Vertic Palexeralfs | JA03 | 1.491 |
| | | Rhodoxeralfs | Calcic Rhodoxeralfs | CA03 ,GR10 | 1.087 |
| | | | RupticLithic Rhodoxeralfs | JA05 | 1.102 |
| | | | Typic Rhodoxeralfs | **CA06,**GR05, **JA01**, SE02 | 4.835 |
| ARIDISOLS | Argids | Haplargids | Vertic Haplargids | AL05 | 1.254 |
| | Orthids | Camborthids | Torrertic Camborthids | AL06 | 1.196 |
| ENTISOLS | Aquents | Fluvaquents | Salorthidic Fluvaquents | AL04, HU06, **SE05** | 2.202 |
| | Arents | Rendollic Arents | Typic Rendollic Arents | CA05 | 747 |
| | Fluvents | Xerofluvents | Aquic Xerofluvents | GR11 | 1.368 |
| | | | Typic Xerofluvents | AL08, **CO07**, SE09 | 3.719 |
| | Orthents | Xerorthents | Lithic Xerorthents | HU02 | 1.129 |
| | | | Rendollic Xerorthents | CO01, GR08, MA03 | 3.325 |
| | | | Typic Xerorthents | AL01, GR01, GR03, GR06 | 6.073 |
| INCEPTISOLS | Ochrepts | Eutrochrepts | Dystic Eutrochrepts | HU07 | 3.013 |
| | | Xerochrepts | Calcixerollic Xerochrepts | AL02, GR07, **MA01** | 4.818 |
| | | | Lithic Xerochrepts | CO03, **HU01**, **GR04**, MA02 | 7.056 |
| | | | Palexerollic Xerochrepts | AL07 | 1.146 |
| | | | Rendollic Xerochrepts | JA06, JA09 | 2.389 |

| | | | | | |
|---|---|---|---|---|---|
| | | | Typic Xerochrepts | CO04 | 2.540 |
| | Umbrepts | Cryumbrepts | Typic Cryumbrepts | GR02 | 1.139 |
| | | Xerumbrepts | Entic Xerumbrepts | HU04 | 1.472 |
| MOLLISOLS | | Rendolls | Lithic Rendolls | JA08 | 1.932 |
| | | | RupticLithic Rendolls | AL03 | 708 |
| | Ustolls | Haplustolls | Udic Haplustolls | MA05 | 1.374 |
| | Xerolls | Haploxerolls | Entic Haploxerolls | SE04 | 589 |
| | | | Typic Haploxerolls | MA04 | 1.666 |
| ULTISOLS | Xerults | Parexerults | Typic Parexerults | SE06 | 3.748 |
| VERTISOLS | Xererts | Chromoxererts | Entic Chromoxererts | GR09 | 656 |
| | | | Typic Chromoxererts | CA02, **CO02**, JA04,**SE03** JA02, SE07 | 11.945 |
| | | Pelloxererts | Chromic Pelloxererts | CA01 | 1.841 |
| | | | Entic Pelloxererts | HU03 | 1.249 |
| 7 | 14 | 19 | 37 | 62 | 87.600 |

(*) In bold are highlighted the variability of typical profiles of the Mediterranean region. Source : (Catalogo de suelos de Andalucía; De la Rosa et al., 1984).

## 22.3 Measured soil properties and methods

The SEIS.net data was codifies into the SDBm Plus database which includes the following soil attribute datasets: (i) site characteristics, information related to the identification and taxonomic classification of the soil profile; (ii) horizon description; (iii) conventional soil survey analytical results; (iv) soluble salts and most trace elements present in the soil or considered as major soil contaminants; (v) general soil physical analytical results; (vi) water retention and hydraulic conductivity at different tensions; (vii) photographs; and (viii) analytical methods and procedures used.

Then, all data was re-codified attending to the EU-HYDI guidelines database, as results we obtained a new database with the below information:

EU-HYDI database structure of Andalusia region

| Full name | Unit | Labels | Method-Code |
|---|---|---|---|
| Profile identification (primary key) | - | PROFILE_ID | |
| Local coordinates X or longitude | | LOC_COOR_X | |
| Local coordinates Y ot latitude | | LOC_COOR_Y | |
| Elevation above sea level | m | ELEV | |
| Country code (ISO 3166-1 alpha-2) | - | ISO_COUNTRY | |

EU-HYDI database structure of Andalusia region

| Full name | Unit | Labels | Method-Code |
|---|---|---|---|
| Region code level 1 (NUTS 2, OBLAST) | - | RC_L1 | |
| Region code level 2 (NUTS 3, ...) | - | RC_L2 | |
| Land Cover at sampling location (LUCAS) level 2 | - | LC_L2 | |
| Land Cover at sampling location (LUCAS) level 3 | - | LC_L3 | |
| Slope position code (FAO guidelines) | - | SITE_SLOP_POS | |
| Slope form code (FAO guidelines) | - | SITE_SLOP_FORM | |
| Slope gradient code (FAO guidelines) | - | SITE_SLOP_GRAD | |
| Soil surface: rock outcrops: cover (FAO guidelines) | - | SRF_ROCK_COV | |
| Soil surface: coarse fragments: cover (FAO guidelines) | - | SRF_COAR_COV | |
| Soil surface: coarse fragments: size (FAO guidelines) | - | SRF_COAR_SIZ | |
| Soil surface: erosion: category (FAO guidelines) | - | SRF_ERO_CAT | |
| Soil surface: erosion: degree (FAO guidelines) | - | SRF_ERO_DEG | |
| Soil surface: sealing: thickness (FAO guidelines) | - | SRF_SEAL_THIC | |
| Parent material code (ESDB 2002): 4 numbers | - | PAR_MAT | |
| Contact person | - | CONTACT_P | |
| Contact e-mail | - | EMAIL | |
| Sampling depth top | cm | SMPL_DEP_TOP | |
| Sampling depth bottom | cm | SMPL_DEP_BOT | |
| Structure grade (FAO guidelines) | - | STR_GRADE | |
| Structure size (FAO guidelines) | - | STR_SIZE | |
| Structure shape (FAO guidelines) | - | STR_SHAPE | |
| Porosity | vol% | POR | |
| Bulk density | g/cm3 | BD | 111 |
| Coarse fragments (>2 mm) | weight% | COARSE | 121 |
| Organic carbon content | weight % | OC | 131-132 |
| Calcium carbonate | weight % | CACO3 | 141-142 |
| pH in soil-water suspension | - | PH_H2O | 151-152-153-154 |

EU-HYDI database structure of Andalusia region

| Full name | Unit | Labels | Method-Code |
|---|---|---|---|
| Electrical conductivity | mS/cm | EC | 171-172 |
| Soluble salt | weight % | SALT | |
| Cation exchange capacity | meq/100g | CEC | 191-192-193-194-196 |
| exchangeable Na | meq/100g | EX_NA | 201-202-204 |
| exchangeable Mg | meq/100g | EX_MG | 211-212-214 |
| exchangeable K | meq/100g | EX_K | 221-222-224 |
| exchangeable Ca | meq/100g | EX_CA | 231-232-234 |
| Weight % | weight % | P_PERCENT | |
| Water content | cm3/cm3 | THETA | 600-601-602-603-604-605-606-607 |
| Conductivity | cm/day | COND | 801-802 |

## 22.4 Acknowledgements

The SDBm Plus database system was developed by CSIC/IRNAS with the collaboration of FAO/AGLL through a joint project (Letter of Agreement PR#15621). This work was funded by the Spanish Ministry of Environment through the SEIS.net project, 1998–2000 (Agreement between MIMAM and CSIC).

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# 23 Soil data from Sweden

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## 23.1 Introduction

Hydraulic properties in Swedish agricultural soils investigated mainly during the period 1952 to 1973 were compiled in a series of 11 department reports (Andersson & Wiklert, 1977a-c; Wiklert et al., 1983a-h). The equipment and methods used for these investigations are described in detail by Andersson (1955, 1962), Andersson & Wiklert (1970, 1972) and Johansson (1964). These reports (in Swedish) contain site and profile descriptions, photographs and structural soil characteristics but no soil classification. Most of the data were digitized during the early 1990th (Jansson & Moon, 2001) and used for developing pedotransfer functions for estimating plant available water and bulk density from soil texture and soil organic matter content (Kätterer et al., 2006). The records in this digital database were recently all crosschecked with those in the original reports. Physical and hydraulic data from soil profiles investigated after the 1970th have been frequently published in scientific journals and department reports. However, these more recent publications have not yet been compiled.

## 23.2 Number of samples, geographical distribution and pedological variability

The database presented here comprises 187 agricultural soil profiles with about 1740 soil layers of normally 10 cm thickness. Most of the profiles are sampled to 1 m depth. The geographical distribution of these profiles approximately corresponds to the distribution of arable land, decreasing sampling intensity from southern to northern Sweden (Figure 23.1). Compared with the national inventory of Swedish agricultural topsoil (3000 samples at 0 – 20 cm depth), clay soils are somewhat overrepresented in the database; whereas average clay (<2 µm) and sand (0.2 – 2 mm) size fractions are 22 and 21%, respectively, according to the national survey (Eriksson et al., 1998), corresponding fractions are 26 and 19% in the database. As much as 25% of the topsoil layers (0 – 20 cm) have a clay content exceeding 40%. According to the inventory, these heavy clay soils are comprise only 15% of all agricultural soils.

Heavy clays soils are mainly found in the central part of Sweden and along the east coast towards the south. Silty soils with varying clay content are dominating are found from the Norwegian border west of lake Vänern towards the east across the country and along the Bothnian gulf towards the north. Sandy soils deriving from Archean till are the dominating in the Southern Swedish Uplands. The cultivated soils in most southern part of Sweden are dominating by calcareous clay tills (Eriksson et al., 1998).

## 23.3 Measured soil properties and methods

### 23.3.1 Soil texture and loss on ignition

Soil texture was determined using sieving and pipetting according standard methods. In the original publications, 7 fine earth fractions (< 2 mm) and one or one coarse fraction (> 2 mm) are reported. In the present form of the database, the two sand fractions (0.2 – 0.6 mm and 0.6 – 2 mm) were merged into one. The data are presented here in six fine and one coarse fraction with the particle size boundaries 0.002, 0.006, 0.02, 0.06, 0.2 and 2 mm. Loss on ignition, which can be used as a proxy for soil organic matter, was determined in a furnace at 550 °C for 2 hours.

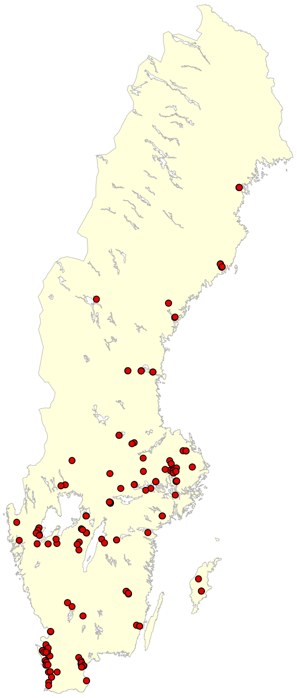

Figure 23.1 Distribution of the 187 agricultural soil profiles included in the database

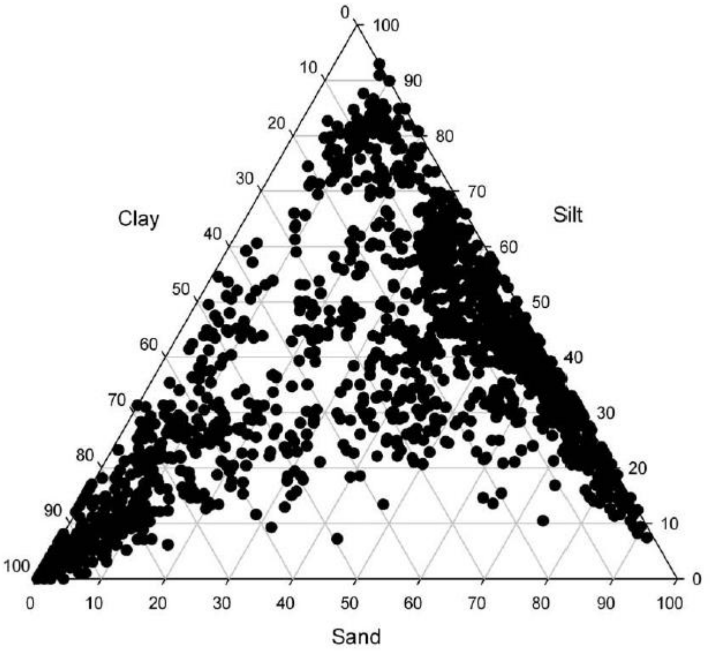

Figure 23.2 Percentage of clay (<2 µm), silt (2 - 60 µm) and sand (60 - 2000 µm) in the fine earth fraction (<2mm) in 1684 layers in Swedish soils

### 23.3.2 Bulk density and porosity

Bulk densities measurements were conducted on 4 replicated steel cylinders (407 $cm^3$; 10 cm height and 7.2 cm diameter) taken in each profile, usually in 10 cm layers. He cylinders were dried at 105°C for 48 hours before weighing. Density of solids was determined by pouring 5 g of dry soil into a flask and measuring the volume of ethyl alcohol (96%) that was need to fill the flask to a volume of 50 $cm^3$. The ratio between bulk density and density of solids was then used for calculating soil porosity.

### 23.3.3 Water retention characteristics

Soil water retention was measured at different tensions as described by Andersson & Wiklert (1972). The mass of water retained at different tensions was determined gravimetrically. Sand boxes with 407 $cm^3$ undisturbed samples in steel rings were used at low tension. At medium tensions, a pressure plate apparatus with undisturbed samples (407 $cm^3$ steel rings). At high tensions, disturbed samples were used.

### 23.3.4 Saturated hydraulic condcutivity

Saturated hydraulic conductivity was measured in an apparatus designed by Andersson (1955). All measurements were done at a constant hydraulic gradient = 1, i.e. the height difference between inlet and outlet of water corresponding to the height of the soil sample (10 cm). The values recorded in the database refer to mean values determined at 1 and 24 hours after start of the experiment.

## 23.4 Acknowledgements

I would like to thank Dr. Abraham Joel for his help with setting geographical coordinates for the sites from the descriptions proved in the original reports, and Dr. Stefan Andersson for his help with Figure 6.1

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# 24 Soil data from Ukraine

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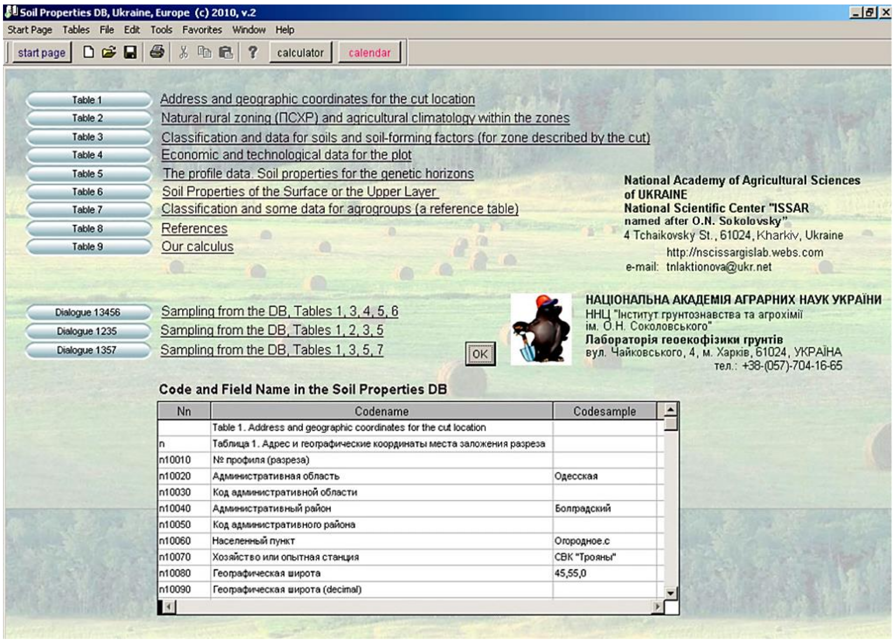
## 22.1 Introduction

The dataset was compiled in the database «Ukrainian Soil Properties», created in Laboratory SoilGeoecophysics of National Scientific Center «Institute for Soil Science and Agrochemistry Research named after O. N. Sokolovsky». The database includes original measurement results in 9 spreadsheets containing the information about profile distribution of soil properties from more, than 2000 profiles. The sources of the information are materials of soil expeditions of laboratory for research purposes in territory of Ukraine during 1960-2010, results of different scientific works and other published data. The starting page of a database is depicted in Figure 24.1. The DB is used for own researches of laboratory, including creation of maps (http://nscissargislab.webs.com/ourpublications.htm ), and also repeatedly participated in the national and international projects (including SOVEUR).



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**Code and Field Name in the Soil Properties DB**

| Nn | Codename | Codesample |
|---|---|---|
| | Table 1. Address and geographic coordinates for the cut location | |
| n | Таблица 1. Адрес и географические координаты места заложения разреза | |
| n10010 | № профиля (разреза) | |
| n10020 | Административная область | Одесская |
| n10030 | Код административной области | |
| n10040 | Административный район | Болградский |
| n10050 | Код административного района | |
| n10060 | Населенный пункт | Огородное.с |
| n10070 | Хозяйство или опытная станция | СВК "Трояны" |
| n10080 | Географическая широта | 45,55,0 |
| n10090 | Географическая широта (decimal) | |

Figure 24.1 Starting page of the Database «Ukrainian Soil Properties»

## 22.2 Number of samples, geographical distribution and pedological variability

The distribution of sampling sites within Ukraine is made according to structure of a soil cover, which is shown on a map (Figure 24.2). Sampling sites are located in each region of Ukraine. Profiles are chosen also in view of a variety of soil properties in territory of Ukraine.

The sample consist in 95 sampling sites with a total of 530 samples, taken from different soil depths (from 0 to 210 cm).

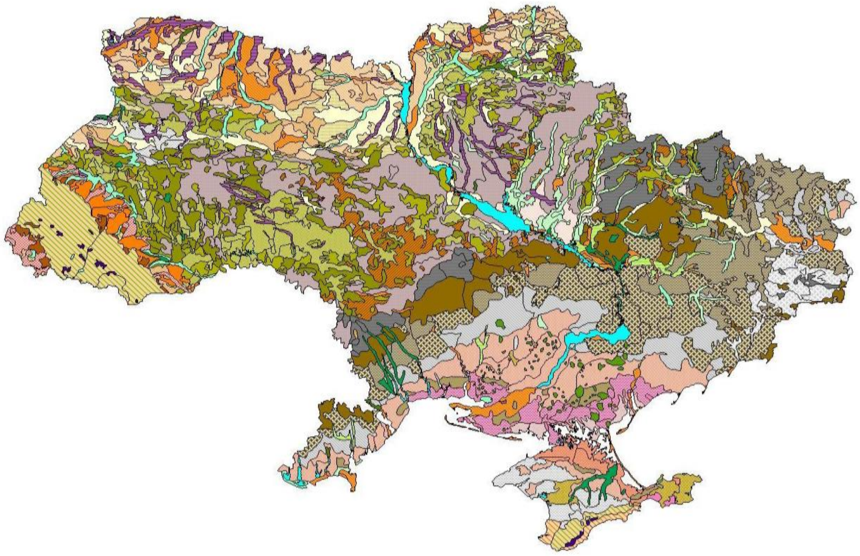

Figure 24.2 Soil map of Ukraine (1:1500000) (Medvedev et al., 2003)

The biggest group of profiles has been derived from Chernozems (n=55). This reflects the distribution of soil types in Ukraine where about 60 % of all soils belong to Chernozems. In the Ukrainian classification Chernozems share on such subtypes: Typical (19 profiles are included in dataset), Ordinary (14 profiles), Southern (8 profiles) and Podzolized (14 profiles).

The samples cover a wide variety of soil texture as it is reflected in Table 24.1.

Each soil profile is presented by several layers - one or two layers within genetic horizon down to parent material. In Figure 24.3, the number of soil samples by soil profile within dataset is demonstrated. 3 profiles have 3 layers; 5 profiles - 4 layers; 38 profiles - 5 layers; 38 profiles - 6 layers; 9 profiles -7 layers; 1 profile - 9 layers and 1 profile – 10 layers.

Table 24.2 shows the summary descriptive statistics of the Ukrainian dataset and gives an overview about the spread of some basic properties of the soil samples.

Table 24.1 Distribution of samples on texture classes

| FAO texture class | Number of samples | Content particles < 0.001 mm, % | | |
|---|---|---|---|---|
| | | min | max | mean |
| Sand | 23 | 0.9 | 7.5 | 3.1 |
| Loam | 34 | 7.5 | 24.4 | 18.4 |
| Silty clay | 124 | 30.1 | 51.8 | 39.7 |
| Clay loam | 19 | 22.3 | 35.1 | 27.4 |
| Silty loam | 108 | 4.0 | 24.5 | 18.6 |
| Sandy loam | 41 | 1.8 | 16.3 | 5.6 |
| Silty clay loam | 111 | 23.2 | 36.3 | 30.2 |
| Sandy clay loam | 6 | 21.4 | 29.9 | 26.4 |

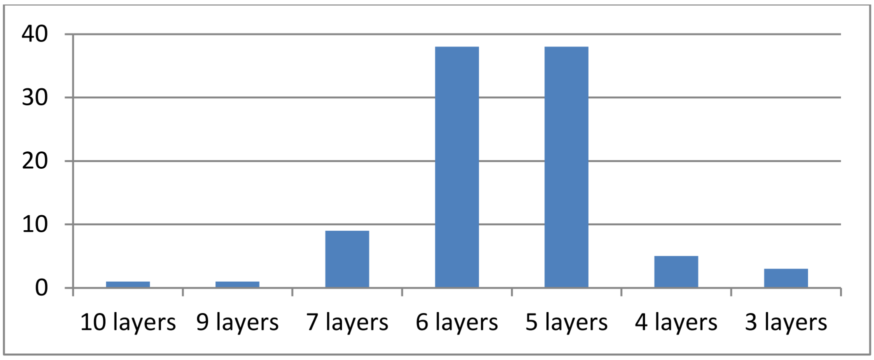

Figure 24.3 Number of soil samples by soil profile

Table 24.2 Number available data and some statistics of the Ukrainian dataset

| Determination of | n | Min | Max | Mean | Median | Мода | Std. deviation |
|---|---|---|---|---|---|---|---|
| Porosity (Vol. %) | 454 | 30,1 | 64,9 | 48,6 | 49,2 | 52 | 6,91 |
| Dry bulk density (g cm$^{-3}$) | 476 | 0,9 | 1,86 | 1,37 | 1,4 | 1,39 | 0.19 |
| pH in soil-$H_2O$ suspension | 102 | 6,0 | 8,4 | 7,44 | 7,5 | 7,6 | 0.54 |
| pH in soil-KCl suspension | 43 | 4.4 | 7.73 | 6,22 | 6,3 | 6,3 | 0,96 |
| Exchangeable cations content (meq(100g)$^{-1}$): | | | | | | | |
| $Ca^{2+}$ | 86 | 1,2 | 52,1 | 25,28 | 23,9 | 35,34 | 12,49 |
| $Mg^{2+}$ | 60 | 0,1 | 13,5 | 5,03 | 5,0 | 5,5 | 3,29 |
| $K^{+}$ | 65 | 0,01 | 1,7 | 0,49 | 0,4 | 0,05 | 0,39 |
| $Na^{+}$ | 70 | 0,04 | 7,58 | 0,51 | 0,2 | 0,2 | 1,02 |
| Texture (weight %): | | | | | | | |
| 1.0-0.25 mm | 489 | 0,0 | 86,9 | 3,19 | 0,2 | 0,0 | 11,18 |
| 0.25-0.05 mm | 489 | 0,0 | 96,3 | 17,59 | 8,1 | 0,0 | 22,35 |
| 0.05-0.01 mm | 489 | 0,2 | 79,3 | 36,2 | 36,5 | 35,3 | 15,99 |
| 0.01-0.005 mm | 489 | 0,0 | 45,6 | 7,96 | 7,7 | 8,8 | 5,74 |
| 0.005-0.001 mm | 489 | 0,0 | 25,6 | 8,35 | 8,2 | 10,9 | 4,97 |
| < 0.001mm | 489 | 0,9 | 60,5 | 26,7 | 27,1 | 31,7 | 12,53 |
| Cation exchange capacity (meq(100g)$^{-1}$) | 33 | 0,36 | 52,85 | 32,96 | 34,1 | 52,35 | 17,68 |
| Organic carbon content (weight %) | 369 | 0,02 | 12,18 | 1,18 | 1,0 | 1,06 | 1,04 |

## 22.3 Measured soil properties and methods

### 24.1.1 Bulk density

Bulk density is measured from undisturbed samples taken to the steel cylinders with volume 100 cm3 according to the Core method where samples are oven-dried at 105°C for 48 hours. (ISO 11272:1998).

### 24.1.2 Particle size distribution

Sieving and sedimentation of 10 grams of fine earth (<1 mm) by method N.A.Kachinskyi (with sequential treatments of soil sample by HCl, and NaOH with boiling). (DSSU 4730:2007).

### 24.1.3 Porosity

Calculation of differential porosity. Porosity POR=(1-bulk density/particle density )*100; The particle density is determined by the piknometers method. (Kachinskyi, 1965).

### 24.1.4 pH in soil-H2O suspension

Determination of pH using a glass electrode in a 1:5 (volume fraction) suspension of soil in water (pH in H2O) (ISO 10390:2005).

### 24.1.5 pH in soil-KCl suspension

Determination of pH using a glass electrode in a 1:5 (volume fraction) suspension of soil in 1 mol/l potassium chloride solution (pH in KCl) (ISO 10390:2005).

### 24.1.6 Exchangeable cations (Ca++, Mg++, Na+, K+) content

Method I.Shollenberger. Extraction of soil exchangeble cations of calcium, magnesium, sodium and potassium by solution of acetic ammonium. Further definition of calcium and magnesium on atomic absorption spectroscopy, sodium and potassium - on a flame photometer.

### 24.1.7 Organic carbon content

Oxidation of soil organic matter by a solution of potassium bichromate in a sulfuric acid and further definition of the rest potassium bichromate by titration or spectrophotometer (DSSU 4289:2004).

## 22.4 Acknowledgements

We would like to acknowledge all employees of Laboratory SoilGeoecophysics of National Scientific Center «Institute for Soil Science and Agrochemistry Research named after O. N. Sokolovsky» (Kharkiv, Ukraine) which during many years, beginning from 1960 participated in accumulation of results of field and laboratory researches, and also authors of publications and those researchers which were given own data for a database of soil properties of Ukraine.

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Soils of Ukraine and raising of their fertility. Kyiv: Urozai, 1988, V. 1: 293 p.; V. 2: 177 p. (in Russian)

# 25 Soil data from the United Kingdom (England and Wales)

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## 25.1 Introduction

Established and developed over the last 30 years, the Land Information System (LandIS) holds significant national soil-environmental datasets collected primarily by the Soil Survey of England and Wales between 1939 and 1987, and latterly by the National Soil Resources Institute (NSRI) at Cranfield University. Soil information was collected systematically in England and Wales from the early 1930s until the mid-1990s. Field soil surveys were conducted at a variety of scales (1:10,000 to 1:63,360), and the first National Soil Map was completed only in 1984 and published at a scale of 1:250,000.

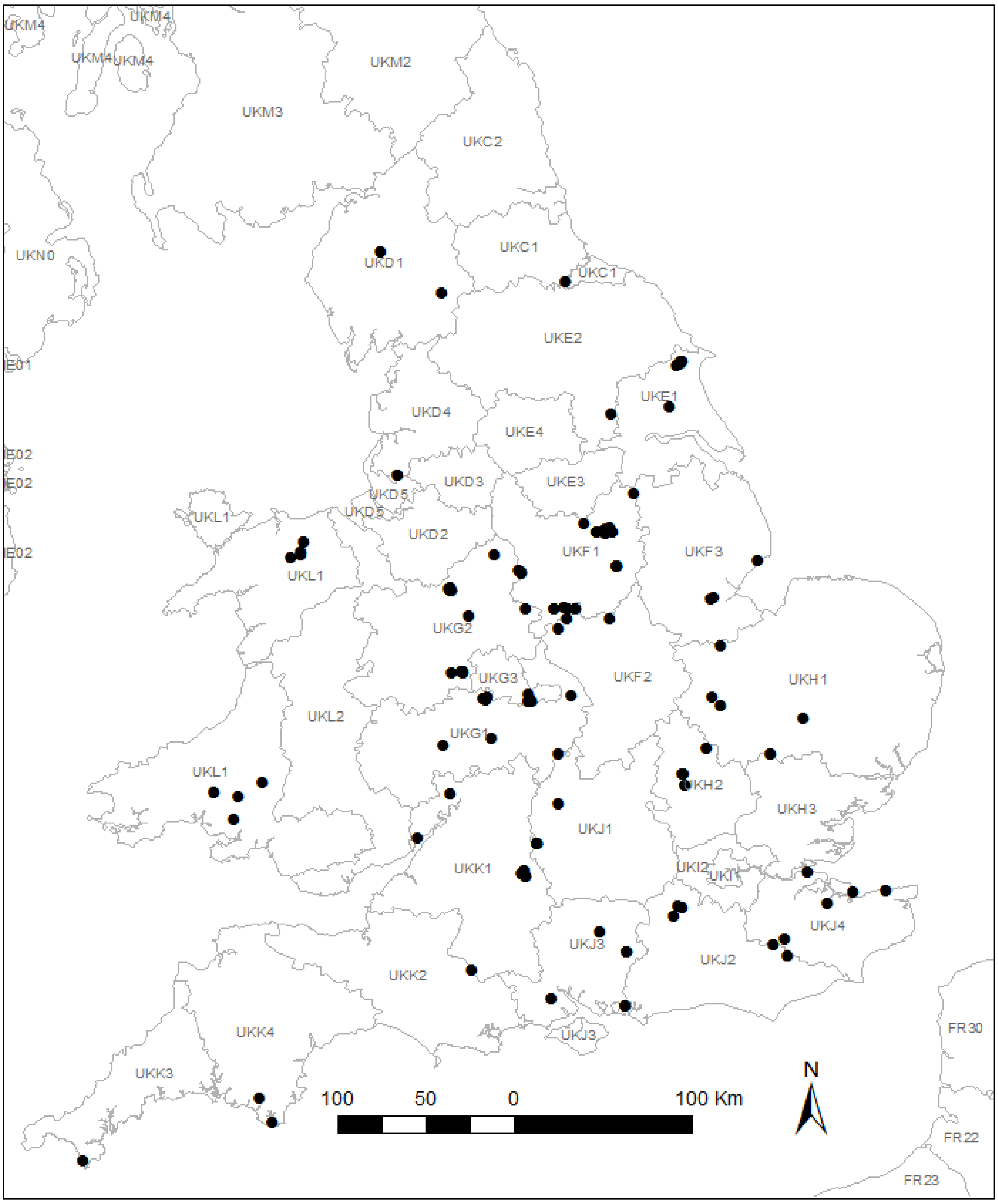

Figure 25.1 Geographical Distribution of samples from England and Wales

## 25.2 Number of samples, geographical distribution and pedological variability

Samples from England and Wales have been provided for 120 profiles, selected to represent the major soil types. These data were originally collated for the HYPRES project. For this exercise the soil type has been reclassified to WRB 2006, the location information converted to the WGS84 coordinate system, the landuse has been expressed in Lucas format and the relevant NUTS region identified, extra chemical data has also been added.

Figure 25.1 shows the distribution of the 120 selected profiles across England and Wales.

Figure 25.2 shows the distribution of the texture classes of the soil horizons.

Table 25.1 shows the spread of some of the basic properties of the soil samples.

Table 25.2 shows the distribution of profiles by WRB 2006 soil classification.

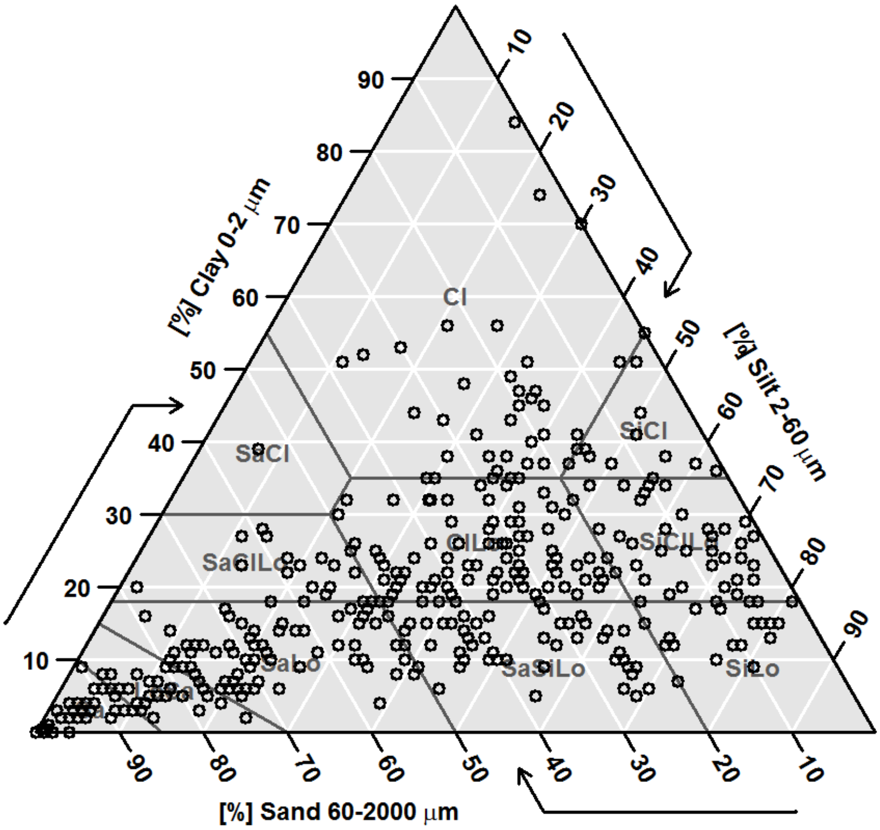

Figure 25.2 Distribution of texture classes of the investigated soils according to (Hodgson, 1976)

Table 25.1 Number of available data, means, median values, minimum and maximum values for the data set

| Determination of | n | Min | Max | Mean | Median |
|---|---|---|---|---|---|
| Porosity [Vol.-%] | 426 | 17.3 | 87.1 | 49.4 | 48.2 |
| Dry bulk density [g/cm³] | 426 | 0.20 | 1.95 | 1.32 | 1.35 |
| Organic carbon [Mass-%] | 426 | 0.00 | 50.00 | 2.01 | 0.70 |
| Carbonate content [Mass-%] | 85 | 0.01 | 79.00 | 9.20 | 0.80 |
| Clay content [Mass-%] | 426 | 0.0 | 84.0 | 18.6 | 17.0 |
| pH in water | 236 | 3.50 | 8.90 | 6.49 | 6.70 |
| Cation Exchange Capacity (pH 8.1) | 54 | 3.40 | 165.70 | 25.46 | 19.30 |
| Extractable Na (ppm) | 32 | 0.01 | 5.20 | 0.94 | 0.14 |
| Extractable Mg (ppm) | 29 | 0.03 | 14.00 | 3.17 | 0.58 |
| Extractable K (ppm) | 31 | 0.01 | 2.60 | 0.69 | 0.11 |
| Extractable Ca (ppm) | 30 | 0.10 | 36.70 | 7.93 | 0.87 |
| Extractable Acidity (pH 7 approx) | 26 | 1.30 | 75.00 | 16.65 | 8.10 |
| Water Available at 50 cm | 426 | 0.077 | 0.835 | 0.381 | 0.375 |
| Water Available at 100 cm | 370 | 0.064 | 0.805 | 0.361 | 0.354 |
| Water Available at 330 cm | 65 | 0.036 | 0.383 | 0.197 | 0.206 |
| Water Available at 400 cm | 361 | 0.037 | 0.714 | 0.322 | 0.317 |
| Water Available at 2000 cm | 408 | 0.018 | 0.642 | 0.245 | 0.245 |
| Water Available 15000 cm | 426 | 0.011 | 0.431 | 0.191 | 0.184 |

## 25.3 Measured soil properties and methods

### 25.3.1 Determination of dry bulk density (Avery and Bascomb (1982) p42)

The bulk density of soil (Db) is calculated from the mass of oven-dry soil (Me) and its field volume (V). This measurement is essential to express water release determinations in terms of volume. The oven-dry mass of three replicate cores is summed and divided by the total volume (666 $cm^3$).

### 25.3.2 Determination of porosity

The porosity, as a % of total soil, is calculated from the measured bulk density and an assumed particle density of 2.65 (adjusted in topsoils to account for organic matter fraction).

### 25.3.3 Determination of organic carbon (Avery and Bascomb (1982) p25)

Organic Carbon is determined by a wet oxidation method.

### 25.3.4 Determination of carbonate equivalent content (Avery and Bascomb (1982) p29)

A calcimeter as described by Bascomb (1961) was used to measure the % $CaCO_3$ in the sample expressed as '$CaCO_3$ equivalent' as some samples contain $MgCO_3$.

Table 25.2 WRB2006 Soil Types included

| WRB 2006 | No of Profiles | WRB 2006 | No of Profiles |
|---|---|---|---|
| **AC - Acrisol** | **1** | **HS - Histosol** | **1** |
| Haplic Acrisol | 1 | Eutric Histosol | 1 |
| **AR - Arenosol** | **13** | **LP - Leptosol** | **5** |
| Brunic Arenosol | 11 | Rendzic Leptosol | 5 |
| Gleyic Arenosol | 2 | **LV - Luvisol** | **25** |
| **CM - Cambisol** | **29** | Chromic Luvisol | 5 |
| Calcaric Cambisol | 3 | Gleyic luvisol | 2 |
| Calcaric, gleyic Cambisol | 4 | Haplic Luvisol | 7 |
| Calcric Skeletic Cambisol | 2 | Leptic Luvisol | 1 |
| Chromic Cambisol | 1 | Profundic Luvisol | 1 |
| Dystric Cambisol | 2 | Stagic Luvisol | 2 |
| Endolithic Cambisol | 1 | Stagnic Luvisol | 7 |
| Eutric Cambisol | 9 | **PH - Phaeozem** | **2** |
| Fluvic, Calcaric Cambisol | 1 | Luvic Phaeozem | 1 |
| Gleyic Cambisol | 1 | Stagnic, luvic Phaeozem | 1 |
| Skeletic Cambisol | 1 | **PZ - Podzol** | **4** |
| Stagnic Cambisol | 3 | Gleyic podzol | 1 |
| Vertic, Stagnic Cambisol | 1 | Haplic Podzol | 1 |
| **FL - Fluvisol** | **13** | Placic, Stagnic Podzol | 1 |
| Calcaric Fluvisol | 1 | Stagnic Podzol | 1 |
| Eutric Fluvisol | 2 | **ST - Stagnosol** | **22** |
| Gleyic calcaric Fluvisol | 1 | Clayic Stagnosol | 1 |
| Gleyic Fluvisol | 7 | Histic Stagnosol | 2 |
| Gleyic, calcaric Fluvisol | 2 | Luvic Stagnosol | 2 |
| **GL - Gleysol** | **4** | Mollic Stagnosol | 11 |
| Dystric Gleysol | 1 | Vertic Stagnosol | 6 |
| Histic Gleysol | 1 | | |
| Luvic Gleysol | 1 | | |
| Umbric Gleysol | 1 | | |

### 25.3.5 Determination of particle size < 2 mm (Avery and Bascomb (1982) p15)

Particle size distribution in the fine earth (<2mm) was determined after pretreatment with $H_2O_2$ to remove organic matter and dispersion overnight with Calgon (sodium hexametaphosphate). Fine clay (<0.2 µm) was determined by centrifugal sedimentation following pipette sampling. Clay ( <2 µm) and fine silt (2-20 µm) were determined by the pipette method, the sand factions by appropriate British Standard sieves and the coarse fraction (20-60 µm) by difference. Where fractions are reported to the nearest whole percentage, the hydrometer method of sedimentation analyses was used.

### 25.3.6 Determination of water retention characteristic (Avery and Bascomb (1982) p15)

Undisturbed triplicate core samples are taken from selected horizons in tinned metal sleeves of 222 $cm^3$ volume and 7.6 cm diameter using a special coring tool. The water retained by the samples is measured at suctions of 0.05 bar (approximately field capacity), 0.1 and 0.4 bar on sand and kaolin tension tables and at 2 and 15 bar (wilting point for most plants) in pressure membrane cells. Each replicate is dispersed and sieved to determine stone content. Particle density is determined for all surface horizons, but its range for most subsoils is sufficiently small (±0.1 g $cm^{-3}$) to accept a general value of 2.65 g $cm^{-3}$.

Mean values for the water content at each suction are expressed in terms of mass (%) of oven-dry soil or, more usually, as a volumetric water content (%) on the basis of total soil volume including stones.

### 25.3.7 Determination of Exchangeable Metallic Cations (Avery and Bascomb (1982) p19)

Exchangeable metallic cations (Na, Mg, K and Ca) were determined in a neutral normal ammonuium acetate leachate. Magnesium was determined by atomic absorption and calcium, sodium and potassium using an EEL flame photometer.

### 25.3.8 Determination of Cation Exchange Capacity (Avery and Bascomb (1982) p24)

Cation exchange capacity was determined where applicable for calcareous and non-calcareous soils, and to <2 µm clay separates. This is determined by a method described by Bascomb (1964)

### 25.3.9 Determination of Exchangeable Acidity (Avery and Bascomb (1982) p23)

Exchangeable acidity is estimated by a method based on that of Parker (1929).

## 25.4 Acknowledgements

The majority of the data made available here was originally collated by John Hollis at NSRI, Cranfield University.

## 25.5 References

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# 26 Soil data from the United Kingdom (Scotland)

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## 26.1 Introduction

The soil hydrological and associated  pedological data for Scottish soils came from two sources and are part of the Scottish Soils Database held by the James Hutton Institute (formerly, the Macaulay Institute). The majority of the data were collected primarily as input data for simulation modeling of the soil water regime of selected Scottish soils (Lilly, 1995 and Lilly, 1999). In addition, a small number were collected as part of an investigation into the variability in soil hydraulic properties due to different cultivation techniques. In all cases the soil profiles were fully characterized according to the protocols of the Soil Survey of Scotland (for example see Lilly et al, 2010).

## 26.2 Number of samples, geographical distribution and pedological variability

The data comprise 44 soil profiles (133 soil horizons) selected from the Scottish Soils Database. 5 of which (19 horizons) were characterized as part of an investigation into tillage effects on soil physical properties and the remainder (39 profiles, 114 horizons) were part of a study to quantify and model soil water regimes across Scotland.

The soil profiles from the tillage experiment were located in the north east of Scotland, 18 km north of Aberdeen (Figure 26.1). Four of these soil profiles were freely drained Brown Earths (Soil Survey of Scotland revised classification system) and the fifth was an imperfectly drained Brown Earth with some gleying in the subsoil. All were developed on a mixed glacial drift derived from acid and basic, igneous and metamorphic rocks and all but the gleyed profile had an indurated (fragic) horizon that limits root penetration but allows water infiltration and hence have been classified as fragic Cambisols (IUSS Working Group WRB, 2007 & 2010). The gleyed profile was classed as a stagnic Cambisol though the stagnic features are not well expressed. All the profiles had a cultivated (anthric) topsoil and have been in an arable rotation for many years.

The remaining profiles were from a number of different sites throughout the Midland Valley of Scotland, around Aberdeen and from the far north east around Wick and Thurso (Figure 26.1). As the main focus of the work was on quantifying the water regimes of soils with perched water table, the soils are mainly imperfectly drained Brown Earths with gleying or imperfectly and poorly drained noncalcareous and Brown gleys (Soil Survey of Scotland revised classification system) and were developed on glacial lodgement till derived from a number of parent materials such as Old Red Sandstone sediments, Flagstones or from carboniferous sediments. As the soils all had perched watertables, they were classified as either Stagnosols or stagnic Cambisols according to the World Reference Base classification system (IUSS Working Group WRB, 2007 & 2010). The land use varied from intensive arable agriculture to long term grass pastures but all had a cultivated (anthric) topsoil. Five profiles only had the topsoil characterized but for the others, soil hydrological and pedological parameters were derived for each horizon including the subsoil and parent material.

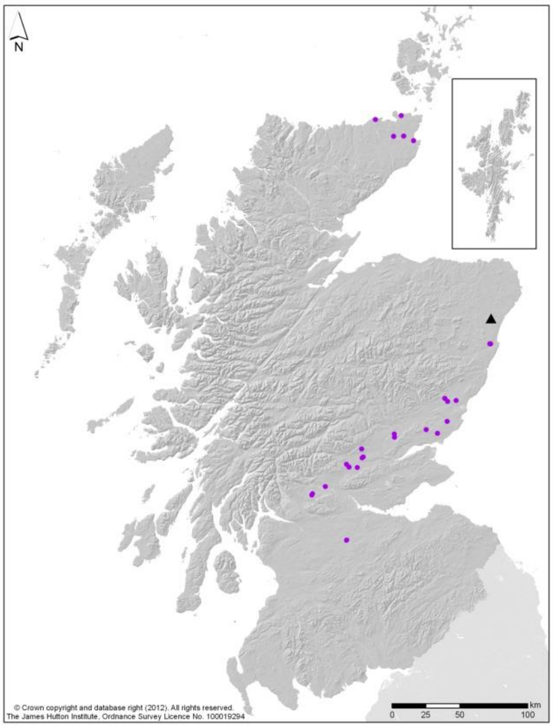

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Figure 26.1 Distribution of the 44 Scottish soils. The site marked as ▲ is the tillage experimental site with 5 closely spaced profiles. The sites marked ● are from sites where water tables were measured.

## 26.3 Measured soil properties and methods

At each site a soil profile pit was excavated and the soil horizons were identified and described according to the Soil Survey of Scotland protocols (for example, Lilly et al 2010). After each profile was described, the turf was removed and a 'bench' smoothed off (without smearing the surface). Three food-grade stainless steel rings (5 cm high and 7.3 cm internal diameter giving a volume of around 210 cm$^3$) and three small rings of approximately 9.25 cm$^3$ were carefully carved into the soil from above. The cores were then excavated, trimmed and any projecting stones removed. The resulting gap was then filled with soil packed to the same bulk density. The larger soil cores then had plastic lids placed over them, were labeled and placed in plastic bags to prevent desiccation. The small cores were labeled and carefully placed inside a plastic bag. The 'bench' was then cut down to expose a horizontal face of the next horizon and the sampling procedure repeated until all horizons were sampled. These cores were then transported to the laboratory for the determination of the soil moisture characteristic and bulk density.

Where hydraulic conductivity measurements were also determined, the profile pit ‘bench’ was then extended into the face of the pit and measurements of the field-saturated hydraulic conductivity of each of the horizons were made using a Guelph Permeameter. Approximately 1 kg of the soil excavated around the cores was also collected as a disturbed bulk sample for chemical and particle size analyses

### 26.3.1 Soil moisture retention

The soil moisture retention curve was determined by applying a series of known pressures to saturated blocks of soil contained within the metal sample rings collected from the soil profile. Tension tables were used to establish an equilibrium in the soil cores at 10, 50 and 100 cm pressures and pressure plates to equilibrate soils at 500 and 2000 cm, while pressure membrane apparatus were used to establish the moisture retained at 15000 cm.

The tension tables followed the design of Clement (1966) but were made of moulded fibre glass with dimensions 520 mm long by 350 mm wide and 100 mm deep. The tables comfortably held 18 to 20 large (210 $cm^3$) cores at any time. A sheet of glass microfibre paper (Whatman grade GF/A) 5 mm smaller than the floor of the tray was used to avoid the internal drainage channels becoming clogged. The paper was covered with a 20 mm thick layer of silica flour (grade HPF2, particles in the size range of 10 to 50 µm in diameter). Finally, two sheets of nylon gauze were placed on top to prevent soil particles mixing with the silica flour. A length of clear plastic tubing connected the tension table to a constant head reservoir which could be adjusted on a retort stand to give the required pressure (normally up to 100 cm head of water).

The pressure vessels and ceramic plates manufactured by Soil Moisture Equipment Corporation of Santa Barbara were used to establish the moisture retained at pressures of 500 and 2000 cm, while the pressure membrane apparatus used to determine the soil moisture retained at 15000 cm following the design described by Reeve and Carter (1991). Compressed air was use to pressurize the pressure vessels and a bottled nitrogen supply was used in conjunction with the pressure membrane cells. The outlets of both pressure systems were connected to clear bottles to aid in visual inspection of the amount of extruded water. These bottles were easily disconnected to facilitate weighing.

Once in the laboratory, the plastic lid from the lower end of the core was removed and replaced by a piece of nylon gauze secured with a rubber band. The cores were numbered both on the metal ring and upper plastic lid, placed in a tray at least 70 mm depth which was then filled with water to a depth of 5 mm and left for 48 hours. Water was then added to increase the depth to 25 mm for a further four hours after which the cores were totally immersed in water for another four hours (after Ball and Hunter, 1980). The cores were then quickly transferred to a small 'drip-tray' which had been previously weighed and the balance tarred. This ensured that any water lost due to rapid drainage of the large pores was retained within the drip-tray and was weighed, allowing the saturated (0cm pressure head) moisture content to be determined. The surface of the tension table (see below) was then wetted and the saturated cores carefully and firmly placed onto the silica flour in such a way as to avoid trapping air and to obtain a good hydraulic contact between the core and the flour. The cores were left for approximately one week, then weighed every two days until the change in weight was less than 1 g. The cores were then weighed and transferred to another tension table set at the next tension in the sequence.

The small cores (9.25 $cm^3$) were trimmed and wetted on a ceramic plate by spraying the surface with water from a house-plant mister. They were covered and left to allow the water to be adsorbed and then placed in the 500 cm pressure vessel. The outflow was collected and weighed daily. When the weights fell at a constant rate, then the moisture content of the cores were deemed to be in equilibrium with the applied pressure. The cores were then weighed and transferred to the next pressure vessel in the sequence.

After desorption, the soil from the larger 210$cm^3$ cores was gently crushed and sieved to remove stones (> 2000 µm) and the volumetric moisture content of the fine-earth (< 2000 µm) fraction was determined using the formula based on that described by Hall, Reeve, Thomasson and Wright (1977) which assumes the density of water to be 1 g $cm^{-3}$

$$\theta \upsilon f = \frac{Ms - Md}{Vc - Vs}$$

where θυf is the volumetric moisture content of the fine-earth fraction (< 2000 µm) Ms is the mass of soil at specific tensions, Md is the mass of oven dry soil, Vc is the volume of the core and Vs is the volume of stones. The volume of stones was determined by dividing the mass of stones by an assumed bulk density of 2.55 g cm$^{-3}$.

## 26.3.2 Dry bulk density

The Dry bulk Density (Db) was determined on the same cores used to derive the soil moisture retention curve after the soil cores had been desorbed on tension tables. Three 201cm3 soil cores were dried at 105$^{o}$C for 48 hours and weighed. In general, the soils had a number of stones (>2000 µm) and so a corrected dry bulk density was determined as:

$$Dbf = \frac{Md - Ms}{Vc - Vs}$$

Where *Md* is the mass of oven dry soil, Ms is the mass of stones, *Vc* is the volume of the core and *Vs* is the volume of stones determined by dividing the mass (g) by the assumed bulk density of 2.55 g cm$^{-3}$.

## 26.3.3 Field saturated hydraulic conductivity

Field-saturated hydraulic conductivity (Kfs) was measured using the Guelph permeameter, a constant head, in-hole permeameter operating on the Mariotte bottle principle. Measurements were made in the field of the steady state recharge necessary to maintain a constant depth of water (pressure head) within an unlined well terminating above a water-table (Reynolds & Elrick, 1986). A stable zone of saturation is assumed to form around the well and the dimensions of this zone relate to the pressure head, the radius of the well and also to the soil texture and structure (Elrick *et al.*, 1989).

The one-head method was used which relied on determining the flow rate at only one pressure head and subsequently using the Richards analysis to calculate Kfs. This method divides flow out of a well into saturated and unsaturated components by estimating the $\alpha^*$ parameter on the basis of the soil structure and texture. By substituting $\alpha^*$ into the equations, Kfs can be calculated without the need to determine two flow rates from each well (two-head method) and then solve simultaneous equations. This two-head method can lead to negative Kfs values being calculated. According to Elrick *et al*. (1989), $\alpha^*$ varies from 1/m to 100/m, and they suggested $\alpha^*$ values of 1, 4, 12 or 36/m for the combined structural and textural conditions from compacted clays through structured soils to coarse and gravelly sands.

The thickness of soil horizons identified from the excavated soil profile pit were used to decide at which depth each well should be set and what pressure head should be applied such that the zone of saturation did not intersecting horizon boundaries. Where possible, three wells were set in each horizon giving triplicate measurements of the outflow. Measurements on the subsoil horizons were made by digging down to the upper surface of the horizon as previously described. The wells consisted of a simple auger hole in which any smear layer was removed by picking the sides with a long bladed knife and scooping out the debris to avoid the pores being subsequently blocked when the well was filled with water. The permeameter was set into the well which was back-filled with clean, coarse sand (0.6 - 1.18 mm) to minimize slaking or collapse of the sides. The rate of fall of water in the permeameter reservoir was recorded at two minute intervals until it reached a steady rate over three successive readings. To avoid under-estimating the rate of flow from the well, it was important that there was no external supply of water into the well and that there was no free water (matric potentials approaching zero) within the horizon being investigated or in any horizon above. Computer software were used to convert the steady state outflow, the estimated $\alpha$*, the well radius and the height of the ponded water to field-saturated hydraulic conductivity. Full details of the sampling and calculation methodologies are given in Lilly (1994).

### 26.3.4 Particle size

The particle size classes in use during this sampling period were the British Standard Texture classification (British Standards Institution, 1981) where clay was < 2µm, silt 2-60µm and sand 60-2000µm. The proportions of particles in these size ranges were determined by the hydrometer method after Bouyoucos (1927). Approximately 500 $cm^3$ of distilled water with 10 $cm^3$ of sodium hexametaphosphate was added to 50 g of soil and shaken overnight. The suspension was then poured into a cylinder and made up to 1 litre with the hydrometer in place. The hydrometer was withdrawn and the suspension shaken for one minute, replaced on the bench and the hydrometer read at specified times based on the settling velocities of the different particle size fractions, to record density of the solution. The readings were corrected for organic matter content by adjusting the proportion of sand sized particles.

### 26.3.5 Soil organic carbon concentration

Soil elemental carbon was measured by CHN analyser using 0.5-5mg of finely ground soil.

### 26.3.6 Soil pH

Soil pH was determined using a glass electrode inserted into a suspension comprising 15 g of <2 mm air dried soil and 45 ml distilled $CO_2$ – free water. The soil and water were mixed, thoroughly shaken and left to stand for a minimum of 2 hours before inserting the class electrode.

### 26.3.7 Exchangeable cations

Base saturation is the ratio of the sum of the base cations (Ca, Mg, K, Na) to the sum of cations (Ca, Mg, K, Na, H, Al) expressed as a percentage. The exchangeable base cations in 10 g of air dried soil were removed in solution by exchanging them with 1M $NH_4$ from an ammonium acetate solution (buffered to pH7 using ammonium acetate). The soil/$NH_4$ solution is allowed to equilibrate overnight and the suspension is filtered. The concentration of cations which are exchanged are then estimated using inductively coupled plasma-atomic emission spectroscopy (ICP-AES).

In acid soils hydrogen ions are capable of releasing aluminium ions from clay minerals. The sum of these ions is known as the exchangeable acidity. Extraction of hydrogen and aluminium ions by a neutral salt solution and back titration with a known alkali solution enables an estimate of the exchangeable acidity present within the soil. Approximately 5 g of air dried soil was mixed with 25 ml barium acetate buffered to pH 7 before use, using either ammonia solution or acetic acid. This was left overnight. Using an auto-titrator, barium hydroxide solution was added and the volume recorded.

## 26.4 Acknowledgements

The map of the distribution of soils was prepared by NJ Baggaley. This work was funded by the Scottish Government Rural Affairs and the Environment portfolio; Underpinning Capacity -Soils.

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# 27 Quality assurance and harmonization

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## 27.1 Introduction

Guidelines for data contributors were provided for formatting the contributors' datasets according to the EU-HYDI specifications (Annex 2). Nevertheless additional effort was needed to verify the compliance with the specifications, to group the measurement methods and to harmonize part of the data to a common standard (particle size distribution and organic carbon content mostly).

The minimum requirements initially sought (see Annex 2) were discarded and all contributed data were kept in the database. Compared to the guidelines to contributors, a column named SOURCE was added in all tables with the name of the data contributor or the source of the data. Also there is an additional table with harmonized estimated particle size distributions: PSD_EST.

Although some harmonization was required for particular data, the database contains primarily raw data and documentation on the methods used to derive the values where available. This leaves the user the possibility to exploit the database more freely and thoroughly, according to his/her preferences for certain models or methodologies.

## 27.2 Compliance with specifications

When importing the data from each contributor, some basic validation tests were run to check the data compliance with the EU-HYDI guidelines for contributors (Annex 2). Where the data failed these validation tests, either the format was corrected where the reason of non-compliance was easily understood and solved or the contributor was contacted and asked to clarify or resubmit the data.

Firstly, the uniqueness of the profile and sample identifiers was ensured. Acting as primary keys in tables GENERAL, BASIC and CHEMICAL, they also link these tables and the others: PSIZE, RET, COND.

All categorical data in tables GENERAL and BASIC had to match the possible values given in the guidelines. Obvious mistyping errors were corrected while unexplained values were removed and transformed into missing data.

For continuous data, values falling outside the usual ranges were highlighted and contributors were asked to confirm their validity.

Whenever possible, geographical coordinates that were contributed in local projection systems were converted to longitudes and latitudes in decimal degrees (WGS84).

The guidelines specifically mentioned that data taken in the same profile at the same depth were to be submitted as averages for that specific sampling depth level. When this was not the case, replicated samples were grouped and only the median of all replicated measurements was retained in the database.

Some data were further harmonized to facilitate the use of the database. Details are given below.

## 27.3 The METHOD table

The guidelines for contributors required that they document the measurement methods used to obtain their data. The METHOD table contains all the method codes found in the other tables and describes the methods used. The descriptions given by the contributors had often to be clarified to allow the methods to be grouped in order to decrease the number of entries in the table. Even where methods relied on the same principles, they were distinguished according to sample size, reagents, temperatures etc. For example, 10 different codes were kept for bulk density to account for the different sample sizes although the methodology is almost always to dry a sample in the oven at 105°C for 48 hours (exception of the clod method used in France). Also where details of the methods remained uncertain, the entry was left as is as to not amalgamate it with better described similar methods.

From its initial 366 entries, table METHOD was shortened to 177. The methods are coded with 3 digits, the first two referring to the property measured.

## 27.4 Soil organic carbon and its standardization

The guidelines initially asked for organic carbon content without any further specification. However, during the quality assurance procedure it appeared that there was great confusion in the data between organic matter, organic carbon and total carbon. The methods descriptions were not clear enough to understand to what pre-treatments the samples were subjected, the exact conditions of the carbon oxidation and the correction factors applied to the results. After clarification of the methods, the initial organic carbon methods were split into loss on ignition (LOI), organic carbon (OC) and total carbon (TC). Besides, a new column was added to the CHEMICAL table in an attempt to harmonize these three properties with comparable organic carbon data (HOC). The standard chosen is the dry combustion after destruction of the carbonates or followed by calcimetric correction. Based on the METHOD table, conversions towards this standard were applied for the different methods. The conversions were based on results found in the literature (see Annex 3). Given the large variety of soils in the EU-HYDI and the lack of exactly the same conditions in the published studies, an ensemble of equations was run for each method conversion and the arithmetic mean was used as harmonized organic carbon.

## 27.5 Particle size distribution data and their standardization

The guidelines required particle size distribution (PSD) as mass percentage of soil at any measured particle size smaller than 2000 µm. Harmonization towards standard clay, silt and sand contents could then be run with a consistent methodology.

It is a known obstacle in international soil-related research that different countries – and often different institutions within a country – measure particle-size distribution by different standards. Differences can result from using different measurement techniques, from conforming to different national or international standards for fractionation of the various sizes of particles, and/or different nationally adapted protocols.

Differences in measurement techniques and procedures can range from different sampling protocols, through using measurement devices that are based on the same theory (e.g.

hydrometer vs. pipette technique), to using techniques that use different theories and assumptions to calculate particle-size distribution (e.g. laser diffractometer). In EU-HYDI, the methodology used by the contributing partners to determine PSD has been registered in the database. Only a very small proportion of the collected particle-size data were determined by a non-sedimentation technique, so the database is rather homogeneous in terms of measurement theory.

It is to be noted that the treatment of organic carbon (OC) in the soil sample is handled loosely in internationally applied measurement protocols. The applicable ISO standard allows the user to either eliminate or to retain OC from the soil sample during pre-treatment prior to PSD measurements, which can yield some degree of bias between respective measurements. The degree of any such bias is currently unknown. The treatment of OC in PSD measurements was logged in the database where such information was available.

There are a number of internationally recognized standards for describing and classifying solid particles into size classes within, but also beyond soil science (e.g. material science). Historically, European countries adapted different such size standards for the description of soils. The wide variety in the determined size-ranges of the PSD of soils contributed to EU-HYDI is reflected in Table 27.1.

A number of observations can be readily made from Table 27.1. First and foremost, one can note that some countries are listed more than once – each row showing a different pattern. This may reflect that there is either no fixed national standard that the various local institutions would strictly need to adhere to; but it can also mean that there had been a change of standard in the given country over time. However, a country being listed only once does not necessarily mean that such changes or differences have never taken place, it only means that the contributed data has not been affected by it.

Countries in Central and Eastern Europe have or had adapted Katschinski's system (Katschinski, 1956), which recognizes the clay/silt boundary at 1 µm. A number of those countries have moved away from using that system some time ago, others continued using it. There is large heterogeneity in what fraction different countries recognize as the boundary between the silt and sand fractions. Some countries use standards that recognizes the ISSS standard of 20 µm (International Society of Soil Science, 1929) as such boundary (e.g. Portugal), others use the FAO/USDA standard of 50 µm (United States Department of Agriculture, 1951; Food and Agriculture Organization, 1990), yet others, for example, the United Kingdom and Scandinavian countries, use 60 µm (British Standards Institution, 1981), while the German system recognizes 63 µm for such a boundary (ISO 11277:1998). There is also variation in the data at the coarse end of the PSD curve. Katschinski's system recognizes 1 mm as the upper size boundary of the fine earth fraction, whereas all other systems defined that boundary to be at 2mm. This means that the examined mass of fine earth is different for Katschinski's system, and an extrapolation to 2 mm would be necessary to allow scaling the clay and silt content to the same reference.

Since most international applications adhere to the FAO/USDA particle-size distribution classification system, it has been decided that data in EU-HYDI should primarily be interpolated as best as possible to conform this system. It is noted that the original, raw data have been preserved, allowing and facilitating any future work to interpolate them using different methods or conforming any different systems. In the following we describe the interpolation process that was undertaken to allow conformity of EU-HYDI data with the FAO/USDA system.

Table 27.1 List of unique combinations of particle-size fractions submitted by EU-HYDI's contributors.

| |0.2|1|2|4|5|6|6.3|8|10|16|20|32|50|60|63|75|100|105|125|150|180|200|210|250|300|500|600|630|1000|2000|
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
|Austria| | |x| | | | | | | | | | | |x| | | | | | | | | | | | | | |x|
|Belgium| | |x| | | | | | | | | |x| | | | | | | | | | | | | | | | |x|
|Belgium| | |x| | | | | | | |x| |x| | | |x| | | | |x| | | |x| | | |x|
|Belgium| | |x| | | | | |x| |x| |x| | | |x| | | | | | |x| |x| | |x|x|
|Belgium| | |x| | | | | |x| |x| |x| | | |x| | | | |x| | | |x| | |x|x|
|Belgium| | |x| | | | | | | | | | | |x| | | | | | | | | | | | | | |x|
|Belgium| | |x| | | | | | | | | |x| | | | | | | | | | | | | | | | |x|
|Czech Republic| | |x| | | | | | | | | |x| | | | | | | | | | | | | | | | |x|
|France| | |x| | | | | | | |x| |x| | | | | | | | |x| | | | | | | |x|
|Germany| | |x| | | | | | | |x| | | |x| | | |x| | |x| | | | | |x| |x|
|Germany| | |x| | | |x| | | |x| | | |x| | | | | | |x| | | | | |x| |x|
|Greece| | |x| | | | | | | | | |x| | | | | | | | | | | | | | | | |x|
|Hungary| | |x| |x| | | |x| |x| |x| | | | | | | | | | |x| | | | | |x|
|Italy| | |x| | | | | | | | | |x| | | | | | | | | | | | | | | | |x|
|Italy|(5-6 points in the 1-30 µm range)| | | | | | | | | | | |x| | | |x| | | | | | |x| |x| | |x|x|
|Italy| | |x| | | | | | | | | |x| | | | | | | | | | | | | | | | |x|
|The Netherlands| | |x| | | | | | |x| | |x| | | | |x| |x| | |x| |x| | | | |x|
|The Netherlands| | |x| | | | | |x| |x| |x| | | |x| | | | |x| | | |x| | |x|x|
|The Netherlands| | |x| | | | | | |x| | |x| | |x| |x| |x| | |x| | | | | | |x|
|The Netherlands| | | | | | | | | | | | |x| |x| | | |x|x|x| | |x| |x| | |x|x|
|The Netherlands| | |x|x| | | |x| |x| |x| | |x| | | |x| | | | |x| |x| | |x|x|
|The Netherlands| | |x|x| | | | | |x| |x| | |x| | | |x| | | | |x| |x| | |x|x|
|The Netherlands| | |x| | | | | | |x| | | | |x| | | |x| | | | |x| |x| | |x|x|
|The Netherlands| | | |x| | | |x| |x| |x| | |x| | | |x| | | | |x| |x| | |x|x|
|Norway| | |x| | | | | | | | | | |x| | | | | | | | | | | | | | | |x|
|Norway| | |x| | |x| | | | |x| | |x| | | | | | | |x| | | | |x| | |x|
|Norway| | |x| | |x| | | | |x| | |x| | |x| | | | |x| | | | |x| | |x|
|Norway| | |x| | | | | | | | | | |x| | | | | | | |x| | | | |x| | |x|
|Poland| | |x| |x| | | | | |x| |x| | | |x| | | | | | | | | | | |x| |
|Portugal| | |x| | | | | | | |x| | | | | | | | | | |x| | | | | | | |x|
|Russia| | |x| |x| | | |x| |x| |x| | | | | | | | | | |x| | | | | |x|
|Scotland| | |x| | | | | | | | | | |x| | | | | | | | | | | | | | | |x|
|Slovakia| |x| | | | | | |x| | | |x| | | | | | | | | | |x| | | | | |x|
|Spain| | |x| | | | | | | | | | | |x| | | | | | | | | | | | | | |x|
|Sweden| | |x| | |x| | | | |x| | |x| | | | | | | |x| | | | | | | |x|
|UK| | |x| | | | | | | | | |x| | | |x| | | | |x| | | |x| | | |x|
|UK| | |x| | | | | | | | | | |x| | | | | | | |x| | | | |x| | |x|
|UK|x| |x| | | | | | | | | | |x| | |x| | | | |x| | | | |x| | |x|
|UK| | |x| | | | | | | |x| | |x| | |x| | | | |x| | | | |x| | |x|
|UK|x| |x| | | | | | | |x| | |x| | |x| | | | |x| | | | |x| | |x|
|UK|x| |x| | | | | | | | | | |x| | | | | | | |x| | | | |x| | |x|
|UK| | |x| | | | | | | | | | |x| | |x| | | | |x| | | | |x| | |x|
|Ukraine| |x| | |x| | | |x| | | |x| | | | | | | | | | |x| | | | |x| |

## 27.5.1 Obtaining an estimate of the 2000 µm fraction

The data sets submitted from Poland and Ukraine have had their particle-size distribution determined on a fine earth fraction that was defined as the individual particles smaller than 1000 µm in equivalent diameter. If such historic data are to be converted to a 2000 µm-based system, an extrapolation of the existing data is necessary. Extrapolation is a highly uncertain task that will require substantial additional research. We have not taken up this task within the context of the EU-HYDI data harmonization; therefore the particle-size distribution data of those two data collections – at the time of releasing this report - remained incompatible with the rest of the data.

## 27.5.2 Obtaining an estimate of the 50 µm fraction

As stated before, there is substantial heterogeneity in what size limit different countries recognize as the boundary between the silt and sand fractions. This, along with the varying number and position of available fractions poses a complex interpolation problem to bring those data to the same particle-size class standard.

In the context of a similar earlier interpolation task it has been recommended that when it comes to choosing an interpolation method, there is significance in how many points are available from the raw measurements and what their distribution is on the size scale (Nemes et al. 1999). It was found that when measured points are available relatively closely to the point to be estimated, fitting a free-form curve (spline) can be most efficient, while in case where the measured points are sparse and/or distant from the point to be estimated, a k-nearest neighbour type pattern recognition algorithm (termed 'similarity procedure' at the time) was found to be most suitable among the tested estimation/interpolation tools. In the European HYPRES database, any missing particle-size fraction at the silt/sand limit recognized by FAO and USDA (i.e. 50 µm) has been interpolated according to such guidelines. It is noted that the developed pattern-recognition technique was found suitable for the task for all data patterns; the spline curve-fit was chosen for application for some of the data due to its convenience.

Nearly 6000 samples in EU-HYDI had PSD data with an existing measured 50 µm fraction. An additional 1800+ samples were taken from the HYPRES database that had their 50 µm fraction interpolated using the combination of tools described above. Those estimations were directly taken from HYPRES. However, nearly 7000 additional samples required the 50 µm fraction to be interpolated. Approximately 54% of those data had only a few points and/or had sparse distribution of particle sizes around the 50 µm target, therefore those were interpolated using the pattern-recognition technique. Those data include all samples from Portugal, Spain, Scotland and Austria, most data from England and Wales, many from Norway and some of the data from Belgium. The rest of the data (all of those from Germany and Sweden, many from Norway and some from England and Wales) were candidates for either curve-fitting or the pattern recognition technique.

The application of the referred pattern recognition technique requires the pre-existence of a substantially large external data set with examples of the same data pattern (list of measured fractions) as the sample for which an interpolation is to be made. When the HYPRES database was established, such a collection was not available for some combinations of measured fractions, hence the curve-fitting technique was used in those cases. Today, with HYPRES's availability, a large collection of European soils is available that shows good diversity of fraction-patterns with either a measured or an estimated 50 µm fraction among them. Such external source can be mined to support EU-HYDI interpolation tasks; therefore, it was both desirable and possible to use the pattern recognition technique of Nemes et al. (1999) to interpolate 50 µm data for EU-HYDI.

This pattern recognition technique involves recognizing samples in the external data set (later called 'donor sample(s)') that present the most similar distribution of particle fractions at the same size limits than the actual target sample. The sum of squared differences of the existing fractions between the target sample and each individual donor sample in the external database was used to judge what is most similar. Once that measure is generated, the donor samples are ranked by ascending order of their similarity, and a limited number of them (k) are selected for further calculations. In our application, as an enhancement to the original proposed technique, the number of selected samples (k) was not fixed, but was varied as a function of the number of available donor samples (N) as: $k=0.655*N^{0.493}$ , as recommended by Nemes et al. (2006a). The 50 µm fraction readings of the donor samples were then weighted in an inverse-distance based scheme (Nemes et al., 2006a), and the resulting weighted average value was used as the estimate for the target sample. Further details of this technique, its development and assessment for the estimation and interpolation of soil physical and hydraulic properties, and tests performed to evaluate its capabilities and robustness can be found in Nemes et al. 1999, 2006a, 2006b, 2010.

The database that provided the external donor samples was HYPRES, the database of soil hydraulic properties for Europe (Wösten et al., 1999). We were able to extract PSD data of 2978 suitable samples for the interpolation task. They represented different sequences of measured fractions, which could be donor samples for interpolating for different groups of EU-HYDI samples. For each sequence that needed interpolations, the pattern recognition technique could be used on a minimum of 309 and a maximum of 2240 samples as donors. Given that the method does not require any single PSD curves that exactly match the target curve but rather a distribution of similar shaped curves, these numbers are considered sufficient. When the target samples had only 3 or 4 points available on the PSD curve (e.g. Spain, Portugal, Scotland, Austria, some Norwegian and some Belgian samples), all points were always compared between the target sample and the donor samples. In most cases when 5 or more points were available, the comparison was made the same way. However, in few cases, there were no (or insufficient) donors with all matching data points available on the PSD curve. In such cases, having more donor samples but using one point fewer to assess similarity was preferred. This was typically the case for some of the UK data for which 0.2 µm measurements existed. It is noted, however, that the eliminated point was never a point that immediately neighboured the 50 µm target fraction.

There are a few additional notes to be added. First, it is noted again that data of any samples that were also included in HYPRES were not interpolated again; the existing interpolated values were imported from HYPRES. Second, we note that interpolations were only made for samples whose PSD data were assumedly correct. To judge that, it has been agreed by the contributors that we use a relatively strict criterion that only allows for rounding errors. Any PSD data that did not sum to between 99 and 101 per cent were assumed to be erroneous and were not interpolated. It is also noted that since the applied pattern recognition technique relies on selecting a number of samples as donors for estimation; the technique is suitable to provide not only an estimate but also a distribution measure (e.g. standard deviation) of any such estimates. Such uncertainty estimates may become desirable for certain future mapping or modelling applications, therefore developing and applying techniques that are capable of providing such measures may be seen as a potential extra benefit.

### 27.5.3 Obtaining an estimate of the 2 µm fraction

Data of three contributors required interpolation of the 2 µm fraction. In Ukraine, fractions of 1 and 5 µm have been determined; and in Slovakia, 1 and 10 µm fractions have been determined. For some soils in Italy, several points on the PSD curve were available in the 1 to 8 µm range, but the determined µm size limits varied irregularly.

For this interpolation task, the Slovakian partners proposed an empirical equation to be used for their data, which they developed locally. We declined to use that equation as we sought to use a standard method across the database that is not dependent on local properties of data of one partner, and because the technique would not have been applicable for the Italian data, as those do not contain the 1 µm fraction. The pattern recognition technique used for the interpolation of the 50 µm point was not feasible for use on the 2 µm fraction, due to not having sufficient donors in the available external data sources with the 1 µm fraction measured. Fitting a curve/spline was another possible alternative. However, since in each case there was only one point available in the zone finer than 2 µm, it was expected that the shape of the curve in that zone would have been near-linear, i.e. would not have differed much from that of a straight line. Hence, we have chosen to use a simple-to-apply log-linear interpolation (as in e.g. Leij et al., 1996) to estimate 2 µm particle fraction for soils of the listed contributors.

## 27.6 Water retention and hydraulic conductivity

The guidelines required raw water retention and hydraulic conductivity data, without any model assumption where possible. Given the large number of samples and the variability of measurement methods, the quality of the data was not properly assessed and no model was fitted on the data.

A column was however added to table RET to flag data that seemed unreliable. By default FLAG=1, meaning the entry can be trusted. Where some points of the retention curve fall obviously outside the rest of the curve, they are flagged as FLAG=0. It is important to note that that flag is not the outcome of an exhaustive control of the data. Not all curves were visually checked. It is therefore very likely that many unreliable data remain unflagged.

The user has the freedom to use all the data available or to filter them according to his/her preference, based on the flag mentioned above or creating a new filter.

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# 28 Annexes

Annex 1: Terms of reference (Report of the kick-off meeting updated at EU-HYDI workshop)

Annex 2: Guidelines for contributors

Annex 3: Conversions between organic carbon measurement methods

## Annex 1

# Terms of Reference
# EU-HYDI

Scientists from institutions from across Europe assembled in Ispra, Italy on the 12 April 2012 and again on 4-5 March 2013 with the goal to assemble a common European Hydropedological Data Inventory (EU-HYDI).

These scientists hereafter referred to as “the participants” listed by name and affiliation at the end of this document have agreed as follows:

## 1. Rationale

There is a common need for reliable hydropedological information in Europe.

In the last decades research institutes, universities and government agencies have developed local, regional and national datasets containing soil physical, chemical, hydrological and taxonomic information often combined with land use and landform data. A hydrological database for western European soils was also created in the mid-1990s. However, a comprehensive European hydropedological database, with possible additional information on chemical parameters and land use is still missing.

A comprehensive joint European hydropedological inventory can serve multiple purposes, including scientific research, modelling and application of models on different geographical scales.

The participants share the common interest to establish a joint database (the European Hydropedological Data Inventory – EU HYDI) with equal access rights for the advancement of hydropedological research and applications in Europe.

## 2. Objective

The objective of the joint effort of the participants is to establish the European Hydropedological Data Inventory (EU-HYDI), further referred to as “the database”. The database holds soil properties with a special but not exclusive focus on hydrological properties, i.e. soil moisture retention and hydraulic conductivity as functions of matric potential. Its main purpose is the calibration of pedotransfer functions (PTFs) for predicting soil hydrological and other soil properties at the European scale. Other applications are also foreseen. Therefore, it holds various other soil properties associated to the same samples that can be used as predictors in the PTFs and for other applications. Annex A gives an exhaustive list of those properties.

## 3. Forms of collaboration

Participants agree to open the possibility to contribute to the construction of the database on a voluntary basis according to the principles laid down in this document effective from 12/04/2012.

With the recognition of the need for a formal collaboration agreement by institutions of the participants, the participants might launch the process for the signature of such an agreement, which includes the elements agreed hereafter.

Participants agree to work towards setting up other means of support (e.g. proposals for research funds) to enhance and utilize the database.

# 4. Contribution and access to the database

## 4.1. Contribution to the database

Each participant contributes to the database according to its capacity. A minimum proportion of the original databases should be contributed based on the number of soil samples in the local source databases to avoid unbalances between data provision and access and to create a regionally and thematically well-adjusted database.

Between 200 and 2000, the number of data contributed, Nc, depends on the size of the source database, N:

$$Nc = 200 + \exp(-N/2000)*(N-200)$$

Above 2000, the number is fixed to a minimum of 900.

The proportion of data provided decreases with the size of the original dataset. For example:

| Original dataset size | Contributed dataset size | Proportion (%) |
|---:|---:|---:|
| 200 | 200 | 100 |
| 500 | 434 | 87 |
| 1000 | 685 | 69 |
| 2000 | 862 | 43 |
| 3000 | 900 | 30 |
| 5000 | 900 | 18 |

Voluntary offer of larger proportion of data or full databases is encouraged.

The participants try to make the best effort to provide variability and representativeness across the region their original data cover.

Stratification of the database, according to geographical distribution, texture or any other criteria, is left to the end-user of the database.

## 4.2. Access to the database

All raw data provided to the database are fully accessible only to the contributing participants and the JRC. The database based on voluntary contributions is only accessible to the voluntary contributors. The database is hosted at the European Soil Data Centre (ESDAC), at the Joint Research Centre (JRC). Copies are distributed to the participants.

Public data distribution, exclusively for non-commercial scientific research purposes and without exact geographical coordinates, will be considered in the future. The intellectual property rights remain with the data providers. When data are used, the participants are cited through authorship of the report specified below (see section 7). For uses of data originating from three or less institutions, the original data providers should be approached for offering co-authorship.

The participants assign the JRC to distribute the value added products, strictly excluding raw data, to third parties through ESDAC using a free open access procedure, including only a questionnaire for the registration of the user and the purpose of the use.

# 5. Project coordination

The JRC coordinates the efforts of all participants and holds the data in the ESDAC infrastructure.

## 6. Progress of the work

The EU-HYDI initiative remains open to new participants suggested by current. Potential contributors should contact the JRC.

Participants notify JRC whether they can contribute data on a voluntary basis.

All voluntary contributions are to be sent to JRC in the agreed format (see Annex A). JRC integrates all contributions in a unique database. The database will be ready and shared among all voluntary participants by 15/07/2013.

Further effort based on formal collaboration agreements between JRC and the participants' institutions will be specified after the signature of such agreements.

## 7. Reports and publications

The participants will produce together a report describing the database. The first version of the database EU-HYDI 1.0, based on the voluntary contributions will be published in this report.

The participants are free to publish any research paper individually or in cooperation with each-other or external partners; given that the database is not distributed outside the participating institutions and external partners can access only derivatives for joint publications.

The Joint Research Centre develops and publishes pedotransfer rules and functions for continental scale applications.

## 8. Funding possibilities

### 8.1. Meetings

The JRC funded the organisation of two meetings for which it financed travel, accommodation and daily allowances of the participants.

### 8.2. Database

JRC is attempting to contribute to the effort of local database developments, including data harmonization and formatting of the data to the agreed database structure (Annex A).

Further formal financial commitment is to be investigated.

## 9. List of participants of the EU-HYDI projects

The following participants take part in the EU-HYDI initiative and agree to the terms of reference of the project as explained in this document.

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|---|---|---|---|
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| | | | |
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# 10. Annexes

The database structure, which lies down the requirements for the harmonized data provision, is provided in Annex 2: European Hydropedological Inventory (EU-HYDI) Guidelines for contributors Version 1.2

Ispra, 05/03/2013

# Annex 2

# **Eu**ropean **Hy**dropedological **D**ata **I**nventory (EU-HYDI)

Guidelines for contributors
Version 1.2

*The EU-HYDI Team*

# 1. Introduction to the database and its general structure

The European Hydropedological Data Inventory (EU-HYDI) is a database containing information on hydrological and other related properties of soils of Europe.

The EU-HYDI is a relational database. Its nine tables (Table 1) contain different types of information regarding the soil profiles, horizons and samples. Unique keys identify each profile and each horizon and allow the user to establish relationships between the different tables.

Table 1: List of tables in EU-HYDI database

| | Description |
|---|---|
| GENERAL | General profile properties |
| BASIC | Basic and physical data at the sampling layer level |
| CHEMICAL | Chemical data at the sampling layer level |
| PSIZE | Measured particle size distribution data at the sampling layer level |
| RET | Measured soil water retention data at the sampling layer level |
| COND | Measured soil hydraulic conductivity data at the sampling layer level |
| METHOD | Measurement methods |
| TSERMETA | Time series metadata |
| TSERDATA | Time series data |

**Important!** In the tables described hereafter, the mandatory fields are marked with a star (*). All other fields are to be filled if the data are available. When no data are available, the convention is the following: for text data, use ND; for numbers, -999 .

The database is compiled and hosted at the Joint Research Centre of the European Commission. Participants submit their contributions as a series of flat tables according to the following instructions and helping themselves with the attached templates. The accepted formats are Microsoft Excel sheets in one workbook (*.xls, *.xlsx), Coma separated files (*.csv) or Tab separated files (*.txt). The data are delivered to the JRC on a CD-ROM/DVD (att.: Gergely Toth TP 280, Joint Research Centre, Institute for Environment and Sustainability, Via E. Fermi 2749, 21027 Ispra (VA), Italy) and also sent by email to Gergely Toth (gergely.toth@jrc.ec.europa.eu).

# 2. General properties

The GENERAL table contains information which is valid for the entire soil profile. Table 2 provides a summary description of the attributes held in table GENERAL.

Table 2: GENERAL

| NAME | DESCRIPTION | TYPE | SIZE |
|---|---|---|---|
| **PROFILE_ID*** | Profile identification (primary key) | integer | 8 |
| **LOC_COOR_X*** | Local coordinates X or longitude | text | 30 |
| **LOC_COOR_Y*** | Local coordinates Y or latitude | text | 30 |
| **LOC_COOR_SYST*** | Local coordinate system | text | 50 |
| **X_WGS84*** | GPS coordinates (WGS84) longitude in decimal degree | real number | 3.6 |
| **Y_WGS84*** | GPS coordinates (WGS84) latitude in decimal degree | real number | 2.6 |
| **ELEV** | Elevation above sea level (meter) | integer | 4 |
| **ISO_COUNTRY*** | Country code (ISO3166-1alpha-2) | text | 2 |
| **RC_L1*** | Region code level1 (NUTS1, OBLAST) | text | 3 |
| **RC_L2*** | Region code level2 (NUTS2, RAION) | text | 4 |
| **LC_L1** | Land Cover at sampling location (LUCAS)level 1 | text | 3 |
| **LC_L2** | Land Cover at sampling location (LUCAS)level 2 | text | 3 |

| | | | |
|---|---|---|---|
| **LC_L3** | Land Cover at sampling location (LUCAS)level 3 | text | 3 |
| **LU_L1** | Land Use at sampling location (LUCAS) level 1 | text | 4 |
| **LU_L2** | Land Use at sampling location (LUCAS) level 2 | text | 4 |
| **SITE_LANDFORM** | Major land form code (FAO guidelines) | text | 2 |
| **SITE_SLOP_POS** | Slope position code (FAO guidelines) | text | 2 |
| **SITE_SLOP_FORM** | Slope form code (FAO guidelines) | text | 1 |
| **SITE_SLOP_GRAD** | Slope gradient code (FAO guidelines) | text | 2 |
| **SRF_ROCK_COV** | Soil surface: rock outcrops: cover (FAO guidelines) | text | 1 |
| **SRF_ROCK_DIS** | Soil surface: rock outcrops: distance (FAO guidelines) | integer | |
| **SRF_COAR_COV** | Soil surface: coarse fragments: cover (FAO guidelines) | text | 1 |
| **SRF_COAR_SIZ** | Soil surface: coarse fragments: size (FAO guidelines) | text | 1 |
| **SRF_ERO_CAT** | Soil surface: erosion: category (FAO guidelines) | text | 2 |
| **SRF_ERO_COV** | Soil surface: erosion: cover (FAO guidelines) | integer | |
| **SRF_ERO_DEG** | Soil surface: erosion: degree (FAO guidelines) | text | 1 |
| **SRF_ERO_ACT** | Soil surface: erosion: activity (FAO guidelines) | text | 1 |
| **SRF_SEAL_THIC** | Soil surface: sealing: thickness (FAO guidelines) | text | 1 |
| **SRF_SEAL_CON** | Soil surface: sealing: consistence (FAO guidelines) | text | 1 |
| **SRF_CRAC_WID** | Soil surface: cracks: width (FAO guidelines) | text | 1 |
| **SRF_CRAC_DEP** | Soil surface: cracks: depth (FAO guidelines) | text | 1 |
| **SRF_CRAC_DIS** | Soil surface: cracks: distance (FAO guidelines) | text | 1 |
| **SRF_SAL_COV** | Soil surface: salt: cover (FAO guidelines) | integer | |
| **SRF_SAL_THIC** | Soil surface: salt: thickness (FAO guidelines) | text | 1 |
| **PARMAT** | Parent material code (ESDB2002): 4numbers | number | integer |
| **AGE** | Age of land surface (FAO guidelines) | text | 3 |
| **WRB2006_RSG** | WRB 2006 classification code – reference soil group | text | 2 |
| **WRB2006_PQ1** | WRB 2006 classification code – first prefix qualifier | text | 2 |
| **WRB2006_PQ2** | WRB 2006 classification code – second prefix qualifier | text | 2 |
| **WRB2006_PQ3** | WRB 2006 classification code – third prefix qualifier | text | 2 |
| **WRB2006_SQ1** | WRB 2006 classification code – first suffix qualifier | text | 2 |
| **WRB2006_SQ2** | WRB 2006 classification code – second suffix qualifier | text | 2 |
| **WRB2006_SQ3** | WRB 2006 classification code – third suffix qualifier | text | 2 |
| **WRB1998_RSG** | WRB 1998 classification code – reference soil group | text | 2 |
| **WRB1998_ADJSPE1** | WRB 1998 classification code – first soil unit adjective with specifier | text | 3 |
| **WRB1998_ADJSPE2** | WRB 1998 classification code – second soil unit adjective with specifier | text | 3 |
| **WRB1998_ADJSPE3** | WRB 1998 classification code – third soil unit adjective with specifier | text | 3 |
| **WRB1998_ADJSPE4** | WRB 1998 classification code – fourth soil unit adjective with specifier | text | 3 |
| **WRB1998_ADJSPE5** | WRB 1998 classification code – fifth soil unit adjective with specifier | text | 3 |
| **WRB1998_ADJSPE6** | WRB 1998 classification code – sixth soil unit adjective with specifier | text | 3 |
| **NAT_CLAS** | National classification name | text | 100 |
| **NAT_CLAS_REF** | National classification reference | text | 300 |
| **YEAR** | Year of sampling | number | integer |
| **MONTH** | Month of sampling [1,12] | number | integer |
| **DAY** | Day of sampling [1,31] | number | integer |
| **SURVEYOR_P** | Surveyor | text | 50 |

| | | | |
|---|---|---|---|
| **PUBL_REF** | Publication reference | text | 300 |
| **CONTACT_P*** | Contact person | text | 50 |
| **CONTACT_A** | Contact address | text | 150 |
| **EMAIL*** | Contact e-mail | text | 40 |
| **REL_ID** | Related profiles (comma separated PROFILE IDs) | text | 100 |
| **REL_T_SER** | Related time series | text | 20 |
| **COMMENTS1** | Comment 1 | text | 150 |
| **COMMENTS2** | Comment 2 | text | 150 |
| **COMMENTS3** | Comment 3 | text | 150 |

## 2.1. Profile identifier (PROFILE_ID*)

The profile identification code is composed of 8 digits. The first 3 are the ISO 3166 numeric country code (see Table 3) and the 5 others identify the profile in the country.

## 2.2. Coordinates*(LOC_COOR_X, LOC_COOR_Y, LOC_COOR_SYST or X_WGS84 and Y_WGS84)

Coordinates, at least approximative, has to be provided. The GPS coordinates in WGS84, degraded to a precision of 1000 m for privacy reasons, are preferred. If they are not available, coordinates can be given in a local coordinate system, but this has to be documented in LOC COOR SYST. If possible LOC_COOR_SYST has to be given as epsg code (example: “Projected CRS epsg::3035” for ETRS89 / LAEA Europe). The codes can be found on the EPSG geodetic parameter repository: http://www.epsg-registry.org/

## 2.3. Elevation (ELEV)

Elevation above see level is given in meters.

## 2.4. ISO ountry code (ISO_COUNTRY*)

Country code according to ISO 3166 alpha 2. See Table 3.

Table 3: ISO 3166 country codes

| | Alpha_2 | Numeric |
|---|---|---|
| Åland Islands | AX | 248 |
| Albania | AL | 008 |
| Andorra | AD | 020 |
| Armenia | AM | 051 |
| Austria | AT | 040 |
| Azerbaijan | AZ | 31 |
| Belarus | BY | 112 |
| Belgium | BE | 56 |
| Bosnia and Herzegovina | BA | 70 |
| Bulgaria | BG | 100 |
| Croatia | HR | 191 |
| Cyprus | CY | 196 |
| Czech Republic | CZ | 203 |
| Denmark | DK | 208 |
| Estonia | EE | 233 |
| Faroe Islands | FO | 234 |
| Finland | FI | 246 |
| France | FR | 250 |
| Georgia | GE | 268 |
| Germany | DE | 276 |
| Gibraltar | GI | 292 |

| | | |
|---|---|---|
| Greece | GR | 300 |
| Guernsey | GG | 831 |
| Holy See (Vatican City State) | VA | 336 |
| Hungary | HU | 348 |
| Iceland | IS | 352 |
| Ireland | IE | 372 |
| Isle of Man | IM | 833 |
| Italy | IT | 380 |
| Jersey | JE | 832 |
| Kazakhstan | KZ | 398 |
| Latvia | LV | 428 |
| Liechtenstein | LI | 438 |
| Lithuania | LT | 440 |
| Luxembourg | LU | 442 |
| Macedonia | MK | 807 |
| Malta | MT | 470 |
| Moldova | MD | 498 |
| Monaco | MC | 492 |
| Montenegro | ME | 499 |
| Netherlands | NL | 528 |
| Norway | NO | 578 |
| Poland | PL | 616 |
| Portugal | PT | 620 |
| Romania | RO | 642 |
| Russian Federation | RU | 643 |
| San Marino | SM | 674 |
| Serbia | RS | 688 |
| Slovakia | SK | 703 |
| Slovenia | SI | 705 |
| Spain | ES | 724 |
| Svalbard and Jan Mayen | SJ | 744 |
| Sweden | SE | 752 |
| Switzerland | CH | 756 |
| Turkey | TR | 792 |
| Ukraine | UA | 804 |
| United Kingdom | GB | 826 |

## 2.5. Region codes (RC_L1*, RC_L2*)

Level 1 and level 2 NUTS codes are given for EU countries.

See http://epp.eurostat.ec.europa.eu/portal/page/portal/nuts_nomenclature/introduction.

For non-EU countries (RU and UA) OBLAST and RAION should be given instead.

## 2.6. Land cover and land use (LC_1, LC_2, LC_3, LU_1, LU_2)

Land use and land cover according to the LUCAS 2009 classification. In LUCAS (Land Use /Cover Area frame statistical Survey, EUROSTAT (2009)), land use and land cover are coded using a three levels nomenclature (see http: //epp.eurostat.ec.europa.eu/portal/page/portal/lucas/documents /Nomenclature_LUCAS2009_C_3.pdf).

## 2.7. Site description (SITE_LANDFORM, SITE_SLOP_POS, SITE_SLOP_FORM, SITE_SLOP_GRAD)

The site description is done according to the FAO guidelines (FAO, 2006). The codes used for the various features can be found in the document mentioned before, in the tables referred to in Table 4.

Table 4: References of tables and figures to code the site description and soil features are from the FAO guidelines for soil description (FAO 2006)

| NAME | | Table(s) | Figure(s) | Page |
|---|---|---|---|---|
| SITE_LANDFORM | | T4-T5 | | 11 |
| SITE_SLOP_POS | | | F2 | 12 |
| SITE_SLOP_FORM | | T6 | F3 | 12 |
| SITE_SLOP_GRAD | | T7 | | 12 |
| SRF_ROCK_COV | | T14 | | 21 |
| SRF_ROCK_DIS | | T14 | | 21 |
| SRF_COAR_COV | | T15 | | 22 |
| SRF_COAR_SIZ | | T15 | | 22 |
| SRF_ERO_CAT | | T16 | | 22 |
| SRF_ERO_COV | | T17 | | 22 |
| SRF_ERO_DEG | | T18 | | 22 |
| SRF_ERO_ACT | | T19 | | 23 |
| SRF_SEAL_THIC | | T20 | | 23 |
| SRF_SEAL_CON | | T20 | | 23 |
| SRF_CRAC_WID | | T21 | | 24 |
| SRF_CRAC_DEP | | T21 | | 24 |
| SRF_CRAC_DIS | | T21 | | 24 |
| SRF_SAL_COV | | T22 | | 24 |
| SRF_SAL_THIC | | T22 | | 24 |
| AGE | | T13 | | 19 |
| STRUCTURE1 / STRUCTURE2 | grade | T47 | | 45 |
| | size | T50-T51 | | 47 |
| | shape | T49 | F6 | 46 |
| STR_COMB | | T52 | | 47 |

## 2.8. Soil surface (SRF_ROCK_COV, SRF_ROCK_DIS, SRF_COAR_COV, SRF_COAR_SIZ, SRF_ERO_CAT, SRF_ERO_COV, SRF_ERO_DEG, SRF_ERO_ACT, SRF_SEAL_THIC, SRF_SEAL_CON, SRF_CRAC_WID, SRF_CRAC_DEP, SRF_CRAC_DIS, SRF_SAL_COV, SRF_SAL_THIC)

The soil surface is described according to the FAO guidelines (FAO, 2006). The codes used for the various features can be found in the document mentioned before, in the tables referred to in Table 4.

## 2.9. Parent material (PAR_MAT)

Parent material is coded following the nomenclature used in the European Soil Database (EC, 2003; Lambert et al., 2003): 4 digits corresponding to the major class level, the group level, the type level and the sub-type level respectively. Table 5 gives the codes.

Table 5: Nomenclature of parent material (PAR_MAT) following (ESDB)

| **Major class level** | | **Group level** | | **Type level** | | **Sub-type level** | |
|---|---|---|---|---|---|---|---|
| 0000 | No information | 0000 | No information | 0000 | No information | 0000 | No information |
| 1000 | Consolidated clastic sedimentary rocks | 1100 | psephite or rudite | 1110 | conglomerate | 1111 | pudding stone |
| | | | | 1120 | breccia | | |
| | | 1200 | psammite or arenite | 1210 | sandstone | 1211 | calcareous sandstone |
| | | | | | | 1212 | ferruginous sandstone |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | 1213 | clayey sandstone |
| | | | | | | 1214 | quartzitic sandstone / orthoquartzite |
| | | | | | | 1215 | micaceous sandstone |
| | | | | | | 1216 | feldspathic sandstone |
| | | | | 1220 | arkose | | |
| | | | | 1230 | greywacke | 1231 | feldspathic greywacke |
| | | 1300 | pelite, lutite or agillite | 1310 | claystone/ mudstone | 1311 | kaolinite |
| | | | | | | 1312 | bentonite |
| | | | | 1320 | siltstone | | |
| | | 1400 | facies bound rocks | 1410 | flysch | 1411 | sandy flysch |
| | | | | | | 1412 | clayey and silty flysch |
| | | | | | | 1413 | conglomeratic flysch |
| | | | | 1420 | molasse | | |
| 2000 | Sedimentary rocks (chemically precipitated, evaporated, or of organogenic or biogenic origin) | 2100 | calcareous rocks | 2110 | limestone | 2111 | hard limestone |
| | | | | | | 2112 | soft limestone |
| | | | | | | 2113 | marly limestone |
| | | | | | | 2114 | chalky limestone |
| | | | | | | 2115 | detritial limestone |
| | | | | | | 2116 | carbonaceous limestone |
| | | | | | | 2117 | lacustrine or freshwater limestone |
| | | | | | | 2118 | travertine / calcareous sinter |
| | | | | | | 2119 | cavernous limestone |
| | | | | 2120 | dolomite | 2121 | cavernous dolomite |
| | | | | | | 2122 | calcareous dolomite |
| | | | | 2130 | marlstone | | |
| | | | | 2140 | marl | 2141 | chalk marl |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | | | 2142 | gypsiferous marl |
| | | | | 2150 | chalk | | |
| | | 2200 | evaporites | 2210 | gypsum | | |
| | | | | 2220 | anhydrite | | |
| | | | | 2230 | halite | | |
| | | 2300 | siliceous rocks | 2310 | chert, hornstone, flint | | |
| | | | | 2320 | diatomite / radiolarite | | |
| 3000 | Igneous rocks | 3100 | acid to intermediate plutonic rocks | 3110 | granite | | |
| | | | | 3120 | granodiorite | | |
| | | | | 3130 | diorite | 3131 | quartz diorite |
| | | | | | | 3132 | gabbro diorite |
| | | | | 3140 | syenite | | |
| | | 3200 | basic plutonic rocks | 3210 | gabbro | | |
| | | 3300 | ultrabasic plutonic rocks | 3310 | peridotite | | |
| | | | | 3320 | pyroxenite | | |
| | | 3400 | acid to intermediate volcanic rocks | 3410 | rhyolite | 3411 | obsidian |
| | | | | | | 3412 | quartz porphyrite |
| | | | | 3420 | dacite | | |
| | | | | 3430 | andesite | 3431 | porphyrite (interm.) |
| | | | | 3440 | phonolite | 3441 | tephritic phonolite |
| | | | | 3450 | trachyte | | |
| | | 3500 | basic to ultrabasic volcanic rocks | 3510 | basalt | | |
| | | | | 3520 | diabase | | |
| | | | | 3530 | pikrite | | |
| | | 3600 | dike rocks | 3610 | aplite | | |
| | | | | 3620 | pegmatite | | |
| | | | | 3630 | lamprophyre | | |
| | | 3700 | pyroclastic rocks (tephra) | 3710 | tuff / tuffstone | 3711 | agglomoratic tuff |
| | | | | | | 3712 | block tuff |
| | | | | | | 3713 | lapilli tuff |
| | | | | 3720 | tuffite | 3721 | sandy tuffite |
| | | | | | | 3722 | silty tuffite |
| | | | | | | 3723 | clayey tuffite |
| | | | | 3730 | volcanic scoria / volcanic breccia | | |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | 3740 | volcanic ash | | |
| | | | | 3750 | ignimbrite | | |
| | | | | 3760 | pumice | | |
| 4000 | Metamorphic rocks | 4100 | weakly metamorphic rocks | 4110 | (meta-)shale / argillite | | |
| | | | | 4120 | slate | 4121 | graphitic slate |
| | | 4200 | acid regional metamorphic rocks | 4210 | (meta-)quartzite | 4211 | quartzite schist |
| | | | | 4220 | phyllite | | |
| | | | | 4230 | mica schist | | |
| | | | | 4240 | gneiss | | |
| | | | | 4250 | granulite (sensu stricto) | | |
| | | | | 4260 | migmatite | | |
| | | 4300 | basic regional metamorphic rocks | 4310 | greenschist | 4311 | prasinite |
| | | | | | | 4312 | chlorite schist |
| | | | | | | 4313 | talc schist |
| | | | | 4320 | amphibolite | | |
| | | | | 4330 | eclogite | | |
| | | 4400 | ultrabasic regional metamorphic rocks | 4410 | serpentinite | 4411 | greenstone |
| | | 4500 | calcareous regional metamorphic rocks | 4510 | marble | | |
| | | | | 4520 | calcschist, skarn | | |
| | | 4600 | rocks formed by contact metamorphism | 4610 | contact slate | 4611 | nodular slate |
| | | | | 4620 | hornfels | | |
| | | | | 4630 | calcsilicate rocks | | |
| | | 4700 | tectogenetic metamorphic rocks or cataclastic metamorphism | 4710 | tectonic breccia | | |
| | | | | 4720 | cataclasite | | |
| | | | | 4730 | mylonite | | |
| 5000 | Unconsolidated deposits (alluvium, weathering residuum and slope deposits) | 5100 | marine and estuarine sands | 5110 | pre-Quaternary sand | 5111 | Tertiary sand |
| | | | | 5120 | Quaternary sand | 5121 | Holocene coastal sand with shells |
| | | | | | | 5122 | delta sand |
| | | 5200 | marine and estuarine clays and silts | 5210 | pre-Quaternary clay and silt | 5211 | Tertiary clay |
| | | | | | | 5212 | Tertiary silt |

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | | | | 5220 | Quaternary clay and silt | 5221 | Holocene clay |
| | | | | | | 5222 | Holocene silt |
| | | 5300 | fluvial sands and gravels | 5310 | river terrace sand or gravel | 5311 | river terrace sand |
| | | | | | | 5312 | river terrace gravel |
| | | | | 5320 | flood plain sand or gravel | 5321 | flood plain sand |
| | | | | | | 5322 | flood plain gravel |
| | | | | | | 5323 | floodplain loam |
| | | | | | | 5324 | floodplain clay and silt |
| | | 5400 | fluvial clays, silts and loams | 5410 | river clay and silt | 5411 | terrace clay and silt |
| | | | | | | 5412 | terrace loam |
| | | | | 5420 | overbank deposits | 5421 | overbank clay and silt |
| | | | | | | 5432 | overbank loam |
| | | 5500 | lake deposits | 5510 | lake sand and delta sand | | |
| | | | | 5520 | lake marl, bog lime | | |
| | | | | 5530 | lake silt | | |
| | | 5600 | residual and redeposited loams from silicate rocks | 5610 | residual loam | 5611 | stony loam |
| | | | | | | 5612 | clayey loam |
| | | | | 5620 | redeposited loam | 5621 | running-ground |
| | | 5700 | residual and redeposited clays from calcareous rocks | 5710 | residual clay | 5711 | clay with flints |
| | | | | | | 5712 | ferruginous residual clay |
| | | | | | | 5713 | calcareous clay |
| | | | | | | 5714 | non-calcareous clay |
| | | | | | | 5715 | marly clay |
| | | | | 5720 | redeposited clay | 5721 | stony clay |
| | | 5800 | slope deposits | 5810 | slope-wash alluvium | | |
| | | | | 5820 | colluvial deposits | | |

|  |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|
|  |  |  |  | 5830 | talus scree | 5831 | stratified slope deposit |
| 6000 | Unconsilidated glacial deposits / glacial drift | 6100 | morainic deposits | 6110 | glacial till | 6111 | boulder clay |
|  |  |  |  | 6120 | glacial debris |  |  |
|  |  | 6200 | glaciofluvial deposits | 6210 | outwash sand, glacial sand |  |  |
|  |  |  |  | 6220 | outwash gravel, glacial gravel |  |  |
|  |  | 6300 | glaciolacustrine deposits | 6310 | varves |  |  |
| 7000 | Eolian deposits | 7100 | loess | 7110 | loamy loess |  |  |
|  |  |  |  | 7120 | sandy loess |  |  |
|  |  | 7200 | eolian sands | 7210 | dune sand |  |  |
|  |  |  |  | 7220 | cover sand |  |  |
| 8000 | Organic materials | 8100 | peat (mires) | 8110 | rainwater fed moor peat (raised bog) | 8111 | folic peat |
|  |  |  |  |  |  | 8112 | fibric peat |
|  |  |  |  |  |  | 8113 | terric peat |
|  |  |  |  | 8120 | groundwater fed bog peat |  |  |
|  |  | 820 8 200 | slime and ooze deposits | 8210 | gyttja, sapropel |  |  |
|  |  | 8300 | carbonaceaous rocks (caustobiolite) | 8310 | lignite (brown coal) |  |  |
|  |  |  |  | 8320 | hard coal |  |  |
|  |  |  |  | 8330 | anthracite |  |  |
| 9000 | Anthropogenic deposits | 9100 | redeposited natural materials | 9110 | sand and gravel fill |  |  |
|  |  |  |  | 9120 | loamy fill |  |  |
|  |  | 9200 | dump deposits | 9210 | rubble / rubbish |  |  |
|  |  |  |  | 9220 | industrial ashes and slag |  |  |
|  |  |  |  | 9230 | industrial sludge |  |  |
|  |  |  |  | 9240 | industrial waste |  |  |
|  |  | 9300 | organic materials |  |  |  |  |

## 2.10. Age of soil (AGE)

The FAO guidelines for soil description (FAO, 2006) propose a nomenclature for coding the age of soil (see Table 4 for reference).

## 2.11. Soil type (WRB2006_RSG, WRB2006_PQ1, WRB2006_PQ2, WRB2006_PQ3, WRB2006_SQ1, WRB2006_SQ2, WRB2006_SQ3, WRB1998_RSG, WRB1998_ADJSPE1, WRB1998_ADJSPE2, WRB1998_ADJSPE3, WRB1998_ADJSPE4, WRB1998_ADJSPE5, WRB1998_ADJSPE6, NAT_CLAS, NAT_CLAS_REF)

Soil type information using the nomenclature of the World Reference Base for Soil Resources 2006 (WRB2006; IUSS Working Group 2006) is to be provided in columns starting with WRB2006. The levels are given as codes of the WRB reference soil group (RSG) with prefix (WRB2006_PQ1, 2, 3) and suffix qualifiers (WRB2006_SQ1, 2, 3). Codes of reference soil groups and qualifiers can be found in Table 6 and 7 (reference: WRB2006 guide: ftp://ftp.fao.org/docrep/fao/009/a0510e/a0510e00.pdf.) The possible prefix and suffix qualifiers and the order of them for each RSG are listed in Chapter 3 (page 53-65) of the WRB2006 guide. An example is given in Figure 1 for the coding of WRB2006 name.

| WRB2006 name | WRB2006_RSG | WRB2006_PQ1 | WRB2006_PQ2 | WRB2006_PQ3 | WRB2006_SQ1 | WRB2006_SQ2 | WRB2006_SQ3 |
|---|---|---|---|---|---|---|---|
| Stagnic Leptic Cutanic **Luvisol** (Ruptic, Humic, Chromic) | LV | ct | le | st | rp | hu | cr |

Figure 1: Example of coding of WRB2006 name.

Table 6: WRB2006's reference soil groups and their coding

| RSG | Code | RSG | Code | RSG | Code | RSG | Code |
|---|---|---|---|---|---|---|---|
| Acrisol | AC | Chernozem | CH | Kastanozem | KS | Podzol | PZ |
| Albeluvisol | AB | Cryosol | CR | Leptosol | LP | Regosol | RG |
| Alisol | AL | Durisol | DU | Lixisol | LX | Solonchak | SC |
| Andosol | AN | Ferralsol | FR | Luvisol | LV | Solonetz | SN |
| Anthrosol | AT | Fluvisol | FL | Nitisol | NT | Stagnosol | ST |
| Arenosol | AR | Gleysol | GL | Phaeozem | PH | Technosol | TC |
| Calcisol | CL | Gypsisol | GY | Planosol | PL | Umbrisol | UM |
| Cambisol | CM | Histosol | HS | Plinthosol | PT | Vertisol | VR |

Table 7: List of WRB2006's prefix and suffix qualifiers and their coding

| Qualifier | Code | Qualifier | Code | Qualifier | Code | Qualifier | Code | Qualifier | Code |
|---|---|---|---|---|---|---|---|---|---|
| Abruptic | ap | Endofluvic | nf | Hemic | hm | Mollic | mo | Salic | sz |
| Aceric | ae | Endogleyic | ng | Histic | hi | Molliglossic | mi | Sapric | sa |
| Acric | ac | Endoleptic | nl | Hortic | ht | Natric | na | Silandic | sn |
| Acroxic | ao | Endosalic | ns | Humic | hu | Nitic | ni | Siltic | sl |
| Albic | ab | Entic | et | Hydragric | hg | Novic | nv | Skeletic | sk |
| Alcalic | ax | Epidystric | ed | Hydric | hy | Nudilithic | nt | Sodic | so |
| Alic | al | Epieutric | ee | Hdrophobic | hf | Ombric | om | Solodic | sc |
| Aluandic | aa | Epileptic | el | Hyperalbic | ha | Ornithic | oc | Sombric | sm |
| Alumic | au | Episalic | ea | Hyperalic | hl | Ortsteinic | os | Spodic | sd |
| Andic | an | Escalic | ec | Hypercalcic | hc | Oxyaquic | oa | Spolic | sp |
| Anthraquic | aq | Eutric | eu | Hyperdystric | hd | Pachic | ph | Stagnic | st |
| Anthric | am | Eutrosilic | es | Hypereutric | he | Pellic | pe | Sulphaquatic | sq |
| Arenic | ar | Ferralic | fl | Hypergypsic | hp | Petric | pt | Sulphatic | su |
| Aric | ai | Ferric | fr | Hyperochric | ho | Petrocalcic | pc | Takyric | ty |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Aridic | ad | Fibric | fi | Hypersalic | hs | Petroduric | pd | Technic | te |
| Arzic | az | Floatic | ft | Hyperskeletic | hk | Petrogleyic | py | Tephric | tf |
| Brunic | br | Fluvic | fv | Hypocalcic | wc | Petrogypsic | pg | Terric | tr |
| Calcaric | ca | Folic | fo | Hypogypsic | wg | Petroplinthic | pp | Thaptandic | ba |
| Calcic | cc | Fractipetric | fp | Hypoluvic | wl | Petrosalic | ps | Thaptovitric | bv |
| Cambic | cm | Fractiplinthic | fa | Hyposalic | ws | Pisoplinthic | px | Thionic | ti |
| Carbic | cb | Fragic | fg | Hyposodic | wn | Placic | pi | Thixotropic | tp |
| Carbonatic | cn | Fulvic | fu | Irragric | ir | Plaggic | pa | Tidalic | td |
| Chloridic | cl | Garbic | ga | Lamellic | II | Plinthic | pl | Toxic | tx |
| Chromic | cr | Gelic | ge | Laxic | la | Posic | po | Transportic | tn |
| Clayic | ce | Gelistagnic | gt | Leptic | le | Profondic | pf | Turbic | tu |
| Colluvic | co | Geric | gr | Lignic | lg | Protic | pr | Umbric | um |
| Cryic | cy | Gibbsic | gi | Limnic | lm | Puffic | pu | Umbriglossic | ug |
| Cutanic | ct | Glacic | gc | Linic | lc | Reductaquic | ra | Urbic | ub |
| Densic | dn | Gleyic | gl | Lithic | li | Reductic | rd | Vermic | vm |
| Drainic | dr | Glossalbic | gb | Lixic | Ix | Regic | rg | Vertic | vr |
| Duric | du | Glossic | gs | Luvic | Iv | Rendzic | rz | Vetic | vt |
| Dystric | dy | Greyic | gz | Magnesic | mg | Rheic | rh | Vitric | vi |
| Ekranic | ek | Grumic | gm | Manganiferric | mf | Rhodic | ro | Voronic | vo |
| Endoduric | nd | Gypsic | gy | Mazic | mz | Rubic | ru | Xanthic | xa |
| Endodystric | ny | Gypsiric | gp | Melanic | ml | Ruptic | rp | Yermic | ye |
| Endoeutric | ne | Haplic | ha | Mesotrophic | ms | Rustic | rs | | |

If information is available on WRB1998 classification - and especially if it is not possible to convert it into WRB2006 due to several changes applied on definition of diagnostic horizons and reference soil groups - columns describing WRB1998 soil type should be filled. The WRB1998 reference soil group name, soil unit adjective and specifier are given with codes, an example can be found in Figure 2. Please find the code of the reference soil groups, soil unit adjectives and specifiers in Table 8, 9 and 10. (Reference: WRB 1998.

http://www.fao.org/docrep/W8594E/w8594e0h.htm#appendix%202:%20codes%20for%20the%20reference%20soil%20groups%20and%20soil%20subunits)

WRB1998_ADJSPE1, 2, 3, 4 contains information about soil unit adjectives and specifiers (if the adjective has specifier). It is string and consists of three characters. The first two is for the soil unit adjective, the third is for the specifier (Figure 3). If there is no specifier, the third character it is left blank.

Any other local soil classification can be given in NAT_CLAS, provinding its reference in NAT_CLAS_REF.

| WRB1998 name | WRB1998_ RSG | WRB1998_ ADJSPE1 | WRB1998_ ADJSPE2 | WRB1998_ ADJSPE3 | WRB1998_ ADJSPE4 | WRB1998_ ADJSPE5 | WRB1998_ ADJSPE6 |
|---|---|---|---|---|---|---|---|
| Acri-Geric Ferralsol (Abruptic and Xanthic) | FR | gr | ac | ap | xa | ND | ND |

Figure 2: Example of coding of WRB1998 name.

| Name of soil unit adjective and specifier | Code | | |
|---|---|---|---|
| hyperalbic | a | b | h |
| umbric | u | m | |

Figure 3: Examples for coding of soil unit adjectives and specifiers for WRB1998

Table 8: List of the reference soil group codes according to WRB1998.

| RSG | Code | RSG | Code | RSG | Code |
|---|---|---|---|---|---|
| Acrisol | AC | Durisol | DU | Nitisol | NT |
| Albeluvisol | AB | Ferralsol | FR | Phaeozem | PH |
| Alisol | AL | Fluvisol | FL | Planosol | PL |
| Andosol | AN | Gleysol | GL | Plinthosol | PT |
| Anthrosol | AT | Gypsisol | GY | Podzol | PZ |
| Arenosol | AR | Histosol | HS | Regosol | RG |
| Calcisol | CL | Kastanozem | KS | Solonchak | SC |
| Cambisol | CM | Leptosol | LP | Solonetz | SN |
| Chernozem | CH | Lixisol | LX | Umbrisol | UM |
| Cryosol | CR | Luvisol | LV | Vertisol | VR |

Table 9: Soil unit adjectives codes according to WRB1998.

| Adjective | Code | Adjective | Code | Adjective | Code | Adjective | Code | Adjective | Code |
|---|---|---|---|---|---|---|---|---|---|
| Abruptic | ap | Densic | dn | Haplic | ha | Pellic | pe | Siltic | sl |
| Aceric | ae | Duric | du | Histic | hi | Petric | pt | Skeletic | sk |
| Acric | ac | Dystric | dy | Hortic | ht | Petrocalcic | pc | Sodic | so |
| Acroxic | ao | Entic | et | Humic | hu | Petroduric | pd | Spodic | sd |
| Albic | ab | Eutric | eu | Hydragric | hg | Petrogypsic | pg | Spolic | sp |
| Alcalic | ax | Eutrisilic | es | Hydric | hy | Petroplinthic | pp | Stagnic | st |
| Alic | al | Ferralic | fl | Hyperskeletic | hk | Petrosalic | ps | Sulphatic | su |
| Alumic | au | Ferric | fr | Irragric | ir | Placic | pi | Takyric | ty |
| Andic | an | Fibric | fi | Lamellic | II | Plaggic | pa | Tephric | tf |
| Anthraquic | aq | Fluvic | fv | Leptic | le | Planic | pn | Terric | tr |
| Anthric | am | Folic | fo | Lithic | li | Plinthic | pl | Thionic | ti |
| Anthropic | ah | Fragic | fg | Lixic | Ix | Posic | po | Toxic | tx |
| Arenic | ar | Fulvic | fu | Luvic | Iv | Profondic | pf | Turbic | tu |
| Aric | ai | Garbic | ga | Magnesic | mg | Protic | pr | Umbric | um |
| Aridic | ad | Gelic | ge | Mazic | mz | Reductic | rd | Urbic | ub |
| Arzic | az | Gelistagnic | gt | Melanic | me | Regic | rg | Vermic | vm |
| Calcaric | ca | Geric | gr | Mesotrophic | ms | Rendzic | rz | Vertic | vr |
| Calcic | cc | Gibbsic | gi | Mollic | mo | Rheic | rh | Vetic | vt |
| Carbic | cb | Glacic | gc | Natric | na | Rhodic | ro | Vitric | vi |
| Carbonatic | cn | Gleyic | gl | Nitic | ni | Rubic | ru | Xanthic | xa |
| Chernic | ch | Glossic | gs | Ochric | oh | Ruptic | rp | Yermic | ye |
| Chloridic | cl | Greyic | gz | Ombric | om | Rustic | rs | | |
| Chromic | cr | Grumic | gm | Orthic | or | Salic | sz | | |
| Cryic | cy | Gypsic | gy | Oxyaquic | oa | Sapric | sa | | |
| Cutanic | ct | Gypsiric | gp | Pachic | ph | Silic | si | | |

Table 10: Soil unit specifier codes according to WRB1998.

| Specifier | Code | Specifier | Code | Specifier | Code |
|---|---|---|---|---|---|
| Bathi | d | Hyper | h | Para | r |
| Cumuli | c | Hypo | w | Proto | t |
| Endo | n | Orthi | o | Thapto | b |
| Epi | p | | | | |

## 2.12. Sampling information (YEAR, MONTH, DAY, SURVEYOR_P, PUBL_REF, CONTACT_P*, CONTACT_A, EMAIL*)

General information about the sampling date, the surveyor and contact are given in the following format. YEAR, MONTH and DAY are given as integers. The surveyor name, the contact name, address and email are given as free text. The contact name and email address are mandatory. The eventual publication is preferably given as doi. If doi is not available, free text can be used instead, using these rules: (Author surname). (year). (Journal Name or Book Title). (doi or url if available). If there are two authors, use (First author surname) and (Second author surname). (year) etc. If there are more than two authors, use (First author surname) et al. (year) etc.

## 2.13. Related profiles and time series (REL_ID, REL_T_SER)

In case the profile is part of a time-series assessment, a list of the same profile at different times can be given in REL ID as PROFILE ID values separated by commas. The identification key of the time series to which it belongs is given in REL T SER.

## 2.14. Comments

Comments can be left as free text in the three dedicated fields.

# 3. Basic and physical data

Table 11 gathers the basic and physical data valid for the sample.

Table 11: BASIC

| NAME | DESCRIPTION | TYPE | SIZE | UNITS |
|---|---|---|---|---|
| PROFILE_ID* | Profile identification | integer | 8 | - |
| SAMPLE_ID* | Sample identification code (primary key) | integer | 10 | - |
| SAMPLE_POS | Sample position | integer | 1 | - |
| SAMPLE_DEP_TOP* | Sample depth top | real number | 3.0 | cm |
| SAMPLE_DEP_BOT* | Sample depth bottom | real number | 3.0 | cm |
| HOR1_NAME | Horizon designation | text | 7 | - |
| HOR1_TOP | Top depth of the first horizon included in the sample | real number | 3.0 | cm |
| HOR1_BOT | Bottom depth of the first horizon included in the sample | real number | 3.0 | cm |
| HOR2_NAME | Horizon designation | text | 7 | - |
| HOR2_TOP | Top depth of the second horizon included in the sample | real number | 3.0 | cm |
| HOR2_BOT | Bottom depth of the second horizon included in the sample | real number | 3.0 | cm |
| HOR3_NAME | Horizon designation | text | 7 | - |
| HOR3_TOP | Top depth of the third horizon included in the sample | real number | 3.0 | cm |
| HOR3_BOT | Bottom depth of the third horizon included in the sample | real number | 3.0 | cm |
| STRUCTURE1 | Structure grade (FAO guidelines) | text | 6 | - |
| STR_COMB | Combination of soil structure | text | 1 | - |
| STRUCTURE2 | Structure shape (FAO guidelines) | text | 6 | - |
| POR | Porosity | real number | 2.1 | vol % |
| POR_M | Porosity method code | integer | 3 | - |
| BD* | Bulk density | real number | 1.3 | g cm$^{-3}$ |
| BD_M* | Bulk density method code | integer | 3 | |
| COARSE* | Coarse fragments (>2 mm) | real number | 2.1 | weight% |
| COARSE_M* | Coarse fragments (>2 mm) method code | integer | 3 | - |

## 3.1. Sample identifier (SAMPLE_ID*)

Attention! No duplicate samples. When the sampling of a soil layer (or horizon) has been replicated, the properties have to be averaged using a method that is found most appropriate for the specific purpose by the data provider.

**Sample identifier is unique to the soil layer where soil sample(s) is (are) taken from. If measurements are carried out on different samples (composite, disturbed, undisturbed) from the same soil layer, these measurements can - and suggested to - be associated to the same sample identifier.**

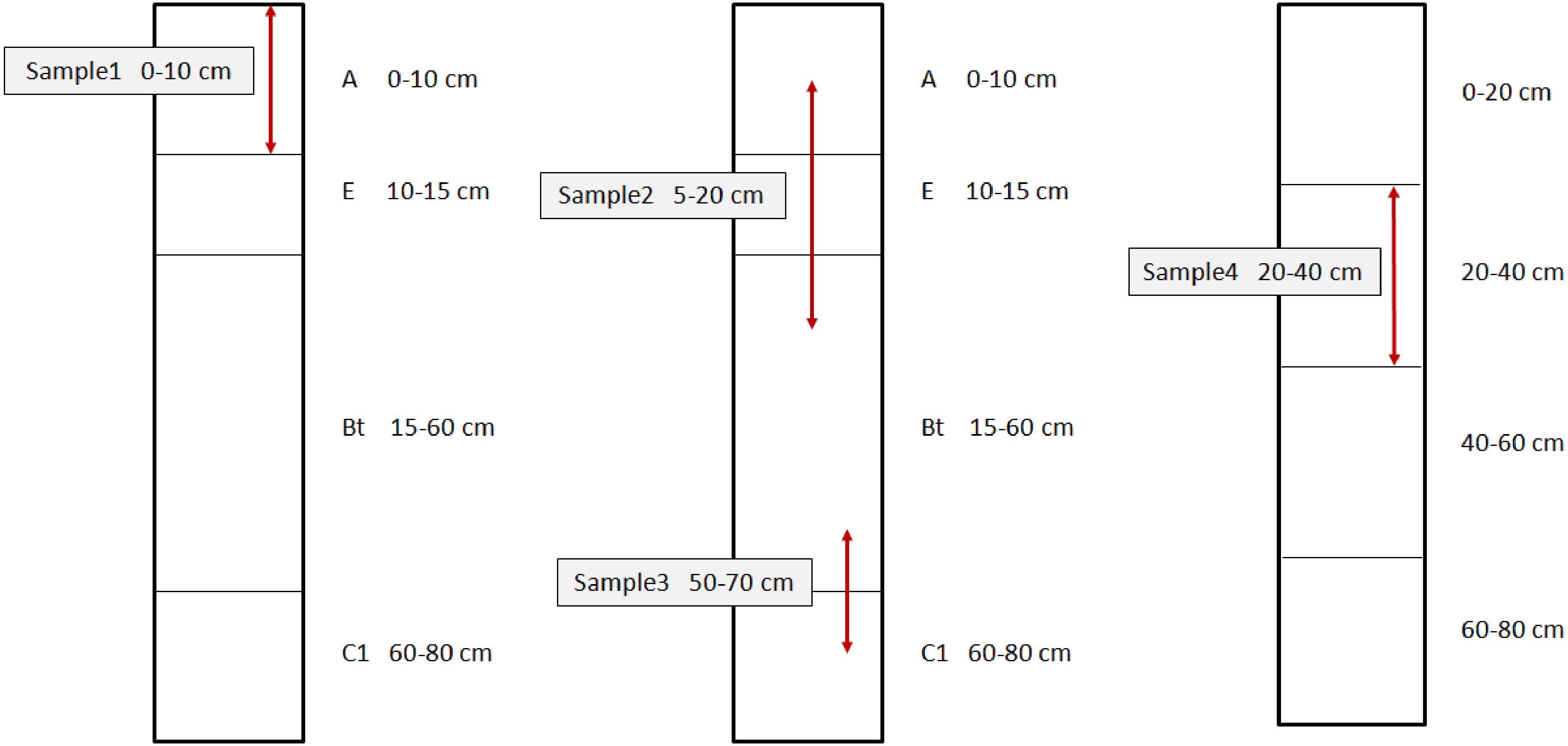
The sample identifier is composed of 10 digits: the first 8 are the same as for the profile while the last 2 identify the sample within the profile.

## 3.2. Sample position (SAMPLE_POS)

Integer indicating the position of the sample in the sequence of layers in the profile. For example, if four samples are identified in a profile, they are numbered 1 to 4, starting from the top and going down.

## 3.3. Sample depths (SAMPLE_DEP_TOP*, SAMPLE_DEP_BOT*)

The depth at which the sample was taken is mandatory information. The top and bottom depths from the soil surface must be given in centimetres (see Figure 4).



| Sample | SAMPLE_ID | SAMPLE_DEP_TOP* | SAMPLE_DEP_BOT* | HOR1_NAME | HOR1_TOP | HOR1_BOT | HOR2_NAME | HOR2_TOP | HOR2_BOT | HOR3_NAME | HOR3_TOP | HOR3_BOT |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Sample1 | 3480608701 | 0 | 10 | A | 0 | 10 | ND | -999 | -999 | ND | -999 | -999 |
| Sample2 | 3480609301 | 5 | 20 | A | 0 | 10 | E | 10 | 15 | B t | 15 | 60 |
| Sample3 | 3480609302 | 50 | 70 | B t | 15 | 60 | C 1 | 60 | 80 | ND | -999 | -999 |
| Sample4 | 3480612501 | 20 | 40 | ND | -999 | -999 | ND | -999 | -999 | ND | -999 | -999 |

Figure 4: Example of sample and horizon depth.

## 3.4. Horizon name and depth (HOR1_NAME, HOR1_TOP, HOR1_BOT)

The code of the horizon(s) from which the sample was taken has to be linked to sample.

If a sample is taken from more than one horizon (Figure 4), depth of each horizon which is included in the sample has to be given, if there is information about it. Figure 4 presents examples for sample and horizon depth recording possibilities.

The horizon name is coded following the guidelines of the FAO (2006, pp. 67-77). Figure 5 illustrates the coding principles. The string contains seven characters, each corresponding to a particular designation. The first character is reserved for a numeral which identifies lithological discontinuities within the profile. The second, third and fourth characters accommodate the master horizon designation. The fifth and sixth characters hold the subhorizon designations. The seventh character is for the numeric designation of vertical subdivisions. Some examples are given in Figure 5.

*(Note: The different components of the horizon name are put together following the same logic as was done for the HYPRES database but containing one more character).*

| Horizon name | HOR_NAME | | | | | | |
|---|---|---|---|---|---|---|---|
| Ap | | A | | | p | | |
| 2BCgx1 | 2 | B | | C | g | x | 1 |
| A/B | | A | / | B | | | |
| B1 | | B | | | | | 1 |
| A | | A | | | | | |
| 2ABb | 2 | A | | B | b | | |
| 2Btb2 | 2 | B | | | t | b | 2 |

Figure 5: Examples of coding of horizon designation (HOR_NAME)

## 3.5. Soil structure (STRUCTURE1, STR_COMB, STRUCTURE2)

The sample structure grade, type and size is given following the FAO guidelines for soil description (FAO, 2006). The references to the relevant tables and figures are given in Table 4.

Structure is described by three columns, called STRUCTURE1, SRUCTURE2 and STR_COMB. STRUCTURE1 describes grade, size and shape of the structure (or primary structure). Grade gives the first and second character (Table 47, FAO, 2006), size is described by third and fourth character (Table 50 and 51, FAO, 2006), shape is the fifth and sixth characters (Table 49, FAO, 2006). Column of STRUCTURE2 is used if combination of structures is present and described in the same way as STRUCTURE1. Examples are given in Figure 6.

If you have data on structure combination, describe its type according to Table 12, except in one case: If you have a "primary breaking to secondary structure" please use dash ("-") instead of arrow ("→"). (Reference: Table 52 of the FAO guideline; FAO 2006).

If only one structure is present the combination of structure (STR_COMB) is filled with zero (0).

Table 12: Coding of type of structures combination (STR_COMB).

| Type of combination | Code of combination type |
|---|---|
| Both structures are present. | + |
| Primary structure is breaking to secondary structure. | - |
| One structure is merging into the other. | / |
| Only one structure is present. | 0 |

| Soil structure | Code of soil structure | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | STRUCTURE1 | | | | | | STR_COMB | STRUCTURE2 | | | | | |
| both a moderate, fine subangular blocky structure and a moderate, fine granular structure | M | O | F | I | S | B | + | M | O | F | I | G | R |
| strong, course platy primary structure breaking into moderate medium angular blocky | S | T | C | O | P | L | - | M | O | M | E | A | B |
| massive | | | | | M | A | 0 | N | D | | | | |
| single grain | | | | | S | G | 0 | N | D | | | | |
| moderate to strong, medium nutty subangular blocky | M | S | M | E | S | N | 0 | N | D | | | | |

Figure 6: Some examples for coding soil structure (STRUCTURE1, STR_COMB and STRUCTURE2).

### 3.6. Porosity (POR, POR_M)

The porosity is given in volume percentage of soil, with one decimal digit. The measurement method is given as a code of three digits, referring to table METHOD (section 7).

### 3.7. Bulk density (BD*, BD_M*)

The bulk density and its measurement methods are mandatory fields. Bulk density must be given in gram per cubic centimeter (g $cm^{-3}$) with a precision of two decimal digits. The measurement method is given as a code of three digits, referring to table METHOD (section 7).

### 3.8. Coarse fragments (COARSE*, COARSE_M*)

The proportion of coarse fragments (> 2 mm) and its measurement methods are mandatory fields. The proportion of coarse fragments is given in mass percentage of soil, with a precision of one decimal digit. The measurement method is given as a code of three digits, referring to table METHOD (section 7).

# 4. Chemical data

Table 13 holds soil chemical information measured in the laboratory.

Table 13: CHEMICAL

| NAME | DESCRIPTION | TYPE | SIZE | UNITS |
|---|---|---|---|---|
| PROFILE_ID* | Profile identification | integer | 8 | |
| SAMPLE_ID* | Sample identification code (primary key) | integer | 10 | |
| OC* | Organic carbon content | real number | 2.2 | weight % |
| OC_M* | Organic carbon content method code | integer | 3 | |
| LOI | Carbon content from loss on ignition | real number | 2.2 | weight % |
| LOI_M | Loss on ignition method code | integer | 3 | |
| TC | Total carbon content | real number | 2.2 | weight % |
| TC_M | Total carbon content method code | integer | 3 | |
| CACO3 | Calcium carbonate content | real number | 2.2 | weight % |
| CACO3_M | Calcium carbonate content method code | integer | 3 | |
| PH_H2O | pH in soil-water suspension | real number | 2.2 | |
| PH_H2O_M | pH in soil-water suspension method code | integer | 3 | |
| PH_KCL | pH in soil-KCl suspension | real number | 2.2 | |
| PH_KCL_M | pH in soil-KCl suspension method code | integer | 3 | |
| EC | Electrical conductivity | real number | 3.2 | mS $cm^{-1}$ |
| EC_M | Electrical conductivity method code | integer | 3 | |
| SALT | Soluble salt content | real number | 2.2 | weight % |
| SALT_M | Soluble salt content method code | integer | 3 | |
| CEC | Cation exchange capacity | real number | 3.2 | $meq(100g)^{-1}$ |
| CEC_M | Cation exchange capacity method code | integer | 3 | |
| EX_NA | Exchangeable Na | real number | 3.2 | $meq(100g)^{-1}$ |
| EX_NA_M | Exchangeable Na method code | integer | 3 | |
| EX_MG | Exchangeable Mg | real number | 3.2 | $meq(100g)^{-1}$ |
| EX_MG_M | Exchangeable Mg method code | integer | 3 | |
| EX_K | Exchangeable K | real number | 3.2 | $meq(100g)^{-1}$ |
| EX_K_M | Exchangeable K method code | integer | 3 | |
| EX_CA | Exchangeable Ca | real number | 3.2 | $meq(100g)^{-1}$ |
| EX_CA_M | Exchangeable Ca method code | integer | 3 | |
| BASE_CATIONS | Sum of Na, K, Ca and Mg cations | real number | 3.2 | $meq(100g)^{-1}$ |
| ACIDITY_EXCH | Exchangeable acidity | real number | 3.2 | $meq(100g)^{-1}$ |
| ACIDITY_EXCH_M | Exchangeable acidity method code | integer | 3 | |
| ACIDITY_POT | Potential acidity | real number | 3.2 | $meq(100g)^{-1}$ |
| ACIDITY_POT_M | Potential acidity method code | integer | 3 | |

## 4.1. Profile and sample identifiers*

The profile and sample identifiers given in table GENERAL and BASIC are repeated here and allow the user of the database to link the chemical data with the sample they belong to.

## 4.2. Organic carbon content, loss on ignition and total carbon content and their measurement methods (OC*, OC_M*, LOI, LOI_M, TC, TC_M)

Soil organic carbon/matter content can be approximated by different methods leading to very different results. A conversion factor might be needed to harmonize data to a reference standard.

Three different concepts are included in the database: organic carbon content, loss on ignition (proxy to organic matter content) and total carbon content.

The organic carbon content or loss on ignition or total carbon content is given in weight percentage of the soil sample, with a precision of 2 decimal digits. The measurement method is given as a code of three digits, referring to table METHOD (section 7).

### 4.3. Carbonate content and its measurement method (CACO3, CACO3_M)

The calcium carbonate content is given in weight percentage of the soil sample, with a precision of 2 decimal digits. The measurement method is given as a code of three digits, referring to table METHOD (section 7).

### 4.4. pH values and their measurement methods (PH_H2O, PH_H2O_M, PH_KCL, PH_KCL_M)

The pH measured in water and/or in a KCl solution is given with a precision of one decimal digit. The measurement methods (dilution) are gievn as a code of three digits, referring to table METHOD (section 7).

### 4.5. Electrical conductivity and its measurement method (EC, EC_M)

The electrical conductivity is given in miliSiemens per centimeter (mS $cm^{-1}$) with a precision of two decimal digits. The measurement method is given as a code of three digits, referring to table METHOD (section 7).

### 4.6. Soluble salt content and its measurement method (SALT, SALT_M)

The soluble salt content is given in percentage weight of the soil sample with a two decimal digits precision. The measurement method is given as a code of three digits, referring to table METHOD (section 7).

### 4.7. Cation exchange capacity and its measurement method (CEC, CEC_M)

The cation exchange capacity is given in mili-equivalent per 100 grams (meq($100g^{-1}$)) with a precision of two decimal digits. The measurement method is given as a code of three digits, referring to table METHOD (section 7).

### 4.8. Exchangeable cations contents and their measurement methods (EX_NA, EX_NA_M, EX_MG, EX_MG_M, EX_K, EX_K_M, EX_CA, EX_CA_M, BASE_CATIONS)

The exchangeable sodium, magmesium, potassium and calcium contents, as well as their sum are given in miliequivalent per 100 grams (meq($100g^{-1}$)) with a precision of two decimal digits. The associated measurement methods are each given as a code of three digits, referring to table METHOD (section 7).

### 4.9. Potential and exchangeable acidity and their measurement method (ACIDITY_EXCH, ACIDITY_EXCH_M, ACIDITY_POT, ACIDITY_POT_M)

Potential and exchangeable acidity are given in mili-equivalent per 100 grams (meq($100g^{-1}$)) with a precision of two decimal digits. The associated measurement methods are each given as a code of three digits, referring to table METHOD (section 7). Exchangeable acidity is the amount of acidic cations which can be extracted from the soil by unbuffered salt solution. We refer potential acidity as the sum of exchangeable and residual acidity (Chesworth, 2008).

## 5. Measured particle size

Table 14 holds the measured particle size distribution of the samples, with no particular requirements regarding the cut-off values between particle size classes.

Table 14: PSIZE

| NAME | DESCRIPTION | TYPE | SIZE | UNITS |
|---|---|---|---|---|
| PROFILE_ID* | Profile identification code | integer | 8 | |
| SAMPLE_ID* | Sample identification code | integer | 10 | |
| P_SIZE* | Upper limit of particle size class | real number | 3.1 | µm |
| P_PERCENT* | Weight % | real number | 2.1 | weight % |
| P_M* | Particle size method code | integer | 3 | |

### 5.1. Profile and sample identifiers*

The profile and sample identifiers given in table GENERAL and BASIC are repeated here and allow the user of the database to link the particle size distribution data with the sample they belong to.

### 5.2. Particle size (P_SIZE*)

The format adopted for the particle size distribution allows for heterogeneous limits between particle size classes among contributing institutions. The particle size intended here is the maximum size the particles accounted for in this line are. It is given in micrometers (µm). An example of how sand, silt and clay contents are translated to the PSIZE table is given in Figure 7.

### 5.3. Particle size content (P_PERCENT*)

The weight percentage of the particles between two seccesive size limits is given with one decimal digit. An example of how to a sand, silt and clay contents are translated to the PSIZE table is given in Figure 7.

### 5.4. Particle size method code (P_M*)

The measurement method is given as a code of three digits, referring to table METHOD (section 7). An example of how to a sand, silt and clay contents are translated to the PSIZE table is given in Figure 7.

| PROFILE_ID | SAMPLE_ID | clay(],2]) | silt(]2,63]) | sand(]63,2000]) |
|---|---|---|---|---|
| 04000001 | 0400000101 | 12 | 51 | 37 |
| 04000001 | 0400000102 | 16 | 49 | 35 |

| PROFILE_ID | SAMPLE_ID | P_SIZE | P_PERCENT | P_M |
|---|---|---|---|---|
| 04000001 | 0400000101 | 2 | 12 | 501 |
| 04000001 | 0400000101 | 63 | 51 | 501 |
| 04000001 | 0400000101 | 2000 | 37 | 501 |
| 04000001 | 0400000102 | 2 | 16 | 501 |
| 04000001 | 0400000102 | 63 | 49 | 501 |
| 04000001 | 0400000102 | 2000 | 35 | 501 |

Figure 7: Example of PSIZE table entries

# 6. Measured soil water retention

Table 15 contains the soil water retention data. Whenever possible, direct measurement of water retention are desired. When the measurement technique does not allow to produce directly couples of matric potential and water content, the parameters describing the water retention curve obtained by inverse modelling are given.

Table 15: RET

| NAME | DESCRIPTION | TYPE | SIZE | UNITS |
|---|---|---|---|---|
| PROFILE_ID* | Profile identification code | integer | 8 | |
| SAMPLE_ID* | Sample identification code | integer | 10 | |
| HEAD* | Matric potential | real number | 6.1 | cm |
| THETA* | Water content | real number | 0.3 | $cm^3\ cm^{-3}$ |
| THETA_M* | Measurement method code | integer | 3 | |
| TH_INV_P1 | Water retention: Inverse modelling parameter 1 | real number | 5.5 | |
| TH_INV_P2 | Water retention: Inverse modelling parameter 2 | real number | 5.5 | |
| TH_INV_P3 | Water retention: Inverse modelling parameter 3 | real number | 5.5 | |
| TH_INV_P4 | Water retention: Inverse modelling parameter 4 | real number | 5.5 | |
| TH_INV_P5 | Water retention: Inverse modelling parameter 5 | real number | 5.5 | |
| TH_INV_P6 | Water retention: Inverse modelling parameter 6 | real number | 5.5 | |
| TH_INV_P7 | Water retention: Inverse modelling parameter 7 | real number | 5.5 | |
| TH_INV_P8 | Water retention: Inverse modelling parameter 8 | real number | 5.5 | |
| TH_INV_MOD | Water retention: model code | integer | 3 | |

## 6.1. Profile and sample identifiers*

The profile and sample identifiers given in table GENERAL and BASIC are repeated here and allow the user of the database to link the water retention data with the sample they belong to.

## 6.2. Matric potential, associated water content and measurement method (HEAD* , THETA*, THEAT_M*)

The matric potential absolute value is given in centimeters of water column with a precision of one decimal digit. The water content measured at that matric potential is given in volume of water by unit volume of soil with a precision of three decimal digits. When no direct measurements are available, modelled values are given instead at ten matric potentials (-0.1, ) but the parameters and the code of the model MUST be given too. The measurement method is given as a code of three digits, referring to table METHOD (section 7).

## 6.3. Inverse modelling parameters and model code (TH_INV_P1 to TH_INV_P8, TH_INV_MOD)

When the measurement method does not give direct measurement of the water retention curve, the parameters obtained by inverse modelling must be given along with a code referring to the model used. The information about the model and its parameters are stored in table METHOD (section 7). Any excessive parameter (for models with less than eight parameters) is given the value -999.

## 7. Measured hydraulic conductivity

Table 16 contains the soil hydraulic conductivity data. Whenever possible, direct measurement of soil hydraulic conductivity is desired. When the measurement technique does not allow producing directly couples of matric potential or water content and hydraulic conductivity, the parameters describing the unsaturated hydraulic conductivity curve obtained by inverse modelling are given.

Table 16: COND

| NAME | DESCRIPTION | TYPE | SIZE | UNITS |
|---|---|---|---|---|
| PROFILE_ID | Profile identification code | integer | 8 | |
| SAMPLE_ID | Sample identification code | integer | 10 | |
| IND_VALUE | Matric potential (1)/water content (0) | integer | 1 | |
| VALUE | Value of matric potential or water content | real number | 6.1/ 0.3 | cm/ cm$^3$ cm$^-$ |
| COND | Conductivity | real number | 3.5 | cm d$^{-1}$ |
| COND_M | Measurement method code | integer | 3 | |
| K_INV_P1 | Conductivity: Inverse modelling parameter 1 | real number | 5.5 | |
| K_INV_P2 | Conductivity: Inverse modelling parameter 2 | real number | 5.5 | |
| K_INV_P3 | Conductivity: Inverse modelling parameter 3 | real number | 5.5 | |
| K_INV_P4 | Conductivity: Inverse modelling parameter 4 | real number | 5.5 | |
| K_INV_P5 | Conductivity: Inverse modelling parameter 5 | real number | 5.5 | |
| K_INV_P6 | Conductivity: Inverse modelling parameter 6 | real number | 5.5 | |
| K_INV_P7 | Conductivity: Inverse modelling parameter 7 | real number | 5.5 | |
| K_INV_P8 | Conductivity: Inverse modelling parameter 8 | real number | 5.5 | |
| K_INV_MOD | Conductivity: model code | integer | 3 | |

### 7.1. Profile and sample identifiers*

The profile and sample identifiers given in table GENERAL and BASIC are repeated here and allow the user of the database to link the hydraulic conductivity data with the sample they belong to.

### 7.2. Matric potential or water retention, associated measured hydraulic conductivity and measurement method (IND_VALUE, VALUE, COND, COND_M)

The soil hydraulic conductivity can be given associated with a matric head value or a water content value. In the first case, IND VALUE is set to 1 and the matric potential absolute value (VALUE) is given in centimetres with a precision of one decimal digit. In the second case, IND VALUE is set to 0 and the water content (VALUE) is given in volume of water per unit volume of soil with a precision of 3 decimal digits. The soil hydraulic conductivity associated to either the matric potential or the water retention given in VALUE is given in centimetres per day, with a precision of five decimal digits. The measurement method is given as a code of three digits, referring to table METHOD (section 7).

### 7.3. Inverse modelling parameters and model code (TH_INV_P1 to TH_INV_P8, TH_INV_MOD)

When the measurement method does not give direct measurement of the unsaturated hydraulic conductivity curve, the parameters obtained by inverse modelling must be given along with a code referring to the model used. The information about the model and its parameters are stored in table METHOD (section 7). Any excessive parameter (for models with less than eight parameters) is given the value -999.

## 8. Methodology

Table 17 holds the measurement methods codes and their meaning.

Table 17: METHOD

| NAME | DESCRIPTION | TYPE | SIZE |
|---|---|---|---|
| CODE_M* | Method code(primary key) | integer | 3 |
| METHOD* | Method description | text | 150 |
| METH_REF | Method reference (Author name, year/ISO | text | 300 |
| METH_PAR* | Name of measured parameter | text | 20 |
| SAMPLE_VOL | Sample volume ($cm^3$) | Integer | 4.0 |
| SAMPLE_MAS | Sample mass (g) | Integer | 4.0 |

### 8.1. Method code (CODE_M*)

All method codes are composed of three digits. To easily build the codes, the following approach is proposed. Codes starting with 1 or 2 refer to methods used to measure parameters from tables BASIC and CHEMICAL. Codes starting with 5 are reserved for particle size distribution, 6 for water retention measurements, 7 for retention models, 8 for conductivity measurements and 9 for conductivity models. Details are provided in Table 18.

Table 18: Method codes allocation

| CODE | METH_PAR | TABLE |
|---|---|---|
| 10x | POR_M | BASIC |
| 11x | BD_M | BASIC |
| 12x | COARSE_M | BASIC |
| 13x | OC_M | CHEMICAL |
| 14x | CACO3_M | CHEMICAL |
| 15x | PH_H2O_M | CHEMICAL |
| 16x | PH_KCL_M | CHEMICAL |
| 17x | EC_M | CHEMICAL |
| 18x | SALT_M | CHEMICAL |
| 19x | CEC_M | CHEMICAL |
| 20x | EX_NA_M | CHEMICAL |
| 21x | EX_MG_M | CHEMICAL |
| 22x | EX_K_M | CHEMICAL |
| 23x | EX_CA_M | CHEMICAL |
| 24x | ACIDITY_NA4O_M | CHEMICAL |
| 25x | ACIDITY_KCL_M | CHEMICAL |
| 5xx | P_M | PSIZE |
| 6xx | THETA_M | RET |
| 7xx | TH_INV_MOD | RET |
| 8xx | COND_M | COND |
| 9xx | K_INV_M | COND |

### 8.2. Method description and literature reference (METHOD*, METH_REF)

The method is described using free text and/or a reference in the literature. The free text field (METHOD) is limited to 150 characters. Please provide as much details as possible to thoroughly understand the measurement protocol. Particularly any pre-treatment applied to the sample must be detailed Temperatures, durations, concentrations must be given. Also, specify the sample size or mass and state (disturbed/undisturbed)

If the measurement method has been published, please provide the ISO code or the reference in the literature, according to the following rules: (Author surname). (year). (Journal Name or Book Title). (doi or url if available). If there are two authors, use (First author surname) and (Second author surname). (year) etc. If there are more than two authors, use (First author surname) et al. (year) etc.

### 8.3. Parameter name (METH_PAR*)

This field contains the name of the parameter to which the measurement method refers. Be careful to spell it exactly how it is in the tables overviews.

## 9. Time series metadata

Table 19 hold the metadata relative to time series related to some soil profiles.

Table 19: TSERMETA

| NAME | DESCRIPTION | TYPE | SIZE |
|---|---|---|---|
| T_SER_ID | Time series identification key (primary key) | integer | 5 |
| REL_PROFILE_ID | Related profile identifications keys | text | 50 |
| DESC | General description of time series data | text | 200 |
| DESC_V1 | Description of variable 1 | text | 100 |
| DESC_V2 | Description of variable 2 | text | 100 |
| DESC_V3 | Description of variable 3 | text | 100 |
| DESC_V4 | Description of variable 4 | text | 100 |
| DESC_V5 | Description of variable 5 | text | 100 |
| DESC_V6 | Description of variable 6 | text | 100 |
| DESC_V7 | Description of variable 7 | text | 100 |
| DESC_V8 | Description of variable 8 | text | 100 |
| DESC_V9 | Description of variable 9 | text | 100 |
| DESC_V10 | Description of variable 10 | text | 100 |

## 10. Time series data

Table 20 hold the time series data relative to some soil profiles.

Table 20: TSERDATA

| NAME | DESCRIPTION | TYPE | SIZE |
|---|---|---|---|
| T_SER_ID | Time series identification key | integer | 5 |
| TIME | Time <YYYYMMDD>T<hh:mm:ss> (ISO8601) | text | 17 |
| V1 | Variable 1 | real number | 5.5 |
| V2 | Variable 2 | real number | 5.5 |
| V3 | Variable 3 | real number | 5.5 |
| V4 | Variable 4 | real number | 5.5 |
| V5 | Variable 5 | real number | 5.5 |
| V6 | Variable 6 | real number | 5.5 |
| V7 | Variable 7 | real number | 5.5 |
| V8 | Variable 8 | real number | 5.5 |
| V9 | Variable 9 | real number | 5.5 |
| V10 | Variable 10 | real number | 5.5 |

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# Annex 3

## Conversion factors to harmonize organic carbon content

Table A3.1. Ensembles of equations applied to convert organic carbon measurements towards dry combustion.

| E. | N. | Target Method Y = | Source Method X | * Slope | +Inter. (g/kg) | + Inter. (%) | R2 | Reference | Applic. |
|---|---|---|---|---|---|---|---|---|---|
| 1 | 1 | Dry Combustion | Loss on Ignition (LOI) | 0.633 | -9.36 | -0.936 | 0.98 | Soon and Abboud (1991) | northwestern Canadian prairie |
| 1 | 2 | DC (Leico at 875 C) | LOI at 360 C MLRA 95B | 0.5743 | 0.1025 | 0.01025 | 0.98 | Konen et al., 2002 | Central-North US |
| 1 | 3 | DC (Carlo–Erba at 1020 C) | LOI at 360 | 0.43 | 0.65 | 0.065 | 0.98 | Brye and Slaton, 2003 | Typic Albaqualf |
| 1 | 4 | DC (Leico at 1000 C) | LOI at 360 | 0.48 | -0.003 | -0.0003 | 0.89 | Brye and Slaton, 2003 | Typic Albaqualf |
| 1 | 5 | DC (Leico at 875 C) | LOI at 550 C | 0.624 | 0 | 0 | 0.99 | Jolivet et al., 1998 | sandy Spodosols of France |
| 1 | 6 | DC (Leico at 1000 C) | LOI at 375 C combined | 0.726 | -1.598 | -0.1598 | 0.96 | Wang et al., 1996 | soils of eucalypt plantations in Tasmania |
| 1 | 7 | Loss on Ignition (LOI) | Dry Combustion | 2.24194 | 1.6947 | 0.16947 | 0.96 | Hegymegi et al. 2007 | Austria, Bulgaria, Hungary and UK |
| 2 | 1 | Dry Combustion | Walkley-Black | 1.05 | 0 | 0 | 0.98 | Soon and Abboud (1991) | northwestern Canadian prairie |
| 2 | 2 | DC (at 680 C) | Wet combustion | 0.992 | 0 | 0 |  | Kalembasa & Jenkinson, 1973 | ? |
| 2 | 3 | Walkley-Black (classic) | DC (Leico at 1000 C) | 0.89 | -0.09 | -0.009 | 0.99 | Brye and Slaton, 2003 | Typic Albaqualf |
| 2 | 4 | Walkley-Black (classic) | DC (Carlo–Erba at 1020 C) | 1.02 | 0.15 | 0.015 | 0.99 | Brye and Slaton, 2003 | Typic Albaqualf |
| 2 | 5 | DC (Shimadzu at 900 C) | Walkley-Black corrected | 1.2 | 0 | 0 | 0.96 | De Vos et al., 2007 | forest, belgium |
| 2 | 6 | Walkley-Black NRCS 1995 | DC (Leico at 875 C) | 0.918 | 1 | 0.1 | 0.99 | Jolivet et al., 1998 | sandy Spodosols of France |
| 2 | 7 | Walkley-Black NRCS 1995 | DC (Leico at 875 C) | 0.947 | 0 | 0 | 0.99 | Jolivet et al., 1998 | sandy Spodosols of France |
| 2 | 8 | Walkley-Black 6A1 | DC (Leico at 1000 C) | 0.97 | 0 | 0 | 0.99 | Wang et al., 1996 | soils of eucalypt plantations in Tasmania |
| 2 | 9 | Walkley-Black 1934 | DC (Variomax CNS) | 1.034 | 0.016 | 0.0016 | 0.99 | Sleutel et al., 2007 | Belgian agricultural soils |
| 2 | 10 | Walkley-Black 1934 | DC (Variomax CNS) | 1.013 | 0 | 0 | 0.99 | Sleutel et al., 2007 | Belgian agricultural soils |
| 3 | 1 | DC (Dumas at 1000) | Walkley-Black | 1.25 | 0.126 | 0.0126 | 0.99 | Grewal et al., 1991 | New Zealand |
| 3 | 2 | DC (Leico at 1000 C) | Walkley-Black (classic) | 1.47 | 0 | 0 | 0.84 | Meersmans et al., 2009 | Belgium |
| 3 | 3 | DC (Shimadzu at 900 C) | Walkley-Black not corrected | 1.58 | 0 | 0 | 0.96 | De Vos et al., 2007 | forest, belgium |
| 3 | 4 | DC (Shimadzu at 900 C) | Walkley-Black NRCS 1995 | 1.506 | 0 | 0 | 0.99 | Lettens et al., 2007 | Belgium |
| 3 | 5 | DC (Shimadzu at 900 C) | Walkley-Black NRCS 1995 | 1.594 | 0 | 0 | 0.99 | Lettens et al., 2007 | Belgium |
| 3 | 6 | DC (Shimadzu at 900 C) | Walkley-Black NRCS 1995 | 1.774 | 0 | 0 | 0.98 | Lettens et al., 2007 | Belgium |

|  |  |  |  |  |  |  |  |  |  |
|---|---|---|---|---|---|---|---|---|---|
| 3 | 7 | Walkley-Black 6A1 | DC (Leico at 1000 C) other | 0.739 | -1.759 | -0.1759 | 0.95 | Wang et al., 1996 | soils of eucalypt plantations in Tasmania |
| 3 | 8 | Walkley-Black | Dry Combustion | 0.79165 | 0.28413 | 0.028413 | 0.99 | Hegymegi et al. 2007 | Austria, Bulgaria, Hungary and UK |
| 4 | 1 | DC (at 680 C) | Tyurin | 0.933 | 0 | 0 |  | Kalembasa & Jenkinson, 1973 | ? |
| 4 | 2 | Tyurin titrametric classic | DC (Vario EL at 1150 C) | 0.869 | 0.162 | 0.0162 | 0.91 | Jankauskas et al., 2006 | Lithuanian Eutric Albeluvisols |
| 4 | 3 | Tyurin titrametric classic | Dry Combustion | 0.74495 | 0.06516 | 0.006516 | 0.99 | Hegymegi et al. 2007 | Austria, Bulgaria, Hungary and UK |
| 4 | 4 | Tyurin pretreated | Dry Combustion | 0.72013 | 0.06245 | 0.006245 | 1 | Hegymegi et al. 2007 | Austria, Bulgaria, Hungary and UK |
| 4 | 5 | DC (Leico at 875 C) | Tyurin titrametric classic | 1.28±0.19 |  | 0 | 0.88 | Kogut, Frid, 1993 | Russia |
| 4 | 6 | DC (Leico at 875 C) | Tyurin titrametric classic | 1.2596 | 0.3105 | 0.03105 | 1 | Milanovskiy,2009 | Russia |
| 4 | 7 | DC (Leico at 875 C) | Tyurin titrametric classic | 1.2399 | 0.0073 | 0.00073 | 1 | Milanovskiy,2009 | Russia |
| 5 | 1 | DC (Leico at 1000 C) | Walkley-Black (modified) | 1.2 | 0 | 0 | 0.87 | Meersmans et al., 2009 | Belgium |
| 5 | 2 | Walkley-Black (modified) | DC (Leico at 1000 C) | 0.72 | 0.63 | 0.063 | 0.73 | Brye and Slaton, 2003 | Typic Albaqualf |
| 5 | 3 | Walkley-Black (modified) | DC (Carlo–Erba at 1020 C) | 0.81 | 0.58 | 0.058 | 0.73 | Brye and Slaton, 2003 | Typic Albaqualf |
| 5 | 4 | Walkley-Black (modified) | Dry Combustion | 0.30188 | 0.7583 | 0.07583 | 0.9 | Hegymegi et al. 2007 | Austria, Bulgaria, Hungary and UK |
| 5 | 5 | Walkley-Black mod. 135 C (oxydation sulfochromique) | DC (CHN) | 1.0066 | 0 | 0 | 0.97 | Caria et al. 2007 | France |
| 5 | 6 | Walkley-Black mod. 135 C (oxydation sulfochromique) | DC (CHN pretreated (decarbonated)) | 0.9901 | 0 | 0 | 0.99 | Caria et al. 2007 | France |

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Abstract

There is a common need for reliable hydropedological information in Europe. In the last decades research institutes, universities and government agencies have developed local, regional and national datasets containing soil physical, chemical, hydrological and taxonomic information often combined with land use and landform data. A hydrological database for western European soils was also created in the mid-1990s. However, a comprehensive European hydropedological database, with possible additional information on chemical parameters and land use is still missing.

A comprehensive joint European hydropedological inventory can serve multiple purposes, including scientific research, modelling and application of models on different geographical scales.

The objective of the joint effort of the participants is to establish the European Hydropedological Data Inventory (EU-HYDI). This database holds data from European soils focusing on soil physical, chemical and hydrological properties. It also contains information on geographical location, soil classification and land use/cover at the time of sampling. It was assembled with the aim of encompassing the soil variability in Europe. It contains data from 18 countries with contributions from 29 institutions. This report presents an overview of the database, details the individual contributed datasets and explains the quality assurance and harmonization process that lead to the final database.

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