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Development and use of a database of hydraulic properties of European soils

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Abstract

Many environmental studies on the protection of European soil and water resources make use of soil water simulation models. A major obstacle to the wider application of these models is the lack of easily accessible and representative soil hydraulic properties. In order to overcome this apparent lack of data, a project was initiated to bring together the available hydraulic data which resided within different institutions in Europe into one central database. This information was then used to derive a set of pedotransfer functions applicable to studies at a European scale. These pedotransfer functions predict the hydraulic properties from parameters collected during soil surveys and can be a good alternative for costly and time-consuming direct measurement of these properties. A total of 20 institutions from 12 European countries collaborated in establishing the database of HYdraulic PRoperties of European Soils (HYPRES). This database has a flexible relational structure capable of holding a wide diversity of both soil pedological and hydraulic data. As these data were contributed by 20 different institutions it was necessary to standardise both the particle-size and the hydraulic data. A novel similarity interpolation procedure was successfully used to achieve standardization of particle-sizes according to the FAO clay, silt and sand particle-size ranges. Standardization of hydraulic data was achieved by fitting the Mualem-van Genuchten model parameters to the individual $\theta(h)$ and $K(h)$ hydraulic properties stored in HYPRES. The HYPRES database contains information on a total of 5521 soil horizons (including replicates). Of these, 4030 horizons had sufficient data to be used in the derivation of pedotransfer functions. Information on both water retention and hydraulic conductivity was available for 1136 horizons whereas 2894 horizons had only information on water retention. Each soil horizon was

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allocated to one of 11 possible soil textural/pedological classes derived from the six FAO texture classes (five mineral and one organic) and the two pedological classes (topsoil and subsoil) recognised within the 1:1 000 000 scale Soil Geographical Data Base of Europe. Next, both class and continuous pedotransfer functions were developed. By using the class pedotransfer functions in combination with the 1:1 000 000 scale Soil Map of Europe, the spatial distribution of soil water availability within Europe was derived.

Keywords: pedotransfer function; texture class; soil physics; computer simulation; water availability

1. Introduction

The quality of European soils and waters are deteriorating due to intensive agricultural and industrial activities in many regions of Europe (Eijsackers and Hamers, 1993). Scientist have developed complex computer models to simulate water and solute movement in the unsaturated zone in order to control and ultimately rectify this damage (e.g., Boesten and Van der Linden, 1991; Kabat et al., 1992; Teng and Penning de Vries, 1992). However, the use of these models has been limited especially by the lack of accurate soil hydraulic properties, in particular water retention and hydraulic conductivity (van Genuchten and Leij, 1992). An attractive alternative to the direct and often difficult measurement of hydraulic properties is the estimation by pedotransfer functions. Pedotransfer functions relate hydraulic properties to more easily measured soil data such as soil texture, organic matter content and/or other data routinely measured by Soil Surveys (e.g., Bouma and Van Lanen, 1987; Larson and Pierce, 1991; Wösten, 1997).

A prerequisite for deriving pedotransfer functions which can be applied at a European scale, is the availability of these basic soil data and soil hydraulic properties from a wide range of soils across Europe. Until now, these data were fragmented, of varying degrees of detail and reliability and held by different institutions scattered throughout Europe. However, a group of 20 institutions from 12 European countries recently collaborated to bring together the available measured hydraulic properties held by different institutions in Europe into one central database. Table 1 shows the countries and the institutions that contributed data. Analysis of the information gathered in this database resulted in a set of pedotransfer functions applicable on a European scale. It is envisaged that the database and the derived pedotransfer functions will be a unique source of information and be useful for scientists working in agriculture, environment and nature preservation.

In establishing and using this database a number of specific objectives were identified:

– Development of a flexible database structure capable of holding a wide diversity of soil hydraulic and pedological data and which allows easy manipulation of these data.

Table 1
Origin of the data within HYPRES

Country	Institution	Number of samples for which data were provided
The Netherlands	The Winand Staring Centre	659
The Netherlands	Wageningen Agricultural University	72
Spain	Consejo Superior de Investigaciones Cientificas	54
France	Institut National de la Recherche Agronomique-Orléans	105
France	Institut National de la Recherche Agronomique-Montpellier	66
England	Soil Survey and Land Research Centre	423
Scotland	Macaulay Land Use Research Institute	170
Denmark	The Danish Institute of Plant and Soil Science	350
Italy	Istituto di Idraulica Agraria Universita' degli Studi di Napoli	194
Germany	Technische Universität Berlin	42
Germany	Technische Universität Braunschweig	172
Germany	GSF—Forschungszentrum für Umwelt und Gesundheit	106
Germany	Zentrum für Agrarlandschafts-und Landnutzungsforschung	462
Germany	Bundesanstalt für Geowissenschaften und Rohstoffe	1527
Greece	Aristotle University of Thessaloniki	72
Greece	Agricultural University of Athens	66
Portugal	Estaçäo Agronómica Nacional	104
Belgium	Catholic University Leuven	785
Sweden	Swedish University of Agricultural Sciences	19
Northern Ireland	Department of Agriculture	15
Slovakia	Soil Fertility Research Institute	58
Total		5521

– Populating the database with soil data from institutions across Europe.
– Pre-processing the soil data which includes standardisation of particle-size classes and parameterisation of the hydraulic properties with the Mualem-van Genuchten equations (van Genuchten, 1980).
– Development of both class and continuous pedotransfer functions.
– Demonstration of the practical use of the database by linkage with the existing 1:1 000 000 scale Soil Geographical Database of Europe (Jamagne et al., 1994).

2. Materials and methods

Prior to any analysis or the derivation of pedotransfer functions, a database for the storage and manipulation of the data had to be developed and the data entered. Next, a degree of standardisation of the data had to be undertaken in order to ensure compatibility.

2.1. Database structure

As there was great diversity in the data being collected and manipulated, it was important to have a database with a relational structure which allowed flexibility in data extraction, for example, using a variety of fields or by a combination of fields. Therefore HYPRES was developed within the Oracle Relational Database Management System™. The desire to have compatibility with existing EU-wide soils databases led directly to the selection of the key identifying fields used throughout HYPRES as well as many of the attributes stored (Wösten et al., 1998).

The HYPRES database comprises six separate tables each of which uses a European standard system of geo-referencing as the primary key and, where appropriate, also the horizon notation as the secondary key. Fig. 1 gives the structure of the database. The BASICDATA table contains the 'descriptor' data, for example, information on the soil type, where the soil profile was located and a description of the site and other environmental conditions. The unique primary key field, (Oracle field *gridref*), ensures that referential integrity is maintained within the subsequent tables so that all data can be related to these descriptor data. This field also provides a link between the database and other European soil datasets and allows the data to be related to other spatially referenced geo-physical factors such as climate or land use. The five remaining tables are linked by both the geo-reference and the horizon notation as each soil profile generally contains more than one sampled horizon. The horizon notation follows the FAO system (FAO, 1990) and is formatted in such a way that selection of data is simplified and that greater refinement in this selection process is allowed. As the horizon field is a key identifying attribute which links tables, it follows

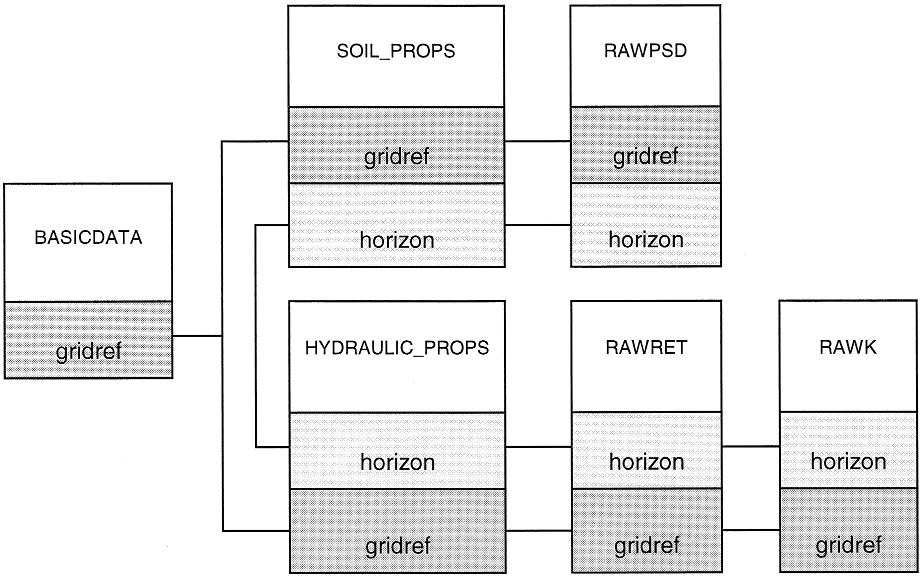

Fig. 1. HYPRES database structure.

that there must also be an unique combination of geo-reference and horizon for each sample in the database.

The table SOIL_PROPS stores most of the data essential to the derivation of pedotransfer functions such as particle-size class, organic matter contents and bulk densities as well as additional pedological information. The HYDRAULIC_PROPS table holds only derived or standardised data such as the Mualem-van Genuchten parameters and calculated soil moisture retention and hydraulic conductivities at 14 pre-determined pressure heads. The 'RAW' tables, that is, RAWRET, RAWK and RAWPSD, store the data on moisture retention, conductivity and particle-size distributions. These were the data contributed by the institutions and are in their 'raw' state, that is, prior to any standardisation. The RAWRET and RAWK tables are very large, containing over 16 Megabytes of data and are not particularly suitable for general use. However, it is important that these 'raw' data are stored for future use if, for example, new or improved parameterisation methods become available or for testing and comparing novel methods of analysis.

2.2. Collating data

The 20 institutions contributed their data in various forms for example, as paper copies of internal reports, or in digital form such as ASCII text, spreadsheets and various database systems. Substantial effort was spent transforming the contributed data into a standard format that allowed easy, computerised manipulation of the data.

HYPRES Version 1.0 comprises around 25 Megabytes of data held in six separate data tables and represents 95 different soil types according to the modified FAO soil legend (CEC, 1985) used in the 1:1 000 000 Soil Geographical Database of Europe. There are 1777 sampled locations with 5521 samples (including replicates) from 4486 soil horizons. Table 2 gives the summary statistics of the HYPRES data. The RAWRET and RAWK tables have over 197 000 $\theta(h)$ and about 120 500 $K(h)$ data pairs, respectively. Simple checks were carried out prior to loading the data into the main database to ensure that as many fields as possible had data entered, and that the data values were within expected limits. After all the data were loaded, checks were made to ensure the uniqueness of the geo-referencing and the geo-reference/horizon combinations so that all sets of data in any table could be related to data in either the BASICDATA or SOIL_PROPS tables.

2.3. Pre-processing of data

Different soil classification systems are used throughout Europe, resulting in incompatibilities in the class intervals used to describing the soil particle-size distribution within the contributed data. To achieve compatibility within HYPRES and with other European soil databases, it was decided to standardise the particle-size data to three size limits where clay is defined as the particle-size fraction < 2 μm, silt as the fraction between 2 and 50 μm and sand as the fraction between 50 and 2000 μm (FAO, 1990; USDA, 1951).

The main differences between the European systems of defining particle-size limits and the FAO system are in the distinction between silt and sand sized fractions. Where the FAO system defines sand as particles greater than 50 μm, European systems generally define sand as having a particle-size > 63 μm. Therefore, a separate study was initiated to find methods applicable to the prediction of the proportion of particles within the FAO sand- and silt-size ranges where this was not known (Nemes et al., 1999). The accuracy of the various methods was evaluated using data from the HYPRES database and from the Soil Information System of the Netherlands (Finke, 1995).

Table 2
Summary statistics of data within HYPRES

Soil units	95
Soil profiles	1777
Soil samples (including replicates)	5521
Soil horizons (excluding replicates)	4486
Used in class pedotransfer	4030
Both water retention and hydraulic conductivity	1136
Only water retention	2894

A total of four methods were tested to describe the cumulative particle-size distribution curves and to derive the equations to be used in the interpolation of the proportion of the FAO sand and silt fractions. These were loglinear, Gompertz (a type of logistic curve), splines and a novel similarity procedure. This latter procedure involved comparing the cumulative particle-size distribution with a well quantified reference set in which the proportions of particles less than 50 μm were known, that is, the Soil Information System of the Netherlands. The cumulative particle-size fractions which were common to both datasets were compared and an iteration procedure was used to select at least 10 of the most appropriate curves from the reference set. The average proportions of particles in the 2–50 μm range were then read from the reference set and applied to the deficient dataset. Nemes et al. (1999) found that for the data within HYPRES, the mean squared errors were greatest for the loglinear method, followed by splines, Gompertz and finally the similarity procedure. However, the Gompertz method could not be used for datasets where there were less than four particle-size classes as it has four parameters which need to be optimised. As a consequence, the similarity interpolation procedure was mainly used to reclassify the soil particle-size classes according to the FAO system, although splines were occasionally used. Once these particle-size data were in a standardised form, they were then stratified according to their texture class and pedology giving 11 classes, that is, five topsoil, five subsoil and one organic class. For the definition of organic (Histic) layers see FAO (1990). Table 3

Table 3
Texture classes used to classify the available data

Name	Definition	Number of horizons
Topsoils		
Coarse	Clay < 18% and sand > 65%	510
Medium	18% < clay < 35% and 15% < sand or clay < 18% and 15% < sand < 65%	644
Medium Fine	Clay < 35% and sand < 15%	208
Fine	35% < clay < 60%	217
Very Fine	60% < clay	21
Subsoils		
Coarse		947
Medium		1181
Medium Fine		526
Fine		596
Very Fine		132
Organic[a]		148

[a]Within the organic soils no distinction is made in topsoils and subsoils.

shows the 11 classes, their texture ranges and the number of samples in each class.

Like the soil textural data, the soil hydraulic data was also derived by various methods resulting in a marked imbalance in the number of data pairs for the soil samples in HYPRES. Therefore, there was also a necessity to standardise these data prior to the development of pedotransfer functions to reduce the possibility of statistical bias. The volumetric soil water content, θ, and hydraulic conductivity, K, as functions of pressure head, h, were parameterised with the equations derived by van Genuchten (1980). The nonlinear least-squares optimisation program RETC (van Genuchten et al., 1991) was used to predict the unknown Mualem-van Genuchten parameters (θ_r, θ_s, K_s, α, l and n) simultaneously from measured water retention and hydraulic conductivity data. The subscripts r and s refer to residual and saturated values and α, l and n are parameters that determine the shape of the curves.

Once the parameterisation was completed, the optimised Mualem-van Genuchten model parameters were used to generate water content and hydraulic conductivity values for the following selected pressure head values: 0, -10, -20, -50, -100, -200, -250, -500, -1000, -2000, -5000, $-10\,000$, $-15\,000$ and $-16\,000$ cm. In this way, all soil horizons, regardless of the number of original measured data points, could be represented by an equal weight in the process of development of class pedotransfer functions. The derived data are stored in the HYDRAULIC_PROPS table.

3. Results and discussion

3.1. Development of pedotransfer functions

Pedotransfer functions for each of the 11 classes were derived by firstly using the optimised Mualem-van Genuchten parameters to determine the moisture contents and conductivities at 14 pressure heads as described above. As the $\theta(h)$ and $K(h)$ relationships are lognormally distributed, the geometric mean moisture contents and conductivities at the 14 pressure heads were calculated. In addition to the geometric mean values, the θ and K values within one standard deviation were calculated. These standard deviations give an indication of the degree of variation of the individual curves around the geometric mean curve. Next the geometric mean values at the 14 pressure heads were again fitted with the Mualem-van Genuchten equations to give typical values for the seven model parameters for each of the 11 texture classes (Table 4). Since these parameters represent the average soil hydraulic properties for a soil texture class they are called class pedotransfer functions. Fig. 2 shows the calculated geometric mean water retention and hydraulic conductivity properties and the standard deviations

Table 4
Mualem-van Genuchten parameters for the fits on the geometric mean curves

	θ_r	θ_s	α	n	m	l	K_s
Topsoils							
Coarse	0.025	0.403	0.0383	1.3774	0.2740	1.2500	60.000
Medium	0.010	0.439	0.0314	1.1804	0.1528	−2.3421	12.061
Mediumfine	0.010	0.430	0.0083	1.2539	0.2025	−0.5884	2.272
Fine	0.010	0.520	0.0367	1.1012	0.0919	−1.9772	24.800
Very Fine	0.010	0.614	0.0265	1.1033	0.0936	2.5000	15.000
Subsoils							
Coarse	0.025	0.366	0.0430	1.5206	0.3424	1.2500	70.000
Medium	0.010	0.392	0.0249	1.1689	0.1445	−0.7437	10.755
Mediumfine	0.010	0.412	0.0082	1.2179	0.1789	0.5000	4.000
Fine	0.010	0.481	0.0198	1.0861	0.0793	−3.7124	8.500
Very Fine	0.010	0.538	0.0168	1.0730	0.0680	0.0001	8.235
Organic[a]	0.010	0.766	0.0130	1.2039	0.1694	0.4000	8.000

[a]Within the organic soils no distinction is made in topsoils and subsoils.

for the texture class 'Medium Fine Topsoils'. The Mualem-van Genuchten fits to the geometric mean values are shown as a dotted line. In general, the calculated geometric means and the fitted curves agree very well, except for the saturated hydraulic conductivities (K_s) of the coarse and very fine texture classes. The presence of macro pores and/or cracks in these soils can cause an error in the estimation of the saturated conductivities when the Mualem-van Genuchten equations are used. However, Fig. 2 shows that the deviation of the fit on the calculated geometric mean K_s value is well within the range of plus and minus one standard deviation.

In addition to the development of class pedotransfer functions, linear regression was also used to investigate the dependency of each model parameter on more easily measured, basic soil properties. To comply with a number of physical boundary conditions, transformed parameters rather than the original model parameters were used in the regression analysis. In this case, the imposed boundary conditions were: $K_s > 0$, $a > 0$, $n > 1$ and $-10 < l < +10$. As a consequence, parameters are transformed as follows; $K_s^* = \ln(K_s)$, $a^* = \ln(a)$, $n^* = \ln(n-1)$ and $l^* = \ln((l+10)/(10-l))$. The following basic soil properties were used as regressed variables: percentage clay, percentage silt, percentage organic matter; bulk density and also the qualitative variable topsoil or subsoil. Linear, reciprocal, and exponential relationships of these basic soil properties were used in the regression analysis, and possible interactions were also investigated. As a consequence, the resulting regression model or continuous pedotransfer function consists of various basic soil properties and their interactions, all of which contribute significantly to the description of the

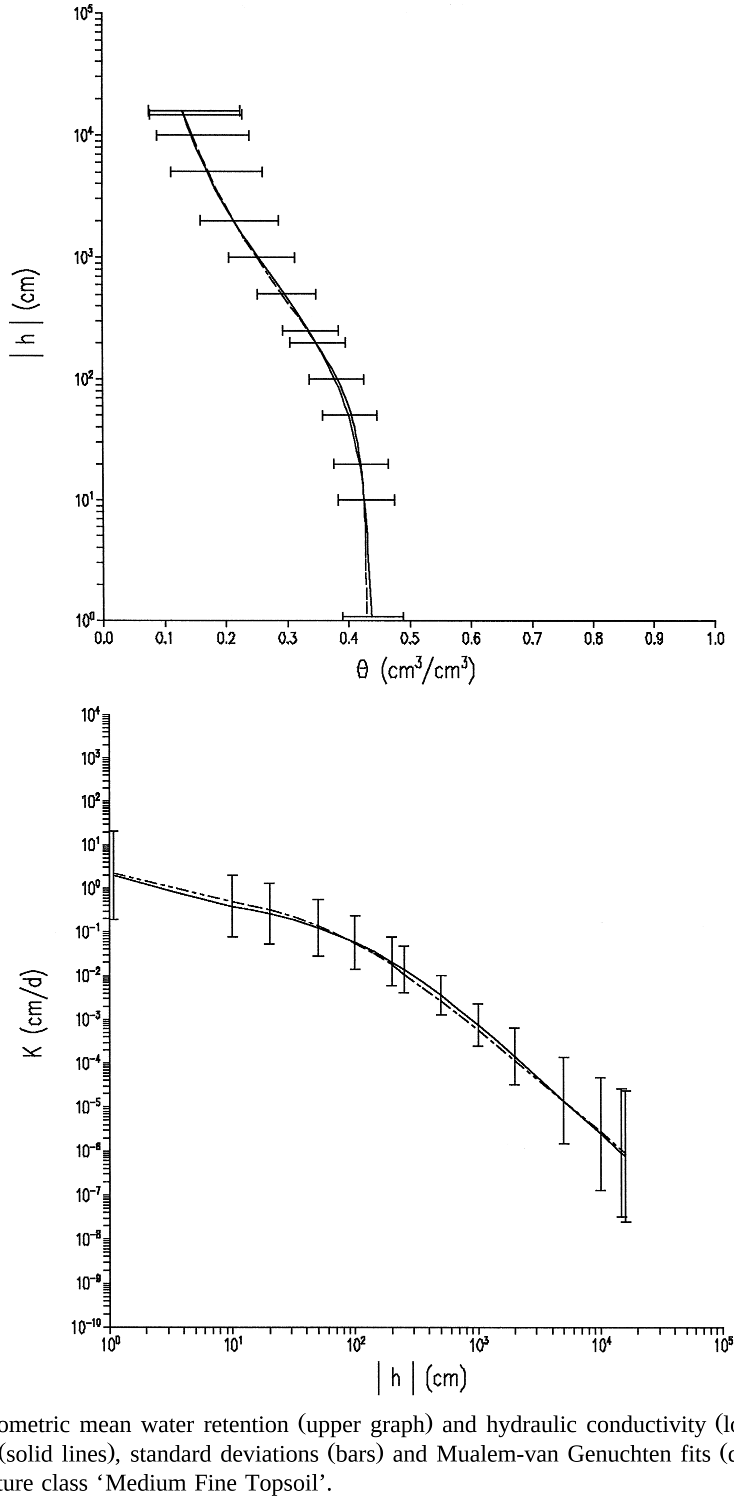

Fig. 2. Geometric mean water retention (upper graph) and hydraulic conductivity (lower graph) properties (solid lines), standard deviations (bars) and Mualem-van Genuchten fits (dotted lines) for the texture class ‘Medium Fine Topsoil’.

transformed model parameters. The models were selected using the subset selection method of Furnival and Wilson (1974). After prediction of the transformed model parameters with these functions, the hydraulic properties are obtained by back-transformation to the original model parameters. Since these pedotransfer functions require point specific soil data instead of class average texture data, they are called continuous pedotransfer functions (Vereecken, 1992; Tietje and Tapkenhinrichs, 1993). The continuous pedotransfer functions developed using the HYPRES database are presented in Table 5.

While class pedotransfer functions predict the hydraulic properties for rather broadly defined soil texture classes, and therefore, do not provide site specific information, continuous pedotransfer functions can be applied in case of more site specific applications. The R^2 values obtained, indicate that the predictions of the hydraulic properties when using continuous pedotransfer functions are not very accurate. Subdividing the complete dataset in subsets of similar soil texture might improve these predictions. In addition, further analysis should reveal if the inclusion of other properties or the application of neural networks instead of regression, are feasible options.

3.2. Application of pedotransfer functions

Throughout the study care was taken to ensure that the HYPRES database and the derived products were compatible with existing EU-wide soil databases and with the 1:1 000 000 Soil Geographical Database of Europe (Jamagne et al., 1994) in particular. For example, the class pedotransfer functions comprise geometric mean water retention and hydraulic conductivity properties (plus standard deviations) for the 11 soil textural/pedological classes which accord with those used in the 1:1 000 000 Soil Geographical Database of Europe. These 11 'building blocks' allow a soil physical interpretation of existing soil maps to be made and thus generate information on the soil physical composition of the unsaturated zone for areas of land (Wösten et al., 1985). Using the class pedotransfer functions in this way, available water capacities were calculated for the different topsoil and subsoil horizons of the Soil Geographical Database. In this case, available water was considered to be the water held between field capacity (pressure head = −50 cm) and wilting point (pressure head = −15 000 cm). These limits are similar to those set by Thomasson (1995) as a method for estimating profile available water. Each Soil Typological Units (STU) of the Soil Geographical Database of Europe was characterised by its topsoil and subsoil textures, soil depths and horizon thickness. The depths of the topsoils and subsoils were based on the available descriptions of the STU attributes (King et al., 1995). The amount of available water for each horizon was derived from the appropriate class pedotransfer function multiplied by the thickness of each horizon. Next, the total available water in mm for each STU was calculated

Table 5
Continuous pedotransfer functions for the prediction of hydraulic properties

$$\theta_s = 0.7919 + 0.001691{*}C - 0.29619{*}D - 0.000001491{*}S^2 + 0.0000821{*}\mathrm{OM}^2 + 0.02427{*}C^{-1} + 0.01113{*}S^{-1}$$
$$+ 0.01472{*}\ln(S) - 0.0000733{*}\mathrm{OM}{*}C - 0.000619{*}D{*}C - 0.001183{*}D{*}\mathrm{OM} - 0.0001664{*}\mathrm{topsoil}{*}S$$
$(R^2 = 76\%)$

$$\alpha^* = -14.96 + 0.03135{*}C + 0.0351{*}S + 0.646{*}\mathrm{OM} + 15.29{*}D - 0.192{*}\mathrm{topsoil} - 4.671{*}D^2 - 0.000781{*}C^2$$
$$- 0.00687{*}\mathrm{OM}^2 + 0.0449{*}\mathrm{OM}^{-1} + 0.0663{*}\ln(S) + 0.1482{*}\ln(\mathrm{OM}) - 0.04546{*}D{*}S - 0.4852{*}D{*}\mathrm{OM} + 0.00673{*}\mathrm{topsoil}{*}C$$
$(R^2 = 20\%)$

$$n^* = -25.23 - 0.02195{*}C + 0.0074{*}S - 0.1940{*}\mathrm{OM} + 45.5{*}D - 7.24{*}D^2 + 0.0003658{*}C^2 + 0.002885{*}\mathrm{OM}^2 - 12.81{*}D^{-1}$$
$$- 0.1524{*}S^{-1} - 0.01958{*}\mathrm{OM}^{-1} - 0.2876{*}\ln(S) - 0.0709{*}\ln(\mathrm{OM}) - 44.6{*}\ln(D) - 0.02264{*}D{*}C + 0.0896{*}D{*}\mathrm{OM} + 0.00718{*}\mathrm{topsoil}{*}C$$
$(R^2 = 54\%)$

$$l^* = 0.0202 + 0.0006193{*}C^2 - 0.001136{*}\mathrm{OM}^2 - 0.2316{*}\ln(\mathrm{OM}) - 0.03544{*}D{*}C + 0.00283{*}D{*}S + 0.0488{*}D{*}\mathrm{OM}$$
$(R^2 = 12\%)$

$$K_s^* = 7.755 + 0.0352{*}S + 0.93{*}\mathrm{topsoil} - 0.967{*}D^2 - 0.000484{*}C^2 - 0.000322{*}S^2 + 0.001{*}S^{-1} - 0.0748{*}\mathrm{OM}^{-1}$$
$$- 0.643{*}\ln(S) - 0.01398{*}D{*}C - 0.1673{*}D{*}\mathrm{OM} + 0.02986{*}\mathrm{topsoil}{*}C - 0.03305{*}\mathrm{topsoil}{*}S$$
$(R^2 = 19\%)$

θ_s is a model parameter, α^*, n^*, l^* and K_s^* are transformed model parameters in the Mualem-van Genuchten equations; C = percentage clay (i.e., percentage < 2 μm); S = percentage silt (i.e., percentage between 2 μm and 50 μm); OM = percentage organic matter; D = bulk density; topsoil and subsoil are qualitative variables having the value of 1 or 0; and ln = natural logarithm.

by summation of the calculated moisture availability of the appropriate topsoil and subsoil horizons.

Using the estimated values for each STU of the Soil Geographical Database of Europe, Fig. 3 shows the map of total available water on a European scale. This map is just one example of the type of new spatial information that can be

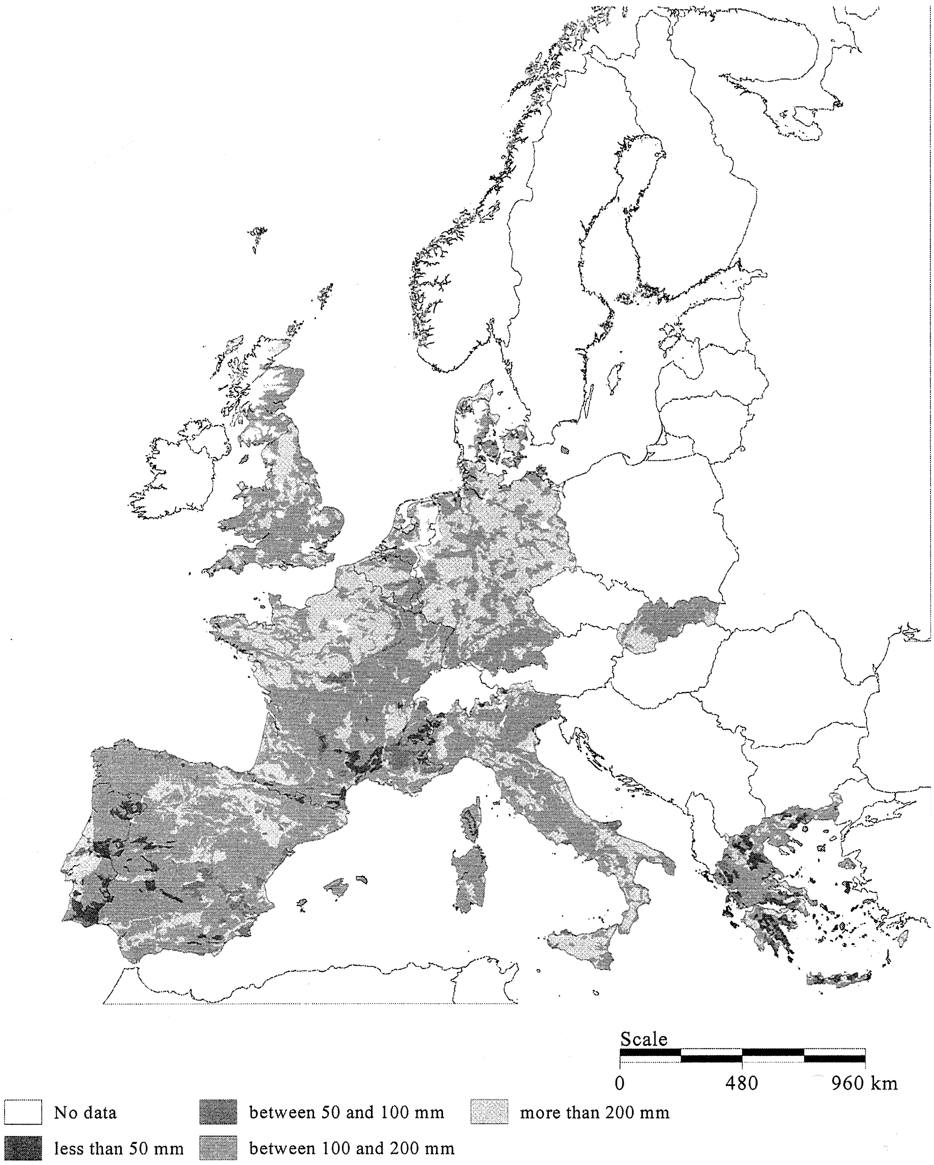

Fig. 3. Total available water (mm) between field capacity ($h = -50$ cm) and wilting point ($h = -15\,000$ cm).

generated when the derived pedotransfer functions are used in combination with other existing European soil data such as the Soil Geographical Database of Europe. Other possible new products could be a travel time map for solutes and an infiltration rate map for erosion studies.

4. Conclusions and recommendations

A number of conclusions and recommendations can be drawn from this work.

4.1. Conclusions

The HYPRES database and its derived pedotransfer functions make it possible to assign soil hydraulic properties to soils with a textural composition comparable to the soils for which these pedotransfer functions have been derived. However, the functions should not be used for the assignment of hydraulic properties to soils outside Europe. In the first case, an acceptable form of data interpolation is carried out, whereas in the second case a very risky form of data extrapolation is applied.

Class pedotransfer functions give the mean hydraulic properties for rather broadly defined soil texture classes. As a consequence, these functions are more general applicable, but they give limited site specific information. In contrast, continuous pedotransfer functions are more site specific, however, their general applicability is limited.

The number of individual, measured properties varies greatly for the different texture classes. For example, for very fine textured topsoils the mean characteristic is based on only 21 properties. Whereas for medium textured subsoils the mean characteristic is based on as many as 1181 properties. These differences in numbers have consequences for how representative these mean properties are for any particular texture class.

Classification of measurements is based on texture information of the soil horizons on which the measurements are carried out. This implies that differences in, for example, geological formation or soil structure, which may well lead to a different hydraulic behaviour, are not yet taken into account.

Use of different measurement techniques by the institutions that contributed soil hydraulic properties, will contribute to the within class variability. This 'method-effect' cannot be distinguished from the spatial variability.

By making use of the 11 texture classes of the 1:1 000 000 scale Soil Geographical Database of Europe, the derived pedotransfer functions can be applied on a pannational scale of 1:1 000 000 or more general. The presented class pedotransfer functions are not applicable for more detailed applications. In the latter case, it is necessary to measure the hydraulic properties of the profile at the particular location.

4.2. Recommendations

The HYPRES database constitutes a unique source of information on soil hydraulic properties of European soils. Continuing creative and innovative use of this information (e.g., neural networks, other types of correlation, linkage with other international databases) is highly recommended. In particular, linking with the 1:1 000 000 scale Soil Geographical Database of Europe offers the possibility to generate new spatial information such as a water availability map. This information is useful for scientists, planners and politicians.

It is recommended that periodic updates of the pedotransfer functions be made when more data become available. The ongoing process of adding new data and updating will result in improvement of the end products and will increase the applicability of the end products for Europe as a whole. In collecting new data, emphasis should be on those countries that until now contributed relatively few data.

It is recommended that along with periodic updates attention is given to the harmonisation of soil physical measurement techniques among the different institutions. This will minimise the 'method-effect' on the within class variability of the soil hydraulic properties.

It is expected that the HYPRES database and the other end products of this in-depth investment will be used by many researchers working on European agricultural and environmental issues as it represents the first attempt at standardising the disparate hydraulic data from around Europe. It is recommended that national institutions develop a similar approach to the organisation of data within their own countries.

It is recommended that soil hydraulic data from countries in Central and Eastern Europe be added to the HYPRES database whenever possible. This is of particular importance as these countries already co-operate in the formation of other soils-related European databases.

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