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Abstract

Among the numerous pedotransfer functions (PTFs) published, class-PTfs have received little attention because their accuracy is often considered as limited. However, recent studies show that performance of class-PTFs can be similar to the more popular continuous-PTFs. In this study, we compare the performance of PTFs that were derived from a set of 456 horizons collected in France grouped by combinations of texture, bulk density and type of horizon (topsoil and subsoil). The performance of these class-PTFs was validated against water retained at -33 and -1500 kPa. Our results show that the best performance was obtained with class-PTFs that used both texture and bulk density (texture-structural class-PTFs). They showed also that incorporation of horizon type into the PTF did not improve prediction performance. Comparison of performance at -33 and -1500 kPa showed very little difference, thus indicating no bias according to the value of water potential. Finally, the class-PTFs developed are well suited for predicting water retention properties at continental and national scales because only very basic soils data is available at these scales. A map of the available water capacity (AWC) was established for France using the 1:1 000 000 Soil Geographical Database of France and an averaged AWC of 104 mm was computed for France.

Keywords: Class pedotransfer function, prediction bias, prediction precision, available water capacity, digital soil mapping

INTRODUCTION

Pedotransfer functions (PTFs) use basic soil properties that are relatively easily available to less frequent and more difficult to measure soil properties such as hydraulic ones (Bouma and van Lanen, 1987). Many are continuous pedotransfer functions (continuous-PTFs) developed over the last three decades and are empirical regression functions relating hydraulic parameters to basic soil properties including texture, organic matter content and bulk density (e.g. Bastet *et* al., 1999; Wösten *et al.*, 2001; Pachepsky *et al.*, 2006). Thus continuous-PTFs enabling the prediction of water content at particular water potentials (Rawls *et al.*, 1982 & 2004) or the estimation of the parameters of models of the water retention curve (Vereecken *et al.*, 1989; Bruand *et al.*, 1994; Leenhardt, 1995; Minasny *et al.*, 1999; Wösten *et al.*, 2001; Cresswell *et al.*, 2006; Tranter *et al.*, 2007).

In addition to the development of continuous-PTFs, class pedotransfer functions (class-PTFs) were also developed (Wösten *et al*., 1995; Pachepsky *et al*., 2003; Rawls *et al*., 2003). Most class-PTFs provide class average water contents at particular water potentials or one average water retention curve for every textural class (e.g. Nemes *et al*, 2001; Nemes, 2002; Bruand *et al*., 2003 & 2004). They received little attention because their accuracy was considered limited (Wösten *et al*., 1995). Due to the large range in particle size distribution, clay mineralogy, organic matter content and structural development within each texture class, water retention properties for individual soils vary considerably (Wösten *et al*., 1999). Class-PTFs are easy to use given that they require little soil information and are well suited for predicting water retention properties at continental and national scales because only very basic soils data is available at these scales (Wösten *et al*. 1995; Lilly *et al*., 1999; Wösten *et al*. 1999; Nemes *et al*., 2003).

Several studies provide information on the performance of continuous-PTFs (Minasny *et al*., 1999; Wösten *et al*., 2001; Cornelis *et al*., 2001; Donatelli *et al*., 2004) and class-PTFs (Pachepsky and Rawls, 1999; Wösten *et al*., 2001; Ungaro *et al*., 2005). However, there are very few studies comparing the performance of continuous- and class-PTFs when applied to the same dataset (Wösten *et al*., 1995). Al Majou et al. (2007) compared the performance of class- and continuous-PTFs and showed that they perform equally well despite better incorporation of individual soil properties within the continuous-PTFs. These results reinforced the significance of class-PTFs as developed by Bruand et al. (2003) that were based on texture alone or on both texture and clod bulk density, the latter giving the best performance. However, use of these class-PTFs has remained limited because clod bulk density is not available in most soil databases This study develops the study by Al Majou *et al*. (2007) for predicting volumetric water content at several water potentials by combining texture, bulk density and type of horizon. The validity of these class-PTFs was assessed at -33 and -1500 kPa water potential and the class-PTFs developed in this study were used to derive maps of available water capacity for France.

MATERIAL AND METHODS

Data collection

Class-PTFs were developed using a set of 456 horizons comprising 138 topsoil horizons (from 0 to 30 cm depth) and 318 subsoil horizons (> 30 cm depth) collected from Cambisols, Luvisols, Planosols, Albeluvisols, Podzols and Fluvisols (ISSS Working Group WRB, 1998) located in the Paris basin, Brittany, the western coastal marshlands and Pyrenean piedmont plain (Figure 1a). A set of 197 horizons from Cambisols, Luvisols and Fluvisols (ISSS Working Group WRB, 1998), from several areas of France and developed on a large range of parent materials was collated in order to test the derived class-PTFs (Figure 1b).

Basic and water retention properties

Particle size distribution was measured using the pipette method after pre-treatment with hydrogen peroxide and sodium hexametaphosphate (Robert & Tessier 1974). The soil textural triangle of the Commission of the European Communities was used to derive classes (Commission of the European Communities, 1985) (Figure 2). The cation exchange capacity ($cmol_c\,kg^{-1}$ of oven-dried soil) was measured using the cobalt-hexamine trichloride method (Ciesielski & Sterckeman 1997) and organic carbon by oxidation using excess potassium dichromate in sulphuric acid at 135°C (Baize 2000). Bulk density (D_b) was measured by using cylinders 1236 cm^3 in volume taken when the soil was near to field capacity. The gravimetric water content was determined by using pressure plate apparatus for the 456 horizons data set at –1, –3.3, –10, –33, –100, –330 and –1500 kPa water potential, and for the 197 horizon data set at –33 and –1500 kPa water potential, by using undisturbed samples (10–15 cm^3) collected when the soil was near to field capacity for both sets (Bruand and Tessier, 2000). Then, the volumetric water content (θ) for each horizon was computed using the bulk density of horizon (Table 1).

Analysis of the class-PTFs performance

Most discussions of PTFs performance are based the root mean square error (*RMSE*), also called root mean squared deviation or root mean square residual (Wösten *et al.*, 2001). Because *RMSE* varies according to both prediction bias and precision, we also computed the mean error of prediction (*MEP*) to enable discussion of prediction bias and the standard deviation of prediction (*SDP*) for assessment of prediction precision. Thus we computed the *RMSE*, *MEP* and *SDP* at –33 and –1500 kPa water potential as following:

$$RMSE = \left\{ \frac{1}{l' \cdot l} \sum_{j=1}^{l'} \sum_{i=1}^{l} \left(\theta_{p,j,i} - \theta_{m,j,i} \right)^2 \right\}^{1/2}$$

$$MEP = \frac{1}{l' \cdot l} \sum_{j=1}^{l'} \sum_{i=1}^{l} (\theta_{p,j,i} - \theta_{m,j,i})$$

$$SDP = \left\{ \frac{1}{l' \cdot l} \sum_{j=1}^{l'} \sum_{i=1}^{l} \left[(\theta_{p,j,i} - \theta_{m,j,i}) - MEP \right]^2 \right\}^{1/2}$$

where $\theta_{p,j,i}$ is the predicted water content at potential *i* for horizon *j*, $\theta_{m,i,j}$ is the measured water content at potential *i* for horizon *j*, and *l* is the number of water potentials for each horizon (*l*=7 in this study) and *l'* is the number of horizons (*l'* ≤ 197 in this study). The *MEP* corresponds to the bias and indicates whether the class-PTFs overestimated (positive) or underestimated (negative) the water content, whereas *SDP* measures the precision of the prediction.

RESULTS AND DISCUSSION

Deriving the class-PTFs

The class-PTFs developed in this study comprised average water content at seven water potentials. They were first established according to the soil texture classes (texture class-PTFs) used by the Commission of European Communities (1985) for all horizons (Table 2). Then, as topsoils and subsoils often have different pore size distribution particularly with respect to macroporosity, texture class-PTFs were also developed after stratification by type of horizon (topsoil and subsoil horizons) (Table 3). Then, due to differences in bulk density (D_b), class-PTFs were established according to both texture and D_b (texture-structural class-PTFs) for the whole set of horizons without any other stratification (Table 4) and also after stratification by the type of horizon (topsoil and subsoil horizons) (Table 5).

Validity of the textural and texturo-structural class-PTFs

The texture class-PTFs underestimated water retained (*MEP* = –0.015 cm^3.cm^{-3}) when applied to the test dataset (Table 6). The precision of the estimation was small with *SDP* = 0.041 cm^3.cm^{-3}. There was a 0.011 cm^3.cm^{-3} decrease in the prediction bias and a 0.009 cm^3.cm^{-3} increase in the precision with texture-structural class-PTFs. With the texture class-PTFs, the greatest bias and the least precision were recorded for the Fine texture class (*MEP* = -0.025 cm^3.cm^{-3} and *SDP* = 0.042 cm^3.cm^{-3}), and the improvement in estimation performance was particularly significant for that texture with the texture-structural class-PTFs (*MEP* = -0.005 cm^3.cm^{-3} and *SDP* = 0.032 cm^3.cm^{-3}). Therefore, the high *RMSE* recorded with the texture class-PTFs (*RMSE* = 0.044 cm^3.cm^{-3}) was related to a relatively poor prediction precision (*SDP* = 0.041 cm^3.cm^{-3}), the bias being small (*MEP* = -0.015 cm^3.cm^{-3}). However, this *RMSE* was smaller than the *RMSE* recorded by Bruand *et al*. (2003) for volumetric water content with texture class-PTFs that enabled prediction of the gravimetric water content at -33 and -1500 kPa water potential. The smaller *RMSE* recorded with the texture-structural class-PTFs ($\Delta RMSE$ = 0.011 $cm^3.cm^{-3}$) was related to the significant decrease in the estimation bias and increase in precision. The *RMSE* recorded with the texture-structural class-PTFs was again smaller than the *RMSE* recorded by Bruand *et al*. (2003) for the volumetric water content with texture-structural class-PTFs developed in their study.

Validity of the texture and texture-structural class-PTFs after stratification by horizon type

Establishing textural class-PTFs after stratification according to the type of horizon (i.e. by separating topsoil and subsoil horizons) did not improve the performance of the texture class-PTFs (ΔMEP = 0.001 $cm^3.cm^{-3}$ and ΔSDP = 0.002 $cm^3.cm^{-3}$) (Table 6). There was also no improvement in the performance with the texture-structural class-PTFs after stratification by horizon type (ΔMEP = 0.001 $cm^3.cm^{-3}$ and ΔSDP = 0.003 $cm^3.cm^{-3}$) (Table 6). This lack of improvement explains the similar *RMSE* that were recorded with the texture and texture-structural class-PTFs with or without stratification by horizon type (Table 6).

Validity of the texture and texture-structural class-PTFs according to water potential

Analysis of the results according to water potential showed that each type of class-PTF studied led to roughly similar performance at -33 and -1500 kPa (Figure 3). The bias was however slightly improved at -33 kPa for each type of PTF discussed (Figure 3). On the other hand, the precision was a little greater and the *RMSE* smaller at -1500 kPa except for the texture-structural PTFs (Table 7). This weak difference in performance at -33 and -1500 kPa means similar performance in a large range of water potential for the discussed class-PTFs.

Application of class-PTFs to France

Class-PTFs as developed in this study were used to compute available water capacity (AWC) for Soil Typological Units (STU) in the 1:1 000 000 Soil Geographical Database of France (King *et al*., 1995). Available water was taken as the water held between wilting point (-1500 kPa water potential) and field capacity (-10 kPa water potential). A water potential of -10 kPa was shown as the water potential at field capacity for the studied soil (Al Majou *et al*., 2008). The depth, texture and bulk density of the topsoils and subsoils were based on available descriptions of STU attributes (King *et al*., 1995). The amount of available water for each topsoil and subsoil was derived from the appropriate class-PTFs multiplied by the thickness of each horizon. Then, the total available water in mm for each STU was computed by summation of the corresponding topsoil and subsoil. Next, the available water in mm for each Soil Mapping Unit (SMU) was computed according to the proportion of the different STU present in each SMU (King *et al*., 1995; Wösten et al., 1999). A map of the AWC was established by using the texture-structural class-PTFs that showed the best performance (Table 4, Figure 4). The average AWC of 104 mm was computed for France by taking into account the surface area of each SMU.

CONCLUSION

Our results show that the best performing PTF was based on both texture and bulk density (texture-structural class-PTFs). It was also shown that incorporation of horizon type did not improve prediction performance. Comparison of the performance at -33 and -1500 kPa showed very little difference, thus indicating no bias according to value of water potential. Finally, the class-PTFs developed require little soil information and are well suited for predicting water retention properties at continental and national scales because only very basic soils data is available at these scales. This was illustrated with the use of the class-PTFs developed to generate a map of the available water capacity (AWC) for the whole of France using the 1:1 000 000 Soil Geographical Database of France; as a result the average AWC was computed for France.

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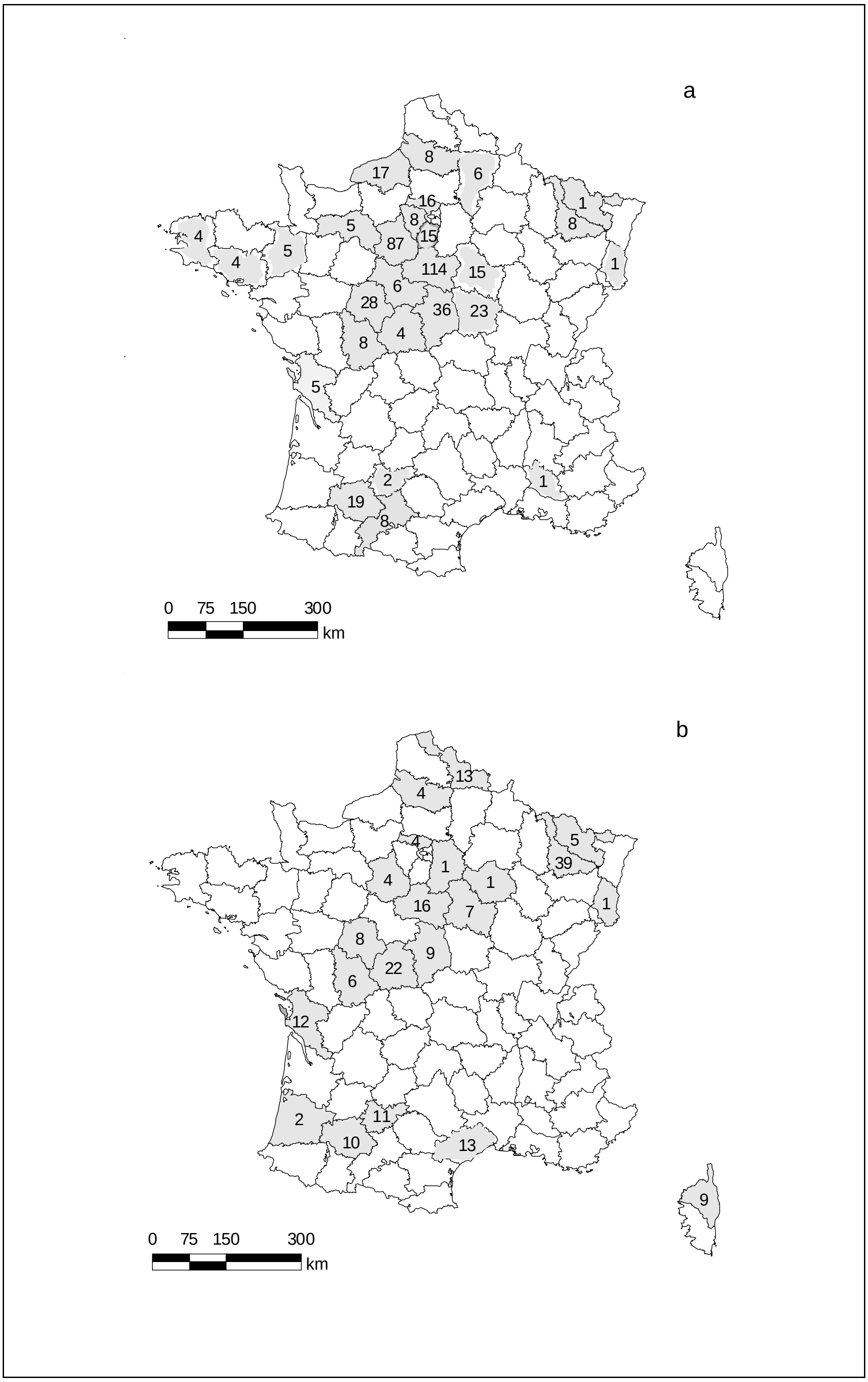

Figure 1. Location of the studied soils (number of horizon by department) that were used to establish the class-PTFs (a) and to test their validity (b).

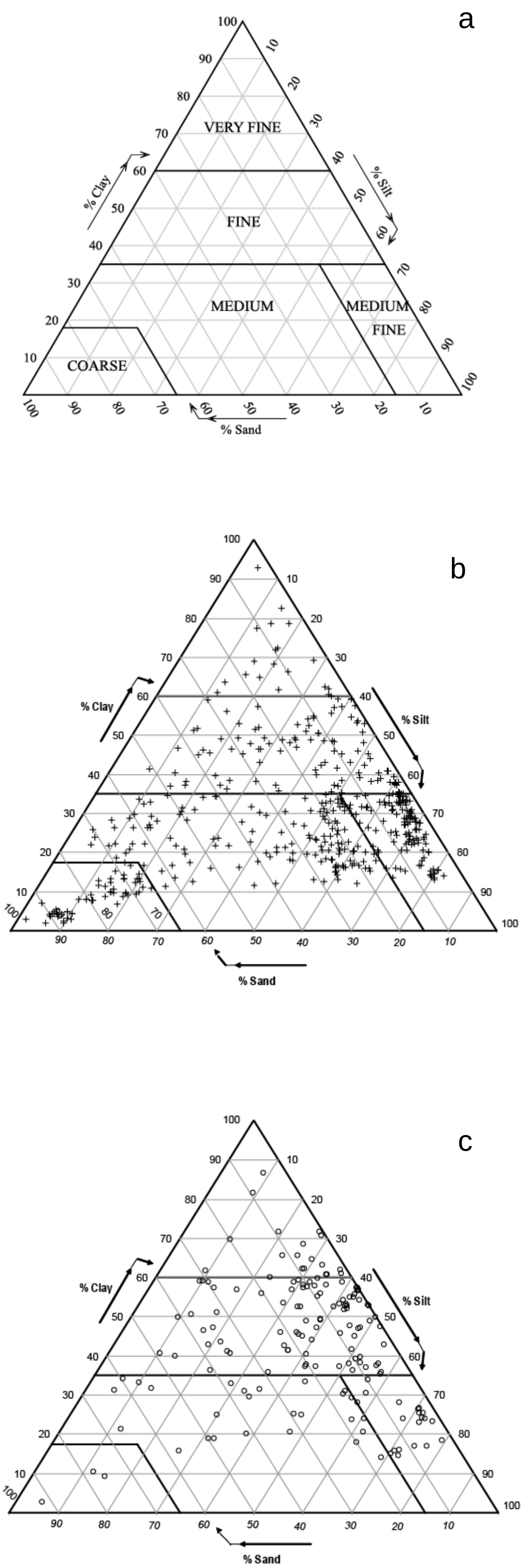

Figure 2. Texture triangle used (a), texture of the horizons used to establish the class-PTFs (b) and texture of those used to test their validity (c).

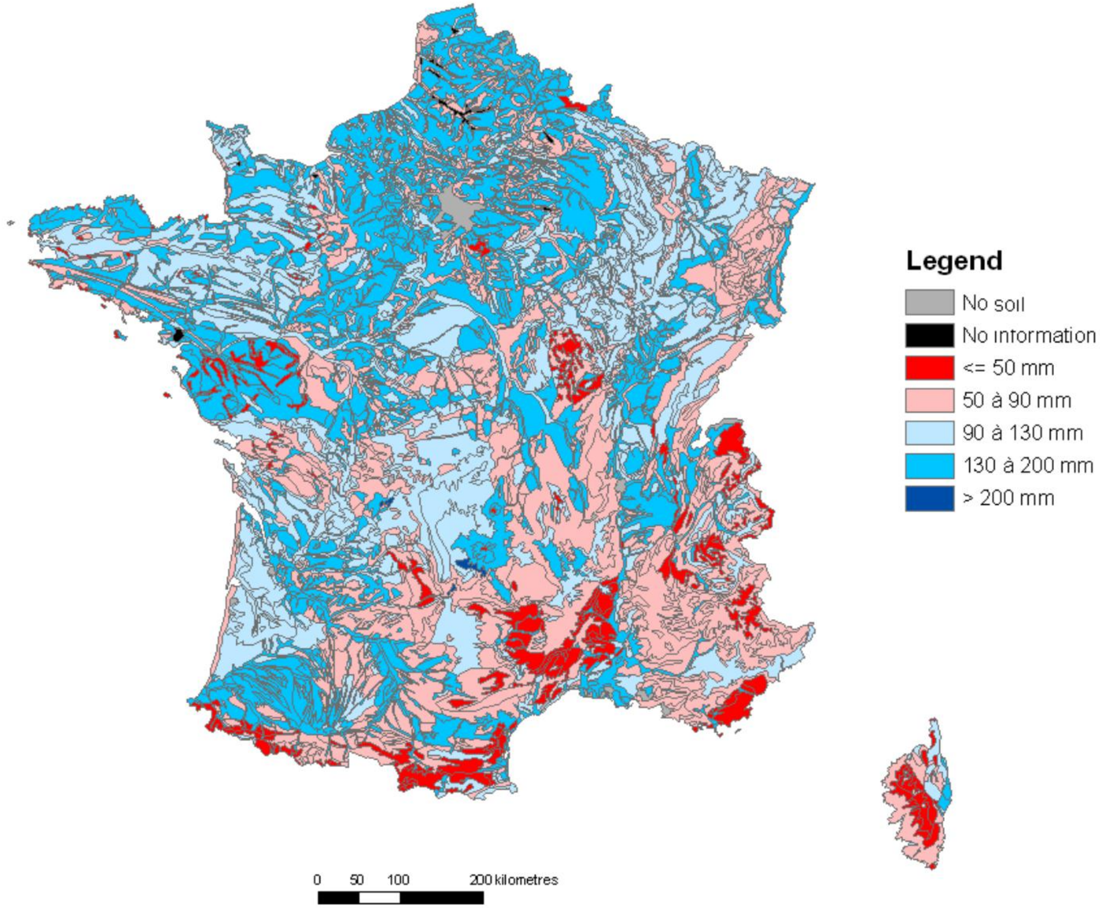

Figure 3. Available water capacity (mm) for France using the texture-structural class-PTFs.

Table 1. Characteristics of the horizons used to establish the PTFs.

	Particle size distribution (%)			Organic carbon content	Calcium carbonate content	Cation exchange capacity	Bulk Density	Volumetric water content ($cm^3.cm^{-3}$)						
	<2 µm	2-50 µm	50-2000 µm	$g.kg^{-1}$	$g.kg^{-1}$	$cmol_c kg^{-1}$	$g.cm^{-3}$	θ_1	$\theta_{3.3}$	θ_{10}	θ_{33}	θ_{100}	θ_{330}	θ_{1500}
Horizons used to derive the class-PTFs (n = 456)														
mean	29.3	43.8	26.9	6.0	54.2	14.8	1.52	0.354	0.335	0.315	0.289	0.259	0.221	0.187
s.d.	15.4	21.8	25.6	5.1	171.3	9.0	0.15	0.068	0.070	0.075	0.076	0.079	0.076	0.073
min.	1.9	1.6	0.1	0.0	0.0	0.6	0.95	0.134	0.100	0.080	0.056	0.045	0.033	0.013
max.	92.9	82.1	95.4	28.8	982	52.8	1.98	0.605	0.596	0.586	0.557	0.510	0.462	0.370
Horizons used to test the class-PTFs (n = 197)														
mean	39.4	39.3	21.3	5.6	31.5	19.9	1.45	-	-	-	0.330	-	-	0.235
s.d.	16.9	17.1	19.2	5.8	58.7	7.8	0.16	-	-	-	0.071	-	-	0.070
min.	2.7	5.4	0.0	0.0	0.0	3.3	1.16	-	-	-	0.107	-	-	0.065
max.	86.7	79.4	91.9	40.3	212.0	40.4	1.94	-	-	-	0.468	-	-	0.360

Table 2. Texture class-PTFs.

	Volumetric water content ($cm^3.cm^{-3}$)						
	θ_1	$\theta_{3.3}$	θ_{10}	θ_{33}	θ_{100}	θ_{330}	θ_{1500}
After stratification by texture alone (n = 456)							
Very fine (n = 20)	0.457	0.439	0.426	0.404	0.387	0.352	0.327
Fine (n = 102)	0.405	0.390	0.374	0.351	0.333	0.299	0.262
Medium fine (n = 127)	0361	0.345	0.329	0.300	0.257	0.211	0.178
Medium (n = 151)	0.336	0.318	0.300	0.273	0.244	0.204	0.164
Coarse (n = 56)	0.257	0.220	0.180	0.150	0.123	0.102	0.082

Table 3. Texture class-PTFs developed according to type of horizon (topsoil and subsoil horizons).

	Volumetric water content ($cm^3.cm^{-3}$)						
	θ_1	$\theta_{3.3}$	θ_{10}	θ_{33}	θ_{100}	θ_{330}	θ_{1500}
Topsoil horizons (n = 138)							
Very fine (n = 2)	0.468	0.450	0.431	0.402	0.378	0.332	0.293
Fine (n = 17)	0.437	0.410	0.392	0.367	0.354	0.304	0.272
Medium fine (n = 48)	0.359	0.340	0.324	0.297	0.250	0.196	0.155
Medium (n = 40)	0.346	0.328	0.311	0.289	0.260	0.208	0.161
Coarse (n = 31)	0.272	0.235	0.198	0.167	0.138	0.115	0.091
Subsoil horizons (n = 318)							
Very fine (n = 18)	0.456	0.438	0.425	0.405	0.388	0.354	0.330
Fine (n = 85)	0.399	0.386	0.370	0.348	0.328	0.298	0.261
Medium fine (n = 79)	0.363	0.349	0.332	0.302	0.262	0.221	0.192
Medium (n = 111)	0.332	0.315	0.296	0.267	0.238	0.203	0.165
Coarse (n = 25)	0.237	0.201	0.158	0.129	0.104	0.086	0.070

Table 4. Texture-structural class-PTFs.

		n	Volumetric water content ($cm^3.cm^{-3}$)						
			θ_1	$\theta_{3.3}$	θ_{10}	θ_{33}	θ_{100}	θ_{330}	θ_{1500}
Very fine (n = 20)	$1.10 \leq D_b < 1.30$	9	0.491	0.469	0.450	0.423	0.405	0.361	0.334
	$1.30 \leq D_b < 1.50$	7	0.463	0.443	0.430	0.408	0.386	0.346	0.330
	$1.50 \leq D_b < 1.70$	4	0.390	0.374	0.376	0.370	0.367	0.354	0.308
Fine (n = 102)	$1.00 \leq D_b < 1.20$	6	0.529	0.503	0.492	0.462	0.438	0.368	0.270
	$1.20 \leq D_b < 1.40$	21	0.444	0.429	0.411	0.380	0.364	0.325	0.281
	$1.40 \leq D_b < 1.60$	61	0.392	0.375	0.359	0.340	0.320	0.288	0.258
	$1.60 \leq D_b < 1.80$	14	0.353	0.346	0.331	0.309	0.295	0.278	0.249
Medium fine (n = 127)	$1.20 \leq D_b < 1.40$	24	0.360	0.344	0.326	0.293	0.241	0.192	0.159
	$1.40 \leq D_b < 1.60$	84	0.363	0.346	0.329	0.300	0.259	0.211	0.178
	$1.60 \leq D_b < 1.80$	19	0.356	0.346	0.331	0.308	0.271	0.238	0.200
Medium (n = 151)	$1.20 \leq D_b < 1.40$	17	0.361	0.340	0.320	0.285	0.253	0.202	0.154
	$1.40 \leq D_b < 1.60$	66	0.347	0.328	0.307	0.275	0.240	0.200	0.160
	$1.60 \leq D_b < 1.80$	65	0.319	0.304	0.289	0.267	0.245	0.207	0.169
	$1.80 \leq D_b < 2.00$	3	0.296	0.294	0.276	0.273	0.269	0.245	0.209
Coarse (n = 56)	$1.20 \leq D_b < 1.40$	6	0.255	0.200	0.175	0.136	0.114	0.094	0.076
	$1.40 \leq D_b < 1.60$	20	0.254	0.208	0.163	0.137	0.111	0.092	0.078
	$1.60 \leq D_b < 1.80$	26	0.262	0.239	0.199	0.167	0.138	0.113	0.088
	$1.80 \leq D_b < 2.00$	4	0.237	0.181	0.153	0.127	0.100	0.091	0.065

Table 5. Texture-structural class-PTFs developed according to type of horizon (topsoil and subsoil horizons).

		n	Volumetric water content ($cm^3.cm^{-3}$)						
			θ_1	$\theta_{3.3}$	θ_{10}	θ_{33}	θ_{100}	θ_{330}	θ_{1500}
Topsoil horizons (n = 138)									
Very fine	$1.10 \le D_b < 1.30$	2	0.468	0.450	0.431	0.402	0.378	0.332	0.293
Fine (n = 17)	$1.00 \le D_b < 1.20$	2	0.468	0.422	0.402	0.383	0.376	0.312	0.280
	$1.20 \le D_b < 1.40$	6	0.453	0.431	0.410	0.382	0.378	0.324	0.293
	$1.40 \le D_b < 1.60$	9	0.420	0.394	0.377	0.354	0.332	0.289	0.256
Medium fine (n = 48)	$1.20 \le D_b < 1.40$	19	0.358	0.343	0.325	0.294	0.239	0.189	0.153
	$1.40 \le D_b < 1.60$	29	0.360	0.338	0.324	0.299	0.257	0.200	0.156
Medium (n = 40)	$1.20 \le D_b < 1.40$	11	0.372	0.353	0.335	0.302	0.270	0.214	0.164
	$1.40 \le D_b < 1.60$	20	0.349	0.328	0.311	0.294	0.265	0.215	0.171
	$1.60 \le D_b < 1.80$	9	0.308	0.295	0.281	0.261	0.236	0.186	0.133
Coarse (n = 31)	$1.20 \le D_b < 1.40$	5	0.265	0.206	0.178	0.146	0.120	0.100	0.077
	$1.40 \le D_b < 1.60$	13	0.258	0.210	0.171	0.148	0.120	0.098	0.085
	$1.60 \le D_b < 1.80$	13	0.290	0.271	0.234	0.195	0.164	0.136	0.103
Subsoil horizons (n = 318)									
Very fine (n = 18)	$1.10 \le D_b < 1.30$	8	0.487	0.463	0.445	0.421	0.406	0.367	0.344
	$1.30 \le D_b < 1.50$	7	0.463	0.443	0.430	0.408	0.386	0.346	0.330
	$1.50 \le D_b < 1.70$	3	0.378	0.370	0.378	0.374	0.371	0.354	0.295
Fine (n = 85)	$1.00 \le D_b < 1.20$	4	0.560	0.544	0.536	0.502	0.469	0.396	0.265
	$1.20 \le D_b < 1.40$	15	0.440	0.429	0.411	0.379	0.358	0.325	0.276
	$1.40 \le D_b < 1.60$	52	0.387	0.372	0.356	0.337	0.318	0.287	0.259
	$1.60 \le D_b < 1.80$	14	0.353	0.346	0.331	0.309	0.295	0.278	0.249
Medium fine (n = 79)	$1.20 \le D_b < 1.40$	5	0.366	0.349	0.331	0.291	0.249	0.207	0.180
	$1.40 \le D_b < 1.60$	55	0.365	0.350	0.332	0.301	0.259	0.217	0.190
	$1.60 \le D_b < 1.80$	19	0.356	0.346	0.331	0.308	0.271	0.238	0.200
Medium (n = 111)	$1.20 \le D_b < 1.40$	6	0.340	0.317	0.293	0.254	0.222	0.179	0.134
	$1.40 \le D_b < 1.60$	46	0.346	0.328	0.306	0.267	0.228	0.194	0.154
	$1.60 \le D_b < 1.80$	56	0.321	0.305	0.290	0.268	0.246	0.211	0.175
	$1.80 \le D_b < 2.00$	3	0.296	0.294	0.276	0.273	0.269	0.245	0.209
Coarse (n = 25)	$1.40 \le D_b < 1.60$	8	0.241	0.199	0.150	0.114	0.093	0.077	0.066
	$1.60 \le D_b < 1.80$	13	0.235	0.207	0.164	0.139	0.112	0.089	0.073
	$1.80 \le D_b < 2.00$	4	0.237	0.181	0.153	0.127	0.100	0.091	0.065

Table 6. Validity of the class pedotranfer functions derived after stratification by texture alone, after stratification by texture and bulk density of horizon and according to the horizon.

	n	Mean error of prediction (*MEP*) $cm^3.cm^{-3}$	Standard deviation of prediction (*SDP*) $cm^3.cm^{-3}$	Root mean squared error (*RMSE*) $cm^3.cm^{-3}$
Texture class-PTFs				
Very fine	18	-0.005	0.026	0.026
Fine	98	-0.025	0.042	0.049
Medium fine	22	-0.004	0.035	0.035
Medium	51	-0.007	0.043	0.044
Coarse	8	0.003	0.021	0.020
All textures together	197	-0.015	0.041	0.044
Texture-structural class-PTFs				
Very fine	18	0.003	0.024	0.024
Fine	98	-0.005	0.032	0.032
Medium fine	22	-0.0003	0.036	0.036
Medium	51	-0.005	0.036	0.037
Coarse	8	-0.005	0.014	0.015
All textures together	197	-0.004	0.032	0.033
Textural class-PTFs after stratification by the type of horizon				
Very fine	18	-0.003	0.026	0.026
Fine	98	-0.026	0.043	0.050
Medium fine	22	0.002	0.037	0.037
Medium	51	-0.005	0.046	0.046
Coarse	8	0.012	0.019	0.022
All textures together	197	-0.014	0.043	0.045
Texture-structural class-PTFs after stratification by type of horizon				
Very fine	18	0.004	0.026	0.026
Fine	98	-0.007	0.032	0.032
Medium fine	22	0.003	0.037	0.037
Medium	51	-0.003	0.043	0.043
Coarse	8	0.003	0.013	0.013
All textures together	197	-0.003	0.035	0.035

[1] Volumetric water content at water potential h ($\theta_{\log|h|}$)

Table 7. Validity of the texture and texture-structural class pedotranfer functions according to water potential (test dataset: n = 197).

	Mean error of prediction (*MEP*) $cm^3.cm^{-3}$		Standard deviation of prediction (*SDP*) $cm^3.cm^{-3}$		Root mean squared error (*RMSE*) $cm^3.cm^{-3}$	
	-33 kPa	-1500 kPa	-33 kPa	-1500 kPa	-33 kPa	-1500 kPa
Texture class-PTFs						
All textures together according to the water potential	-0.016	-0.015	0.042	0.039	0.045	0.042
Texture-structural class-PTFs						
All textures together according to the water potential	-0.003	-0.005	0.033	0.032	0.033	0.033
Texture class-PTFs after stratification by type of horizon						
All textures together according to the water potential	-0.015	-0.013	0.045	0.041	0.047	0.043
Texture-structural class-PTFs after stratification by type of horizon						
All textures together according to the water potential	-0.002	-0.005	0.034	0.035	0.034	0.035