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Analysis of the suitability of Polish soil texture classification for estimating soil water retention and hydraulic properties

Abstract: The objective of this study was to examine whether the Polish soil textural classification is useful for evaluation of soil water retention and hydraulic properties and, furthermore, for determining which textural classes are characterized by the highest diversity of soil water retention and hydraulic properties. The texture triangle was divided into a 1% grid of particle-size classes resulting in 5151 different data points. For each data point, soil water retention parameters and saturated hydraulic conductivity were obtained using the ROSETTA program. The silt classes showed the highest uncertainty in the estimation of the saturated water content based on the soil texture. These classes are characterized by high variations of saturated water content within the class. Estimations of field capacity and permanent wilting point on the basis of textural classes are encumbered with highest errors for *gp*, *pg*, *pl* and *pyg* soils, which are characterized by the highest values of coefficient of variation. Saturated soil hydraulic conductivity is better classified into homogeneous classes by the Polish texture classes than by the clusters obtained by the *k*-means cluster analysis based on the soil hydraulic and retention properties. Soil water retention parameters are better classified into homogeneous groups by the *k*-means cluster analysis than by the traditional textural classes. Cluster analysis using the *k*-means can be helpful for grouping similar soils from the point of view of their retention properties.

Keywords: soil textural classes, soil hydraulic properties, cluster analysis

INTRODUCTION

Understanding the soil-water-atmosphere-plant processes, in particular on regional scales, requires grouping soils on the basis of their hydraulic properties. Classical methods of direct measurement of soil hydraulic properties are known to be costly, time consuming and impractical for regional scale application (Dane and Topp 2002, Ramos et al. 2013). Hence, pedotransfer functions (PTFs) have been developed as an alternative to traditional methods to indirectly estimate soil water retention properties and hydraulic parameters from basic soil physical and chemical properties (Bouma 1989, Vereecken et al. 1989, McBratney et al. 2002, Pachepsky and Rawls 2004) especially on regional scales. The use of PTFs in soil-water modelling is well accepted if no detailed data are available. The majority of the available PTFs are based on the assumption that soil texture is the dominant variable in determining the soil water retention and hydraulic properties whereas the other soil variables, such as bulk density or organic matter content, only have secondary effects (Twarakavi et al. 2010). The simplest PTFs have been developed to provide estimates of average soil water retention properties or hydraulic parameters for different

textural classes (Wösten et al. 1995, Schaap and Leij 1998, Al Majou et al. 2008, Bruand et al. 2003, Ramos et al. 2013). Soil texture refers to the proportions of various particle-size classes in a given soil volume and is described in terms of soil textural class usually presented in a ternary diagram.

Saxton et al. (1986) have divided the soil texture triangle into grids of 10% sand and 10% clay content increments to develop the texture based PTFs for generalized predictions of soil hydraulic properties in each grid cell. Twarakavi et al. (2010) have also focused on the relations between the texture triangle and soil hydraulic properties using the ROSETTA PTFs (Schaap et al. 2001) taking into account various soil texture possibilities (i.e., combinations of sand, silt, and clay percentages). Bormann (2007, 2008, 2010) has shown that some soil textural classes from the German soil texture (Ad-Hoc-AG Boden 2005) classification show a large variation in simulated soil water balances, and that this variability significantly differs between different soil texture classes. Similar results have been obtained by Groenendyk et al. (2015) using the USDA (Soil Survey Division Staff 1993) soil texture classification, hence texture classification has not been primarily designed for hydrological mapping purposes (Groenendyk et al. 2015).

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The objective of this study was to examine whether the Polish soil textural classification PTG 2008 (Polskie Towarzystwo Gleboznawcze 2009) is useful for prediction of soil water retention and hydraulic properties and, further, for determining which textural classes are characterized by the highest diversity of the soil hydraulic parameters. PTFs were used as it is difficult to represent the entire soil texture triangle by soil hydraulic properties obtained from direct field and laboratory measurements.

MATERIALS AND METHODS

According to the Polish soil texture classification PTG 2008 (Polskie Towarzystwo Gleboznawcze 2009) the soil texture triangle is divided into 16 texture classes: six loam classes, four clay classes, three silt classes and three sand classes. In our study, we used the following procedure for soil classification from the hydraulic and water retention standpoint. Firstly, the four soil hydraulic parameters θ_r , θ_s , α , n from the van Genuchten (1980) equation and saturated hydraulic conductivity (K_s) were estimated throughout the entire soil texture triangle using the ROSETTA program (Schaap et al. 2001) so that the various soil texture possibilities were considered:

$$\theta(h) = \begin{cases} \theta_r + \frac{\theta_s - \theta_r}{[1 + (ah)^n]^m} & h < 0 \\ \theta_s & h \geq 0 \end{cases}$$

where $\theta(h)$ is the volumetric water content ($\text{cm}^3 \cdot \text{cm}^{-3}$) as a function of the pressure head h (cm), θ_s and θ_r are the saturated and residual volumetric water contents ($\text{cm}^3 \cdot \text{cm}^{-3}$), respectively, α (cm^{-1}), n and m (dimensionless) are the van Genuchten shape parameters where $m = 1 - 1/n$. The ROSETTA PTFs (pedotransfer functions) use artificial neural networks and can predict the soil hydraulic parameters needed as a function of the soil texture and bulk density (H3 model). By changing each soil particle size fraction by 1% intervals, 5151 unique data points (soils) were identified in the textural triangle. Percentages of sand, silt, clay and bulk density were used as an input to ROSETTA, so that the results of soil water retention parameters and saturated hydraulic conductivity shown in a ternary diagram are only a function of soil fraction proportion and bulk density. Bulk density (ρ_b) is an important soil physical property needed for estimating soil water characteristic (Boucné et al., 1998). Differences in bulk density values among soils are primarily attributed to differences in particle size distribution and organic carbon contents (Manrique and Jones 1991, Hollis et al. 2012, Abdelbaki 2016). For this reason,

the pedotransfer function (PTFs) proposed by Leona-viciute (2000) was used to estimate the bulk density values in 5151 soil data points, assuming 1.2% of organic carbon content as a mean for Polish topsoils (Terelak et al. 2001). According to Schaap et al. (2001) for H3 model, the root mean square error (RSME) values of estimated K_s and water retention data (on the basis of van Genuchten (1980) equation) were $0.666 \log \text{cm} \cdot \text{d}^{-1}$ and $0.068 \text{ cm}^3 \cdot \text{cm}^{-3}$ respectively.

Using the soil hydraulic parameters from the van Genuchten (1980) equation, the field capacity (θ_{fc}) and the permanent wilting point (θ_{wp}) were calculated at the water potentials of -10 kPa and -1500 kPa respectively. On the basis of θ_s , θ_{fc} and θ_{wp} the drainable porosity ($DP = \theta_s - \theta_{fc}$) and the available water capacity ($AWC = \theta_{fc} - \theta_{wp}$) were calculated. Then the 5151 data points representing various combinations of particle-size classes and the bulk density were grouped according to PTG 2008 (Polskie Towarzystwo Gleboznawcze 2009). For individual soil textural classes, the basic statistics of soil water retention parameters and saturated hydraulic conductivity were calculated. The next step was to use the k -means clustering method for classifying (into 16 clusters) the data of soil hydraulic and water retention parameters (K_s , θ_s , θ_{fc} , θ_{wp} , AWC , DP). Prior to the application of the k -means clustering algorithm, the data were standardized so that each of the soil hydraulic properties had the same impact on the clustering process.

RESULTS AND DISCUSSION

The distributions of the soil water retention parameters and saturated hydraulic conductivity are presented in the ternary diagrams in Figure 1. Table 1 shows the basic statistics of soil water retention parameters and saturated hydraulic conductivity for 16 soil textural classes. The highest mean values of K_s were obtained for the soils with pl , ps , pg and pyz (symbols are explained in the caption of Figure 1) texture but the highest values of the coefficient of variation (CV) were obtained for gz , gpi , pyi and pyg soil textures (from 36 to 50%). Similar results have been obtained by Groenendyk et al. (2015) using the USDA soil textural triangle. As far as θ_s is concerned, the soil textural classes pyz , ipy and $gpyi$ showed the highest mean values (0.453 , 0.436 and $0.435 \text{ cm}^3 \cdot \text{cm}^{-3}$, respectively), while the pl , gp and ps textural classes showed the lowest (0.366 , 0.367 and $0.370 \text{ cm}^3 \cdot \text{cm}^{-3}$, respectively). The values of the CV for θ_s were the highest for pyi , pyg and pyz (from 4.5 to 6.3%), while the lowest were found in the ps and pl soils (0.4 and 0.5%, respectively). With increasing content of clay and silt fractions, the values of θ_s significantly increased

FIGURE 1. Spatial patterns of the saturated hydraulic conductivity (K_s) and the soil water retention parameters (θ_s , θ_{fc} , θ_{wp} , AWC and DP) on the Polish soil texture PTG 2008 triangle: pl – sand, ps – weakly loamy sand, pg – loamy sand, gp – sandy loam, gl – light loam, gpi – sandy clay loam, gz – loam, gi – clay loam, gpyi – silty clay loam, pyg – silt loam, pyi – heavy silt, pyz – silt, ip – sandy clay, ipy – clayey silt, iz – clay, ic – heavy clay

TABLE 1. Basic statistics (minimum – maximum and means) of soil hydraulic and water retention properties for Polish textural classes

Textural classes*	K_s		θ_s		θ_{fc}		θ_{wp}		AWC		DP	
	cm·d ⁻¹	CV%	cm ³ ·cm ⁻³	CV%	cm ³ ·cm ⁻³	CV%	cm ³ ·cm ⁻³	CV%	cm ³ ·cm ⁻³	CV%	cm ³ ·cm ⁻³	CV%
<i>pl</i>	418.5–1433.4 753.8	33	0.363–0.369 0.367	0.5	0.059–0.085 0.067	10	0.043–0.056 0.051	7	0.006–0.029 0.017	38	0.280–0.307 0.299	2
<i>ps</i>	208.4–506.0 317.5	24	0.366–0.372 0.370	0.4	0.071–0.141 0.096	17	0.039–0.059 0.049	12	0.028–0.081 0.046	27	0.226–0.299 0.274	6
<i>pg</i>	78.4–221.3 125.2	30	0.360–0.376 0.371	0.9	0.093–0.203 0.148	17	0.035–0.066 0.047	17	0.053–0.137 0.101	21	0.165–0.278 0.223	11
<i>gp</i>	20.1–88.0 49.8	31	0.344–0.381 0.367	2.9	0.177–0.283 0.228	11	0.041–0.095 0.062	20	0.130–0.223 0.165	11	0.071–0.197 0.140	20
<i>gl</i>	13.2–43.6 25.3	29	0.359–0.383 0.375	1.7	0.228–0.289 0.263	5	0.060–0.095 0.076	13	0.168–0.200 0.186	4	0.094–0.143 0.112	10
<i>gpi</i>	5.8–33.2 13.1	38	0.368–0.392 0.381	1.6	0.255–0.320 0.297	5	0.089–0.165 0.125	16	0.143–0.199 0.172	8	0.065–0.113 0.084	13
<i>gz</i>	5.7–32.2 13.0	50	0.356–0.406 0.380	3.1	0.262–0.352 0.309	6	0.061–0.110 0.084	15	0.199–0.253 0.225	7	0.050–0.097 0.071	17
<i>gi</i>	4.1–7.0 5.0	12	0.390–0.416 0.402	1.8	0.312–0.358 0.333	3	0.103–0.166 0.126	12	0.159–0.255 0.207	10	0.054–0.079 0.068	6
<i>gpyi</i>	4.1–8.9 5.9	22	0.414–0.462 0.436	2.9	0.351–0.405 0.375	4	0.103–0.135 0.120	7	0.217–0.291 0.255	6	0.051–0.068 0.061	8
<i>pyz</i>	25.7–101.6 60.8	33	0.406–0.491 0.453	4.5	0.355–0.425 0.401	4	0.059–0.093 0.076	10	0.296–0.341 0.325	3	0.041–0.075 0.052	14
<i>pyg</i>	21.4–101.3 52.9	36	0.344–0.443 0.379	6.3	0.245–0.402 0.329	11	0.052–0.084 0.063	12	0.192–0.317 0.266	11	0.036–0.099 0.050	27
<i>pyi</i>	7.1–32.6 16.7	38	0.369–0.476 0.421	6.3	0.316–0.423 0.377	7	0.070–0.113 0.090	11	0.246–0.329 0.286	7	0.036–0.056 0.044	11
<i>ip</i>	5.8–12.2 8.1	18	0.372–0.391 0.382	1.1	0.309–0.328 0.321	1	0.150–0.207 0.182	8	0.120–0.171 0.139	8	0.052–0.070 0.060	8
<i>ipy</i>	2.4–4.2 3.5	14	0.418–0.455 0.436	1.9	0.352–0.387 0.369	2	0.135–0.177 0.150	7	0.193–0.249 0.219	6	0.061–0.070 0.067	2
<i>iz</i>	2.4–6.7 4.6	21	0.379–0.429 0.400	3.2	0.325–0.369 0.341	3	0.137–0.208 0.177	10	0.120–0.213 0.164	15	0.051–0.067 0.059	8
<i>ic</i>	2.0–6.0 3.3	26	0.366–0.427 0.386	3.3	0.323–0.368 0.340	3	0.181–0.208 0.202	3	0.120–0.187 0.138	10	0.038–0.059 0.046	11

* Symbols of textural classes were explained in the caption of Fig. 1.

(Fig. 1b). Soil water contents at -10 kPa matric potential (θ_{fc}) were lower in the coarser textural classes and increased diagonally with the increment of clay and silt contents (Fig. 1c), therefore the highest mean values of θ_{fc} were in the *pyz*, *pyi* and *gpyi* soils (0.401, 0.377 and 0.375 $\text{cm}^3\cdot\text{cm}^{-3}$ respectively). For the textural classes *pl*, *ps*, *pg*, *gp* and *pyg* the highest values of the CV (from 10% to 17%) were observed. This means that the extrapolation of θ_{fc} data to another soil within the same textural class will be burdened with high error. These soils, especially *pyg* and *pg*, exhibited also the highest values range of θ_{fc} . For the soil *pyg* it was 0.157 $\text{cm}^3\cdot\text{cm}^{-3}$ while for the *pg* textural class 0.110 $\text{cm}^3\cdot\text{cm}^{-3}$. The values of θ_{wp} were determined mainly by the clay fraction content (vertical limit) (Fig. 1d). The lowest values of θ_{wp} were in the coarser textural classes (from 0.046 to 0.050 $\text{cm}^3\cdot\text{cm}^{-3}$), while the highest in the *ipy*, *iz*, *ip* and *ic* (from 0.150 to 0.202 $\text{cm}^3\cdot\text{cm}^{-3}$) soils. Highest values of the CV of θ_{wp} were obtained for *gp*, *pg*, *gpi* and *gz* soil. From the point of view of plant production, the soil properties related to *AWC* are important. The coarser textural classes and the soils with higher clay content had lower *AWC* then the other classes (Fig. 1e). According to Al Majou et al. (2008), the soils with high clay texture showed a high proportion of water that is not

available for plants. The highest mean values of *AWC* have the soils from the textural classes *pyz*, *pyi*, *pyg* and *gpyi*. These textural classes store from 0.325 $\text{cm}^3\cdot\text{cm}^{-3}$ to 0.256 $\text{cm}^3\cdot\text{cm}^{-3}$ of the water available for growing crops. The highest ranges of *AWC* were established for the textural classes *gp*, *iz*, *gi* and *pyg* (from 0.093 $\text{cm}^3\cdot\text{cm}^{-3}$ for *gp* to 0.125 $\text{cm}^3\cdot\text{cm}^{-3}$ for *pyg*). The highest values of the CV were obtained for *pl*, *ps* and *pg* soil texture, which means that estimation of the *AWC* on the basis of these textural classes and soil bulk density is burdened with high uncertainty. Along with *AWC*, one of the most important properties of soil water retention is the drainable porosity (*DP*). The *DP* is the pore volume of water that is removed when the water table is lowered in response to gravity and in the absence of evaporation. The highest mean values of *DP* were obtained for the soils *pl*, *ps* and *pg* (from 0.299 $\text{cm}^3\cdot\text{cm}^{-3}$ for *pl* to 0.223 $\text{cm}^3\cdot\text{cm}^{-3}$ for *pg*) texture, while the lowest for the soils of the textural classes *pyi*, *ic* and *pyg* (from 0.044 $\text{cm}^3\cdot\text{cm}^{-3}$ for *pyi* to 0.050 $\text{cm}^3\cdot\text{cm}^{-3}$ for *pyg*) (Fig. 1f, Table 1). The highest range of *DP* was found for *ps*, *pg* and *gp* (from 0.072 $\text{cm}^3\cdot\text{cm}^{-3}$ to 0.126 $\text{cm}^3\cdot\text{cm}^{-3}$), while the lowest range of *DP* was obtained for the soil *ipy*, *ip* and *gpyi* (from 0.008 $\text{cm}^3\cdot\text{cm}^{-3}$ to 0.017 $\text{cm}^3\cdot\text{cm}^{-3}$). For *pyg*, *gp*, *gz* and *pyz*, the highest CV values (from

FIGURE 2. Resulting clusters, applying the *k*-means cluster analysis based on K_s , θ_s , θ_{fc} , θ_{wp} , *AWC* and *DP* on the background of Polish soil texture PTG 2008 triangle

TABLE 2. Basic statistics (minimum – maximum and means) of soil hydraulic and water retention properties for clusters

Textural clusters	K_s		θ_s		θ_{fc}		θ_{wp}		AWC		DP	
	cm ³ ·d ⁻¹	CV%	cm ³ ·cm ⁻³	CV%	cm ³ ·cm ⁻³	CV%	cm ³ ·cm ⁻³	CV%	cm ³ ·cm ⁻³	CV%	cm ³ ·cm ⁻³	CV%
1	38.5–104 61.3	21	0.349–0.379 0.370	2.0	0.174–0.231 0.206	6	0.040–0.072 0.056	12	0.121–0.167 0.150	7	0.134–0.167 0.150	9
2	21.5–72.3 38.4	32	0.344–0.381 0.367	3.1	0.218–0.268 0.247	4	0.052–0.092 0.068	15	0.157–0.202 0.178	6	0.090–0.146 0.120	11
3	8.3–101.6 36.3	73	0.393–0.438 0.414	2.8	0.350–0.393 0.373	3	0.058–0.104 0.080	14	0.261–0.316 0.293	4	0.036–0.055 0.041	11
4	73.7–255.4 117.9	29	0.361–0.376 0.371	0.9	0.117–0.181 0.153	10	0.035–0.062 0.047	14	0.069–0.133 0.106	16	0.188–0.252 0.219	7
5	9.4–89.6 33.7	59	0.345–0.383 0.362	2.7	0.257–0.316 0.289	5	0.052–0.091 0.065	14	0.201–0.253 0.224	6	0.053–0.095 0.072	14
6	4.2–10.1 5.9	22	0.380–0.420 0.399	2.3	0.306–0.354 0.332	3	0.083–0.134 0.109	10	0.200–0.254 0.224	6	0.053–0.079 0.067	8
7	7.4–29.6 16.1	29	0.368–0.389 0.380	1.3	0.261–0.309 0.285	4	0.070–0.125 0.100	11	0.163–0.212 0.185	7	0.080–0.115 0.096	8
8	3.1–10.4 5.8	26	0.408–0.460 0.437	2.9	0.355–0.400 0.376	3	0.098–0.150 0.121	9	0.229–0.286 0.255	6	0.059–0.069 0.065	3
9	2.4–4.5 3.6	15	0.404–0.449 0.423	2.5	0.336–0.379 0.358	3	0.128–0.181 0.153	7	0.184–0.229 0.205	6	0.051–0.068 0.061	8
10	2.0–4.8 3.5	22	0.393–0.426 0.405	1.8	0.355–0.367 0.349	2	0.158–0.203 0.184	5	0.148–0.186 0.165	6	0.045–0.065 0.056	8
11	4.2–17.8 7.9	46	0.369–0.404 0.389	2.1	0.289–0.338 0.315	4	0.111–0.159 0.137	7	0.153–0.200 0.177	7	0.065–0.0859 0.050	27
12	2.0–9.9 4.3	38	0.366–0.397 0.382	1.8	0.318–0.351 0.334	2	0.182–0.208 0.202	2	0.120–0.148 0.132	5	0.038–0.059 0.074	7
13	4.5–14.4 7.8	32	0.371–0.398 0.385	1.8	0.301–0.336 0.321	2	0.150–0.189 0.171	5	0.131–0.172 0.150	6	0.057–0.072 0.064	5
14	7.6–100.9 33.8	75	0.361–0.406 0.381	2.7	0.308–0.356 0.335	3	0.053–0.098 0.071	15	0.236–0.290 0.263	5	0.036–0.061 0.046	12
15	153.5–1433.4 429.7	64	0.363–0.373 0.369	0.7	0.059–0.122 0.088	19	0.036–0.58 0.048	11	0.006–0.079 0.041	45	0.247–0.307 0.281	6
16	6.9–96.9 36.3	62	0.432–0.491 0.457	3.0	0.383–0.425 0.406	2	0.065–0.117 0.089	13	0.285–0.341 0.318	4	0.039–0.075 0.050	13

17% for *pyz* to 27% for *pyg*) were obtained, which indicates that approximation of DP on the basis of texture in these soils may be burdened with large error.

The results of *k*-means algorithm application to the dataset describing soil hydraulic and water retention properties (K_s , θ_s , θ_{fc} , θ_{wp}) of the 5151 soil texture triangle realizations are shown in Figure 2. A comparison of the shape and size of the Polish textural classes PTG 2008 (Polskie Towarzystwo Gleboznawcze 2009) to the clusters obtained by the *k*-means clustering algorithm shows that besides the coarser texture soils (*pl*, *ps*, *pg*) also partly *gi*, *gpyi* and *ipy* soils, none of the textural class is entirely coincident with the clusters distinguished on the basis of the soil hydraulic and water retention properties. The remaining textural classes of the Polish classification PTG 2008 (Polskie Towarzystwo Gleboznawcze 2009) include some clusters obtained by the *k*-means clustering algorithm. It is particularly visible for the textural classes of high clay contents, probably because such soils are relatively rare in the real world (Borman 2010). Also *pyg*, *pyi*, *pyz*, *gz* and *gp* soils differ from the clusters based on the soil hydraulic and water retention properties, which is in agreement with the results obtained by Borman (2010) and Twarakavi et al. (2010).

Table 2 presents the basic statistics of soil water retention parameters and saturated hydraulic conductivity for 16 clusters obtained by the *k*-means clustering algorithm. For K_s the highest value of the CV was obtained in the fourteenth cluster, which was 75%, while in the textural classes based on PTG 2008 (Polskie Towarzystwo Gleboznawcze 2009) 50% for *gz* (Table 1). Groenendyk et al. (2015) have also noted that many clusters based on the K_s classification have larger within-cluster variations than the textural classes of the USDA (Soil Survey Division Staff 1993) classification. As to θ_s , the highest values of CV were obtained for the second cluster (3%) and the textural classes *pyi*, *pyg* and *pyz* (from 4.5 to 6.3%). Due to the lack of normal data distribution, the median values of CV for textural classes and clusters were calculated (Table 3). The median value of K_s for texture classes was 30%, while it was 32% for clusters. This means that saturated hydraulic conductivity is better classified into homogeneous groups by the Polish texture triangle than the clusters obtained by the *k*-means cluster analysis. For θ_s , θ_{fc} , AWC and DP , the highest median values of CV were obtained for the textural classes based on PTG 2008 (Polskie Towarzystwo Gleboznawcze 2009) than in the groups obtained by the *k*-means clustering algorithm. This indicates that the soil water retention parameters are better classified into homogeneous groups by the *k*-means cluster

TABLE 3. The CV median values of soil hydraulic and water retention properties for Polish textural classes and clusters

Section	K_s	θ_s	θ_{fc}	θ_{wp}	AWC	DP
	%					
Textural classes	29.5	2.4	5.0	11.5	9.0	10.5
Clusters	32.0	2.2	3.0	11.0	6.0	8.5

analysis than the textural classes based on PTG 2008 (Polskie Towarzystwo Gleboznawcze 2009). According to Borman (2007, 2010) and Groenendyk et al. (2015), the texture classifications currently used in the World are designed on the basis of similarity with respect to grain size distribution. Soil texture classification could also be performed on the basis of their hydrological properties, including the soil water balance.

CONCLUSIONS

1. The highest uncertainty in estimation of saturated water content based on the texture has been found for *pyi*, *pyg* and *pyz*. These soils are characterized by high variations of saturated water content within the class.
2. Estimations of the field capacity and permanent wilting point on the basis of textural classes are encumbered with highest errors for the *gp*, *pg*, *pl* and *pyg* soils, which are characterized by the highest values of coefficient of variation.
3. The soil saturated hydraulic conductivity is better classified into homogeneous classes by the Polish texture triangle than by the clusters obtained by the *k*-means cluster analysis based on the soil hydraulic and retention properties.
4. The soil water retention parameters are better classified into homogeneous groups by the *k*-means cluster analysis than by the traditional textural classes. The cluster analysis using the *k*-means can be helpful for grouping similar soils from the point of view of their retention properties.

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Analiza przydatności Polskiej klasyfikacji uziarnienia gleb PTG 2008 dla potrzeb oceny zdolności retencyjnych i właściwości hydraulicznych

Streszczenie: Celem niniejszego opracowania było zanalizowanie, w jakim stopniu polska klasyfikacja uziarnienia gleb PTG 2008 jest przydatna do określenia zdolności retencyjnych i właściwości hydraulicznych, a ponadto do określenia, które grupy i podgrupy granulometryczne charakteryzują się największym zróżnicowaniem wartości właściwości retencyjnych i hydraulicznych gleb. Diagram uziarnienia został podzielony na siatkę o interwale 1% poszczególnych frakcji części ziemistych, co pozwoliło na otrzymanie 5151 różnych punktów danych. Przy zastosowaniu programu ROSETTA dla każdego punktu uzyskano parametry zdolności retencyjnych i przewodnictwa hydraulicznego nasyconego gleb. Największe wartości współczynnika zmienności przy szacowaniu pełnej pojemności wodnej na podstawie grup granulometrycznych otrzymano dla pyłów. Gleby o takim uziarnieniu charakteryzują się dużym zróżnicowaniem wartości pełnej pojemności wodnej. Oszacowanie połowej pojemności wodnej i wilgotności trwałego wędnięcia, w oparciu o grupy granulometryczne są obarczone największymi błędami w grupach granulometrycznych *gp*, *pg*, *pl* and *pyg*, które charakteryzują się najwyższymi wartościami współczynnika zmienności. Przewodność hydrauliczna gleb jest lepiej klasyfikowana w jednorodne grupy i podgrupy granulometryczne polskiej klasyfikacji uziarnienia gleb PTG 2008 niż klastry uzyskane metodą *k*-średnich w analizie skupień. Zróżnicowanie wartości parametrów charakteryzujących zdolności retencyjne gleb jest lepiej klasyfikowane w jednorodne klastry, otrzymane za pomocą analizy skupień metodą *k*-średnich niż tradycyjne podgrupy granulometryczne. Analiza skupień metodą *k*-średnich może być przydatna do grupowania podobnych gleb pod względem ich zdolności retencyjnych.

Słowa kluczowe: grupy granulometryczne, właściwości hydrauliczne gleb, analiza skupień