DE GRUYTER
OPEN
DOI: 10.2478/ssa-2014-0011

SOIL SCIENCE ANNUAL
Vol. 65 No. 2/2014: 72–79

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Measurements of texture of soils formed from glaciolimnic sediments by areometric method, pipette method and laser diffraction method

Abstract: The aim of the research was to compare the results of texture analyses of glaciolimnic sediments deposited in the basins of ice-dammed lakes origin in north eastern Poland. The study was carried out using aerometric method, pipette method and laser diffraction method. The studied soils were classified as Haplic and Mollic Vertisol, Vertic Cambisol, and Gleyic Chernozem. The soils were formed from clayey (clay, heavy clay), loamy (loam, clay loam, sand clay loam) and silty (silt loam, clay loam) deposits. The studied soils did not contain fractions > 2.0 mm. The amounts of clay fraction (< 0.002 mm) measured by areometric and pipette methods were similar and strongly correlated. In comparison to laser diffraction method, these amounts were 3–4-fold higher. The sub-fraction of fine silt (0.02–0.002 mm) predominated in soil formations analyzed by laser diffraction method. In comparison to areometric or pipette method, the amounts of fine silt were 2–4 fold higher. Basing on the calculated sedimentological indices, it was stated that the examined soils were well sorted and the mean grain diameter (GSS) was very low and did not exceed 0.005 mm in areometric and pipette methods, and 0.011 mm in laser diffraction method for clay sediments.

Key words: soil texture, glaciolimnic sediments, areometric method, pipette method, laser diffraction method

INTRODUCTION

Soil texture influences most soil chemical and water-physical properties as well as their quality usage. The existing regional, national and international classification systems of soil texture have various terminology and size limits of granulometric fractions (Drzymała and Mocek 2004; Kabała and Marzec 2007; IUSS Working Group WRB 2007; Prusinkiewicz et al. 1994; Prusinkiewicz 2003; Soil Survey Staff 1999). In the latest soil texture classification adopted by the Polish Society Soil Science in 2008 (PTG, 2009), which is similar to USDA classification, new particle size limits and terminology were established.

The soils formed from heavy glaciolimnic sediments abundant in clay fraction (<0.002 mm) show a distinction as compared to other Polish soils. These soils are abundant in macro- and microelements, have high sorptive cation capacity and high water retention ability, and they either increase their volume (swelling) or decrease it (shrinkage) depending on their moisture content (Uggla and Witek 1956). The measurements of soil particle size distribution by for example areometric and laser diffraction methods carried out in Poland, gave various results for the same soil material (Ryżak et al. 2004).

The aim of this paper is to present the results of particle size distribution of fine-grained glaciolimnic sediments depositedin shallow basins of ice-dammed lakes origin in north-eastern Poland analyzed by areometric, pipette and laser diffraction methods.

MATERIALS AND METHODS

The research was carried out at glaciolimnic areas in Sępopol Lowland and northern outskirts of Mazurian Lakeland in NE Poland. As a result of ice deglaciation, local shallow water basins were formed and fine-grained material was deposited in them. Some geomorphologists call it a formation of ice-dammed lakes origin and the other call it glaciolimnic sediment (Kondracki 1972; Körnke 1930; Mojski 2005; Roszko 1968). At five glaciolimnic basins located in the vicinity of Kętrzyn, Lidzbark Warmiński, Reszel and Sępopol, which are different in terms of hipsometry, usage and relief, drillings and soil pits were made.The study of mineralogical composition showed that swelling smectite minerals, illites with the addition of mixed layer illite/smectite (I/S) minerals, chlorite minerals

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and small amounts of vermiculite predominate in clay fraction (Długosz et al. 2009). In changing water conditions, the alternating processes of swelling and shrinkage (vertilization) played an important role in the origin and properties of these soils (Uggla and Witek 1956).

Twenty soil samples were taken for the measurements of particle size distribution using three methods, after removal of coagulating components. The soil samples were pretreated in accordance with the valid standards (PN–ISO 11464, 1999). The particle size distribution was analyzed using the following methods: of Bouyoucos modified by Casagrande and Prószyński (areometric) (Mocek et al. 1997), pipette method (Eijkelkamp pipette apparatus; upper and lower pipette matches the requirements of NEN 5753 and PN–ISO 11277 standards), and laser diffraction method using Mastersizer 2000 with dispersing Hydro MU adapter. The samples were dispersed ultrasonically for 2 minutes with stirring speed of 2500 rpm. The analysis was carried out at the obscurance of 18–25%. The Mie theory, which describes Maxwell equation, was used for calculations (refraction of light 1.577, absorption factor 0.10). The methodology of particle size distribution of Cambisols, Luvisols, Phaeozems, Fluvisols and Gleyosols containing clay fraction (1.0–18.0%) was prepared by the scientists from the Institute of Agrophysics, Polish Academy of Sciences (Bieganowski et al. 2013; Ryżak and Bieganowski 2011; Ryżak et al. 2009). In pipette and areometric methods, sand fractions (2.0–0.1 mm) were analyzed by sieving. The results were compiled in accordance with the classification of Polish Society of Soil Science (PTG 2009).

The amounts of soil fractions were analyzed by theSiewca software. Particle size distribution curves were drawn and sedimentological indices determining the state of soil sorting and dominating soil fraction were calculated: mean grain diameter (GSS) for fractions from 2.0 to < 0.002 mm, standard deviation (GSO), skewness (GSK), kurtosis (GSP) and the cumulative curves (Folk and Ward 1957; Prusinkiewicz and Proszek, 1990). The results of texture analysis were used to calculate the granulometric indices which take into account the relations between soil fractions (Kobierski 2010; Kowalkowski and Prusinkiewicz 1963). In the paper, due to fine-grained character of soil formations, the particle size distribution indices were calculated for the following fractions:
A – (0.25–0.05 mm):(0.05–0.002 mm);
B – (0.25–0.05 mm):(< 0.002 mm);
C – (0.05–0.002 mm):(< 0.002mm);
D – (0.02–0.002 mm):(< 0.002 mm);
E – (0.05–0.02 mm):(0.02–0.002 mm)

RESULTS AND DISCUSSION

The studied soils were classified as Haplic and Mollic Vertisol, Vertic Cambisol, and Gleyic Chernozem (IUSS Working Group WRB 2007). These soils were formed from clayey (clay, heavy clay), loamy (loam, clay loam, clay loam sand) and silty (silt loam, clay loam) formations (Table 1). The studied soils did not contain > 2.0 mm fraction and the amount of clay fraction (<0.002 mm) ranged from 8.15 to 85.14%.

The measurements of texture by areometric and pipette methods revealed that clay fractions of < 0.002 mm predominated in the studied soils. However, in laser diffraction method, the sub-fraction of fine silt (0.02–0.002 mm) predominated. In areometric and pipette methods, clay fraction was the highest, amounting to 63.68–85.14% in heavy clays, and 37.00–57.83% in clays (Table 1). The quantity of this fraction in clay

TABLE 1. Texture of analyzed soils (PTG 2008)

Site and sample number	Method	Percentage of fractions with diameter [mm]								Soil texture
		2.0–1.0	1.0–0.5	0.5–0.25	0.25–0.1	0.1–0.05	0.05–0.02	0.02–0.002	<0.002	
Heavy clay (HC)										
Sępopol 7	P*	0	0	0	0	2.19	4.86	7.81	85.14	ic**
	A	0	0	0	0	0	1.00	21.00	78.00	ic
	D	0	0	0.06	0.64	0.73	3.46	70.77	24.34	pyi
Sępopol 2	P	0	0	0	0.60	4.18	3.81	10.84	80.57	ic
	A	0	1.00	2.00	2.00	5.00	5.00	7.00	78.00	ic
	D	0	0.14	1.10	1.64	2.55	8.38	59.97	26.21	pyi
Lidzbark Warmiński 2	P	0	0.34	0.99	2.15	2.87	3.66	14.83	75.16	ic
	A	0	0	2.00	2.00	3.00	3.00	9.00	81.00	ic
	D	0	0.75	1.63	1.71	1.83	8.74	64.60	20.72	pyi
Sępopol 6	P	0	0	0.60	2.15	3.85	6.85	13.61	72.95	ic
	A	0	1.00	2.00	3.00	4.00	5.00	9.00	76.00	ic
	D	0	0	0	1.12	4.36	8.48	62.45	23.58	pyi

TABLE 1. continued

Site and sample number	Method	Percentage of fractions with diameter [mm]								Soil texture
		2.0–1.0	1.0–0.5	0.5–0.25	0.25–0.1	0.1–0.05	0.05–0.02	0.02–0.002	<0.002	
Heavy clay (HC)										
Reszel 15	P	0	0.51	1.15	2.18	2.94	3.92	16.49	72.81	ic
	A	0	0	1.00	2.00	2.00	5.00	20.00	70.00	ic
	D	0.16	0.51	0.48	0.93	1.39	7.54	72.48	16.51	pyi
Kętrzyn 20	P	0	0.52	0.82	1.29	5.26	7.43	16.15	68.54	ic
	A	0	1.00	1.00	2.00	7.00	3.00	16.00	70.00	ic
	D	0	0.08	0.16	1.50	2.58	7.98	70.34	17.34	pyi
Lidzbark Warmiński 12	P	0	0	0	1.38	2.38	9.16	20.32	66.84	ic
	A	0	0	1.00	2.00	3.00	7.00	23.00	64.00	ic
	D	0	0	0	1.48	3.33	10.95	63.98	20.26	pyi
Reszel 12	P	0	1.26	2.65	3.21	4.50	5.10	17.31	65.97	ic
	A	0	1.00	2.00	3.00	4.00	2.00	20.00	68.00	ic
	D	0	0.08	0.88	2.33	2.38	5.22	67.01	22.18	pyi
Reszel 11	P	0	0.39	1.28	6.77	7.02	6.79	14.07	63.68	ic
	A	0	2.00	4.00	6.00	5.00	8.00	7.00	68.00	ic
	D	0	0.49	1.55	3.27	3.56	8.45	64.69	17.99	pyi
Clay (C)										
Reszel 10	P	0.40	0.51	2.01	5.21	7.93	10.74	15.37	57.83	i
	A	2.00	2.00	5.00	7.00	5.00	6.00	21.00	52.00	i
	D	0	0.27	0.94	2.98	4.49	1.46	63.51	14.34	pyi
Lidzbark Warmiński 1	P	0.98	1.19	1.54	4.32	9.07	11.05	20.47	51.37	i
	A	2.00	2.00	4.00	5.00	7.00	8.00	31.00	41.00	i
	D	0	0.48	1.88	3.69	7.96	20.96	53.76	11.27	pyg
Reszel 1	P	0	0.97	4.61	5.80	11.64	13.68	13.85	49.46	i
	A	1.00	2.00	5.00	7.00	10.00	11.00	21.00	43.00	i
	D	0	0	0.47	2.44	5.16	18.36	61.27	12.30	pyi
Kętrzyn 15	P	2.72	1.09	3.32	4.67	6.81	13.56	21.44	46.40	i
	A	3.00	5.00	3.00	7.00	7.000	11.00	27.00	37.00	gi
	D	4.08	1.21	0.56	2.97	6.21	14.38	58.67	11.92	pyg
Lidzbark Warmiński 16	P	0.72	1.61	6.87	11.05	13.72	10.11	13.67	42.26	i
	A	1.00	2.00	7.00	12.00	16.00	8.00	14.00	40.00	gi
	D	0	0.43	2.35	8.11	7.62	12.36	55.40	13.74	pyi
Clay loam (CL)										
Kętrzyn 5	P	0.34	1.59	6.56	14.21	9.18	11.35	19.65	37.12	gi
	A	0	1.00	6.00	13.00	9.00	6.00	25.00	40.00	gi
	D	0	0.18	3.00	7.76	5.88	11.07	57.77	14.48	pyi
Sępopol 1	P	2.98	4.22	6.20	9.51	14.05	16.00	12.37	34.67	gi
	A	3.00	5.00	6.00	10.00	13.00	16.00	24.00	23.00	gz
	D	0	0.36	2.48	6.16	10.88	19.72	51.67	8.72	pyg
Sępopol 14	P	0	1.34	3.82	5.67	18.21	25.03	13.56	32.37	gi
	A	0	1.00	4.00	6.00	19.00	25.00	16.00	29.00	gi
	D	0	0.09	0.28	4.15	12.20	23.14	52.00	8.15	pyg
Kętrzyn 4	P	1.69	3.04	9.76	14.27	10.71	10.42	21.77	28.35	gi
	A	1.00	3.00	10.00	13.00	11.00	7.00	29.00	26.00	gz
	D	0	0.82	3.52	8.24	7.71	17.89	50.86	10.96	pyg
Sandy clay loam (SCL)										
Kętrzyn 6	P	2.07	3.71	13.31	21.30	15.91	6.02	14.31	23.36	gpi
	A	2.00	3.00	13.00	18.00	14.00	7.00	20.00	23.00	gpi
	D	0	1.06	7.51	14.04	8.23	11.06	48.97	9.13	pyg
Loam (L)										
Lidzbark Warmiński 15	P	2.42	4.31	9.39	14.75	14.02	13.29	19.49	22.33	gz
	A	2.00	4.00	9.00	15.00	15.00	14.00	19.00	22.00	gz
	D	0	0.25	2.51	9.83	11.57	18.08	47.75	10.01	pyg

Explanations: P – pipette, A – areometric, D – laser diffraction; gz – loam (L), gi – clay loam (CL), gpi – sandy clay loam (SCL), pyg – silt loam (SL), (pyi – silt clay (SC), i – clay (C), ic – heavy clay (HC).

loams, measured by pipette method, ranged from 28.35 to 37.12% , in sandy clay loam it amounted to 23.36 % and in loam to 22.33%. The amounts of clay fraction (< 0.002 mm) measured by pipette method were similar to the amounts measured by areometric method, but 3–4 fold higher in comparison to laser diffraction method. Considerable differences in the amounts of soil fractions were noted in the measurements by laser diffraction method comparing to other two applied methods. The measurements by laser diffraction method showed that silt fraction, with sub-fraction of fine silt (0.02–0.002 mm), predominated in studied soil formations. Compared to areometric and pipette methods, the amounts of fine silt were 2–4 fold higher in laser diffraction method and ranged from 53.76 to 70.77% in clays and from 47.75 to 57.77% in loams. It may be a result of a very strong aggregation of clay particles. As a result, the microaggregates which diameter exceeds 0.002 mm are formed. They are so stable that they are not destroyed even under prolonged exposure to ultrasound.

The ratio of sub-fraction of coarse silt (0.05–0.02 mm) and fine silt (0.02–0.002 mm) in clay formations was low and ranged between 0.02 and 0.39 in laser diffraction method. In loams the ratio amounted to 0.19–0.45 (Table 3). In clay formations, the ratio of silts was 3–6 fold higher than of clay fraction in laser diffraction method. In pipette and areometric methods this ratio did not exceed 1. The analyses of sand fraction (2.0–0.05 mm) including sub-fractions of very coarse sand (2.0–1.0 mm), coarse sand (1.0–0.5 mm), medium sand (0.5–0.25 mm), fine sand (0.25–0.10 mm) and very fine sand (0.10–0.05 mm), did not show significant differences between three studied methods.

The results of particle size distribution analyses were collated according to the data obtained by the pipette method, which was taken as a reference in this study. The studied soil formations were classified as: heavy clay (HC), clay (C), clay loam (CL), sandy clay (SC), sandy clay loam (SCL) and loam (L) using pipette and aerometric methods, and as: silt loam (SL) and silt clay (SC) using laser diffraction method (Table 2). Nine soil formations which were classified as heavy clay in pipette and aerometric methods, were classified as silt clay in the laser diffraction method. Five soil formations of clay were classified as clay (3 soil formations) and clay loam (2) in pipette and aerometric methods, and in laser diffraction method they were silt clay (3) and silt loam (2). In the group of 6 loams (sandy clay, sandy clay loam , loam) analyzed by areometric and pipette methods, five was classified as silt loam and one as silt clay in laser diffraction method.

Basing on the calculated sedimentological indices, it was stated that studied soils were very well sorted and the values of standard deviation (GSO) did not exceed 0.396. Better state of segregation of soil material was notedin the soil samples analyzed by areometric and pipette methods, where the maximum of GSO index did not exceed 0.153. In other glacial soil formations (boulder loam), studied by Kobierski (2010) and Pakuła (2013) poor and very poor sorting of soil material, and values of the GSO ranging from 2.32 to 4.70 were stated. The mean grain diameter (GSS) was very low, not exceeding 0.005 mm for clays in pipette and areometric methods and 0.011 mm in laser method. In loam formations, mean grain diameter amounted to 0.025 mm (Table 3).

In most analyzed soils samples the skewness index (GSK) was positive (symmetric right-handed distribution) in pipette and areometric methods. The calculated values of GSK ranged from 0.01 to 0.91. In the soil samples analyzed by laser diffraction method, the calculated values of GSK were negative, and except for one, did not exceed a threshold of –0.30 (skew, negative) (Prusinkiewicz and Proszek 1990). In most analyzed soil samples the graphic curve was normal (mezokurtic), and the values of kurtosis (GSP) were in the range of 0.90–1.10, or slightly lower than 0.90 (platykurtic).

Analyzing the cumulative curves and particle size distribution diagrams, it should be noted that heavy clay, clay loam and clay were very similar in pipette and areometric methods, whereas in laser diffraction method these soil formations were different (Figures 1–3). These differences were most evident in the contents of clay and silt fraction.

TABLE 2. Comparison of textural groups according to PTG (2008)

Pipette method	No of samples	Areometric method					Laser diffraction method	
		ic (HC)	i (C)	gi (CL)	gpi (SCL)	gz (L)	pyi (SC)	pyg (SL)
ic (HC)	9	9					9	
i (C)	5		3	2			3	2
gi (CL)	4			2		2	1	3
gpi (SCL)	1				1			1
gz (L)	1					1		1

TABLE 3. Granulometric and sedimentological indices of soils

Site and sample number	Method	Soil texture	Granulometric indices					Sedimentological indices			
			A	B	C	D	E	GSS	GSO	GSK	GSP
Heavy clay											
Sępopol	P	HC	0.17	0.03	0.15	0.09	0.62	0.001	0.004	0.02	0.97
7	A	HC	–	–	0.28	0.27	0.05	0.001	0.153	0.02	0.97
	D	SC	0.02	0.06	3.05	2.91	0.05	0.004	0.396	-0.05	1.05
Sępopol	P	HC	0.33	0.06	0.18	0.13	0.35	0.001	0.030	-0.02	1.04
2	A	HC	0.58	0.09	0.15	0.09	0.71	0.001	0.001	0.10	0.85
	D	SC	0.06	0.16	2.61	2.29	0.14	0.005	0.263	-0.08	1.08
Lidzbark	P	HC	0.27	0.07	0.25	0.20	0.25	0.001	0.027	-0.01	1.00
Warmiński	A	HC	0.42	0.06	0.15	0.11	0.33	0.001	0.007	0.01	0.98
2	D	SC	0.05	0.17	3.54	3.12	0.14	0.005	0.279	-0.10	1.12
Sępopol	P	HC	0.29	0.08	0.28	0.19	0.50	0.001	0.003	0.12	0.84
6	A	HC	0.50	0.09	0.18	0.12	0.56	0.001	0.001	0.10	0.86
	D	SC	0.08	0.23	3.01	2.65	0.14	0.005	0.283	-0.12	1.10
Reszel	P	HC	0.25	0.07	0.28	0.23	0.24	0.001	0.033	-0.01	1.01
15	A	HC	0.16	0.06	0.36	0.29	0.25	0.001	0.040	0.03	0.95
	D	SC	0.03	0.14	4.85	4.39	0.10	0.005	0.351	-0.72	1.06
Kętrzyn	P	HC	0.28	0.10	0.34	0.24	0.46	0.001	0.013	0.08	0.88
20	A	HC	0.47	0.13	0.27	0.23	0.19	0.001	0.050	-0.05	1.06
	D	SC	0.05	0.24	4.52	4.06	0.11	0.005	0.332	-0.10	1.09
Lidzbark	P	HC	0.13	0.06	0.44	0.30	0.45	0.001	0.001	0.27	0.78
Warmiński	A	HC	0.17	0.08	0.47	0.36	0.30	0.001	0.040	0.07	0.91
12	D	SC	0.06	0.24	3.70	3.16	0.17	0.006	0.284	-0.02	1.02
Reszel	P	HC	0.34	0.12	0.34	0.26	0.29	0.001	0.021	0.01	0.97
12	A	HC	0.32	0.10	0.32	0.29	0.10	0.001	0.071	-0.08	1.16
	D	SC	0.07	0.21	3.26	3.02	0.08	0.005	0.311	-0.17	1.24
Reszel	P	HC	0.66	0.22	0.33	0.22	0.48	0.002	0.005	0.15	0.83
11	A	HC	0.73	0.16	0.22	0.10	0.14	0.001	0.001	0.43	0.76
	D	SC	0.09	0.38	4.07	3.60	0.13	0.006	0.261	-0.19	1.21
Clay											
Reszel	P	C	0.50	0.23	0.45	0.27	0.70	0.002	0.002	0.32	0.83
10	A	C	0.44	0.23	0.52	0.40	0.29	0.002	0.023	0.01	0.90
	D	SC	0.11	0.52	4.53	4.43	0.02	0.005	0.326	-0.28	1.53
Lidzbark	P	C	0.42	0.26	0.61	0.40	0.54	0.001	0.019	0.22	0.85
Warmiński	A	C	0.31	0.29	0.95	0.76	0.26	0.004	0.066	-0.08	0.96
1	D	SL	0.16	1.03	6.63	4.77	0.39	0.011	0.243	0.03	1.03
Reszel	P	C	0.63	0.35	0.56	0.28	0.99	0.001	0.019	0.22	0.85
1	A	C	0.53	0.40	0.74	0.49	0.52	0.004	0.066	-0.08	0.96
	D	SC	0.10	0.62	6.47	4.98	0.30	0.011	0.243	0.03	1.03
Kętrzyn	P	C	0.33	0.25	0.75	0.46	0.63	0.001	0.010	0.39	0.96
15	A	CL	0.37	0.38	1.03	0.73	0.41	0.005	0.040	0.09	0.98
	D	SL	0.12	0.77	6.13	4.92	0.25	0.010	0.186	-0.24	1.35
Lidzbark	P	C	1.04	0.59	0.56	0.32	0.74	0.002	0.008	0.47	0.90
Warmiński	A	CL	1.27	0.70	0.55	0.35	0.57	0.004	0.018	0.37	0.88
16	D	SC	0.23	1.14	4.93	4.03	0.22	0.011	0.198	-0.19	0.99
Clay loam											
Kętrzyn	P	CL	0.75	0.63	0.84	0.53	0.58	0.004	0.020	0.39	0.90
5	A	CL	0.71	0.55	0.78	0.63	0.24	0.005	0.050	0.01	0.78
	D	SC	0.20	0.94	4.75	3.99	0.19	0.010	0.198	-0.23	1.08
Sępopol	P	CL	0.83	0.68	0.82	0.36	1.29	0.025	0.068	0.78	1.36
1	A	L	0.58	1.00	1.74	1.04	0.67	0.015	0.057	0.27	1.10
	D	SL	0.24	1.95	8.19	5.93	0.38	0.014	0.230	-0.05	0.98
Sępopol	P	CL	0.62	0.74	1.19	0.42	1.85	0.022	0.029	0.91	1.07
14	A	CL	0.61	0.86	1.41	0.55	1.56	0.025	0.030	0.85	1.01
	D	SL	0.22	2.01	9.22	6.38	0.45	0.014	0.269	0.06	0.92
Kętrzyn	P	CL	0.78	0.88	1.14	0.77	0.48	0.012	0.046	0.29	0.87
4	A	L	0.67	0.92	1.38	1.12	0.24	0.013	0.076	-0.01	0.78
	D	SL	0.23	1.46	6.27	4.64	0.35	0.014	0.198	-0.08	1.04
Sandy clay loam											
Kętrzyn	P	SCL	1.83	1.59	0.87	0.61	0.42	0.023	0.051	0.55	0.90
6	A	SCL	1.19	1.39	1.17	0.87	0.35	0.023	0.065	0.44	0.81
	D	SL	0.38	2.44	6.58	5.36	0.23	0.019	0.163	-0.22	0.78
Loam											
Lidzbark	P	L	0.88	1.29	1.47	0.87	0.68	0.018	0.051	0.39	1.05
Warmiński	A	L	0.91	1.36	1.50	0.86	0.74	0.018	0.052	0.42	1.09
15	D	SL	0.33	2.14	6.58	4.77	0.38	0.015	0.204	-0.04	0.92

Explanations: A – (0.25–0.05 mm):(0.05–0.002 mm), B – (0.25–0.05 mm):(<0.002 mm), C – (0.05–0.002 mm):(<0.002 mm), D – (0.02–0.002 mm):(<0.002 mm), E – (0.05–0.02 mm):(0.02–0.002 mm), GSS – mean diameter [mm], GSO – standard deviation, GSK – skewness, GSP – graphic kurtosis.

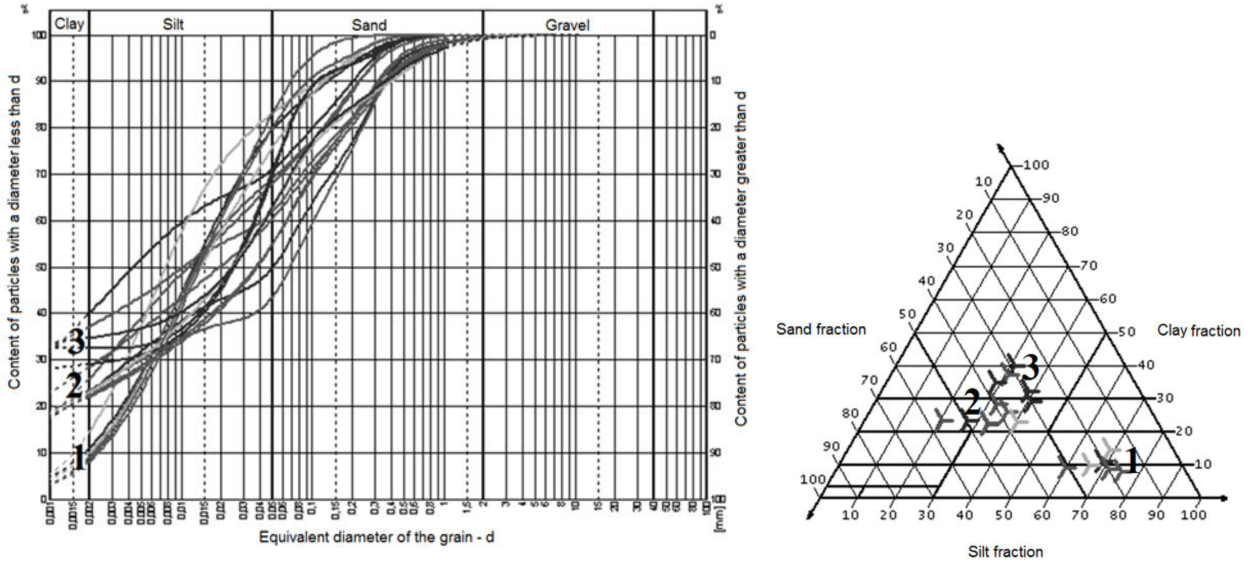

FIGURE 1. Cumulative curves and diagram of heavy clay. Methods: 1 – laser diffraction, 2 – areometric, 3 – pipette

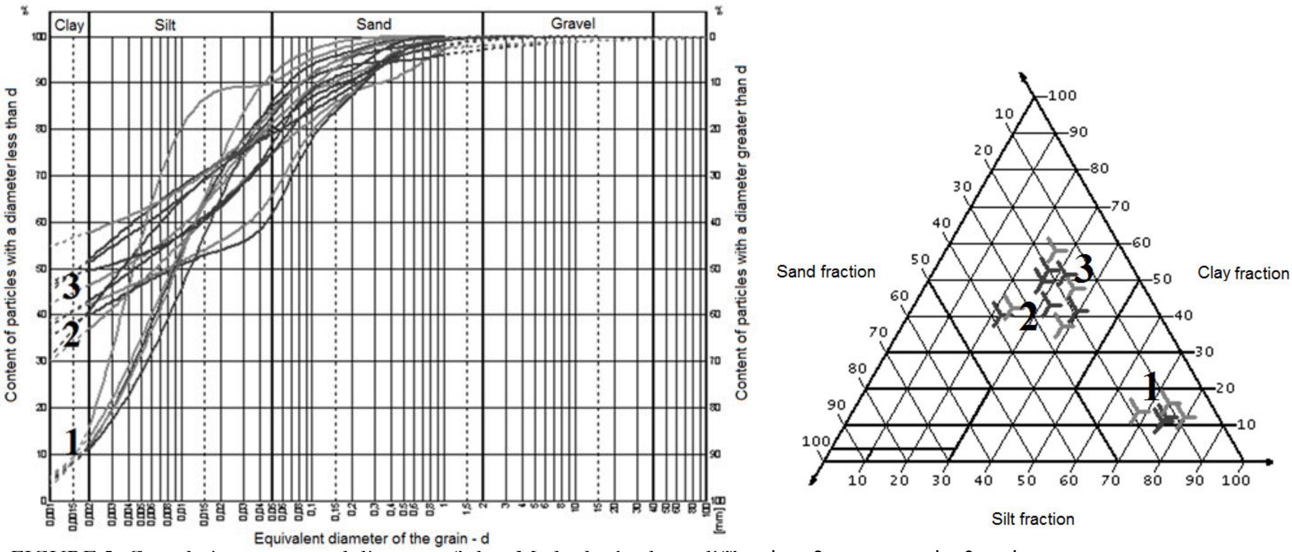

FIGURE 2. Cumulative curves and diagram of clay. Methods: 1 – laser diffraction, 2 – areometric, 3 – pipette

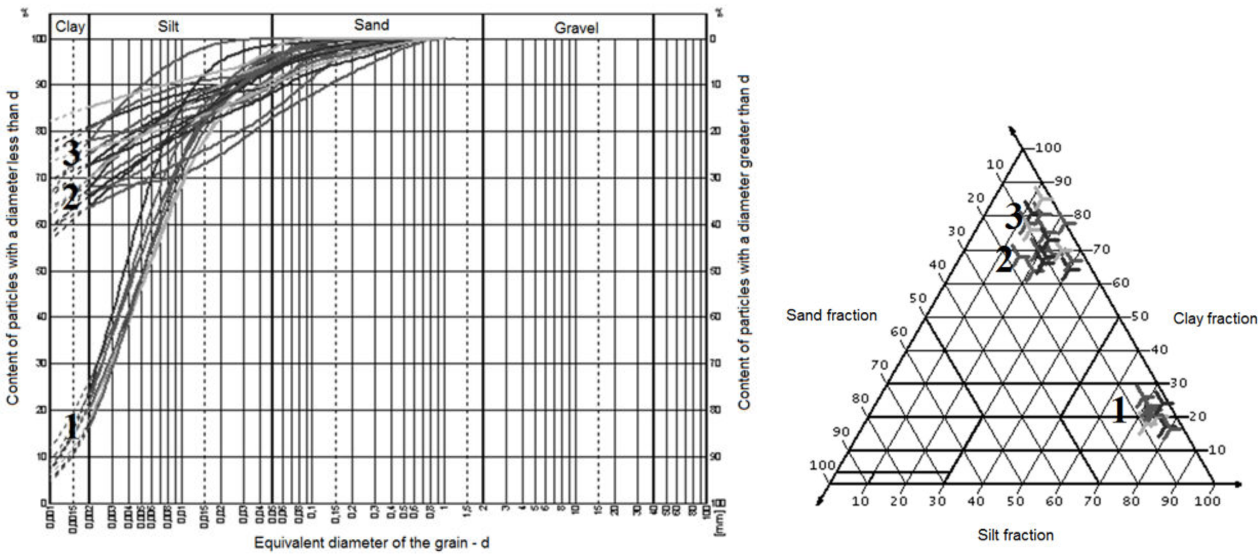

FIGURE 3. Cumulative curves and diagram of clay loam. Methods: 1 – laser diffraction, 2 – areometric, 3 – pipette

The statistical analyses showed that the results of texture measurements by pipette and areometric methods are significantly correlated ($\alpha = 0.01$). However, except for two cases (Kętrzyn 4 and Sępopol 1), there was no such relation between the laser diffraction method, and the pipette and areometric methods (Table 4).

TABLE 4. Correlation coefficients between the methods

Site	Sample number	Correlation coefficients between the methods		
		laser diffraction areometric	laser diffraction pipette	pipette areometric
Reszel	1	0.416	0.231	0.975**
	10	0.400	0.267	0.981**
	11	0.156	0.281	0.989**
	12	0.429	0.393	0.998**
	15	0.332	0.272	0.998**
Lidzbark Warmiński	1	0.599	0.349	0.942**
	2	0.243	0.327	0.996**
	12	0.471	0.426	0.998**
	15	0.624	0.635	0.997**
	19	0.263	0.257	0.994**
Kętrzyn	4	0.738*	0.570	0.951**
	5	0.559	0.467	0.980**
	6	0.572	0.309	0.944**
	15	0.598	0.400	0.964**
	20	0.263	0.257	0.994**
Sępopol	1	0.760*	0.190	0.790*
	2	0.325	0.380	0.998**
	6	0.298	0.370	0.997**
	7	0.446	0.270	0.981**
	14	0.467	0.368	0.992**

* significance level at $\alpha = 0.05$; ** significance level at $\alpha = 0.01$.

CONCLUSIONS

1. Studied eutrophic brown soils with *vertic* features, humic Vertisols and gleyic black earths in north-eastern Poland were formed from the following materials of ice-dammed lakes origin: clay, heavy clay, loam, clay loam, sand clay loam, silt loam and clay loam.
2. The contents of clay fraction (< 0.002 mm) analyzed by aerometric and pipette methods were similar, but in comparison to the laser method, these amounts were 3–4 times higher.
3. The sub-fraction of fine silt (0.02–0.002 mm) predominated, among other fractions of < 2.0 mm, in the soil fractions analyzed by laser diffraction method. Compared to the results obtained by pipette and areometric methods, these quantities were 2–4 fold higher.
4. Basing on the calculated sedimentological indices, the soil materials were very well sorted and mean grain diameter (GSS) was very low, and did not exceed 0.011 mm for clay formations.

ACKNOWLEDGEMENTS

The Project was financially supported by the funds of National Science Centre nr N N310 776040.

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Received: May 28, 2014
Accepted: August 29, 2014

Uziarnienie gleb wytworzonych z osadów glacjolimnicznych (zastoiskowych) w badaniach metodą areometryczną, pipetową i dyfrakcji laserowej

Streszczenie: Celem niniejszej pracy było porównanie wyników badań składu granulometrycznego osadów glacjolimnicznych, zdeponowanych w zbiornikach zastoiskowych na obszarze Polski północno-wschodniej przeprowadzonych metodą areometryczną, pipetową i dyfrakcji laserowej. Badane gleby zakwalifikowano do Haplic i Mollic Vertisol, Vertic Cambisol oraz Gleyic Chernozem. Gleby te wytworzyły się z utworów ilastych (clay, heavy clay), gliniastych (loam, clay loam, sand clay loam) i pyłowych (silt loam, clay loam). Badane gleby nie zawierały frakcji szkieletowych o średnicy > 2,0 mm. Oznaczone zawartości frakcji iłowych (<0,002 mm) metodą pipetową i areometryczną były do siebie zbliżone i istotnie skorelowane. W porównaniu z ilością frakcji iłowej oznaczonej metodą dyfrakcji laserowej wielkości te były około 3–4 krotnie większe. W badanych utworach glebowych analizowanych metodą dyfrakcji laserowej zdecydowanie, spośród wszystkich części ziemistych, dominowała podfrakcją pyłu drobnego (0,02–0,002 mm). W porównaniu z metodą pipetową i areometryczną ilości oznaczonego pyłu drobnego były przeważnie 2–4-krotnie większe. Na podstawie wyliczonych wartości wskaźników sedymentologicznych stwierdzono, że badane gleby charakteryzowały się bardzo dobrym wysortowaniem materiału glebowego, a przeciętna średnica ziaren (GSS) była bardzo mała i w metodzie pipetowej oraz areometrycznej, dla utworów ilastych nie przekraczała wartości 0,005 mm, a w metodzie laserowej 0,011 mm.

Słowa kluczowe: skład granulometryczny, utwory zastoiskowe, metoda areometryczna, metoda pipetowa, metoda dyfrakcji laserowej