Acta Agrophysica, 2002, 78, 287-297

SOME CHEMICAL AND PHYSICAL PROPERTIES OF SOILS DERIVED FROM SANDY-SILT AND LOESS FORMATIONS UNDER DIFFERENT MANAGEMENT*

B. Witkowska-Walczak, M. Turski, J. Lipiec

Institute of Agrophysics, Polish Academy of Sciences, Doświadczalna 4, 20-290 Lublin 27
e-mail: bwitwal@demeter.ipan.lublin.pl

Summary. Sandy silt and silty loam (loess) formations of south east Poland are presented on geological maps as loess. Such presentation is questioned since the textural differences can result in soil properties affecting soil quality. This study aimed to determine texture and some chemical and physical properties in main horizons of Luvisols derived from the both formations under forest and arable cropping. The results indicated that soils derived from sandy silt compared to loess formations at comparable horizons are characterised by greater sand content, bulk density and acidity and lower soil organic carbon, Fe concentration, specific surface area and porosity for pores retaining plant available water. The soils under forest compared to those under arable cropping showed greater soil organic carbon content, acidity, Fe concentration and lower bulk density. The differences were affected by soil horizon.

Keywords: chemical and physical properties, loess, sandy-silt formations, management.

INTRODUCTION

South-east Poland is characterised by relatively high fertility and potential productivity. This region is mostly covered by Cambisols and Luvisols derived from silt formations and Podzols derived from sandy materials. Smaller area is occupied by Phaeozems.

* This work was partially financed by the State Committee for Scientific Research, Poland (Grant No.3 PO6R 133 23).

The Cambisols and Luvisols are characterised by different physical properties as affected by origin of parent material. However, the soils derived from loess, covering large area of Lublin Uppland and Cracow Uppland and small area of Subcarpathian Valley, are relatively better known than those derived from sandy silt formations. On geological maps, the sandy silt formations covering junction of San and Visloka rivers in eastern part of Kolbuszowa Plateau are included to loess. Some soil scientists question this inclusion and based their opinion on data of texture of the soils and parent material [1-3,5,9,12-14,19,20,23].

The differences in texture alter chemical and physical properties such as soil organic carbon, acidity, bulk density and thus affect pore size distribution and air and water relations. However, the properties were not sufficiently investigated. These effects are considerably affected by land use under forest and arable farming. Understanding of the effects of different land uses becomes important since forested area in Poland is now increasing [4,7,15-18].

The aim of this paper was to compare some chemical and physical properties of Luvisols derived from sandy silt and loess formations in south east Poland under forest and arable cropping.

MATERIAL AND METHODS

This study was performed on the Orthic Luvisol (grey-brown podzolic) formed by lessivage process under climate conditions of Polish Upplands. Two sites were selected: Grodzisko Górne (south-east of Leżajsk) where the soils are characterised by sandy silt texture and situated on table-like top being culmination of the Kolbuszowa Plateau that is cut by gorges and second site Czesławice (north-west of Lublin) with silt loam soils (derived from loess) situated on Nałęczów Plateau that is well configured and cut by gorges. Each site was represented by two soil profiles under forest and arable cropping.

In the sandy silt plateau the forest soil (SSF) was localized under fresh mixed forest with predominance of pine and small addition of birch. Whortleberry (*Vaccinium myrtillus* L.) considerably contributed in the under-growth. The soil had typical horizons Oh-Eet-Eg-Bt-BtC for Orthic Luvisols. Cultivated soil (SSC) in the site had Ap-Eet-Bt horizons.

In the silty loam (loess) plateau the forest soil (SLF) was localized on degraded forest with predominance of hornbeam (*Carpinus betulus* L.) and had following horizons: Oh-OhE-Bt1-Bt2-C. Cultivated soil (SLC) had Ap-Eet-Bt-C horizons. Both forest and cultivated soils in Czesławice site are morphologically similar to their counterparts in Grodzisko Górne site.

Soil samples were taken in autumn at depths corresponding to main horizons of the soils. Soil organic carbon concentration was determined by the modified Turin's method, calcium carbon concentration by the Scheibler's method, pH by the electrometric method. Specific surface area was estimated by the water vapour adsorption method. Undisturbed core samples (100 cm^3 volume, 5 cm diameter) were taken for measurements of bulk density. The same cores were used to find the soil water characteristic curves using the pressure cell apparatus. The water characteristic curves were used as the basis for the calculation of the pore-size distribution [6,11].

RESULTS AND DISCUSSION

The basic properties of the investigated soils are presented in Table 1. The results show that the differences in texture between the soils derived from sandy silt and loess formations are mostly pronounced in upper horizons (Oh and Ap). The sand (1-0.1 mm) contents in these horizons of forest (SSF) and cultivated (SSC) soil of sandy silt plateau site were 39 and 19%, respectively whereas corresponding values in Czesławice site were 10 (SLF) and 12% (SLC). This difference becomes lower in deeper horizons where content of sand does not exceed 16% in all profiles. Content of silt particles (0.1-0.02 mm) varies from 44 to 62% in all horizons and generally is not depth dependent. Content of the particles below 0.02 mm increases with increasing soil depth in profiles SSF and SSC from 14 to 38% and from 26 to 31%, respectively. There was not such relationship in profile SLF where the highest content (42 %) of the fraction, occurred in the Bt1 horizon, and the lowest (27-28%) - in Oh, Bt2 and C horizons. In profile SLC, however, maximum content –38% - of the fraction was in Ap horizon and decreased to 28% in the C horizon.

Soil organic C concentration in accumulation horizons of SSF and SLF was 2.84 and 3.61% and in the comparable horizons of SSC and SLC were reduced by more than half. In all profiles soil organic C concentration decreased with increasing soil depth.

Franzluebbers [8] developed the concept of stratification ratio of positive soil attributes in surface soil (few cm) and in deeper soil. The greater ratio of soil organic carbon in this concept is indicator of better soil quality or soil ecosystem functioning. This is due to that the soil surface is the vital interface that receives much of the fertilizers and pesticides applied to cropland and intense impact of rainfall and partitions the flux of gases into and out of soil. In our study the stratification ratio of soil organic C in the top and neighbouring horizons were much higher in forest soils (5.4-7.4) than in cultivated ones (1.8-2.6).

Table 1. Basic properties of the investigated soils

Profile	Horizon	Depth [cm]	Parcticle size [mm] distribution [%, w/w]			C org. [%]	$CaCO_3$ [%]	pH in		Fe [g kg^{-1}]	Total porosity [%]
			1-0.1	0.1 - 0.02	<0.02			KCl	H_2O		
SSF	Oh	0 - 7	39	47	14	2.84	0.00	3.7	4.3	4.2	52
	Eet	7 - 23	36	44	20	0.38	0.01	4	4.5	4.8	40
	Eg	23 - 33	14	56	30	0.28	0.00	4.2	4.7	9.7	39
	Bt	33 - 65	7	55	38	0.06	0.03	4.2	4.7	10.7	33
	BtC	> 65	15	50	35	0.18	0.01	3.9	4.1	10.7	45
SSC	Ap	0 - 16	19	55	26	1.27	0.03	5	5.5	4.0	37
	Eet	16 - 60	12	59	29	0.7	0.02	5.3	5.7	4.0	43
	Bt	> 60	9	60	31	0.2	0.00	5.5	5.9	4.3	30
SLF	Oh	0 - 4	10	62	28	3.61	0.04	3.7	4.5	14.3	61
	OhE	4 - 24	12	49	39	0.67	0.00	4	4.6	18.0	52
	Bt1	24 - 50	11	47	42	0.37	0.00	4	4.6	14.0	47
	Bt2	50 - 80	10	63	27	0.13	0.02	4	4.8	11.7	46
	C	> 80	16	56	28	0.15	0.03	4.1	4.6	12.0	47
SLC	Ap	0 - 15	12	50	38	1.42	0.04	5	5.8	8.7	43
	Eet	15 - 25	9	54	37	0.54	0.00	5.5	6.1	15.7	40
	Bt	25 - 35	10	55	35	0.21	0.04	5.8	6.1	11.3	43
	C	> 35	16	56	28	0.11	0.00	5.4	5.8	11.7	46

Calcium carbonate content was very low in all profiles and in loess-derived soils can indicative of the effects of decalcification occurring in the soils.

Values of pH measured in water varied from 4.1 to 6.1 in all profiles. They ranged from 5.5 to 5.9 in SSC and from 5.8 to 6.1 in SLC. Corresponding ranges in forest profiles were 4.1-4.7 in SSF and 4.5-4.8 in SSC. Values of pH measured in KCl, being indicative of exchangeable acidity, varied in both sites from 5.0 to 5.8 in cultivated soils and from 3.7 to 4.2 in forest soils. Comparison of the above results indicates that the differences in acidity between the cultivated and forest profiles were more pronounced by pH values measured in KCl. There was no clear dependence between both types of acidity and soil depth.

Concentration of Fe in the soils was associated with type of parent material. In profiles derived from loess, both SLF and SLC, it ranges from 8.7 to 18.0 g kg^{-1} whereas in profiles derived from sandy silt formations - from 4.0 to 10.7 g kg^{-1}. Irrespective of parent material, the forest soils are higher in Fe than tilled soils. In profiles derived from sandy silt formations (SSF and SSC) Fe concentration increases with increasing soil depth, while in those derived from loess formations, it reaches maximum in E horizon.

Figure 1 shows that bulk density, irrespective of type of soil use, was greater in soils derived from sandy silt than loess formations. Its values varied in sandy silt profiles under forest from 1.26 to 1.78 g cm^{-3} and under arable cropping - from 1.51 to 1.85 g cm^{-3}. Corresponding ranges for soil profiles derived from silty formations were 1.02-1.42 g cm^{-3} and 1.44-1.60 g cm^{-3}. The differences in bulk density between the land uses were greater in silty loam than sandy silt soils. In both sites the differences were pronounced mostly in upper horizons and decreased in deeper. As expected, profiles of total porosity, as calculated from bulk density and particle density values, similarly reflected distribution of soil compactness as bulk density did (Tab. 1).

Pore size distribution of the investigated soil profiles is presented in Fig. 2. Porosity for pore sizes greater than 18.5 μm of both forest soils (SSF and SLF) decreased with increasing soil depth. In SSF, the percentage of these pores being 20.5 in Oh horizon decreased to 6.3 in Bt horizon and correspondingly in SLF - from 27.6 to 10. In C horizon of both soils the percentage slightly increased. The percentage of pores 18.5 - 0.2 μm (mezopores), retaining plant available water, decreased with increasing soil depth in forest soils till 30 - 40 cm. These reductions were from 25.2 to 16% and from 21 to 20% in SSF and SLF, respectively. In deeper levels the amount of mezopores increase up 25 - 27%. However, in soils under arable farming porosity for these pores was very similar irrespective of soil horizon.

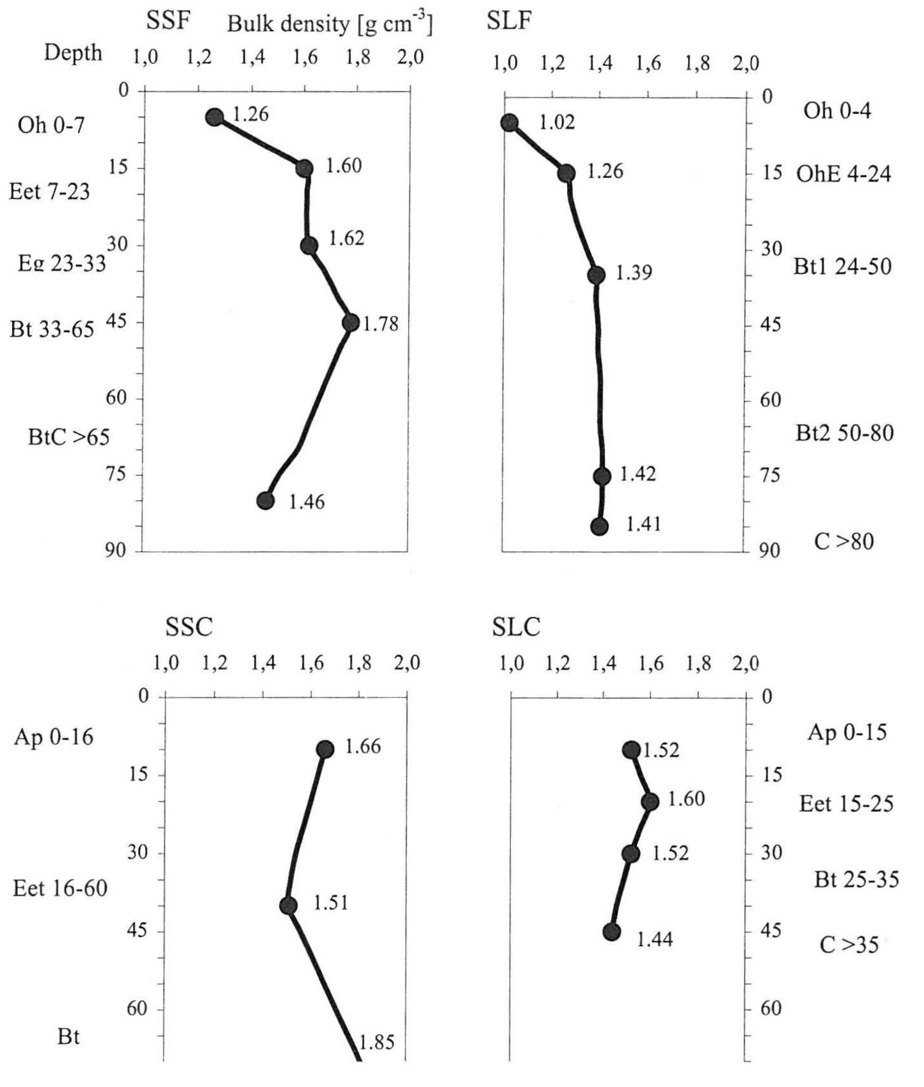

Fig. 1. Bulk density of the investigated soils: SSF- sandy forest soil, SSC – sandy cultivated soil, SLF – loess forest soil, SLC - loess cultivated soil.

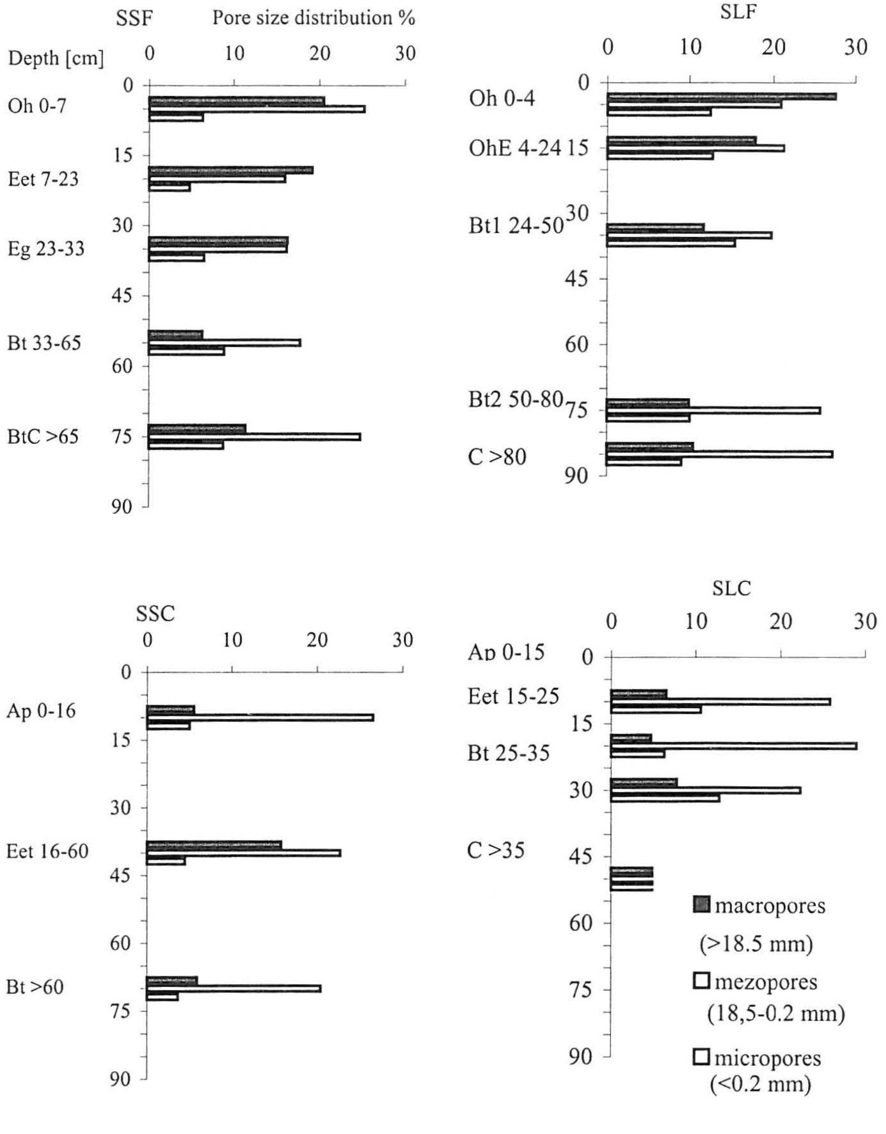

Fig. 2. Pore size distribution of the investigated soils, explanations as in Fig.1.

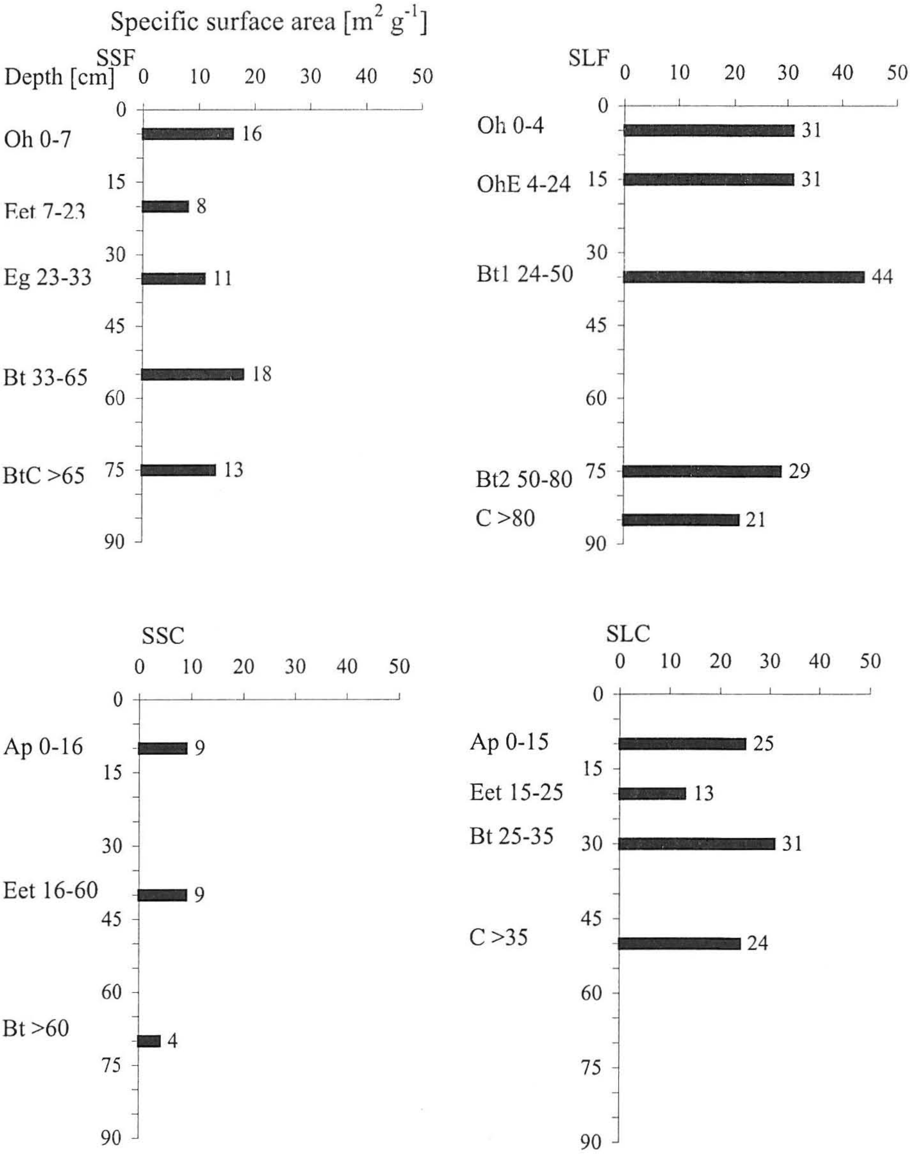

Fig. 3. Specific surface area of the investigated soils, explanations as in Fig.1.

At comparable soil horizons the percentage of these pores was greater for soils derived from loess than sandy silt formations. The percentage of micropores smaller than 0.2 μm was considerably greater for loess-derived SLF and SLC profiles (6.3 – 15.5%) than SSF and SSC profiles derived from sandy-silt formation (3.7 – 8.9 %).

The distribution of specific surface area is shown in Fig. 3. Similarly as Fe concentration, it was related to parent material. In soils derived from loess formation, both SLF and SLC, it is considerably greater (13-44 $m^2 g^{-1}$) than in those derived from sandy-silty (SSF and SSC) (4-18 $m^2 g^{-1}$).

CONCLUSIONS

The soils derived from sandy silt and silty loam (loess) formations of south-east Poland presented on geological maps as loess differ in some soil chemical and physical properties. The differences were more pronounced in the top than deeper genetic horizons of soils.

1. Organic carbon concentration, acidity, pore-size distribution and specific surface area were more favourable in the silty loam soils.
2. The soils under forest compared to those under arable farming are characterised by higher organic carbon content, stratification ratio of organic carbon, Fe concentration and lower bulk density (higher porosity).

REFERENCES

1. **Butrym J.:** Utwory pyłowe wschodniej części Niziny Sandomierskiej. Annales UMCS, B, 23, 87-121, 1968.
2. **Cegła J.:** Porównanie utworów pyłowych kotlin karpackich z lessami Polski. Annales UMCS, B, 18, 69-116, 1963.
3. **Dobrzański B., Malicki A.:** Rzekome loessy i rzekome gleby loessowe okolic Leżajska. Annales UMCS, B, 3, 415-426, 1949.
4. **Domżał H., Słowińska-Jurkiewicz A., Turski R., Hodara J.:** Ugniatanie jako czynnik kształtujący fizyczne właściwości gleby. Rocz. Nauk Roln., D, 198, 1-102, 1984.
5. **Dwucet K.:** Uwagi o zróżnicowaniu rozkładu wybranych cech młodszego Iib na wyżynach Polskich i Nizinie Śląskiej. Georama 2 , 13-22, 1994.
6. **Gliński J., Konstankiewicz K.:** Metody i aparatura do badań agrofizycznych. Problemy Agrofizyki, 64, 9-150, 1991.
7. **Ehlers W.:** Total porosity and pore size distribution in untilled loess soils. Z. Pfl. Ernahr. Dung. Bodenk., 134(3), 193-207, 1973.

8. **Franzluebbers A.J.**: Soil organic matter stratification ratio as an indicator of soil quality. Soil & Tillage Research, 66, 95-106, 2002.
9. **Gerlach T.**: Przesłanki wyróżnienia Karpackiej odmiany lessów. Litologia i stratygrafia czwartorzędowa utworów pyłowych. Mat. Konf., UŚ Sosnowiec, 8, 1994.
10. **Hillel D.**: Environmental Soil Physics. Academic Press, San Diego-London-Tokyo. 1998.
11. **Klute A. (ed.)**: Methods of Soil Analysis. Part 1: Physical and Mineralogical Methods. ASA-SSSA Inc., Madison, Wisconsin, USA, 1986.
12. **Lipiec J.**: Physical properties of soils as an index of their agricultural suitability. Zesz. Probl. Post. Nauk Roln., 197, 167-190, 1977.
13. **Lipiec J., Turski M.**: Zmiany wybranych właściwości fizycznych gleb powodowanych sposobem ich użytkowania. Zesz. Probl. Post. Nauk Roln., 478, 235-242, 2002.
14. **Masch F.D., Denny K.Y.**: Grain size distribution and its effect on the permeability of unconsolidated sands. Water Resources Res., 4, 665-677, 1966.
15. **Raczuk J.**: Rozmieszczenie związków żelaza w glebach płowych Wysoczyzny Siedleckiej. Roczniki Gleboznawcze, **LII**, suplement, 109118, 2001.
16. **Turski M.; Lipiec J.; Nosalewicz A.**: Physical properties of soil aggregates from various horizons of four soils. Polish J. Soil Science, XXXIII, 1, 1-8, 2000.
17. **Turski R.; Turski M.**: Gleba jako jedna z podstaw renaturyzacji obszarów lessowych. [w] Renaturzacja obiektów przyrodniczych – aspekty ekologiczne i gospodarcze. Materiały konferencyjne pod red. Z. Michalczyka. ISBN 83-227-1611-7, 227-233, 2000.
18. **Turski R.; Turski M.**: Kształtowanie i ochrona terenów lessowych na przykładzie Lubelszczyzny. Zesz. Probl. Post. Nauk Roln., 476, 1-8, 2001.
19. **Turski R., Słowińska-Jurkiewicz A.**: Gleby wytworzone z lessów. Lubelskie Towarzystwo Naukowe, Lublin, **68**, 1994.
20. **Uziak S.**: Zagadnienie typologii gleb pyłowych Pogórza Karpackiego. Annales UMCS, B, 17, 1-61, 1962.
21. **Walczak R.**: Modelowe badania zależności retencji wodnej od parametrów fazy stałej gleby. Problemy Agrofizyki, 41, 5-78, 1984.
22. **Witkowska-Walczak B.**: Wpływ struktury agregatowej gleb mineralnych na ich hydrofizyczne charakterystyki. *Acta Agrophysica*, 30, 5-99, 2000.
23. **Zaleski T.**: Pedogenetyczne uwarunkowania właściwości hydrofizycznych gleb płowych wytworzonych z lessów i pyłów lessopodobnych. Praca doktorska wykonana w Katedrze Gleboznawstwa i Ochrony Gleb Wydz. Rolniczego AR w Krakowie, 2000.

WYBRANE CHEMICZNE I FIZYCZNE WŁAŚCIWOŚCI GLEB WYTWORZONYCH Z UTWORÓW PIASZCZYSTO-PYŁOWYCH I LESSOWYCH RÓŻNIE UŻYTKOWANYCH

B. Witkowska-Walczak, M. Turski, J. Lipiec

Instytut Agrofizyki im. Bohdana Dobrzańskiego PAN, ul. Doświadczalna 4, 20-290 Lublin 27
e-mail: bwitwal@demeter.ipan.lublin.pl

S t r e s z c z e n i e. Utwory piaszczysto-pyłowe i pyłowe (lessowe) południowo-wschodniej Polski są przedstawiane na mapach geologicznych jako lessy. Połączenie to jest kwestionowane, ponieważ różnice w uziarnieniu tych gleb mają wpływ na szereg właściwości warunkujących ich jakość. W niniejszej pracy porównano wybrane właściwości chemiczne i fizyczne w poziomach genetycznych gleb płowych (uprawnych i leśnych) wytworzonych z utworów piaszczysto-pyłowych i pyłowych (lessu). Gleby wytworzone z utworów piaszczysto-pyłowych w porównaniu do gleb wytworzonych z utworów pyłowych charakteryzują się w porównywalnych poziomach genetycznych większą zawartością piasku, gęstością, kwasowością i mniejszą zawartością węgla organicznego, żelaza i porów zatrzymujących wodę dostępną dla roślin oraz powierzchnią właściwą. Gleby leśne w porównaniu do uprawnych są zasobniejsze w węgiel organiczny i żelazo i charakteryzują się większą kwasowością i mniejszą gęstością. Zakres tego zróżnicowania zmienia się w zależności od poziomu genetycznego.

S ł o w a k l u c z o w e: chemiczne i fizyczne właściwości, less, utwory piaszczysto-pyłowe, użytkowanie.