

The influence of lake sediments on the fertility of Cambisol

E. Baksiene

Voke Branch of the Lithuanian Institute of Agriculture, Žalioji aikštė 2, Trakų Vokė,
LT-02232 Vilnius; e- mail: eugenija.baksiene@voke.lzi.lt

Abstract. Lake sediments as a potential fertilizer were studied at the Voke Branch of the Lithuanian Institute of Agriculture during 1994–2004. The aim of the research was to establish the influence of lake sediments and their mixtures with other organic matter (manure, sewage) on the crop yield and soil agrochemical and physical properties; to compare the effect of sediments with that of a sediment-manure mixture.

Experimental evidence suggests that lake sediments had no effect on soil acidity. The higher rate of sediments (100 t ha^{-1}) increased the content of total nitrogen in the soil by 0.002–0.021 and humus by 0.53 percentage units. Application of lake sediments had a positive impact on the quality of physical properties of sandy loam Cambisol. Various rates of sediments increased the soil moisture content and porosity, and declined soil bulk density. The rate of lake sediments $50, 100 \text{ t ha}^{-1}$ increased the productivity of crop rotation by 8–30%, manure – by 21–25%. Fertilization with lake sediments at a rate of 100 t ha^{-1} and pure manure produced 25–30% of the yield of energy units per year.

Key words: sediments, manure, soil, properties, yield

INTRODUCTION

The importance of organic matter in soil is indisputable. It is both the source of nutrients necessary for plants and the means for effective functioning of nutritive matter. It is especially important for the soil in case of practicing organic farming. With agriculture becoming more intensive, organic matter in soil is rapidly mineralized and soil becomes exhausted (Loveland & Webb, 2003). It can be amended applying various organic fertilizers. Throughout the world of all the organic waste returned into the soil up to 70% is plant waste, 23% manure, 5% industrial waste, while only 1% of organic substances is of other origin (Foth, 1990). A substantial amount of organic matter accumulated in lakes can be included in this one percent. The deposits formed during the long process of sedimentation of decayed flora and fauna remnants comprise 15–90% organic matter as well as 50–60% CaCO_3 , Si, Mg, Fe, Al, Mn, Zn, Cu, Mo, Co oxides. Moreover, vitamins, amino acids, other biologically active components are found in lake sediments. Amounts of various chemical compounds, their combinations, or other materials differ within a wide range even in the same water body (Hakanson, 1981).

Fertilization with lake sediments enriches the soil with organic matter as well as improves its structure and physical properties. It is also an important measure to prevent wind erosion of soil. Practically all investigators agree that lake sediments function as a long-term measure for improving agrochemical and physical properties of

soil (Booth et al., 2007). Composting the sediments with manure highly increases the positive effect on soil. This leads to the increase in the content of micro-organisms, which results in higher amount of nutritional substances (Kireycheva & Hohlova, 1998).

The aim of this research was to establish the effect of lake sediments and their mixtures with other organic matter (manure, sewage) on the crop yield as well as agrochemical and physical properties of soil, and to compare the impact of sediments with that of the sediment-manure mixture.

MATERIALS AND METHODS

Experimental plots for the investigation of the effect produced by lake sediments (N – 1.11, P – 0.02, K – 0.55, Ca – 1.01, Mg – 0.78%) were established on a sandy loam Cambisol with pH – 6.1–6.4, P₂O₅ – 139–174 mg kg⁻¹, K₂O – 174–204 mg kg⁻¹ of soil (A-L method), humus 1.79–2.27% (Hereus instrument) in a field crop rotation: maize, (*Zea mays* L.), barley (*Hordeum* L.) with under-crop, perennial grasses (*Trifolium pratense* L. and *Pheleum pratense* L.) of the 1st and 2nd year of use, winter rye (*Secale cereale* L.), mixture of oats and lupin (*Avena sativa* L. and *Lupinus angustifolius* L.), barley (*Hordeum* L.), with under-crop, perennial grasses (*Trifolium pratense* L. and *Pheleum pratense* L.), mixture of oats and lupin, and barley (*Hordeum* L.). The following experimental design was used: (1) Control; (2) 25 t ha⁻¹ dry sediments (S); (3) 50 t ha⁻¹ dry sediments (S); (4) 100 t ha⁻¹ dry sediments (S); (5) 25 t ha⁻¹ dry sediments (S) + 10 t ha⁻¹ manure (M); (6) 25 t ha⁻¹ dry sediments (S) + 25 t ha⁻¹ manure (M); (7) 25 t ha⁻¹ dry sediments (S) + 10 m³ ha⁻¹ sewage (Sr); (8) 65 t ha⁻¹ manure (M). The sediments were taken from Lake Musė, Vilnius region. Moisture content of sediments was 60%. Together with sediments 4,500–18,000 kg ha⁻¹ of organic C, 278–1,110 kg ha⁻¹ of total N, 50–200 kg ha⁻¹ of P₂O₅, and 138–550 kg ha⁻¹ of K₂O were introduced into soil, and 19,500 kg ha⁻¹ of organic C, 325 kg ha⁻¹ of total N, 85 kg ha⁻¹ of P₂O₅, and 312 kg ha⁻¹ of K₂O were introduced with manure.

Only maize was fertilized with organic fertilizers (lake sediments, manure, and sewage). Later the impact of the above mentioned organic fertilizers was observed concerning the yield of plants grown in the crop rotation and changes in the agrochemical and physical properties of soil. Agrochemical properties of the arable soil layer (0–20 cm) were determined before establishment of the experimental plots and after the whole crop rotation (in 6 and 11 years). Each year, after sowing in spring (P) and harvesting in autumn (R) soil bulk density, moisture, and total porosity of soil were determined in the most representative treatments: (1) Control (without fertilizers); (2) 25 t ha⁻¹ dry sediments (S); (3) 100 t ha⁻¹ dry sediments (S); (4) 25 t ha⁻¹ dry sediments + 25 t ha⁻¹ manure (M). Soil bulk density, moisture, and total porosity were estimated by the weighing method.

Cumulative curves were calculated by adding the yield increase of each subsequent year to the yield increase of the previous year. The yield increase resulting from only sediments was calculated by deducting the data of the control treatment from the data of each treatment, therefore one treatment (in this case the control) is not included and treatment No 1 is 0 in Fig. 3. Relative feed value (RFV) was calculated from predicted values for both dry matter intake (DMI) and digestible dry matter (DDM), based on laboratory analyses for neutral-detergent fibre (NDF) and acid-

detergent fibre (ADF), respectively. The current equations used by the US National Forage Testing Association (NFTA) are: DMI, % dry weight – 120/(NDF, % of dry matter); DDM, % dry matter – 88.9-0.779x (ADF, % of dry matter); RFV = DMI x DDM/1.29. The divisor 1.29 was chosen so that the RFV of full bloom alfalfa has a value of 100 (Moore & Undersander, 2002).

Soil and crop yield data were processed using EXCEL₂₀₀₀ version 2.2 software to perform One-Way Analysis of Variance. All data were evaluated according to Fisher criteria (F) and LSD₀₅ (Brewbaker, 1995; Tarakanovas & Raudonius, 2003).

RESULTS AND DISCUSSION

The cumulative curve of the crop yield demonstrates that different rates of lake sediments produced a stronger effect on the productivity of plants during the last year of the crop rotation (winter rye) and in case the sediment rates were 50 and 100 t ha⁻¹ (Fig. 1). In the treatments where the sediment-manure mixture and pure manure were used the yield remained stable. Mineralization of manure had probably taken place earlier, and during the 11th year of these treatments plants were already in a shortage of nutrients.

Calculation of the average of feed units per crop rotation revealed that higher rates of sediments (50, 100 t ha⁻¹) augmented the productivity of crop rotation by 8–30%, while manure by 21–25%. Although the yields were not statistically significant, they were still rather high. Fertilization with lake sediments slightly differs from fertilization with manure. According to Russian scientists, lake sediments are most effective. Their research findings based on sod-podzolic sandy loam soil indicate that sediments were not less effective compared with peat-manure compost, on the contrary, in several cases they were even better.

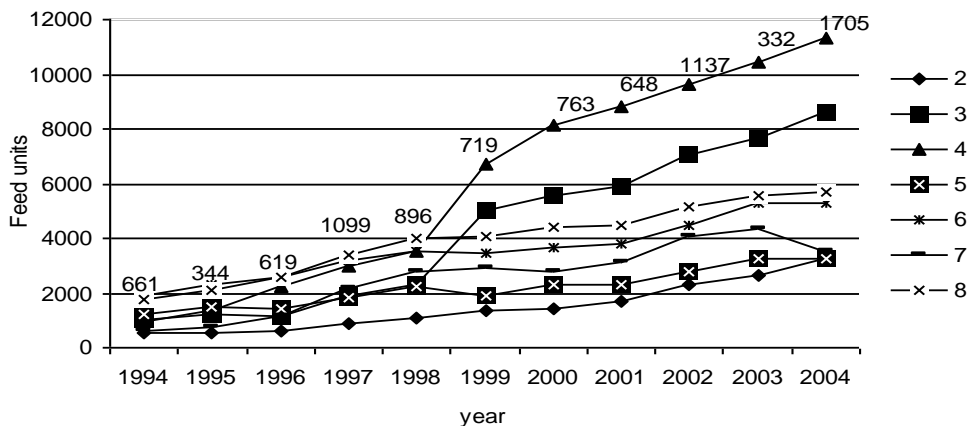


Fig. 1. Cumulative curves of yield increase from lake spropels and their mixture with other fertilizers.

2-8 - treatments of trials: (2) 25 t ha⁻¹ dry sediments (S); (3) 50 t ha⁻¹ dry sediments (S); (4) 100 t ha⁻¹ dry sediments (S); (5) 25 t ha⁻¹ dry sediments (S) + 10 t ha⁻¹ manure (M); (6) 25 t ha⁻¹ dry sediments (S) + 25 t ha⁻¹ manure (M); (7). 25 t ha⁻¹ dry sediments (S) + 10 m³ ha⁻¹ sewage (Sr); (8). 65 t ha⁻¹ manure (M). 661-1705 – LSD₀₅.

Table 1. Relationship between feed units of rotation and soil pH (x_1), hydrolytic acidity (H mekv/kg dirv. - x_2), absorbed bases (S mekv/kg dirv. - x_3), and soil nitrogen (N % - x_4), mobile phosphorus (P_2O_5 mg/kg dirv. - x_5), mobile potassium (K_2O mg/kg dirv. - x_6) amounts.

Agrochemical properties	Regression equation	r^2	Sr
pH, H, S	$y = -31643,81 + 7208,66x_1 + 650,18x_2 - 19,82x_3$	0.43	0.16
N, P_2O_5 , K_2O	$y = 4304,22 + 129299,01x_4 - 43,45x_5 + 55,43x_6$	0.54	0.14

Note: Probability level – 95%.

The rate of 60–80 t ha⁻¹ of sediments provided a yield increase of 0.34–1.61 t ha⁻¹ for barley, while the same rate of peat-manure compost gave a yield increase of 0.28–1.06 t ha⁻¹ (Grigorov & Ovchinnikov, 1994; Orlov & Sadovnikova, 1996).

Analysis of the efficiency of sediments and their mixtures revealed a medium correlation ($r^2 = 0.43$, $Sr = 0.16$), and on the background of mineral fertilizers a weak correlation ($r^2 = 0.09$, $Sr = 0.20$) between the yield of feed units per crop rotation and indices of soil reaction (Table 1).

Research results suggest that the yield of feed units per crop rotation was dependent on the agrochemical properties of soil. The yield of feed units strongly correlated with the amounts of nitrogen, phosphorus, and potassium ($r^2 = 0.54$; $Sr = 0.14$) present in the soil and introduced with organic fertilizers.

Although 1.01% of calcium was identified in lake sediments, it caused no significant changes in soil acidity (Table 2). According to pH, soil acidity remained neutral. The total exchangeable bases changed within the standard error. In case the sediment-manure mixture and sewage mixtures were applied, neutral soil became slightly acidic (pH value 6.0), and in case manure was used it turned more acidic (pH value 5.5). Consequently, in these treatments, the total exchangeable bases decreased by 17.3 to 56.1 mequiv kg⁻¹.

The highest amounts of nitrogen were introduced into the soil with various rates of lake sediments and sediment-manure mixtures. During the eleven years of crop rotation, plants did not exhaust the amounts. Therefore, the amount of total nitrogen in the soil was by 0.009–0.021 percentage units higher. Gradually increased rates of sediments enhanced the amount of total nitrogen from 0.097 to 0.118% in the soil. Fertilization with manure had no impact on the amount of nitrogen. After fertilization with lake sediments at 100 t ha⁻¹ the content of total nitrogen increased by 0.002–0.021 and that of humus by 0.53 percentage units.

Organic fertilizers affected the accumulation of humus in soil. Proportionally increased rates of sediments evenly increased the amount of humus from 0.09 to 0.43%. Mixtures of sediments and manure, and pure manure with mineral fertilizers produced a weaker effect. Under their impact the amount of humus in the soil increased by 0.09–0.17%. Larger amounts of phosphorus were introduced into the soil with higher rates of lake sediments (50, 100 t ha⁻¹), sediment-manure mixture, and pure manure (163.7–196.0 mg kg⁻¹).

Table 2. Effect of saptopel on the agrochemical indices of sandy loam Cambisol.

Treatments	pH _{KCl}	Exchangeable bases, mquiv kg ⁻¹	Total N	Organic carbon	P ₂ O ₅	K ₂ O
			%		mg kg ⁻¹	
1. Control (without fertilizers)	6,2*	146,8	0,102	1,79	170	196
	6,0**	160,5	0,094	1,82	182	155
	6,6***	182,0	0,102	1,67	136	185
2. 25 t/ha S	6,1	76,3	0,097	1,81	148	176
	6,0	93,9	0,105	1,90	138	144
	6,1	103,5	0,111	1,99	162	186
3. 50 t/ha S	6,4	123,8	0,099	2,11	159	193
	6,5	185,5	0,108	2,40	195	161
	6,9	147,21	0,110	1,99	185	203
4. 100 t/ha S	6,1	74,3	0,097	1,93	140	186
	6,5	122,3	0,118	2,36	178	179
	6,7	119,3	0,116	2,07	164	116
5. 25 t/ha S + 10 t/ha M	6,2	125,0	0,101	2,27	174	207
	6,4	193,9	0,101	2,20	196	164
	6,6	146,4	0,103	1,88	104	101
6. 25 t/ha S + 25 t/ha M	6,4	119,2	0,098	2,06	163	179
	6,5	125,1	0,099	2,22	168	159
	6,6	126,4	0,100	1,82	131	131
7. 25 t/ha S + 10 m ³ Sr	6,2	127,1	0,104	2,03	150	176
	6,2	125,1	0,107	2,19	159	171
	6,5	95,8	0,101	1,76	115	131
8. 65 t/ha M	6,1	96,1	0,101	2,05	139	174
	6,1	125,8	0,098	2,17	164	173
	6,6	92,0	0,104	1,90	133	140
LSD ₉₅	0,31	77,4	0,012	0,32	50,2	26,7
	0,83	103,8	0,013	0,30	45,9	34,0
	0,61	138,5	0,011	0,24	91,7	75,2

Notes: * - agrochemical indices before experiments; ** - agrochemical indices after the first crop rotation; *** - agrochemical indices after the second crop rotation.

Similarly, the content of potassium in lake sediments was also rather low. Consequently, due to various fertilization treatments the content of mobile potassium in the soil changed similarly to that of phosphorus. The amount of mobile potassium decreased by 6.8–43.1 mg kg⁻¹ in all the treatments applied with lake sediments and manure. The amount of potassium, sufficient for plants, can be compensated only by mineral fertilizers.

The research results revealed that fertilization of sandy loam Cambisol with lake sediments exerted a positive effect on the soil moisture (Fig. 2). During all experimental years, with the exception of 1997 and 2002, it was lower in spring and increased significantly in autumn after harvesting. The effect of the application of sediment-manure mixture was in many cases equal to that of lower (25 t ha⁻¹) rate of sediments with mineral fertilizers. The 100 t ha⁻¹ sediment rate (treatment 3), which increased soil moisture by 1.00–1.50%, was found to be most effective.

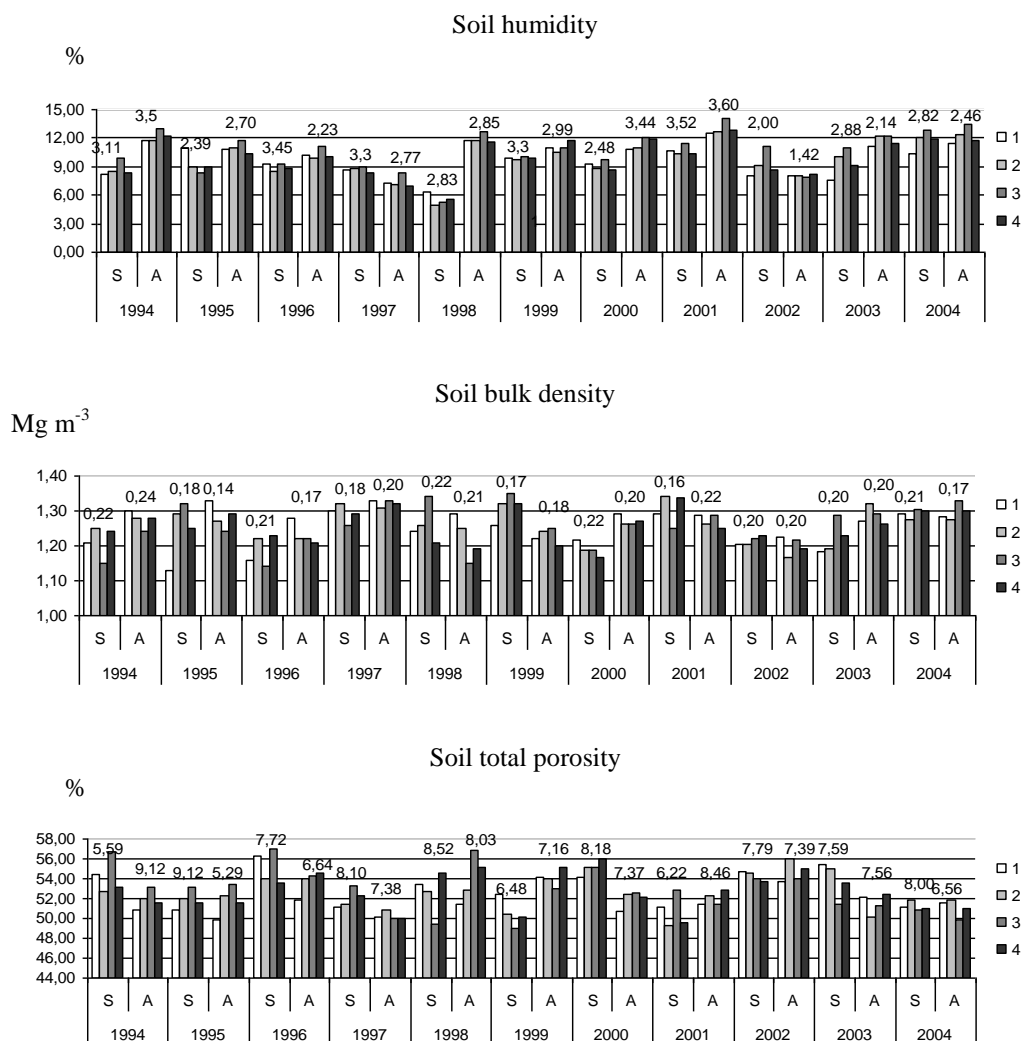


Fig. 2. The effect of lake sediments on sandy loam cambisol humidity, density and total porosity.

S – spring, after sowing of crop; A - autumn, after harvesting; 1-4 - treatments of trials: (1) Control (without fertilizers); (2) 25 t ha⁻¹ dry sediments (S); (3) 100 t ha⁻¹ dry sediments (S); (4) 25 t ha⁻¹ dry sediments + 25 t ha⁻¹ manure (M). 3.11-0.22-5.59 – LSD₀₅.

Analysis of the impact of lake sediments on the soil bulk density revealed that sometimes it was changing unevenly (Fig. 2). After application of 100 t ha⁻¹ lake sediments in the spring of 1995, 1998, 1999 and 2003, the soil bulk density increased up to 1.32–1.35 Mg m⁻³, and up to 1.25–1.33 Mg m⁻³ in 1997 and the autumn of 1999; still in 1994, 1996, 1997, 2003 it reduced to 1.06–1.24 Mg m⁻³. When soil was fertilized with 25 and 100 t ha⁻¹ rates of lake sediments, the soil bulk density declined to 1.035–1.20 Mg m⁻³.

The soil bulk density directly affected the total porosity of soil (Fig. 2). The total porosity indices, similarly to those of soil bulk density, were changing unevenly due to different fertilizers. In case the bulk density was higher, the total porosity was lower, and vice versa. During the whole experimental period, the total porosity of soil was similar in various levels of arable layer; it was higher only in the autumn and spring of 1998, 1999 and 2002. At certain moments the total soil porosity reached 49.01–56.90 and 50.07–55.19%. A more evident effect was produced by the 100 t ha⁻¹ rate of sediments and the sediment-manure mixture. Norwegian and Canadian scientists (Sveistrup et al., 1995; Zebarth et al., 1999) have reported positive effects of lake sediments on soil physical properties. Application of sediments increased soil porosity and moisture retention capacity, improved soil texture and quality.

CONCLUSIONS

1. All rates of lake sediments increased the productivity of the crop rotation by 8–30%, manure by 21–25%. Fertilization with a lake sediment rate of 100 t ha⁻¹ and pure manure produced 25–30% of the yield of feed units per year.

2. The yield of feed units strongly correlated with the amounts of nitrogen, phosphorus, and potassium ($r^2 = 0.54$; $Sr = 0.14$) present in the soil and introduced with organic fertilizers.

3. Fertilization with various rates of lake sediments did not influence soil pH. Soil was neutral and remained unchanged. Exchangeable bases in all treatments (except for fertilization with manure) insignificantly increased by 11.8 – 48.0 mequiv kg⁻¹ of soil. The amounts of total nitrogen, humus, and phosphorus also increased, while the amount of potassium decreased.

4. Soil water, soil bulk density, and total porosity were affected by lake sediments more markedly, compared with the treatments without mineral fertilizers. The 100 t ha⁻¹ lake sediment rate was most efficient. Application of such amount of sediments increased the soil water by 1.00–1.50%, total porosity from 49.01 to 56.90%, and reduced the soil bulk density from 1.35 to 1.20 Mg m⁻³.

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