

## THE INFLUENCE OF LAKE SEDIMENTS ON SANDY LOAM SOIL PROPERTIES AND CROP YIELD

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### ABSTRACT

In the silty Lithuanian lakes about 1.5 milliard m<sup>3</sup> of sediments are accumulated. These sediments represent a valuable organic matter, which can be used for fertilization and improving of soil. In order to study the possibilities of their application for improvement of an infertile environmental object soil: sandy loam cambisol (CM), experiments were carried out at the Voke Branch of Lithuanian Research Centre for Agriculture and Forestry. Investigations on the effectiveness of organic lake sediments were conducted on background material containing no mineral fertilizers and with minimum rate of N30-60P30-40K50-60 fertilizers in 1999-2009. The obtained results verified that soil fertilization with various rates of organic lake sediments and its mixtures with manure and sewage influenced the productivity of crop rotation. The higher rate of organic (40 t ha<sup>-1</sup>) sediments increased the contents of total nitrogen and humus in soil. Fertilization with mineral fertilizers compensated the amounts of mobile phosphorus and potassium, which are needed for plants to grow.

The application of sediments positively influenced the physical properties of sandy loam cambisols. The organic sediments increased the humidity and porosity and reduced the soil density.

**Key words:** lake, sediments, manure, yield, soil properties.

### INTRODUCTION

In light textured soils the preservation of organic soil material is very important. Even if extensive agriculture is being carried on the preservation of nutrients, a sustainable management approach is to aim to its gradual replenishment with organic fertilizers. With intensifying agricultural activities and increasing production, humus is being rapidly mineralized and the soil becomes exhausted (Loveland and Webb, 2003; Enters et al., 2008). One source of organic fertilizers is lake sediments. It abundantly accumulates in lakes situated in the regions with unproductive soils (Roberts et al., 2011a). Anthropogenic activities often lead to contamination of water resources. Therefore, due to natural eutrophication of lakes and anthropogenic activity in lake areas, many lakes worldwide become silty; they are decaying and turning into marsh (Adriaens et al., 2002; Shukla et al., 2010). Most attention is given to mechanical cleaning – removal of sediments

from the already silted lakes, but application of lake sediments as fertilizers seems to be an interesting measure (Alkan et al., 2009). If they are properly used some costs involved in the cleaning of waters could be returned. Investigations carried out in France, Italy, Russia and United Kingdom on the effects of lake sediments allow to suppose that their impact depends upon the chemical composition (Grishina et al., 1990; Andresini et al., 2003). Calcareous lake sediments are more appropriate for soil liming, organic and siliceous sediments are suitable as a source of nutritious materials (Orlov and Sadovnikova, 1996; Roberts et al., 2011b).

In Lithuania, the efficiency of calcareous lake sediments has been extensively studied. In sandy loam soil and sandy soil in crop rotation fields the application of 50, 100, 150 and 200 t ha<sup>-1</sup> (of dry matter) of calcareous sediments from Lake Ilgutis (Vilnius district) was investigated; various rates of sediments functioning as long-term measure for improvement of agrochemical and physical

properties of soil were tested. After fertilization with lake sediments, the acidity of soil was reduced, while humus content increased, and qualitative composition improved. All applied rates of sediments improved soil texture and moisture regime. However, different rates of the used calcareous sediments produced no positive effect on the productivity of crop rotation. The study results showed that the application of sediments in sandy loam soil ( $\text{pH}_{\text{KCl}} 6.0$ ) during the 1<sup>st</sup> crop rotation season increased the yield of agricultural plants by 2-5%. Only after application of the largest rate ( $200 \text{ t ha}^{-1}$ ) of dry sediments, during the 2<sup>nd</sup> crop rotation season the productivity increased by 7%. It may be predicted that sediments containing larger amount of organic material are more effective to increase the yield of agricultural plants (Baksiene and Janusiene, 2005).

In Lithuania, studies on the possibilities to apply organic lake sediments for soil fertilization started in 1999. The objective of this work is to study the application of lake sediments for fertilization of sandy loam Cambisol and improvement of its properties. The aim of the performed tests was to determine the influence of various rates of lake sediments and their mixtures with other organic fertilizers (manure, sewage) and mineral NPK fertilizers, on agrochemical and physical characteristics of soil and crop yield, as well as to compare the efficiency of sediments with the effect of manure and sediments-manure mixture.

## MATERIAL AND METHODS

### Field experiments

Experimental plots for the study of organic lake sediments were established in a field crop rotation (maize (*Zea mays* L.), maize, barley (*Hordeum* L.), with under crop, perennial grasses (*Trifolium pratense* L. and *Phleum pratense* L.) on the 1<sup>st</sup> and 2<sup>nd</sup> year of use, winter rye (*Secale cereale* L.), mixture of oats and lupine (*Avena sativa* L. and *Lupinus angustifolius* L.), barley (*Hordeum* L.), with under crop, perennial grasses (*Trifolium pratense* L. and *Phleum pratense* L.), mixture of oats and lupine, barley (*Hordeum* L.).

The studies on the effectiveness of organic lake sediments were conducted on the background with no mineral fertilizers and on the background containing minimum rates of  $\text{N}_{30-60}\text{P}_{30-40}\text{K}_{50-60}$  mineral fertilizers according to the following scheme: 1) control; 2)  $10 \text{ t ha}^{-1}$  dry sediments (S); 3)  $20 \text{ t ha}^{-1}$  dry sediments (S); 4)  $40 \text{ t ha}^{-1}$  dry sediments (S); 5)  $10 \text{ t ha}^{-1}$  dry sediments (S) +  $10 \text{ t ha}^{-1}$  manure (M); 6)  $10 \text{ t ha}^{-1}$  dry sediments (S) +  $25 \text{ t ha}^{-1}$  manure (M); 7)  $10 \text{ t ha}^{-1}$  dry sediments (S) +  $10 \text{ m}^3 \text{ ha}^{-1}$  sewage (Se); 8)  $65 \text{ t ha}^{-1}$  manure (M). The sediments were taken from Lake Guobstas situated on the territory of Voke Branch ( $54^{\circ}49' \text{ N}$ ,  $25^{\circ}10' \text{ E}$ ). The sediments contained: N – 3.29, P – 0.04, K – 0.16, Ca – 1.48, Mg – 0.22 and 90% of organic matter in dry material; humidity was 70-80%.

Organic lake sediments, manure and sewage were applied only at the time of establishment of experimental plots. Later the effect of the mentioned substances was observed considering the changes of soil agrochemical and physical properties and their influence upon the yield of plants grown in crop rotation. Minimal rates of  $\text{N}_{30-60}$ ,  $\text{P}_{30-40}$ ,  $\text{K}_{50-60}$  mineral fertilizers were spread every year before the plant sowing.

### Soil sampling

The experimental plots were established in a rather neutral:  $\text{pH}_{\text{KCl}}$  (6.3-6.5), phosphorous-rich ( $152.2-189.2 \text{ mg kg}^{-1}$  soil) and potassium-rich ( $170.0-191.2 \text{ mg kg}^{-1}$  soil), with humus (1.54-1.81%) sandy loam cambisol (CM) (Buivydaite, 2005).

In order to identify changes in agrochemical properties, soil samples were taken in four replications before the establishment of the experimental plots (in 1999) and after the crop rotation in 2009.

Soil bulk density, moisture, total and aeration porosity after sowing in spring (I) and after harvesting in autumn (II) were measured annually during 1999-2009 in treatments:

- 1)  $10 \text{ t ha}^{-1}$  of dry sediments (S);
- 2)  $40 \text{ t ha}^{-1}$  of dry sediments (S);
- 3)  $10 \text{ t ha}^{-1}$  of dry sediments (S) +  $25 \text{ t ha}^{-1}$  of manure (M);
- 4)  $65 \text{ t ha}^{-1}$  of manure (M).

### Analytical methods

Soil properties were analyzed using the following methods:  $pH_{KCl}$  was determined in 1 M KCl soil sample extracts using a calibrated digital pH meter. Exchangeable bases were determined by the Kappen-Hilkovic method, which is based on hot titration of 0.1 M HCl and soil sample filtrate (ratio sample: extract 1:5) with 0.1 M NaOH (Askinazi, 1975). Total N (%) was determined by the Kjeldahl method, digested in  $H_2SO_4$ , distilled and titrated with 0.1 M NaOH (ISO 11261, 1995). Soil humus (%) was determined by the Tiurin method (Orlov and Grisina, 1981), humified soil organic matter was oxidized using potassium dichromate with sulphuric acid, ratio 1:50 and excess dichromate determined by titration with ferrous sulphate (Mohr solution). Available  $P_2O_5$  and  $K_2O$  ( $mg\ kg^{-1}$ ) were extracted with ammonium acetate-lactate A-L solution, pH 3.7; ratio 1:20). Available  $P_2O_5$  was determined by spectrophotometry and available  $K_2O$  by flame photometry following the Egner-Riehm-Domingo method (Egner et al., 1960).

Soil bulk density, moisture, total and aeration porosity were estimated using the weighing method (Motuzas et al., 2009).

### Statistics

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

Soil and crop yield data were processed using EXCEL<sub>2000</sub> version 2.2 software to perform One-way Analysis of Variance. All data were evaluated according to Fisher criteria (F) and  $LSD_{0.5}$  (Brewbaker, 1995; Tarakanovas and Raudonius, 2003).

### RESULTS

Since soil acidity was neutral before the establishment of experimental plots and the amount of calcium was low in the investigated sediments, the soil acidity did not change after 11 years of crop rotation; on the background without mineral fertilizers pH remained almost the same (Table 1). The content of exchangeable bases increased from 104.8 to 228.8  $meq\ kg^{-1}$  of soil.

On the background with mineral fertilizers, when soil was fertilized with various rates of sediments, mixtures of 10 t  $ha^{-1}$  sediments plus 25 t  $ha^{-1}$  manure, and 10 t  $ha^{-1}$  sediments plus 10  $m^3$  sewage, the soil acidity changed from rather neutral into rather acid. Soil pH changed from 6.5 to 5.7, the exchangeable bases decreased from 108.4 to 97.0  $meq\ kg^{-1}$ .

Fertilization of soil with various rates of sediments, their mixtures and manure slightly influenced the amount of total nitrogen. However, after fertilization with mineral NPK fertilizers, in all treatments the amount of total nitrogen increased by 0.003-0.013% units.

On the background without mineral fertilizers somewhat higher content of humus (1.71%) was recorded in soil fertilized with the highest rate of sediments. In other fertilization treatments higher percentage of humus was recorded due to the impact of mineral nitrogen. Small amount of phosphorus (0.04%) was detected in organic sediments; therefore, some of it reached the soil. Fertilization with mineral (non-organic) fertilizers made a stronger effect on the alterations of mobile phosphorus. On the background without mineral fertilizers in almost all treatments the amount of phosphorus was lower by 7.9-23.2  $mg\ kg^{-1}$  compared with its amount before the establishment of experimental plots; on the background with mineral fertilizers in almost all variants it was higher by 13.2-32.8  $mg\ kg^{-1}$ . Higher amount of phosphorus was detected in soil previously fertilized with manure (214.5  $mg\ kg^{-1}$  of soil) and with sediments-manure mixture (178.3-198.0  $mg\ kg^{-1}$  of soil).

Table 1. Effect of lake sediments on agrochemical indices in sandy loam cambisol

Treatments	pH <sub>KCl</sub>	Exchange able bases, meq kg <sup>-1</sup>	Total N	Organic carbon	P <sub>2</sub> O <sub>5</sub>	K <sub>2</sub> O
			%		mg kg <sup>-1</sup> of soil	
Background without mineral fertilizers						
1) Control	6.4*	106.5	0.087	1.58	176	191
	6.8**	148.4	0.093	1.59	158	159
2) 10 t ha <sup>-1</sup> S	6.4	174.8	0.091	1.56	188	170
	7.1	153.2	0.087	1.53	158	138
3) 20 t ha <sup>-1</sup> S	6.6	137.0	0.087	1.62	179	182
	7.0	110.0	0.100	1.75	147	135
4) 40 t ha <sup>-1</sup> S	6.4	122.5	0.094	1.54	180	179
	6.8	136.9	0.093	1.64	156	130
5) 10 t ha <sup>-1</sup> S + 10 t ha <sup>-1</sup> M	6.7	148.6	0.089	1.70	189	184
	7.0	201.5	0.083	1.55	156	142
6) 10 t ha <sup>-1</sup> S + 25 t ha <sup>-1</sup> M	6.3	108.8	0.090	1.81	152	172
	6.5	106.0	0.087	1.64	149	131
7) 10 t ha <sup>-1</sup> S + 10 m <sup>3</sup> Se	6.5	150.1	0.090	1.62	174	178
	7.1	243.1	0.087	1.60	176	156
8) 65 t ha <sup>-1</sup> M	6.4	133.9	0.084	1.55	183	190
	7.2	157.1	0.080	1.56	146	156
LSD <sub>05%</sub>	0.47	104.8	0.010	0.24	61,3	33,7
	0.72	166.5	0.014	0.18	47.1	47.0
Background with minimal rates of mineral NPK fertilizers						
1) Control	6.4*	106.5	0.087	1.58	176	191
	6.9**	116.7	0.090	1.67	169	189
2) 10 t ha <sup>-1</sup> S	6.4	174.8	0.091	1.56	188	170
	6.7	162.4	0.088	1.60	152	165
3) 20 t ha <sup>-1</sup> S	6.6	137.0	0.087	1.62	179	182
	6.3	98.6	0.103	1.65	124	142
4) 40 t ha <sup>-1</sup> S	6.4	122.5	0.094	1.54	180	179
	6.5	89.4	0.102	1.80	146	203
5) 10 t ha <sup>-1</sup> S + 10 t ha <sup>-1</sup> M	6.7	148.6	0.089	1.70	189	184
	6.9	158.0	0.092	1.63	183	185
6) 10 t ha <sup>-1</sup> S + 25 t ha <sup>-1</sup> M	6.3	108.8	0.090	1.81	152	172
	6.1	69.6	0.105	1.76	138	138
7) 10 t ha <sup>-1</sup> S + 10 m <sup>3</sup> Se	6.5	150.1	0.090	1.62	174	178
	6.4	185.5	0.100	1.82	165	165
8) 65 t ha <sup>-1</sup> M	6.4	133.9	0.084	1.55	183	190
	6.8	104.2	0.098	1.80	192	192
LSD <sub>0.5</sub>	0.47	104.8	0.010	0.24	61.3	33.7
	1.00	137.6	0.020	0.36	82.6	86.6

Similarly, the amount of potassium in organic sediments was rather low, too. Therefore, due to various fertilization modes the amount of active potassium in soil changed similarly to that of phosphorus. On the background without mineral fertilizers (when organic fertilizers were applied) the defined amount of potassium (2.0-28.8 mg kg<sup>-1</sup> of soil) was lower almost in all treatments than its amount before the establishment of the experimental plots. However, on the

background with mineral fertilizers it was higher (2.0-32.3 mg kg<sup>-1</sup> of soil) almost in all treatments.

While analyzing the impact of organic sediments upon the soil moisture it could be observed that in 1999, 2003-2006 the indicators of moisture were lower in spring, and in 2004 – in autumn (Figure 1). During these tests stronger influence was observed when sediments and sediments-manure mixture were used as fertilizers.

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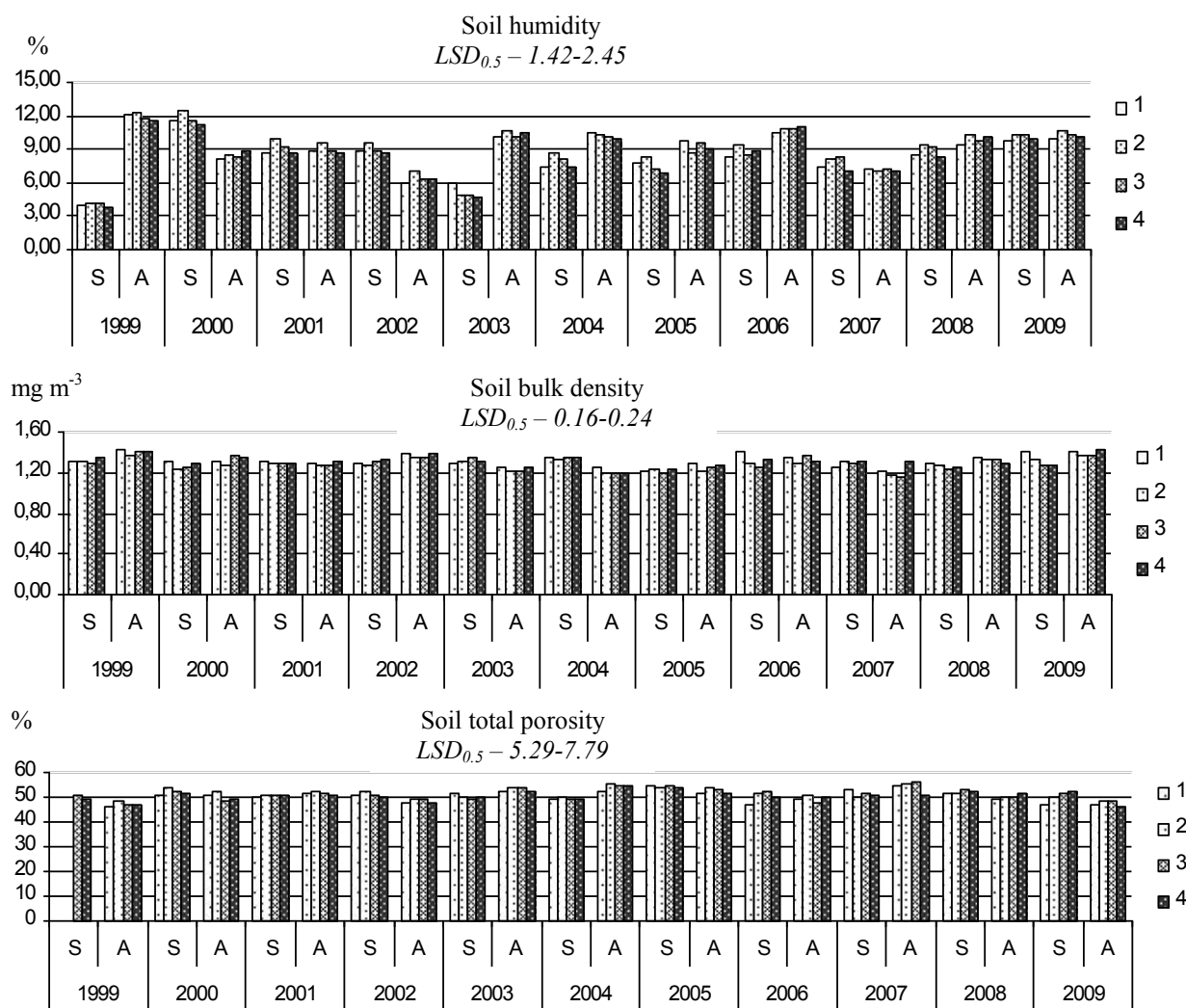


Figure 1. The effect of lake sediments on humidity, density and total porosity of sandy loam cambisols (S – spring, after crop sowing; A – autumn, after harvesting. 1-4 – treatments of trials: 1) 10 t ha<sup>-1</sup> of sediments; 2) 40 t ha<sup>-1</sup> of sediments; 3) 10 t ha<sup>-1</sup> of sediments + 25 t ha<sup>-1</sup> of manure; 4) 65 t ha<sup>-1</sup> of manure)

Compared with the impact produced by the application of manure, the rate of 40 t ha<sup>-1</sup> of sediments increased the moisture of soil by 1.12-1.57% units. The effect of manure equaled the lower rate of sediments (10 t ha<sup>-1</sup>).

Soil bulk density does not depend upon moisture. The data shows the tendency towards the decrease of this parameter only after fertilization with 40 t ha<sup>-1</sup> sediments and sediments-manure mixture. Density varied from 1.27 to 1.41 mg m<sup>3</sup> only at certain periods, and only in autumn of the years 2003, 2004 and 2007 it was lower (1.19-1.26 mg m<sup>3</sup>). During those years the soil bulk density was lower compared with the data of spring investigations, but in 1999-2002 and 2009 on the contrary, the density was higher in autumn. The soil particle density was not investigated during these tests because it

changes insignificantly under the impact of anthropogenic factors and time.

Porosity directly depends upon the soil density. With the decrease of density, the porosity increases. It is proved by the research results.

In 1999-2001 and 2005 total porosity of soil was higher in spring, after soil cultivation, while in autumn it decreased. However, in later years of crop rotation, when perennial grasses and fall rye were cultivated, the parameters of total porosity were increasing in autumn. Almost during the whole period of investigation the highest (48.36-57.65%) total porosity was determined in soil fertilized with 40 t ha<sup>-1</sup> of organic sediments.

The research results showed that in crop rotation cultivation on both backgrounds of mineral fertilization, proportional enlargement

of sediment rates from 10 to 40 t ha<sup>-1</sup> increased the yield of crop rotation feed units from 32341-43377 to 39499-51833 accordingly. However, the largest and most reliable additional yield (from 40165 to 47726 feed units) was obtained after application of the mixture containing 10 t ha<sup>-1</sup> of sediments plus 25 t ha<sup>-1</sup> of manure (Figure 2).

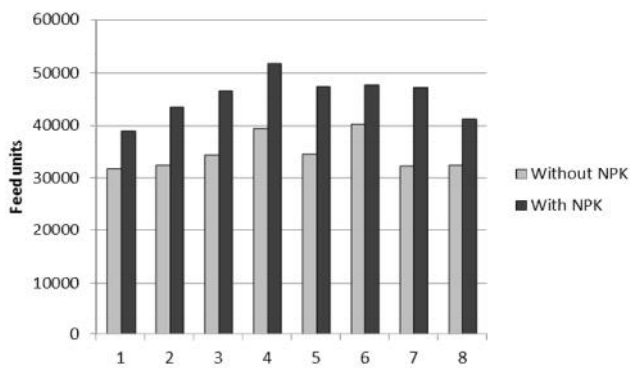


Figure 2. The effect of organic sediments on the yield of feed units in crop rotation

[1-8 treatments of trials: 1) Control; 2) 10 t ha<sup>-1</sup> S; 3) 20 t ha<sup>-1</sup> S; 4) 40 t ha<sup>-1</sup> S; 5) 10 t ha<sup>-1</sup> S + 10 t ha<sup>-1</sup> M; 6) 10 t ha<sup>-1</sup> S + 25 t ha<sup>-1</sup> M; 7) 10 t ha<sup>-1</sup> S + 10 m<sup>3</sup>Se; 8) 65 t ha<sup>-1</sup> M]

The rate of 40 t ha<sup>-1</sup> lake sediments affected most the productivity of all crops in the rotation. Under the impact of sediments-manure and sewage mixture the yield differed

insignificantly, within the standard error. The sum of feed units during the crop rotation of 11 years shows that the rates of organic sediments increased the yield by 3-33%. However, the mixture of 10 t ha<sup>-1</sup> sediments plus 25 t ha<sup>-1</sup> manure was most effective on both backgrounds of mineral fertilization. It reliably increased the yield by 22 and 26%.

While analyzing the efficiency of the interaction of various sediment rates and their mixtures with other fertilizers it was determined that, when mineral N<sub>30-60</sub>P<sub>30-40</sub>K<sub>50-60</sub> fertilizers were applied for background fertilization and without these fertilizers, the yield of feed units in crop rotation depended upon the soil acidity (Table 2).

Strong correlation ( $r^2=0.68$ ,  $Sr=0.12$ ) was determined between the quantity of feed units in crop rotation and parameters of soil acidity. The yield obtained on the background without mineral fertilizers showed a strong correlation ( $r^2=0.51$ ,  $Sr=0.15$ ) with the amounts of nitrogen, phosphorus and potassium naturally present in soil or inserted with organic fertilizers. Fertilization of soil with minimal rates of mineral NPK fertilizers insured only moderate correlation ( $r^2=0.38$ ,  $Sr=0.17$ ) between the yield of crop rotation and the quantity of nutrients in soil.

Table 2. Relation between feed units in rotation and soil pH ( $x_1$ ), hydrolytic acidity (H meq kg<sup>-1</sup> soil -  $x_2$ ), absorbed bases (S m-ekv kg<sup>-1</sup>soil -  $x_3$ ) and the amounts of nitrogen (N % -  $x_4$ ), active phosphorus (P<sub>2</sub>O<sub>5</sub> mg kg<sup>-1</sup> soil -  $x_5$ ), active potassium (K<sub>2</sub>O mg kg<sup>-1</sup> soil -  $x_6$ )

Agrochemical properties	Regression equation	$r^2$	$Sr$
Background without mineral fertilizers			
pH, H, S	$y = 7465.53 + 31.81 x_1 + 498.80 x_2 + 9.67 x_3$	0.68	0.12
N, P <sub>2</sub> O <sub>5</sub> , K <sub>2</sub> O	$y = 7879.47 + 197184.64 x_4 - 35.93 x_5 - 18.38 x_6$	0.52	0.15
Background with minimal rates of mineral NPK fertilizers			
pH, H, S	$y = -17490.14 + 475.02 x_1 + 694.85 x_2 - 7.99x_3$	0.68	0.12
N, P <sub>2</sub> O <sub>5</sub> , K <sub>2</sub> O	$y = 26194.07 - 2253.51 x_4 - 53.00 x_5 + 22.92 x_6$	0.38	0.17

Note: probability level is 95%.

## DISCUSSION

The application of different rates of lake sediments on sandy loam soil produced an evident effect on the increase of productivity of plants in the crop rotation. All rates of

organic sediments increased the crop yields by 4-20%, and the mixture of 10 t ha<sup>-1</sup> of sediments with 25 t ha<sup>-1</sup> of manure increased the yield by 22-25%. A rather large and reliable additional yield (24%) was obtained on the background without mineral fertilizers

after application of the largest ( $40 \text{ t ha}^{-1}$ ) sediments rate. The effect of manure was the same as of the applied lower rates of sediments and sediments-manure mixture. Our results demonstrate that the effect of manure was much shorter than of sediments. It has been established that organic sediments influence agricultural crops more effectively (Orlov and Sadovnikova, 1996).

According to Russian scientists, organic lake sediments are most effective. After field experiments they have determined that in sandy loam soil organic lake sediments were no less efficient than peat-manure compost, sometimes even superior. The rate of  $60\text{-}80 \text{ t ha}^{-1}$  of sediments produced an additional yield of  $0.34\text{-}1.61 \text{ t ha}^{-1}$  of barley, while the same rate of peat-manure compost produced an additional yield of  $0.28\text{-}1.06 \text{ t ha}^{-1}$  (Grigorov and Ovchinnikov, 1994; Trapeznikova, 2011).

The experiments revealed that the use of organic sediments positively influences agrochemical properties of light-textured Cambisol and 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).

All tested rates and mixtures of organic sediments had no effect on soil pH. On the background of mineral fertilizers, sediments increased the content of total nitrogen, humus and mobile phosphorus. The amount of mobile potassium decreased. Only fertilization with mineral fertilizers compensated the amount of mobile potassium, which is needed for plants to grow. Consequently, humus substances incorporated into soil with sediments were stable in terms of decomposition. Humus substances in soil are gradually hydrolyzed, and the regenerated humic acids, analogous to the acids present in the soil, take part in organic matter metabolism (Stepanova and Orlov, 1996). The data have shown that on light-textured soils humus readily mineralizes and hydrolyzed part comprises more than half of its composition (Cherkinsky and Brovkin, 1993).

The application of different rates of lake organic sediments on Cambisol had a pronounced effect on the increase of productivity of plants in the crop rotation.

Summarized results of long-term experiments (Booth et al., 2007; Enters et al., 2008) showed that fertilization with lake sediments improves the soil. Sediments increase soil moisture and porosity, and decrease bulk density. Improvement of chemical and physical conditions of soils is very important in order to protect freshwater reservoirs from the infiltration of nutrients from soil into the ground water.

Norwegian and Canadian scientists (Sveistrup et al., 1995; Zebarth et al., 1999) have reported the 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

Various rates of organic lake sediments used for soil fertilization did not change soil acidity. The amount of total nitrogen and humus increased, while the amounts of phosphorus and potassium decreased. The rate of  $40 \text{ t ha}^{-1}$  of lake organic sediments was most efficient.

The application of lake sediments produced a positive effect on the physical properties of sandy loam soil. The lake sapropel increased soil moisture and porosity and reduced its bulk density.

The application of various rates of organic lake sediments increased the yield by 4-20%. The  $40 \text{ t ha}^{-1}$  of sediments and mixture of  $10 \text{ t ha}^{-1}$  of sediments plus  $25 \text{ t ha}^{-1}$  of manure were most effective and reliably increased the yield by 22 and 25%. The impact of manure was the same as the effect of smaller rates ( $10, 20 \text{ t ha}^{-1}$ ) of sediments and sediments-manure mixture.

The yield of feed units strongly correlated with the indicators of soil acidity and amounts of nitrogen, phosphorus and potassium existing in the soil and introduced with organic fertilizers.

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