Changes in the Properties of Light Textured Soils in Relation to Lake Sediment Fertilization

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Abstract: Studies of the effects of calcareous, organic and siliceous sediments and their mixtures with manure in the crop rotation on a sod-podzolic sandy loam soil were carried out at the Vokė Branch of the Lithuanian Institute of Agriculture in 1994—1999.

Our experimental findings demonstrated that calcareous sediment and limestone reduced soil acidity. Organic and siliceous sediments had no effect on soil acidity. Only a higher rate of organic (40 t/ha) and siliceous (100 t/ha) sediments increased total nitrogen and humus content in the soil. Mineral fertilization compensated the amount of mobile phosphorus and potassium, necessary for plant growth.

The application of sediments had a positive effect on the quality of physical properties of a sod podzolic sandy loam soil. Organic and siliceous sediments increased soil humidity and porosity, and decreased its density to a greater extent than calcareous sediment. Calcareous sediment improved the above mentioned soil physical parameters more markedly than limestone.
Keywords: sediments, manure, soil, properties

1 Subject, i.e. research objective

Lithuania is the land of lakes. Their number (of those above 1 ha in area) is as high as 2,830. Many lakes are silty, they are continuously decaying and turning into marsh.

Organic sediments accumulated in the old lakes are a fossil, which is still underused. Its layers are usually 6—8 m, sometimes as thick as 24 m. The deposits of sediments in the lakes are evaluated to be about 5.8 milliard m^3. Nearly the same quantity accumulated in the former lakes—marshlands of the lacustrine origin.

The lake sediments contain 15%—90 % of organic matter. Their chemical make-up includes macro elements and lime microelements necessary for plants, biologically active substances, vitamins, enzymes, and antibiotics [7]. Furthermore, the region of major resources of lake sediments in Lithuania is also the region characterised by poor and erosive soils. Thus, organic sediments are concentrated in the areas where they are needed most. The sediments extracted from lakes can be used for land amelioration. Their mineralization is slow, so it provides a long-term improvement of light textured soils [1—5].

All sediments are subdivided into organic (50 %—90 % of organic matter), calcareous (30 %—60 % of calcium carbonate), siliceous (25 %—45 % of silicon dioxide) and mixed types. All types of sediments are used to fertilize infertile soils. They improve agrochemical and physical soil properties and increase crop productivity [3, 6].

Experiments to study the possibilities of use of sediments for fertilization were conducted at the Vokė Branch of the Lithuanian Institute of Agriculture in 1994—1999.

2 Experimental materials and methodology

Experimental plots for the investigation of calcareous (N—0.62 %, P—0.02 %, K—0.03 %, Ca—4.10 %, Mg—0.52 %), organic (N—5.07 %, P—0.04 %, K—0.16 %, Ca—1.48 %, Mg—0.22 %), and siliceous (N—1.1 %, P—0.02 %, K—0.55 %, Ca—1.01 %, Mg—0.78 %) sediments were established in the field crop rotation (maize, maize, barley with under-crop, perennial grass of the 1^{st} and 2^{nd} years of use, winter rye) on a sod podzolic sandy loam soil (according to FAO classification-cambisols) with pH 6,0, P_2O_5 130 mg/kg—230 mg/kg, and K_2O 150 mg/kg—210 mg/kg of soil, humus 1.7 %—2.05 %.

While investigating the changes of agrochemical and physical properties in the soil and the yield of crops fertilized with sediments the following treatments were analyzed: 1) control; 2) 10 t/ha limestone ($CaCO_3$); 3) 25 t/ha calcareous sediment (**CS**); 4) 10 t/ha organic sediment (**OS**); 5) 40 t/ha organic sediment (**OS**); 6) 25 t/ha siliceous sediment (**SS**); 7) 100 t/ha siliceous sediment (**SS**); 8) 25 t/ha calcareous sediment (**CS**) + 25 t/ha manure; 9) 10 t/ha organic sediment (**OS**) + 25 t/ha manure; 10) 25 t/ha siliceous sediment (**SS**) + 25 t/ha manure; 11) 65 t/ha manure (**M**).

All fertilizers, except mineral, were applied at the beginning of the rotation, before sowing. During the following years further effect was observed. All rates of sediments were calculated for dry mass. Minimum rates of mineral fertilizers ($N_{30–60}P_{30–40}K_{50–60}$) were applied annually before sowing.

In order to determinate changes in agrochemical properties of the soil, samples were taken before the establishment of the experimental plots (in 1994) and after the first season of the crop rotation. Soil bulk density, moisture, total and aeration porosity were assessed annually in spring after sowing (Ⅰ) and after harvesting in autumn (Ⅱ).

3 Key conclusions

The experimental findings revealed that the use of all types of sediments for fertilization had a positive effect on the agrochemical properties of a sod podzolic sandy loam soil (Fig.1).

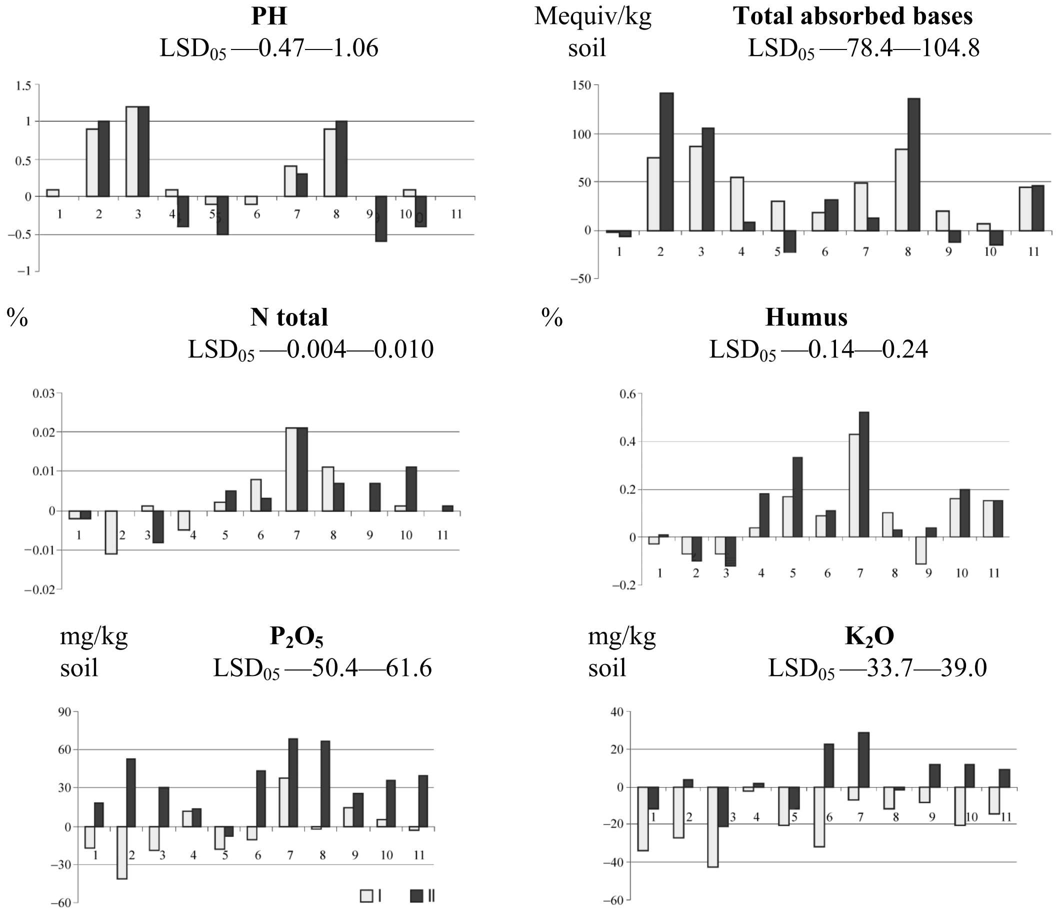

Fig.1 Changes of agrochemical soil parameters after fertilization of sod podzolic sandy loam soil with sediments and their mixtures with other fertilizers (Ⅰ— parameters on the background without mineral fertilizers; Ⅱ— parameters on the background of minimum rates of mineral NPK fertilizers; 1—11— treatments of trials)

Calcareous sediment (treatment 3) such as limestone (treatment 2) reduced soil acidity. All rates and mixtures of organic and siliceous sediments had no effect on soil pH. The amount of nitrogen and humus changed slightly. The content of total absorbed bases increased by 11.8 mg/kg—48.0 mg/kg of soil.

Fertilization of soil with calcareous sapropel, its mixtures and manure had only a slight effect on the amount of total nitrogen and humus. This parameter changed very intangibly. However, after fertilization with 40 t/ha of organic and 100 t/ha siliceous sediments the amount of total nitrogen increased by 0.002—0.021 and that of humus by 0.53 percentage units.

A small content of phosphorus (0.02 %—0.04 %) was detected in various types of lake sediments, therefore some of it reached the soil. Fertilization with mineral (inorganic) fertilizers had a greater effect on the variation of mobile phosphorus. On the background without mineral fertilizers in almost all treatments the amount of phosphorus (except treatment 7 with 100 t/ha siliceous sediment) was 2.2 mg/kg—19.2 mg/kg lower, compared with its amount before the establishment of experimental plots; while on the background with mineral fertilizers in almost all treatments it was higher by 13.2 mg/kg—68.9 mg/kg of soil.

Similarly, the amount of potassium in lake sediments was rather low, too. Therefore, due to various ways of fertilization the amount of mobile potassium in the soil changed similarly to that of phosphorus. On the background without mineral fertilizers (when organic fertilizers were applied) the amount of potassium (2.0 mg/kg—42.5 mg/kg of soil) was lower almost in all treatments, compared with its amount before the establishment of the experimental plots. However, on the background with mineral fertilizers it was higher (1.7 mg/kg—28.5 mg/kg of soil) almost in all treatments. Different organic fertilization did not have any influence on the content of potassium in the soil.

The application of lake sediments had a positive effect on the quality of physical properties of sod podzolic sandy loam soils (Fig. 2).

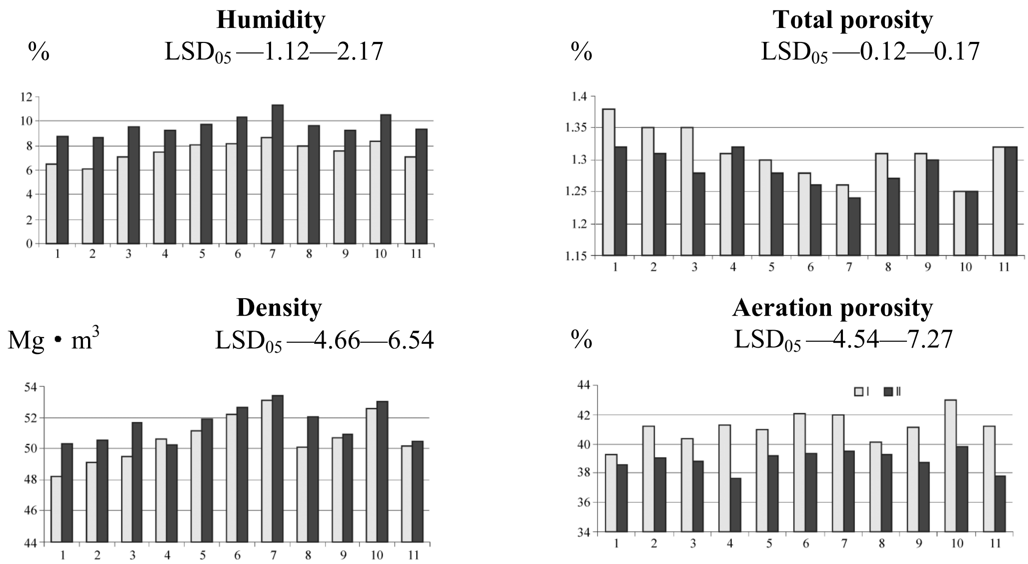

Fig.2 The effect of lake sediments on the humidity, density, total and aeration porosity (Ⅰ—spring, after sowing; Ⅱ—autumn, after harvesting; 1—11—treatments of trials) of soddy-podzolic sandy loam soil

While analyzing the impact of sediments on soil humidity, we noted that moisture content was lower in spring, and higher in autumn. In this experiment a stronger influence was observed when fertilizing with sediments and mixture of sediments-manure. Compared with the impact resulting from manure application, the rate of 40 t/ha of organic and 25, 100 t/ha of siliceous sediment increased soil moisture by 0.93—1.50 and 1.52—2.52 percentage units. The effect of manure equalled the smaller rate of organic sediment (10 t/ha).

Soil bulk density did not depend on moisture. The data show a tendency towards the decrease of this parameter only after fertilization with 40 t/ha of organic, 25,100 t/ha siliceous sediments rate and sediment-manure mixture. Soil bulk density varied from 1.24 to 1.38 Mg • m^3 at specific periods, and only in autumn it was a little lower.

Total porosity directly depends on the bulk density of soil. With a decrease in density, porosity increased. This fact was corroborated by our research results. Total soil porosity was lower in spring, after soil cultivation, and it increased in autumn after harvesting. However, aeration porosity of soil was higher in spring, and it decreased in autumn. The highest (51.16 %—53.43 %) total and (39.16 %—42.99 %) aeration porosity was determined in the soil fertilized with 40 t/ha of organic, 25,100 t/ha siliceous sediments and their mixtures with manure almost during the whole period of investigation.

Summarized results of long-term experiments showed that fertilizing with all types of lake sediments improved the soil. Organic and siliceous sediments increased soil humidity and porosity, and decreased soil bulk density more markedly than calcareous sediment. Calcareous sediment improved the above mentioned soil physical parameters more than limestone.

The application of different rates of sediments on a sandy loam soil had a marked effect on the increase of productivity of plants in the crop rotation (Table 1).

Table 1 The effect of organic sapropel on the yield of feed units of the crop rotation

Treatment	Yield of feed units						Total feed units	
	maize	maize	barley	perennial grass	perennial grass	winter rye	over rotation	%
Background without mineral fertilizers								
1. Control	2,223	1,528	1,981	3,183	3,421	2,512	14,848	100
2. 10 t/ha $CaCO_3$	2,818	1,514	1,892	2,774	2,801	1,505	13,304	90
3. 25 t/ha **CS**	3,100	1,468	2,780	3,499	3,633	2,226	16,706	113
4. 10 t/ha **OS**	2,188	1,416	1,943	4,416	3,111	1,977	15,051	101
5. 40 t/ha **OS**	3,255	1,386	2,120	5,357	3,550	2,113	17,781	120
6.25 t/ha **SS**	2,730	1,237	2,770	4,264	2,462	2,874	16,337	110
7. 100 t/ha **SS**	3,115	1,649	3,614	4,739	2,808	5,818	21,743	146
8. 25 t/ha **CS**+25 t/ha **M**	2,888	1,640	2,490	3,646	3,314	2,414	16,392	110
9. 10 t/ha **OS**+25 t/ha **M**	3,885	1,582	2,040	4,908	3,503	2,394	18,312	123
10.25t/ha **CS**+25 t/ha **M**	4,043	1,663	3,007	4,569	2,643	2,567	18,492	125
11. 65 t/ha **M**	3,255	1,489	1,920	4,496	3,202	2,102	16,464	111
LSD_{05}	686	956	1,494	1,272	730	994	2,599	
Background of minimal rates of mineral fertilizers								
1. Control	2,993	1,549	3,072	3,211	3,291	1,674	15,790	100
2. 10 t/ha $CaCO_3$	2,853	1,493	3,295	2,504	2,953	1,964	15,062	95
3. 25 t/ha **CS**	3,885	1,204	3,803	3,365	3,682	2,574	18,513	117
4. 10 t/ha **OS**	2,695	1,439	3,728	5,423	3,755	2,436	19,476	123
5. 40 t/ha **OS**	3,028	1,736	4,021	5,865	4,063	2,508	21,221	134
6.25 t/ha **SS**	3,518	1,787	3,790	4,406	2,515	2,886	18,902	120
7. 100 t/ha **SS**	3,430	2,107	4,802	4,097	2,471	3,567	20,474	130
8. 25 t/ha **CS**+25 t/ha **M**	4,585	1,482	3,926	2,629	3,483	2,534	18,637	118
9. 10 t/ha **OS**+25 t/ha **M**	4,113	1,946	4,071	5,379	4,061	2,667	22,237	141
10. 25t/ha **CS**+25 t/ha **M**	3,115	1,892	3,991	4,132	2,174	2,332	17,636	112
11. 65 t/ha **M**	3,098	1,925	3,945	4,928	3,791	2,341	20,028	127
LSD_{05}	1,029	973	944	926	759	749	2,212	

On the background without mineral fertilizers great efficiency was established when sandy loam soil had been fertilized with 100 t/ha of siliceous sediment. In this treatment the yield of the crop rotation increased by 3,464 feed units (46 %). The efficiency of treatment 9 and 10 (10 t/ha OS + 25 t/ha M and 25 t/ha SS + 25 t/ha M) was practically identical where the yield was 23 and 25 % higher compared with the control. Soil fertilization with 40 t/ha of organic sediment increased the productivity of the crop rotation by 2,933 (20 %) feed units. The application of manure was equivalent to the application of 25 t/ha of calcareous and siliceous sediments.

On the background of minimal mineral fertilizer rates, more effective was the application of 10 t/ha of organic sediment, which secured the productivity of the crop rotation of 6,447 (41 %) feed units. A fairly large yield increase was obtained in the treatment fertilised with 40 t/ha of organic and 100 t/ha of siliceous sediments that increased the crop rotation productivity by 4,684 and 5,431 feed units (30 % and 34 %). The efficiency of these treatments was identical to that of the treatment with farmyard manure. Application of 65 t/ha of manure resulted in a yield increase of 4,238 (27 %) feed units over the rotation.

The data on the crop rotation productivity resulting from the application of calcareous sediment and limestone suggest that in most cases (except for maize in 1995) sediment fertilization was more effective than limestone application. Based on our experiments we can conclude that calcareous sediment is not only a source of calcareous matter, but also a source of nutrients for plants.

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