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LONG-TERM MANAGEMENT EFFECT ON MAIN HEALTH INDICATORS OF A RETISOL IN WESTERN LITHUANIA

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Abstract

The paper presents achievements of long-term management practices on main health indicators - pH, organic carbon and water stable aggregates of moraine loam Bathygleyic Dystric Glossic Retisol. The study site is Vėžaičiai Branch situated in Western Lithuania (55°43´N, 21°27´E). The object of investigation is a naturally acid soil Bathygleyic Dystric Glossic Retisol (texture – moraine loam with a clay-sized particle content of 12-14%) and the same soil exposed for more than ten years to tillage of different intensity (deep and shallow ploughing; shallow plougless tillage) and for half a century exposed to different periodic liming (0.5 rates every 7 years and 2.0 rates every 3-4 years) whose rates are calculated accoring to soil hydrolytic acidity and liming (1.0 rate every 5 years) in combination with famyard manure (40 and 60 t ha^{-1}). The obtained research findings suggest that soil pH, organic matter and water stable aggregates allow a quick improvement by proper liming and its combination with manuring. The intensive soil tillage (deep ploughing) disturbs some attributes associated with soil health - decreases organic carbon and deteriorates structure, while the less aggresive soil management was shallow soil tillage.

Keywords: soil pH, organic carbon, tillage, liming, weeds, soil aggregates
JEL Codes: Q15

Introduction

Soil health indicators are a composite set of measurable physical, chemical and biological attributes which relate to functional soil processes and can be used to evaluate soil health status, as affected by long-tem managemen and climate change drivers (Allen et al., 2011). Soil organic matter (organic carbon) is one of the most complex and heterogeneous components of soil and considered an important atribute of soil health due to the many functions it provide and support in soil.

Decreases in soil organic matter can lead to a decrease in fertility and biodiversity, as well as a loss of soil structure and aggregate stability (Weil and Magdoff, 2004). Aggregate stability is the resistence of soil aggregates to external energy such as high intensity rainfall and cultivation practices (Moebus et al, 2007). Aggregate stability is considered a useful soil health indicator since it is involved in maintainning important ecosystems functions in soil incuding organic carbon accumulation, infiltration capacity, movement and storage of water and root, and microbial activity (Rimal and Lal, 2009). Soil pH is considered as one of the dominant chemical indicators of soil health, indentifying trends in change for a range of soil biological and chemical functions, including nutrient availability and cycling as well as soil acidification (Dalal and Moloney, 2000). Soil acidification is one of the main problems in point of soil conservation both in Europe and Lithuania. This is one of the form of chemical soil degradation reducing their fertility and ecological stability (Szymanka et all, 2008, Wolsing and Prieme, 2004).

Seeking to maintain the potential soil quality and productivity and to get the stable yield, it is necessary to supplement the pH and organic matter stocks in the optimal level and to regulate the intensity of synthesis and destruction processes in the soil as well as to reduce the soil weed seed bank. This can be achieved by appropriate measures such as liming, fertilization and soil tillage (Karcauskiene and Repsiene, 2016; Skuodiene et al, 2018). The aim of the study was to evaluate the effect of long term management practices on the change of main health indicators of morain loam Retisol situated in Western Lithuania region.

Materials and methods

The article presents scientific achievements carried out in Vezaiciai Branch of Lithuanian Research Centre for Agriculture and Forestry. The site of the study is fields crop rotation at Vezaiciai Branch, located in West Lithuania's eastern fringe of the coastal lowland (55°43'N, 21°27'E).

The soil of the experimental site is *Bathygleyic Dystric Glossic Retisol* (WRB, 2014) (texture – moraine loam with clay-sized particles content of 12-14%). According to the content of clay particles, the soil profile is differentiated into alluvial and illuvial horizons. The soil is very acid (pH_{KCl} 3.9-4.2) in whole profile to the 160cm depth and the amount of the toxic mobile aluminium is very large both in the topsoil and subsoil (respectively 100 and 300 mg kg^{-1}), the occurrence of calcareous rock were found in more than 2 m depth. The deficiency in clay (<0.002 mm), cations of Ca and Mg and organic colloids is the main factor that influences the low stability of acid topsoil aggregates, so the soil structure is poor and changeable under various climatic and anthropogenic factors.

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The climate is moderately warm and humid. West Lithuania region is strongly affected by the maritime climate, because of which it receives the greatest annual amount of precipitation, averaging 923 mm over the last 40 years, compared with the other regions of the country. The average annual air temperature is 7,1 ºC.

The experimental design. The investigations were performed at the three stationary liming, fertilizing and soil tillage field trials:

1. The effects of long term liming on the topsoil health indicators estimated using the following experimental design (Table 1):

Table 1. Experimental design

Liming intensity	Amount of $CaCO_3$ applied, t ha^{-1}		Total amount of $CaCO_3$ applied, t ha^{-1} 1949-2005
	1949-1998	1998-2005	
1. Unlimed *(pH_{KCl} 4.0-4.1)*	–	–	–
2. Periodical liming using ×0.5 of the liming rate calculated based on the soil hydrolytic acidity (3.3 t ha^{-1} $CaCO_3$) every 7 years *(pH_{KCl} 5.4-5.9)*	18.1	–	18.1
3. Periodical liming using ×2.0 of the liming rate calculated based on the soil hydrolytic acidity (15.0 t ha^{-1} $CaCO_3$) every 3-4 years *(pH_{KCl} 6.4-6.8)*	89.9	15.0	104.9

Periodical liming was done by pulverized limestone (92.5% $CaCO_3$) on the background of primary and repeated liming by slaked lime. Crop rotation: spring barley with under-sowing grasses, perennial grass (two years), winter wheat and spring rape. The background mineral $N_{60}P_{60}K_{60}$ fertilizing and traditional soil tillage was used in 4-field crop rotation.

2. The effects of long term liming in combination with famyard manure (FYM) on the topsoil health indicators were estimated using the following experimental design: *unlimed* (pH_{KCl} pH 4,2-4,5) and *limed* (pH_{KCl} 5,9-6,2) soil *non treated* and *treated with FYM 40 and 60 t ha^{-1}*.

The acid soil was periodically limed and manured for 47 years. The rate of fertilizer $N_{60}P_{60}K_{60}$ have been applied for winter wheat and spring barley, $N_{30}P_{60}K_{60}$ - for lupine - oats mixture and $N_{60}P_{90}K_{120}$ - for winter rape. Fungicides and insecticides were used in case of necessity, conventional soil tillage was applied.

3. The effect of different intensity soil primary tillage on topsoil health indicators were estimated using the following experimental design: 1. *deep ploughing (20-25cm); shallow ploughing (10-12cm) and shallow ploughless tillage (8-10cm)*.

Crop rotation and fertilization: spring barley with under-sowing grasses $N_{60}P_{60}K_{90}$; perennial grass (two years) $P_{90}K_{90}$: winter triticale $N_{90}P_{60}K_{90}$ and spring rape $N_{150}P_{90}K_{150}$. Fungicides and insecticides were used in case of necessity.

Methods of analyses: soil pH was determined in 1M KCl according to the standard ISO 10390:2005; soil organic carbon content - by photometric procedure at the wavelenght of 590 nm using the UV- VIS spectrophotometer Cary 50; soil aggregate composition and aggregate stability in water according Savinov method. Soil samples for chemical analyses were taken using an auger from tree replicates of the topsoil (0-20 cm) after harvesting in 2014-2016. Soil samples for stucture analyses were taken from topsoil (0-20 cm) by tree replicates after harvesting in 2015-2016.

Statistical analysis was done using the computer program ANOVA. One - way analysis of variance was used to estimate the differences in the tested parameters among the treatments. The least significant difference method (LSD) at the 95 % and 99 % probability levels was used to test the significance of differences between treatment means.

Results

Long-term complex studies showed that soil pH is a key indicator in assesing Retisol's health because it directly affect the amount and availability of nutrients, soil aggregation, weed seed bank in the soil and the crop yield. Soil pH is one of the most important criteria that demonstrates the ability of the soil to maintain the activity of microorganisms. The most sensitive to soil acidity is the biological transformations of NH_4^+ and NO_3^-. The relatively optimal amounts of phosphates fractions available for plants were determined in soil with a pH_{KCl} of 5.6. Soil organic mater and water stable aggregates are a key factors regulating the most important soil functions- increasing soil buffering capacity, nutrition, water and energy supply, prevention of soil acidification and erosion (Skuodiene et all, 2018; Arlauskienė, 2010; Jokubauskaite et al, 2015; Repsiene and Karcauskiene, 2016).

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These literary results showed that the parameters: pH, organic matter (organic carbon) and water stable aggregates are the most important health indicators of Retisol and their management in agroecosystem is very important.

Liming and it's combination with manuring effect on soil health indicators. Soil acidification can be accelerated by intensive farming or prevented by sustainable management practices. Application of lime is the main management option use for correcting soil acidity caused by acidification (Farhoodi, 2002). The study data showed that lime materials are effective means for improving the moraine loam soil properties and the changes of their indexes depend on the liming intensity (Table 2).

Table 2. Long-term liming effect on moraine loam topsoil pH and amount of water stable aggregates

Treatment	pH_{KCl}	Water stable aggregates >0.25mm, %
1.Unlimed	4.1	43.3
2.Periodic liming 0.5 rates every 7 years	5.3**	49.1
3.Periodic liming 2.0 rates every 3-4 years	6.2**	51.5*

Note: * and ** - significantly different from control (P<0.005) and (P < 0.001).

Systematic long term liming resulted an increase in the pH from 4.1 to 6.2. Periodic liming every 7 years at a rate of 0.5 by hydrolytic soil acidity (3.8 t ha^{-1} $CaCO_3$) allowed maintaining the reaction at a medium acidity level (pH_{KCl} 5.3) and when the soil was intensively limed at a rate of 2.0 every 3-4 years, mobile aluminium was abolished and in the upper layers reached reaction close to neutral (pH_{KCl} 6.2). Increasing pH had a negative effect on soil organic carbon (SOC) content in the soil. SOC content in naturally acid soil (pH – 4.1) was 1.47 % while in the limed soil (pH (5.3 and 6.2) it was by 0.09-0.19 percentage points lower compared to the acid soil (Figure 1).

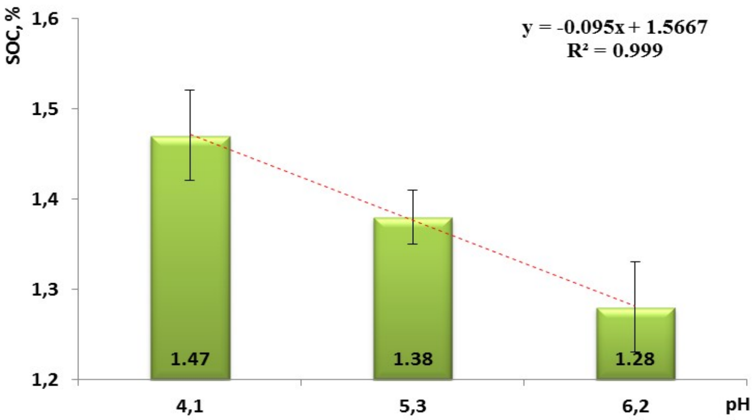

Figure 1. Effect of pH on the amount of organic carbon in the topsoil

Although in the limed soil the amount of organic carbon decreased, but in the limed soil more carbon was stabilized through binding with calcium and clay minerals, revealing the importance of the C-clay in long-term C sequestration. However, the intensive soil liming (at 2.0 liming rate) tended to increase the content of humic acids (Jokubauskaite, 2016). Liming had a positive effect on moraine loam structure. Water – stable aggregates which are more stable in soil and important with respect to long-term SOC sequestration had a tendency to increase parallel to the pH increment.The long-term systematic fertilization with famyard manure (FYM) had a significant effect on agrochemical properties of acid and limed soil (Table 3).

Table 3. Liming and it's combination with manuring effect on soil properties

Treatment	Not manured	Manured by 40 t ha^{-1}	Manured by 60 t ha^{-1}	LSD_{05}
		pH_{KCl}		
Unlimed soil	4.10	4.41**	4.49**	0.058
Limed soil	5.66	6.05*	6.19**	0.287
		C organic, %		
Unlimed soil	1.401	1.583**	1.704**	0.095
Limed soil	1.484	1.630*	1.634**	0.110

Note: * and ** – significantly different from control (P < 0.005) and (P < 0.001).

Incorporation of FYM by 40 and 60 t ha^{-1} per rotation increased the soil pH_{KCl} in the unlimed (from 4.10 to 4.41-4.49) and in the limed (from 5.66 to 6.05-6.19) soil. The highest amounts of organic carbon was obtained in the acid and limed soil (1.70% and 1.63%) applied with FYM 60tha^{-1}. The organic carbon content increases in limed and acid soils by 9 and 21% in the case of manuring in compare to soil without FYM.

Structure of acid moraine loam soil due to low amount of water-stable aggregates is poor and changeable under various climatic and anthropogenic factors. Results of our investigations showed that liming in combination with manuring are effective means to improve moraine loam structure. The largest amount (47.3 % and 50.7 %) of water stable aggregates (>0.25 mm) obtained in acid and limed soil than FYM 60tha^{-1} was applied (Figure 2).

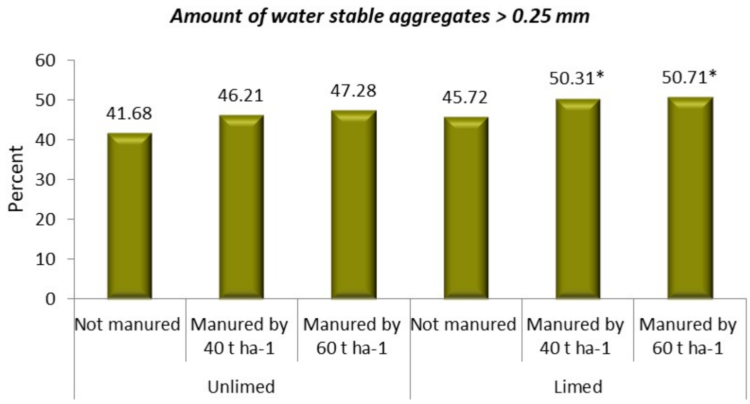

Figure 2. Liming and it's combination with manuring effect on the amount of water stable aggregates in topsoil

Soil tillage effect on soil health indicators. The best soil structure is usually found under natural ecosystem conditions and the structure under frequent and intensive cultivation is deteriorated, so the lowest amount (46.1 %) of water stable aggregates >0.25mm was obtained in the deep ploughing soil (upper 0-10 cm layer) (Table 4).

Table 4. Long-term primary soil tillage effect on moraine loam soil properties

Treatment	Depth, cm	pH_{KCl}	C_{org}	Water stable aggregates >0.25 mm, %
1. Deep ploughing (20-25 cm);	0-10	5.19	1.49	46.11
	10-20	5.04	1.38	49.60
2. Shallow ploughing (10-12 cm)	0-10	5.31	1.60	56.79
	10-20	5.34	1.57	57.67
3. Shallow ploughless tillage (8-10 cm)	0-10	5.17	1.64*	57.51
	10-20	4.81	0.97*	47.24*

The decrease in aggregate stability with application of lower intensity tillage are usually associated with variations in the soil organic matter content. The largest amounts of organic carbon (1.57-1.64%) and water stable aggregates (57%) were obtained in soils with lower tillage intensity - shallow ploughing and shalow tillage.

Conclusions

In the climatic conditions of western Lithuania the main health indicators of a moraine loam Retisol - pH, organic carbon and water stable aggregates was under the effect of different management: liming, it's combination with manuring and soil tillage. Improvement of these parameters in naturaly acid and limed soil can be achieved by application of famyard manure (60tha^{-1}). Shallow tillage means - shallow ploughing and shalow ploughless tillage are the most suitable measures to increase the organic carbon accumulation and stable aggregates formation in moraine loam topsoil.

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