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Acid phosphatase activity under the impact of erosion level in agricultural soils of different type and land use

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Abstract

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The suitability of soil enzyme activities as early and sensitive indicators of changes in soil status due to soil disturbances has been extensively studied. Little is known about the impact of soil erosion level. The aim of the work was to study changes in acid phosphatase activity depending on the degree of water erosion, soil type and land-use practices and to find out the relationships with chemical and physical soil properties. Samples from three soil types (Luvisol, Vertisol and Cambisol) of different land use (undisturbed, arable, abandoned and long fallow) and different degree of water erosion (slight, moderate or severe) were investigated. It was found that acid phosphatase activity varied between 1.69–6.69 µmol pNP.g^{-1}.h^{-1} among studied soils. There was an evidence of negative influence of erosion gradient on the phosphatase activity. Depending on the land use, the activity was arranged in the row: undisturbed=arable> abandoned>fallow. Soil type effect was significant in the order Vertisol = Luvisol > Cambisol. Data pointed on stronger impact of soil type than land-use practices. For all soils, acid phosphatase activity was positively correlated with soil silt, clay and pH, and negatively correlated with soil sand content. Negative relations of erosion gradient with silt, clay, total organic carbon and total nitrogen contents for all soil types were established. The results obtained could contribute to establishment of soil degradation processes indicators and to soil quality monitoring.

Keywords: eroded soil; acid phosphatase activity; degree of erosion; land use

Introduction

Soil water erosion is the major type of physical land degradation. Erosion washes away the top soil layer thus reducing nutrients and the capacity of soil to store moisture. This makes soil conditions unfavorable for plant growth and results in reduced soil productivity and crop yields (Lal, 2005). Along with changes in soil physical and chemical properties, erosion leads to loss of soil biodiversity. The main function of soil biota is residue decomposition and nutrient cycling in soil, with microflora playing a major role in this process.

All biochemical reactions of organic residue mineralization are mediated by soil enzymes, biocatalysts produced by soil microbiota or plant roots. High enzyme activity implies high rate of organic matter transformation and release of more plant available nutrients, thus enzymes are useful in assessing soil fertility (Piotrowska-Długosz, 2014).

Enzymes are characterized by early and sensitive response to alterations in soil system. Their suitability as indicators of changes in soil status due to natural or anthropogenic disturbances has been extensively studied (Trasar-Cepeda et al., 2000; Puglisi et al., 2006; García-Ruiz et al., 2008; Martinez-Salgado et al., 2010). More data on enzyme activities in different soil types and land uses are needed in order to select proper enzymes for soil quality monitoring (Trasar-Cepeda et al., 2000).

In the present work, the activity of soil phosphatase enzyme which is involved in phosphorus mineralization and influences phosphorus availability to plants was studied. Acid phosphatase is a phosphoric monoester hydrolase that acts on ester bonds (Nannipieri et al., 2011). According to scientific reports, soil phosphatase is amongst the most studied enzymes in soil (Puglisi et al., 2006; Banerjee et al., 2012). The influence of many factors – soil properties, plant cover, amendments, management, pollutants, disturbance etc. has been widely studied (Speir & Ross, 2002).

Little information is available about the effect of erosion level on soil enzyme activity. The aim of the work was to study (i) changes in acid phosphatase activity with increasing degree of water erosion, (ii) the influence of soil type and land-use practices and (iii) the relationships between phosphatase activity, chemical and physical soil properties.

Material and Methods

Soil sampling

Eroded soils located in the vicinity of Sofia (Bulgaria) were investigated. Three soil types under different land use and degree of erosion (Stanev, 1979) were included in the study (Table 1).

The undisturbed Luvisols were situated near Souhodol village. The arable Luvisols were located in the North-West of Sofia near the town of Kostinbrod. The arable Vertisols were collected from the area near the town of Bankya. The abandoned arable Cambisols (former agricultural soils that had not been cultivated for 25 years), and Cambisols under 30 year-fallow were located near the village of Mirkovo. The undisturbed, abandoned and fallow soils were covered by native grass vegetation, and the arable (conventional agriculture) soils were planted with cereal crops.

Samples from the top soil layer (0-20 cm) were collected in late spring (May). In each site, soil from three points was taken and then mixed to obtain a representative sample. The soil was stored in a refrigerator at 4°C. All samples were sieved through 2-mm mesh before analyzing.

Soil analyses

Total organic carbon (C) content was determined by the method of Tyurin (Arinushkina, 1975). Total nitrogen (N) was assessed by Kjeldahl's digestion procedure, and available phosphorus (P) content was measured by the method of Ivanov (1984). Soil moisture content was determined after sample drying at 105°C. Soil reaction (pH) was determined in 1:2.5 soil/water solution by potentiometer. Mineral particles content – sand (1.0-0.05 mm), silt (0.05-0.001 mm) and clay (<0.001 mm), were determined by wet sieving following the method of Kachinskiy (1958).

Acid phosphatase assay

Acid phosphatase (EC 3.1.3.2) activity was measured indirectly using p-nitrophenilphosphate (pNPP) as a substrate. Like most enzyme assays, this one shows the potential activity of phosphatases in soil.

Before analysis the fine roots were removed from the sieved soil. Samples were processed according to the assay of Tabatabai & Bremner (1969). The absorbance of the colored filtrate was measured at 420 nm by spectrophotometer WPA-Lightwave II. Samples were analyzed in triplicates.

Table 1. Description of sampling sites

Sample №	Soil type	Land-use	Degree of erosion	Vegetation
1	Luvisol	Undisturbed (Native)	Slight	Natural grasses
2			Moderate	Natural grasses
3			Severe	Natural grasses
4	Luvisol	Arable (Lv)	Non-eroded	Sunflower
5			Moderate	Corn
6	Vertisol	Arable (Vr)	Slight	Wheat
7			Moderate	Wheat
8	Cambisol	Abandoned arable (25 years)	Non-eroded	Natural grasses
9			Moderate	Natural grasses
10			Severe	Natural grasses
11	Cambisol	Long fallow (30 years)	Moderate	Natural grasses
12			Severe	Natural grasses

Values are presented as µmol of the enzyme reaction product – p-nitrophenol (pNP) per gram of soil per 1 hour (µmol pNP.g^{-1}.h^{-1}).

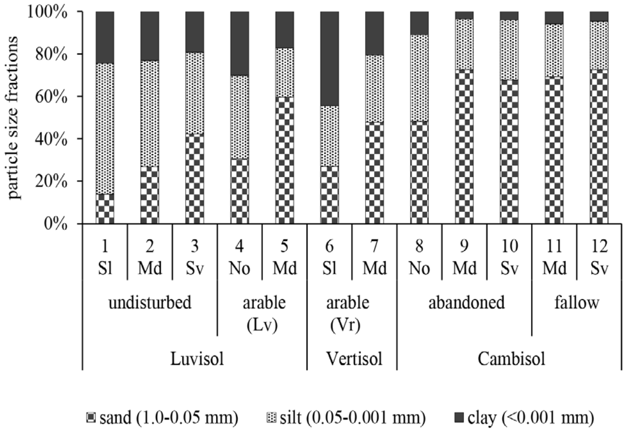

Fig. 1. Particle size distribution of Luvisols, Vertisols and Cambisols under different land use and degree of erosion: slightly eroded (Sl), moderately eroded (Md), severely eroded (Sv) and non-eroded (No)

Statistical analyses

Multiple comparison between means was made by one-way ANOVA followed by LSD test at P<0.05 (SPSS Statistics 19). Soil type, land-use and degree of erosion effects on phosphatase activity were assessed by Welsh statistics with Games-Howell post hoc test. Pearson correlation coefficients were calculated to examine relationships between phosphatase activity and soil properties.

Results

Erosion impact on soil physical and chemical properties

Among studied soils, the Luvisols were characterized with clay loam texture and moderately acid reaction, the Vertisols had clay texture and slightly acid reaction, and the Cambisols had silt loam texture and very strongly acid reaction. In general, total organic carbon (TOC), total nitrogen (N) and available phosphorus (P) contents were low (Figure 1 and Figure 2).

Changes in soil physical and chemical properties due to different levels of erosion were established. Sand fractions increased with increasing the degree of soil erosion and, as a result, silt content decreased considerably in undisturbed and

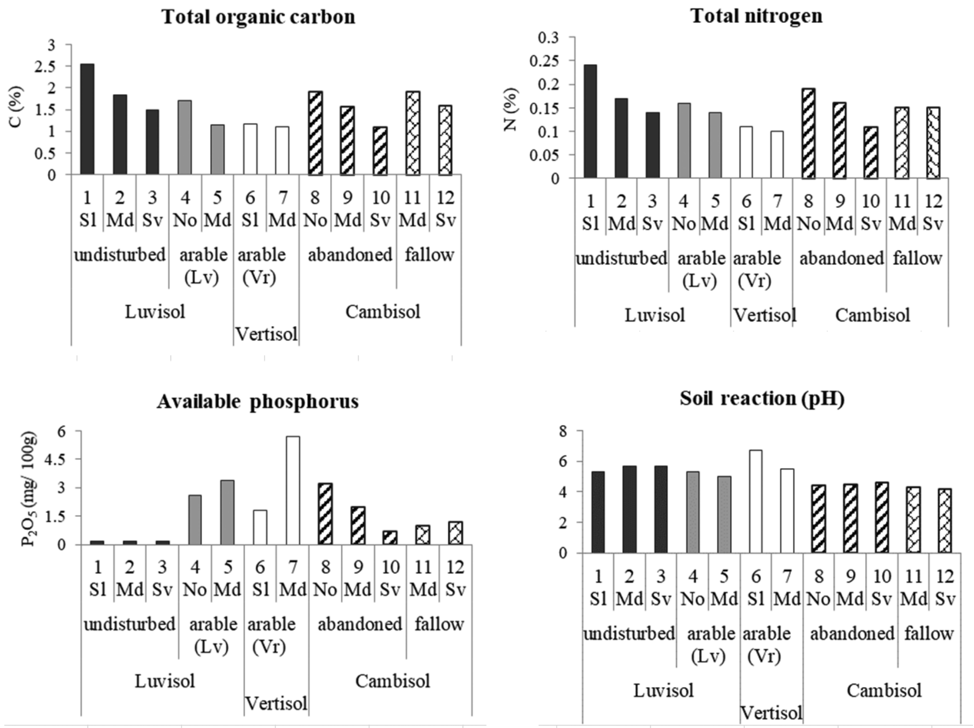

Fig. 2. Total organic carbon (TOC), total nitrogen (N), available phosphorus (P_2O_5) contents and soil reaction (pH) of Luvisols, Vertisols and Cambisols under different land use and degree of erosion: slightly eroded (Sl), moderately eroded (Md), severely eroded (Sv) and non-eroded (No)

abandoned soils, and clay content lowered notably in arable soils (Figure 1).

Total organic carbon and total nitrogen contents gradually decreased with increasing the degree of erosion in undisturbed and abandoned soils. In the arable and long fallow soils values lowered in higher degree eroded samples (Figure 2).

Available phosphorus content was too low in undisturbed soil irrespective of the degree of erosion. In arable and long fallow soils, higher phosphorus content was determined in higher eroded soils. In the abandoned soils phosphorus content decreased with increasing the degree of erosion (Figure 2). Soil reaction had little changes in undisturbed, abandoned and fallow soils depending on the degree of erosion. In higher eroded arable soils the reaction tended to decrease, notably in the arable Vertisol.

Erosion level, land-use and soil type effects on acid phosphatase activity

Acid phosphatase activity decreased with increasing the degree of erosion within each land-use group, as demonstrated in Figure 3. The highest values were determined in the undisturbed soil (3.43-6.69 µmol pNP.g^{-1}.h^{-1}) and in the arable Vertisol (3.58-4.72 µmol pNP.g^{-1}.h^{-1}). Values in the abandoned soil (2.51-3.67 µmol pNP.g^{-1}.h^{-1}) were lower. The lowest phosphatase activity was measured in the arable Luvisol (2.17-2.55 µmol pNP.g^{-1}.h^{-1}) and in the long fallow soil (1.69-2.31 µmol pNP.g^{-1}.h^{-1}).

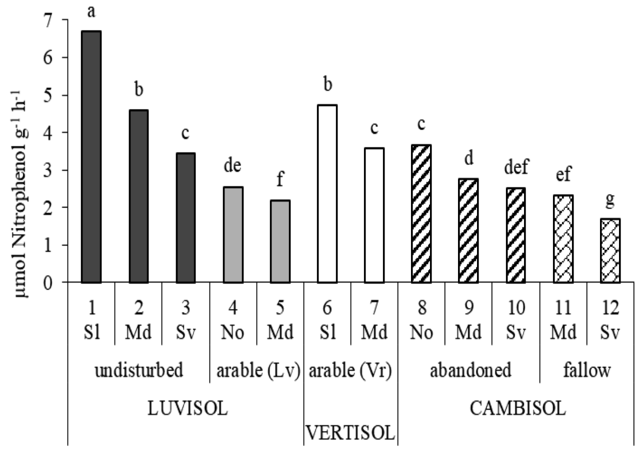

Fig. 3. Changes in acid phosphatase activity depending on degree of erosion, land use and soil type. Legend: slightly eroded (Sl), moderately eroded (Md), severely eroded (Sv) and non-eroded (No). Different letters above columns show significant differences between values at p < 0.05

For all soils studied, acid phosphatase activity was significantly higher in the Vertisol and Luvisol comparing to the Cambisol. Depending on the land-use type, values were the highest in the undisturbed and arable soils, followed by the abandoned and fallow soils.

Relationships between soil properties

There were very close relationships between acid phosphatase activity and the parameters of undisturbed and abandoned soils. Although most of the correlation coefficients were not significant, clear positive relations of phosphatase activity with TOC, total N, silt and clay contents, and negative relations with pH, degree of erosion and sand content were evident (Table 2).

Table 2. Relationships between acid phosphatase activity and soil properties in undisturbed and abandoned soils

Soil properties	Phosphatase activity	
	Undisturbed soil	Abandoned soil
TOC	0.999*	0.917
Total N	0.998*	0.896
Avail. P	–	0.943
Sand	-0.977	-0.924
Silt	0.987	0.901
Clay	0.894	0.924
pH	-0.938	-0.950
Degree of erosion	-0.986	-0.992

Correlation analysis for all soil groups showed highly positive relationships between acid phosphatase activity and soil silt content and positive correlation with the clay content and soil pH. The relation with the soil sand content was negative (Table 3).

Significant relationships between some soil parameters were found, as well. Soil TOC and total N contents were highly positively correlated between each other and positively correlated with the soil silt content. Clay content was in high positive relation with soil pH. Sand content was negatively correlated with silt and clay contents, and with soil pH. A negative trend in relationships between the degree of soil erosion and soil chemical and physical properties, except the sand content, was found.

Discussion

Data obtained showed that water erosion caused marked reduction of fine soil particles and nutrients in the soils studied. The effect differed depending on the degree of erosion, soil and land-use types. In heavy textured soils (Vertisol)

Table 3. Pearson correlation coefficients between soil parameters

Soil properties	TOC	N	P	Sand	Silt	Clay	pH	DE
AP	0.487	0.502	-0.162	-0.837*	0.812**	0.584*	0.600*	-0.373
TOC		0.942**	-0.378	-0.395	0.707*	-0.045	-0.163	-0.395
N			-0.363	-0.387	0.699*	-0.047	-0.218	-0.434
P				0.093	-0.243	0.088	0.014	-0.348
Sand					-0.827**	-0.837**	-0.763**	0.546
Silt						0.385	0.377	-0.414
Clay							0.888**	-0.493
pH								-0.196

Legend: AP – acid phosphatase activity; TOC – total organic carbon; N – total nitrogen; P – available phosphorus; DE – Degree of erosion; * – significant at $p < 0.05$; ** – significant at $p < 0.01$

clay fraction was mostly washed by water erosion, while in medium textured Luvisols and light textured Cambisols silt fraction was predominantly lost. Total organic carbon and total nitrogen contents decreased with erosion gradient. As known, water erosion commonly removes the light and fine soil fractions and worsens the soil structure. Another regular impact of water erosion is depletion of soil organic matter and nutrients (Lal, 2005).

Land-use effect on soil C, N and P contents was proved. Carbon and nitrogen concentrations were the highest in the undisturbed soil, followed by abandoned, fallow and arable soils. As shown by Kharitonov et al. (2004), erosion was more severe on ploughed lands than on those covered with long term vegetation. Available phosphorus was the highest in the arable and abandoned (former arable) soils, obviously due to fertilization. In the long fallow soil available P concentration was very low, and, as expected, it was extremely low in the undisturbed soil.

Acid phosphatase activity was definitely influenced by the degree of soil erosion, land use and soil type. It lowered with increasing the degree of erosion in each land-use group. Negative influence of erosion gradient on phosphatase activity in the undisturbed and abandoned soils was found. Similarly, Kharitonov et al. (2004) found that erosion significantly lowered humus and clay contents of mildly and moderately eroded Mollisols, and phosphatase activity showed a decreasing trend with the erosion severity.

The soil type highly influenced soil phosphatase activity which was well demonstrated by the two arable soils. As a whole, the activity decreased in the order Vertisol =Luvisol > Cambisol. The highest phosphatase activity in the arable Vertisol was most probably related to the slightly acid reaction and the highest clay content of this soil. It is known that 6.5 is the optimum pH for acid phosphatase activity and that clays form clay-enzyme complexes thus keeping extracellular enzymes in soils (Turner & Haygarth, 2005; Gispert et al., 2013).

Land-use effects were stronger within the soil types. Phosphatase activity decreased in the directions: undisturbed > arable in the Luvisol, and abandoned>fallow in the Cambisol. Higher phosphatase activity of undisturbed compared to arable eroded Luvisols was found in our previous study (Nedyalkova et al., 2013). Kobierski & Lemanowicz (2016) also demonstrated a land-use effect – acid and alkaline phosphatase values were higher in orchard than in arable eroded Luvisol.

For all soil types studied, the activity followed the order undisturbed=arable> abandoned>fallow. The high mean value of both arable soils was due to the influence of soil type and pointed that the soil had higher impact on phosphatase activity than the land-use type. Similar results were obtained in the study of Vinhal-Freitas et al. (2017). Within the same land-use type, enzyme activities (β-glucosidase, urease, phosphatase, arylsulphatase) were always higher in clayey soils than in sandy clay-loam soil.

Commonly, soil enzyme activities are related to soil properties (Turner & Haygarth, 2005; Park et al., 2014). In our study, acid phosphatase activity was positively correlated with soil silt, clay and pH, but negatively with soil sand content. Close relationships between erosion gradient and parameters of undisturbed and abandoned soils were established. For all soils studied, negative trend in relations between the degree of soil erosion and soil chemical and physical properties, except the sand content, was found.

Conclusion

As a result of this study, negative relationship of acid phosphatase activity with increasing the degree of soil water erosion was proved for different soil types and agricultural land-use practices. The soil type impact on phosphatase activity was stronger than that of the land-use.

In general, phosphatase activity was highly influenced by soil chemical and physical properties. It was positively correlated with soil silt, clay and pH, and negatively correlated with soil sand content. Results obtained could contribute to the establishment of soil degradation processes indicators and to soil quality monitoring.

References

Arinushkina, E.V. (1975). Agrochemical methods of soil analysis. Science, Moscow, Russia (Ru).

Banerjee, A., Sanyal, S. & Sen, S. (2012). Soil phosphatase activity of agricultural land: A possible index of soil fertility. *Agricultural Science Research Journal, 2(7),* 412-419.

García-Ruiz, R., Ochoa, V., Hinojosa, M. B. & Carreira, J. A. (2008). Suitability of enzyme activities for the monitoring of soil quality improvement in organic agricultural systems. *Soil Biology and Biochemistry*, *40(9),* 2137-2145.

Gispert, M., Emran, M., Pardini, G., Doni, S. & Ceccanti, B. (2013). The impact of land management and abandonment on soil enzymatic activity, glomalin content and aggregate stability. *Geoderma*, *202*, 51-61.

Ivanov, P. (1984). New acetate method for assessing plant available phosphorus and potassium in soil. *Soil Science and Agrochemistry, 19(4),* 88-97 (Bg).

Kachinskiy, N. A. (1958). Soil particles and micro-aggregates composition: Methods for analysis. USSR Academy of Sciences, Moscow, Russia (Ru).

Kharytonov, M., Bagorka, M. & Gibson, P. T. (2004). Erosion effects in the central steppe chernozem soils of Ukraine. I. Soil properties. *Agricultura, 3*, 12-18.

Kobierski, M. & Lemanowicz, J. (2016). Activity of phosphomonoesterases and the content of phosphorus in the eroded Luvisols of orchard and arable soils. *Scientific Review-Engineering and Environmental Science, 25(3),* 323-332.

Lal, R. (2005). Soil erosion and carbon dynamics. *Soil and Tillage Research, 81*, 137-142.

Martinez-Salgado, M. M., Gutiérrez-Romero, V., Jannsens, M. & Ortega-Blu, R. (2010). Biological soil quality indicators: a review. In: *Current research, technology and education topics in applied microbiology and microbial biotechnology*, A. Mendez-Vilas (ed.), FORMATEX Microbiology Series Nº 2, *1,* 319-328.

Nannipieri, P., Giagnoni, L., Landi, L. & Renella, G. (2011) Role of phosphatase enzymes in soil. In: *Phosphorus in action, soil biology 26*, *Springer-Verlag* Berlin Heidelberg, 215-243.

Nedyalkova, K., Donkova, R. & Petkova, G. (2013). Phosphatase activity of eroded (arable and virgin) soils. *Journal of Balkan Ecology*, *16(4),* 367-373.

Park, J. H., Meusburger, K., Jang, I., Kang, H. & Alewell, C. (2014). Erosion-induced changes in soil biogeochemical and microbiological properties in Swiss Alpine grasslands. *Soil Biology and Biochemistry, 69,* 382-392.

Piotrowska-Długosz, A. (2014). Enzymes and soil fertility. In: *Enzymes in agricultural sciences,* L. Gianfreda, M. Rao (eds.), OMICS Group: Foster City, CA, USA, 44-79.

Puglisi, E., Del Re, A. A. M., Rao, M. A. & Gianfreda, L. (2006). Development and validation of numerical indexes integrating enzyme activities of soils. *Soil Biology and Biochemistry, 38(7),* 1673–1681.

Speir, T. W. & Ross, D. J. (2002). Hydrolytic enzyme activities to assess soil degradation and recovery. In: *Enzymes in the environment. Activity, Ecology and Applications*, *Marcel Dekker,* New York, 407-431.

Stanev, I. (1979). Soil Erosion Control. *Techniques,* Sofia, (Bg).

Tabatabai, M. & Bremner, J. (1969). Use of p-nitrophenyl phosphate for assay of soil phosphatase activity. *Soil Biology and Biochemistry, 1*, 301 – 307.h

Trasar-Cepeda, C., Leiros, M. C. & Gil-Sotres, F. (2000). Biochemical properties of acid soils under climax vegetation (Atlantic oakwood) in area of the European temperate-humid zone (Galicia, NW Spain): Specific parameters. *Soil Biology and Biochemistry, 32,* 747-755.

Turner, B. & Haygarth, P. (2005). Phosphatase activity in temperate pasture soils: potential regulation of labile organic turnover by phosphodiesterase activity. *Science of the Total Environment, 344*, 27-36.

Vinhal-Freitas, I. C., Corrêa, G. F., Wendling, B., Bobuľská, L. & Ferreira, A. S. (2017). Soil textural class plays a major role in evaluating the effects of land use on soil quality indicators. *Ecological Indicators*, *74*, 182-190.

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