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Land use influence on micro-aggregates

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Abstract

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There were assessed differences in micro-aggregate composition depending on soil organic matter and soil texture in different ecosystems (forest, meadow and urban ecosystems and in agro-ecosystems on various plots) on Eutric Fluvisols and Haplic Chernozems. Micro-aggregate formation is influenced mainly by soil texture, but in agro-ecosystems, the quantity and quality of soil organic matter play an important role. The content of total organic carbon and its labile fraction positively influence creation of micro-aggregates larger than 0.01 mm. In relation to the quality of soil organic matter, creation of micro-aggregates is influenced mainly by the stabilised humus substances. In this research, the effect of humic acids was positive in case of smaller aggregates, but in case of their bound with the larger fraction of 0.25 mm their degradation occurred, thus the soil organic matter was less stabilised. Conversely, content of fulvic acids was mostly in negative correlation with the individual micro-aggregate fractions, but in case of micro-aggregates to 0.001 mm it was the positive correlation, because with increasing formation of aggressive humus substances, clay content is increasing, as well. Soil organic matter plays an important role especially in the creation of larger aggregates.

Key words

ecosystems, Eutric Fluvisols, Haplic Chernozems, micro-aggregates, soil organic mater, soil texture

Introduction

In the recent years, soil structure is considered important in assessing of carbon sequestration and turnover (Six et al., 2004). Many studies (Six et al., 1998; Martens, 2000; Hernanz et al., 2002; Zaujec and Šimanský, 2006, 2008) have confirmed that the aggregates have an important role in the stabilization of organic matter within aggregates by inhibiting the oxidation of carbon. Organic carbon in micro-aggregates is more protected physically, therefore a higher content of biochemical recalcitrant fraction leads to more stable micro-aggregates and lower intensity of decay inside the aggregates (Jastrow, 1996). Organo-mineral particles and some microbial polysaccharides may also participate in micro-aggregate creation (Angers, 1998). Organo-mineral particles and micro-aggregates are likely to expand the period of resistance of organic carbon against degradation by micro-organisms through chemical complexation or improve physical protection (Powers and Schlesinger, 2002). Different fractions of organic matter participate in creation and stabilization of soil aggregates in different ways (Roberson et al., 1991). In the permanent state of the micro-aggregates (0.053–0.250 mm), degraded aromatic humus substances in conjunction with polyvalent metal ions participate in bindings with clay particles (Tisdall and Oades, 1982). The stabilization of micro-aggregates (<0.25 mm), is participated significantly also by the iron and aluminium hydroxides (Barry et al., 1998). The aim of this work was to assess differences in micro-aggregate composition in different ecosystems, depending on soil organic matter and soil texture.

Material and methods

The study areas are located in the Danubian Lowland consisting of a plain and a hilly part. Localities on Eutric Fluvisols (Fao, 1998) (agro-ecosystem, forest ecosystem, meadow ecosystem) are situated in the plain part of the lowland, all ecosystems on Haplic Chernozems (Fao, 1998) and urban ecosystem on Eutric Fluvisols in the hilly part of the lowland. Geological substrates of the Danubian lowland are neogene clays, sands and gravels, in most areas covered with loess and loess loam. Fluvial sediments are along the Váh and Nitra rivers. The plain part of the Danubian lowland is mostly an alluvial plain. The hilly part is covered by loess and loess loam. In some places, neogene rafts of clays, sands and gravels appear. Sites on Haplic Chernozems are located on a slight slope facing SW (forest and meadow ecosystems, agro-ecosystem) and NE (urban ecosystem).

Samples were taken in the spring down to the depth of 0.3 m in 3 replications in the following ecosystems: forest (CH-FO, FL-FO), meadow (CH-ME, FL-ME), an urban ecosystem (CH-UR, FL-UR), an agro-ecosystem (CH-AG, FL-AG), and from four different plots (CH 01-04, FL 01-04), with different crop composition. From the physical properties, there were determined: the texture composition – by pipette method (Fiala et al., 1999), micro-aggregate composition – by Kačinský method (Hraško et al., 1962). Soil for determination of micro-aggregate fractions was sieved (<2 mm) and dispersioned with water. After 24 h, samples were shaking 2 h and sieved (<0.25mm). Then the procedure is the same with the determination of texture composition, and time periods for pipetation are different. From the chemical properties, there were determined: organic carbon – by Tyurin method (Grišina and Orlov, 1981), labile carbon (Login et al., 1987) and fractional composition of humus substances by Ponomareva and Plotnikova (1975).

The obtained results were analyzed with using the statistical software Statgraphic Plus. In addition to the basic descriptive statistical indicators, multi-factorial analysis of variance (anova) was used for evaluation the relevance of various factors on the observed parameters. Differences between the variants were assessed with the Tukey test at a significance level $P < 0.05$. Correlation analysis was used for exploring mutual dependences. Minimum significant correlation coefficient was determined at significance levels $P < 0.05$ and $P < 0.01$.

Results and discussion

Shares of micro-aggregate fractions in different ecosystems differed, with the highest content of the fraction 0.01–0.05 mm (Fig. 1). Micro-aggregate stability of this fraction was significantly influenced by the content of the total organic carbon ($P < 0.01$, r = 0.674), labile carbon ($P < 0.05$, r = 0.631), amounts of extracted humic acids ($P < 0.05$, r = 0.582) and fulvic acids ($P < 0.05$, r = –0.542), with the strongest effect of fulvic acids bound with Ca^{2+}.

Content of total organic carbon was in a negative linear dependence with the smaller fractions of micro-aggregates <0.01 mm (Table 1). The higher total organic carbon content, the lower amount of micro-aggregates <0.01 mm was. Labile carbon was also in negative correlation with the smaller micro-aggregates. This points to the fact that the smaller micro-aggregates, the less organic matter they consist and in the smallest fraction of the smallest micro-aggregates, organic matter almost is not present. This is too small fraction, in which dominating binding agents are oxides. According to Oades et al. (1989) the aggregating effect of oxides is mainly at the micro-aggregate level.

According to Šimanský and Zaujec (2009) lower contents of labile carbon are just in more intensively cultivated soils.

If there is little organic carbon in soil, the function of binding agents takes over polyvalent metals and silicate clays (Mbagwu, 1989). The portions of smaller micro-aggregates were influenced by the amount of free fulvic acids and fulvic acids bound with mobile R_2O_3 and Ca^{2+}. In the case of fraction 0.01–0.05 mm, there was a positive correlation, but in case of the smaller micro-aggregates <0.001 mm it was a negative correlation. This shows the effect of calcium on colloid coagulation, occurring mainly in smaller particles, and in the case of bivalent calcium and trivalent iron causing irreversible coagulation (Kutílek, 1978; Roth and Pavan, 1991; Baldock et al., 1994). In general, pressure changes result in creation of micro-aggregates (<0.002 mm), but in the case of particles <0.01 mm calcium reduces the effect of the cohesion forces between the particles (Rehák and Janský, 2000). Higher share of free fulvic acids and fulvic acids bound with mobile R_2O_3 resulted in smaller share of the smallest fractions of micro-aggregates (Table 1). In case of larger micro-aggregates 0.01–0.05 mm, correlation is positive, because into the bindings with mineral portion enter all molecules of fulvic acids, which are also stabilized by calcium. On the surface of particles, they form coatings, which act as cement.

Tisdall and Oades (1982) describe this as a permanent state, in which in binding participate degraded aromatic humus substances in conjunction with the polyvalent metal ions, which are strongly bound to the clay particles to produce micro-aggregates (0.053–0.250 mm).

Since fulvic acids are less stable than humic acids, they are more oxidized and the binding is less stable, as well. In contrast, the content of humic acids was in positive correlation with the amount of micro-aggregate

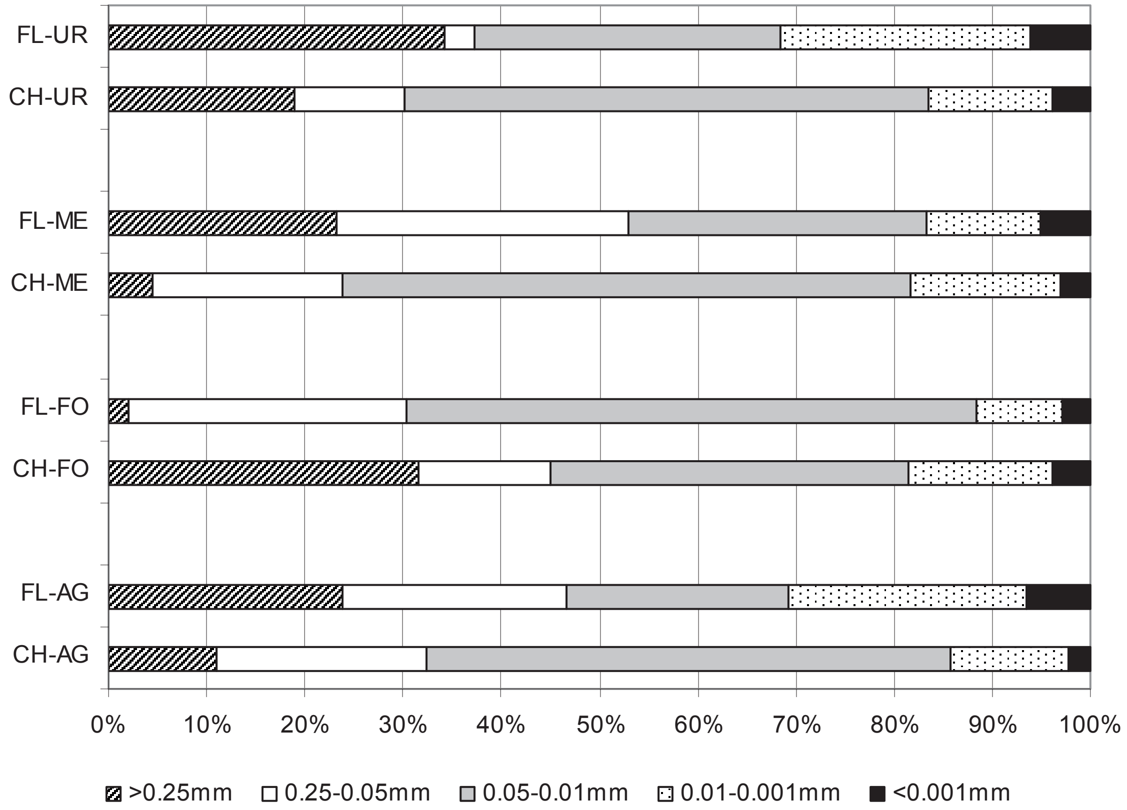

Fig 1. Shares of micro-aggregate fractions in different ecosystems on Eutric Fluvisols and Haplic Chernozems. FL, Eutric Fluvisols; CH, Haplic Chernozems; UR, urban ecosystem; ME, meadow ecosystem; FO, forest ecosystem; AG, agro-ecosystem.

fractions 0.01–0.05 mm. So it seems that the most stable fraction of micro-aggregates is just fraction 0.01–0.05 mm binded with humic acids.

Conversely, in case of larger fraction >0.25 mm, dependence between the content of this fraction and humic acid content was negative. In this case, humic acids are a mediator of binding between mineral particles, but they are more exposed to oxidation. This leads to their degradation, causing aggregate disintegration. This means that the greater share of larger aggregates, the lower share of humic acids, because they decompose and the organic matter is less stabilized. The strongest bindings are formed at the creation of humus substances (Piccolo and Mbagwu, 1990; Rehák and Janský, 2000), and gradually they get weaker. The largest fraction of aggregates was in negative correlation with the fraction of humic acids bound to the mineral component and stable R_2O_3, which is also in accordance with the theory that the most stabilized components are in case when higher portion of larger micro-aggregates are more degraded.

Micro-aggregate stability is given by the shares of granularity fractions. Micro-aggregate creation was influenced mainly by clay and silt (Table 1). According to Rehák and Janský (2000), fractions of sand and silt make micro-aggregate creation impossible. All fractions of micro-aggregates are not affected equally (Table 1). Content of coarse silt (0.01–0.05 mm) negatively correlated with the smallest micro-aggregates <0.001 mm. The fraction of fine and medium silt (0.001–0.01mm) was in turn in a positive correlation primarily with smaller fractions of micro-aggregates <0.01 mm.

Shares of micro-aggregate fractions in each ecosystem (Fig. 1) considerably fluctuated. The highest content of the micro-aggregate fraction (0.01–0.05 mm) was in the forest ecosystem (47.21%), followed by the meadow ecosystem (43.94%), urban ecosystem (42.32 %) and agro-ecosystem with the lowest content (38.04%). The content of this fraction is significantly affected by the total organic carbon, as well as its labile form. The highest shares were just in the forest ecosystem, the richest one in organic matter. Content of this micro-aggregate fraction was in a positive exponential dependence with the content of fulvic acids, having also the highest average portion in the forest ecosystem, in particular the fraction of fulvic acids bound with stable R_2O_3. Their extractability was the highest in the forest ecosystem (9.81%). The values in the meadow and the urban ecosystem were lower by about 19% and 26%, respectively, in the agro-ecosystem even by about 54%. Soil in the forest ecosystem of the same soil types

Table 1. Tendency of dependences between micro-aggregates, macro-aggregates and selected factors

	Linear	r	Logarithmic	r	Power–law	r	Exponential	r
TOC and MI <0.01 mm	y = –0.0015x + 47.786	0.559+	y = –24.274Ln(x) + 258.45	0.558+	$y = 185.016x^{-0.9398}$	0.486	$y = 52.911e^{-6E-05x}$	0.485
TOC and MI 0.001–0.01 mm	y = –0.0012x + 38.663	0.555+	y = –19.876Ln(x) + 211.14	0.554+	$y = 145.104x^{-0.9386}$	0.485	$y = 41.91e^{-6E-05x}$	0.483
TOC and MI 0.01–0.05 mm	y = 0.0025x – 4.9607	0.674++	y = 40.576Ln(x) – 356.2	0.660+	$y = 0.0008x^{1.102}$	0.664++	$y = 10.894e^{7E-05x}$	0.681++
C_L and MI <0.001 mm	y = –0.0012x + 7.5036	0.540+	y = –3.489Ln(x) + 31.422	0.578+	$y = 851.71x^{-0.7036}$	0.599+	$y = 7.0125e^{-0.0003x}$	0.579+
C_L and MI <0.01–0.05 mm	y = 0.0071x + 21.755	0.631+	y = 20.9Ln(x) – 121.89	0.689++	$y = 0.3973x^{0.5857}$	0.715++	$y = 22.237e^{0.0002x}$	0.656+
HA3 and MA >0.25 mm	y = –2.6741x + 47.884	0.656+	y = –32.703Ln(x) + 96.197	0.654+	$y = 20379x^{-3.0411}$	0.788++	$y = 233.99e^{-0.251x}$	0.802++
Σ HA and MA >0.25 mm	y = –1.1663x + 52.133	0.545+	y = –37.477Ln(x) + 144.06	0.577+	$y = 37385x^{-2.3413}$	0.468	$y = 118.4e^{-0.0724x}$	0.438
Σ HA and MI 0.01–0.05 mm	y = 1.7849x – 11.267	0.582+	y = 54.675Ln(x) – 142.94	0.590+	$y = 0.3509x^{1.3936}$	0.557+	$y = 9.9875e^{0.0458x}$	0.553+
FA1 and MI <0.01 mm	y = –2.3877x + 38.624	0.553+	y = –15.56Ln(x) + 51.104	0.573+	$y = 72.613x^{-0.6979}$	0.579+	$y = 41.545e^{-0.1073x}$	0.559+
FA1 and MI 0.001–0.01 mm	y = –1.9682x + 31.238	0.552+	y = –12.466Ln(x) + 40.83	0.557+	$y = 56.513x^{-0.6876}$	0.569+	$y = 33.234e^{-0.1083x}$	0.563+
FA2 and MI 0.01–0.05 mm	y = –2.5284x + 52.124	0.795++	y = –8.7833Ln(x) + 48.797	0.750++	$y = 47.281x^{-0.2418}$	0.765++	$y = 52.568e^{-0.0728x}$	0.848++
FA2 and MI <0.001 mm	y = 0.3568x + 2.6637	0.564+	y = 1.1578Ln(x) + 3.2076	0.497	$y = 2.9704x^{0.1992}$	0.439	$y = 2.8028e^{0.0535x}$	0.434
Σ FA and MI 0.01–0.05 mm	y = –1.7579x + 79.956	0.542+	y = –37.385Ln(x) + 156.02	0.538+	$y = 960.93x^{-1.0486}$	0.559+	$y = 115.37e^{-0.0499x}$	0.571+
CY and MI <0.001 mm	y = 0.2336x – 3.8256	0.606+	y = 8.1249Ln(x) – 24.366	0.563+	$y = 0.0151x^{1.5513}$	0.552+	$y = 0.7727e^{0.0441x}$	0.588+
MFS and MI <0.001 mm	y = 0.3414x – 1.5672	0.628+	y = 5.2651Ln(x) – 10.426	0.566+	$y = 0.1881x^{1.0541}$	0.581+	$y = 1.144e^{0.0665x}$	0.629+
CS and MI <0.001 mm	y = –0.2299x + 12.517	0.698++	y = –8.1164Ln(x) + 33.059	0.734++	$y = 883.53x^{-1.554}$	0.721++	$y = 16.989e^{-0.0435x}$	0.678++
MFS and MI <0.01 mm	y = 1.16x + 1.1506	0.601+	y = 20.079Ln(x) – 35.059	0.607+	$y = 1.1719x^{0.9944}$	0.676++	$y = 7.124e^{0.0568x}$	0.662++
CS and MI 0.01–0.05 mm	y = 0.9295x + 7.4234	0.561+	y = 31.771Ln(x) – 71.925	0.571+	$y = 1.9245x^{0.8403}$	0.560+	$y = 15.598e^{0.0248x}$	0.554+
CY and MI 0.05–0.25 mm	y = –0.8633x + 50.025	0.600+	y = –33.352Ln(x) + 137.65	0.619+	$y = 32.866x^{-2.1465}$	0.684++	$y = 121.32e^{-0.0567x}$	0.676++
MFS and MI 0.05–0.25 mm	y = –1.2239x + 41.027	0.604+	y = –21.955Ln(x) + 81.381	0.632+	$y = 519.17x^{-1.2243}$	0.605+	$y = 55.885e^{-0.0695x}$	0.589+
CY and MA >0.25 mm	y = 0.8069x – 9.8274	0.595+	y = 30.447Ln(x) – 89.169	0.599+	$y = 0.0034x^{2.3648}$	0.604+	$y = 1.9234e^{0.058x}$	0.554+
CS and MA >0.25 mm	y = –0.5258x + 39.566	0.751++	y = –18.213Ln(x) + 84.335	0.702++	$y = 1.9967x^{-1.3582}$	0.679++	$y = 70.905e^{-0.0392x}$	0.727++

MI, micro-aggregates; MA, macro-aggregates; TOC, total organic carbon; C_L, labile carbon; HA3, humic acids binded with the mineral component of soil and stable R_2O_3; FA1, fulvic acids free and bound with mobile R_2O_3; FA2, fulvic acids bound with Ca^{2+}; Σ HA, sum of humic acids; Σ FA, sum of fulvic acids; CY, clay (<0.01 mm); MFS, medium and fine silt (0.001–0.01 mm); CS, coarse silt (0.01–0.05 mm).

is considered as the soil of the highest quality, because its properties are nearly equal to the natural undisturbed territory, in which physical, chemical and biological properties are in equilibrium (Doran and Parkin, 1994). But forest soils are characterized by the highest content of fulvic acids in humus. Ratio of C_{HA} : C_{FA} showed that humus quality decreased from the agro-ecosystem (1.46), meadow ecosystem (1.28), urban ecosystem, (1.23) down to the the forest ecosystem (1.17).

In case of ecosystems, shares of micro-aggregates depended on the shares of clay fraction <0.001 mm, being the highest in the agro-ecosystem (19.48%) and urban ecosystem (19.53%) and lower in the meadow (15.08%) and forest ecosystem (14.36%). More marked than the effect of organic matter on shares of micro-aggregate fractions was the influence of clay content – which is in accordance with the theory that the micro-aggregates are less affected by management system than the macro-aggregates (Six and Jastrow, 2002). There is also a secondary effect – regulating the quantity and quality of soil organic matter in soil.

The reason is a higher intensity of mineralization in macro-aggregates than micro-aggregates (Elliott, 1986).

Even in the case of plots in each agro-ecosystem (Fig. 2), differences in distribution of micro-aggregate fractions were observed. Differences were more marked in Eutric Fluvisols than in Haplic Chernozems. In the agro-ecosystem in Haplic Chernozems, the plots CH-01 and CH-04 exhibited the lowest portion of micro-aggregate fraction <0.01 mm, while only on these plots was recorded positive carbon balance during the 6-year period. In the other two, the balance was found negative. Gartzia-Bengoetxea et al. (2009) report that concentration of organic carbon was not increasing with enlarging aggregates in a forest ecosystem; however, this was found true for agricultural soils by Tisdall and Oades (1982).

In the case of permanent cultivated soils, however, the importance of soil organic matter is indisputable, even in the case of micro-aggregate creation – as the reduction of organic matter in soil results in distortions of micro-aggregates. Oades (1984) reports, that decomposition of particular organic matter is associated with releasing of metabolism products. Macro-aggregates become more stable and micro-aggregates form inside the first.

In case of Eutric Fluvisols, formation of smaller micro-aggregates <0.001 mm was limited by content of sand fraction.

It follows that under natural conditions, the micro-aggregate dynamics is more influenced by natural factors, such as soil texture; but in case of cultivated soils, soil organic matter is the governing factor affecting

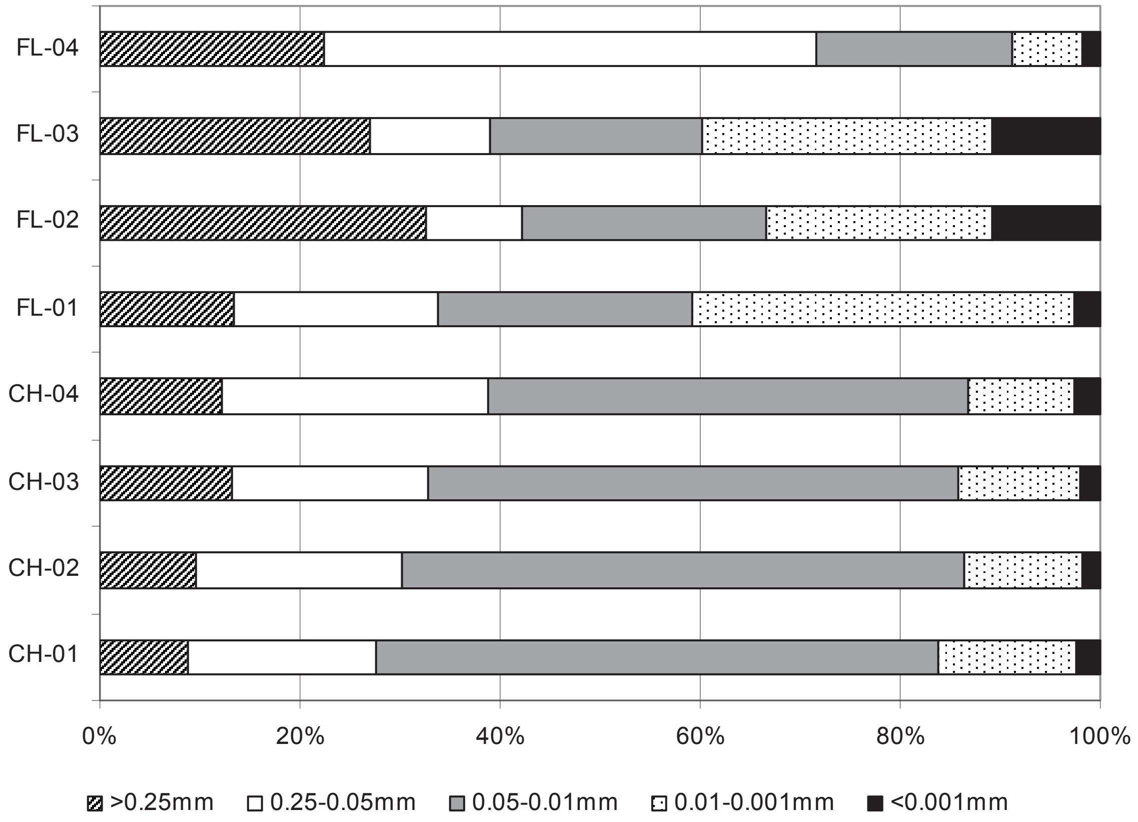

Fig 2. Shares of micro-aggregate fractions in different plots of agro-ecosystems on Eutric Fluvisols and Haplic Chernozems. FL, Eutric Fluvisols; CH, Haplic Chernozems; 01–04, plots in agro-ecosystems.

the micro-aggregate formation. Since the micro-aggregates are the key element in macro-aggregate creating, it is essential to monitor inputs of organic matter in the soil, especially in intensively cultivated soils.

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Vplyv využívania pôdy na mikroagregáty

Súhrn

V rôznych ekosystémoch (lesný, lúčny, urbánny ekosystém a v agroekosystéme aj na rôznych honoch) na černozemi a fluvizemi boli posudzované rozdiely v zastúpení mikroagregátov v závislosti od pôdnej organickej hmoty a pôdnej textúry. Tvorba mikroagregátov je ovplyvňovaná predovšetkým pôdnou textúrou, ale v agroekosystémoch zohráva dôležitú úlohu aj množstvo a kvalita pôdnej organickej hmoty. Obsahy celkového organického uhlíka a jeho labilnej frakcie vplývajú pozitívne na tvorbu mikroagregátov väčších ako 0,01 mm. Vo vzťahu ku kvalite pôdnej organickej hmoty ovplyvňujú tvorbu mikroagregátov predovšetkým stabilizované humusové látky. Vplyv humínových kyselín bol pozitívny v prípade menších agregátov, pričom v prípade ich väzby s väčšou frakciou nad 0,25 mm dochádzalo k ich odbúravaniu, teda stabilizácia pôdnej organickej hmoty bola nižšia. Naopak obsah fulvokyselín bol prevažne v negatívnej korelácii s jednotlivými frakciami mikroagregátov, ale v prípade mikroagregátov do 0,001 mm v pozitívnej, pretože pri zvýšenej tvorbe agresívnych humusových látok sa zvyšuje obsah ílu. Pôdna organická hmota zohráva dôležitú úlohu predovšetkým pri tvorbe väčších agregátov.

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