Suitable parameters for soil organic matter changes evaluation in agro-ecosystems

Vladimír Šimanský, Anton Zaujec

Department of Pedology and Geology, Faculty of Agrobiology and Food Resources, Slovak University of Agriculture in Nitra, Tr. A. Hlinku 2, 949 76 Nitra, Slovak Republic, E-mail: Vladimir.Simansky@uniag.sk

Abstract

Šimanský, V., Zaujec, A. 2009. Suitable parameters for soil organic matter changes evaluation in agro-ecosystems. *Folia oecol.*, 36: 50–57.

In period 1999–2003, we studied suitability of new parameters for determination of soil organic matter (SOM) changes in ecological (ES) and integrated (IS) farming systems established in 1990 in the experimental station Slovak University of Agriculture in Nitra. The lability of carbon (L_C) was higher in spring (0.183) than in autumn (0.158) in both systems. The lability of nitrogen (L_N) was higher in IS (0.080) than in ES (0.074). Carbon management index (CMI) values were increasing more intensively in IS (from 108.7 to 118) than in ES (from 109.3 to 113.3). Higher percentage portions of potentially mineralizable nitrogen (N_L) from total (N_T) were in IS than in ES. It means that higher SOM sources are in ES than IS, but according to parameters L_C, CMI, L_N, more intensive changes in SOM sources can be supposed in IS than in ES. We recorded influence of average annual temperature on parameters of labile carbon ($r = -0.79$, $P < 0.01$), non-labile nitrogen ($r = 0.76$, $P < 0.01$), as well as the year precipitation sum on CMI ($r = -0.58$, $P < 0.01$), labile nitrogen ($r = 0.72$, $P < 0.01$) and L_N ($r = 0.61$, $P < 0.01$). From the point of sustainable development the parameters labile carbon, L_C and non-labile nitrogen (N_{NL}) were the most suitable for the assessment of SOM changes in farming systems.

Key words

carbon sequestration, farming systems, labile carbon and nitrogen, soil organic matter

Introduction

Soil fertility is closely linked to soil organic matter whose status depends on biomass input and management, mineralization, leaching and erosion. Soil organic matter (SOM) improves the productivity and physical properties of soils. The quantity and quality of SOM are the most important characteristics influencing the sustainable development. In natural conditions soils have their characteristic humus contents. This equilibrium state is disturbed by soil cultivation when inputs of organic matter to soil are lower, and decomposition of present organic matter is higher. Its quantity is determined through carbon and nitrogen. Schjonning et al. (2007) recorded changes in soil organic matter fractions in differentiated soil management after 5–6 years. It means that much more sensitive indicators of dynamic changes in C and N are their fractions, labile carbon or potentially mineralizable nitrogen. The most common fractionations of SOM are based on differences in solubility of organic constituents in acid and alkali. The complexity of these fractions means that each of them represents a wide range of chemical forms with very different turnover rates. These fractions are not either conceptual pools or related to their rate of turnover. They are procedurally defined fractions, based largely on their solubility, and thus with limited value in studies of SOM dynamics. Techniques for isolation individual carbon fractions are different. Loginow et al. (1987) developed a fractionating method for SOM and fractions or substrates of SOM based on the susceptibility to oxidation by permanganate. Modification and standardization of $KMnO_4$ oxidation technique by Blair et al. (1995) has increased the precision and simplified the technique to use only one concentration $KMnO_4$, thereby dividing soil carbon into labile (C_L) and non-labile (C_{NL}) carbon. These measurements of labile carbon have been used, in combination with similar data from soil of an uncropped, reference area, to calculate carbon management index (CMI), as a measure of relative sustainability of different agricultural systems. This index compares the changes that occur in the total and labile carbon as a result of agricultural practice, with increased importance assigned to changes in labile, as opposed to non-labile, component of the SOM. Through these parameters, some scientists tried to observe smaller changes and changes in short time period. Conteh et al. (1998) used parameters as lability (L), lability index (LI), carbon pool index (CPI) and CMI for the complex evaluation of differences in soil organic matter between natural ecosystems and agroecosystems. These parameters were used in our study for evaluating the influence of farming systems on the quantity and quality of SOM and on carbon sequestration. Our research has been focused on: i) possibilities how to evaluate changes in soil organic matter through total and labile fractions of SOM, ii) selection of parameters suitable for sensitive detection of organic matter changes in agro-ecosystems, iii) comparison between ecological (ES) and integrated farming systems (IS) through these parameters. This comparison can enable a faster and more sensitive response to negative changes in soil parameters that are very important for sustainable development.

Materials and methods

Experimental site

The studied territory of Dolná Malanta (lat. 48°19'00"; lon. 18°09'00") is located in the lower part of the basin of Selenec creek and its tributaries which belong to the central part of the Nitra river basin. It is located eastwards from the town of Nitra (Slovakia) in the Žitavská Upland. The geological substratum consists of little rocks with high contents of fine materials. Young Neogene deposits are composed of various clays, loams, sands, gravels covered with loess deposited in the Pleistocene (Hrnčiarová and Miklós, 1991). The soil is Orthic Luvisol (Fao, 1998) containing on average 318.8 g kg^{-1} of sand, 567.0 g kg^{-1} of silt and 114.3 g kg^{-1} of clay. Total soil carbon content was 13.9 ± 1.8 g kg^{-1}, total nitrogen content was 1348 ± 108 mg kg^{-1}, sorptive capacity was 157.7 ± 11.2 mmol kg^{-1} and base saturation percentage was 88.9 ± 2.3 %. On average, exchangeable soil pH was 5.16 ± 0.31. Mean maximum and minimum air temperatures (1999–2003) were 21.1 °C (from July to August) and –2.1°C (from December to January). The mean annual temperature of air is 10.7 °C. During the years 1999–2003 the mean annual precipitation was 487 mm, with about 48% of this amount falling from March to July.

Experimental details

The project with ecological (ES) and integrated (IS) farming systems was established in autumn 1990. All plots had the following size: width 10 m, length 10 m, in 4 replications. The plots were separated with 1 m insulation strips. The crop rotation in IS was: winter wheat *(Triticum aestivum* L.*)*, silage corn *(Zea mays* L.*)*, spring barley *(Hordeum vulgare* L.*)*, bean *(Faba vulgaris* M.*)* + alfalfa *(Medicago sativa)*; in ES there were: winter wheat *(Triticum aestivum* L.*)*, pea *(Pisum sativum* L. subsp. *Hortense* (Neitr.), silage corn *(Zea mays* L.*)*, spring barley *(Hordeum vulgare L.)*, bean *(Faba vulgaris* M.*)* + alfalfa *(Medicago sativa)*. Farmyard (FYM) was added in a dose of 40 Mg ha^{-1} to silage corn. In ES, FYM was added in a dose of 40 Mg ha^{-1}, supplementary nitrogen was provided through leguminous crops fixating nitrogen. The soil cultivation in both systems is based on conventional tillage. Crop rotations, fertilization and crop yields on plots 5 and 7 of both farming systems are shown in Table 1. In both farming systems, control variants without fertilization were included. In IS, the average annual doses of fertilizers were: N – 80 kg ha^{-1}, P (P_2O_5) – 40 kg ha^{-1}

Table 1. Schedule of field experiment, farming systems, crop rotation, FYM application and crop yields

Farming system	Plot	1999			2000			2001			2002			2003		
		Crop Rotation	Yield (Mg ha^{-1}) Control	Yield (Mg ha^{-1}) Fertilized	Crop Rotation	Yield (Mg ha^{-1}) Control	Yield (Mg ha^{-1}) Fertilized	Crop Rotation	Yield (Mg ha^{-1}) Control	Yield (Mg ha^{-1}) Fertilized	Crop Rotation	Yield (Mg ha^{-1}) Control	Yield (Mg ha^{-1}) Fertilized	Crop Rotation	Yield (Mg ha^{-1}) Control	Yield (Mg ha^{-1}) Fertilized
IS	5	SB	5.1	7.2	WW	5.9	5.9	pea	3.9	3.4	WW	5.65	5.9	SC	18.6	22.9
	7	WW	6.9	8.3	SC+40tFYM	29.2	29.1	SB	3.2	4.6	B+ AA	4.95	5.4	AA	12.9	10.0
ES	5	pea	4.9	4.6	SC+40tFYM	48.2	53.2	SB	3.1	3.6	B+ AA	4.76	5.0	AA	10.5	8.8
	7	WW	6.0	6.2	pea	1.9	2.0	SC+40tFYM	48.2	53.2	SB	4.40	6.6	B+AA	5.7	5.4

SC, silage corn; AA, alfalfa; WW, winter wheat; SB, spring barley; B, bean; IS – plot 5 – 1990–2003 dose of FYM 100 Mg ha^{-1}, plot 7 dose of FYM 120 Mg ha^{-1}; ES – plot 5 – 1990–2003 dose of FYM 140 Mg ha^{-1}, plot 7 dose of FYM 120 Mg ha^{-1}

and K (K_2O) – 75 kg ha^{-1}. All treatments in IS were protected against detrimental effect of weeds, diseases and pests and in ES only physical protection was permitted.

Soil sampling and analysis

We collected soil samples from layer 0–0.3 m in spring and autumn in years 1999–2003. For each sampled zone, three different locations were chosen randomly. On each location, soil samples were collected and mixed up to an average sample. Soil samples were dried at the laboratory temperature and grinded. We determined the amounts of total organic carbon C_T (Fiala et al., 1999), labile carbon C_L (Loginov et al., 1987), total nitrogen N_T (Fiala et al., 1999) and potentially mineralizable nitrogen N_L (Standford and Smith, 1978) in soil samples. We calculated non-labile carbon (C_{NL}) as difference between C_T and C_L, and CMI according to Blair et al. (1995). We also used this procedure for evaluation of changes in soil nitrogen. We calculated values of the nitrogen parameters determined in soil: lability of soil nitrogen (L_N), lability index of nitrogen (LI_N), nitrogen pool index (NPI) and the nitrogen management index (NMI). The obtained data were analyzed by using the statistic software Statgraphic Plus. Data for each farming system, sampling time and years were prepared by analysis of variance. Differences were considered significant at $P < 0.05$, and differences between treatments means were calculated using the Duncan test. We used correlation analysis to determination of relationships between SOM quality and quantity and climatic conditions (temperature and precipitation).

Results and discussion

Carbon parameters in evaluation of SOM changes

The fluctuation of total organic carbon content (C_T) was the highest in year 2000 from 10.6 g kg^{-1} to 15.8 g kg^{-1} in variants. On average, a higher C_T content was in ES (14.5 g kg^{-1}) than in IS (13.1 g kg^{-1}) and in autumn than in spring (13.7 g kg^{-1} and 11.9 g kg^{-1}) during the testing period (Tobiašová and Pačuta, 2006). In ES, there was a higher portion of forage crops and lower portion of cereals than in IS. The reason of higher C_T content in autumn is accumulation of crop residues. Considering this fact it is not possible to predict quality of organic substances as source of SOM. The carbon content is higher in elemental composition of cereals, but the decomposition rate of crop residues is higher in case of forage crops (Tobiašová, 2001; Tobiašová, 2006; Jurčová and Tobiašová, 2002). Another reason can be nitrogen fertilizer, which might be a result of increased organic carbon mineralization after autumnal application of mineral nitrogen where there may be no crop present to utilize the fertilizer, resulting in adverse changes in SOM quality. The mineral fertilization contributes significantly to the formation of labile humic substances at the expense of Ca-forms of SOM which are more resistent to microbial decomposition (Shevtsova et al., 2003). In summary, a higher average C_T content was in fertilized variants (13.3 g kg^{-1}) than in control variants (11.3 g kg^{-1}). Bhattacharyya et al. (2007) described considerable accumulation of total C_T in the 0.0–0.15 m soil layer in conditions with regular application of FYM in combination with NPK or N alone. The differences between fertilized and non-fertilized variants were higher in IS. The cause is in added inorganic fertilizers influencing nutrient ratios and next transformation processes (Tobiašová and Karabínová, 2002). We determined statistically significant influences of farming system and sampling time on C_T (Table 2). The labile carbon content (C_L) is much more sensitive parameter from the view point of study of short-term changes. The main reason of organic matter losses is the high rate of mineralization. Therefore, the values of C_L more sensitively reflected oxidative processes. Zou et al. (2005) defined the soil labile organic carbon as the fraction of soil organic carbon degradable during microbial growth. Its oxidation drives the flux of CO_2 between soil and atmosphere. According to Bell et al. (1998), labile easy oxidizable carbon plays an important role in soil fertility. Therefore, the increase in content of this carbon fraction is decisive for the sustainable farming system. Generally, higher average contents of labile carbon were determined in spring than autumn in both farming systems. The differences in contents of C_L and C_T were observed between the individual years. In the multi-year studies, the type of interaction varied between years, suggesting that seasonal events, rather than soil type, determine the type of interaction. The greatest benefits of applying organic and mineral fertilizers together, Linquist et al. (2007) observed in years when soil-water conditions were unfavorable (fluctuating anaerobic-aerobic conditions). The highest contents of C_L were in 2001 and the lowest in 2002. Before 2001, a very dry year was year 2000 (added FYM positively affected on crop yields, mainly in ES). This manifests decreasing of soil organic matter transformation processes. Variability in temperature and precipitation during the years very intensively influenced transformation processes. We determined statistically significant influences of farming system, fertilization and sampling time on C_L. The lability of carbon (L_C) was the highest in 2001. This indicated the highest amount of active carbon in labile form, which was probably the result of FYM application in dry year 2000. Blair et al. (2006) proved that C_T, C_{NL} and C_L were greater with addition of FYM than without it and the application of N with FYM increased C_L but not C_T or C_{NL} compared to just FYM. Statistically significant influence of time of sampling on L_C values was determined. Their average values were higher in spring (0.183) than in autumn (0.158). Lower values of this parameter in autumn were the result of increased mineralization during the vegetative period with decreasing content of labile carbon, but also increasing of contents C_T by intensive humification of crop residues. With relation to farming system, on average higher value of L_C was in IS (0.172) than in ES (0.169). The lability index of carbon (LI_C) was the highest in 2000 (autumn), which was a very dry year. Just dryness could be the limiting factor of stabilization of the produced organic substances. Markedly lower values of LI_C in spring than in autumn were the result of a longer period of dryness in summer. On average, LI_C values were lower in spring than in autumn during the whole monitored period. In effect, the intensity of decomposition was higher in spring than in autumn. There were optimal conditions for growth and activity of microorganism. The temperature was the limiting factor in winter and the dryness was the limiting factor in summer. More pronounced changes among variants were not observed in carbon pool index (CPI) values. Conteh et al. (1998) obtained similar values of CPI parameter in soil with and without crop residues. CPI values fluctuated from 0.855 to 1.346, but most of them were above 1. The stable forms of organic carbon are less available for microorganisms. On the other hand, they are important for the production of stabilized condensed humus substances as a potential resource of organic matter in soils. The stabilized humus substances play an important role in optimal soil structure and they also influence other physical, chemical and biological parameters of soils. And that is reason why it is better to consider C_T content together with carbon labile forms and CMI is better for the evaluation of these changes. CMI was designed to express C dynamics of the system. Although the value itself was not important, the changes, as a result of different management strategies, gave an indication of ecosystem response (Blair et al., 1995). On average, the highest value was in 2003 and the lowest in 2000. CMI values showed whether to consider as dominant processes of carbon losses or processes of new organic substances production. Usually, CMI values are strongly influenced by N fertilization. With regard to CMI, it may be stated that simultaneous mineral fertilization and organic manure cause an accumulation of SOM and the rate of these processes is proportional to the fertilizer doses (Janowiak et al., 2001). There is not an ideal CMI value. CMI is suitable for the comparison of carbon changes in different soils and farming systems. The lower CMI value, the higher amount of carbon from soil reserve is changed as a reason of cultivation (Blair et al., 1995). CMI average values were lower in spring than in autumn. They were increasing more intensively in IS (from 108.7 to 118), than ES (from 109.3 to 113.3), which focused on higher intensity of carbon transformation. Fluctuation of CMI values was higher in integrated than in ecological farming system.

Table 2. Mean values of parameters of soil organic matter quality in different farming systems, time sampling and years

		Parameters													
		L_C	LI_C	CPI	CMI	L_N	LI_N	NPI	NMI	C_T	C_L	C_{NL}	N_T	N_L	N_{NL}
										[g kg^{-1}]			[mg kg^{-1}]		
Farming system	ES[a)]	0.169a[c)]	104.53a	1.072a	111.30a	0.074a	102.52a	1.073a	109.33a	14.06b[c)]	2.01b	12.05b	1541.9b	104.6a	1432.3b
	IS[b)]	0.172a	100.33a	1.134a	113.36a	0.080a	94.96a	1.083a	101.36a	12.54a	1.83a	10.71a	1393.1a	97.2a	1290.9a
Sampling time	Spring	0.183b	98.45a	1.109a	108.99a	0.074a	95.34a	1.084a	102.49a	12.77a	1.97a	10.80a	1489.5a	101.3a	1388.2a
	Autumn	0.158a	106.41a	1.097a	115.67a	0.080a	102.14a	1.071a	108.20a	13.83b	1.87a	11.95b	1445.5a	100.5a	1335.0a
Years	1999	0.168ab	107.48a	1.077ab	114.85a	0.079ab	100.43a	1.037ab	101.65a	14.38a	2.06a	12.32b	1364.8a	99.3abc	1265.5a
	2000	0.156a	109.80a	0.959a	106.03a	0.060a	91.18a	0.970a	88.70a	13.69a	1.81a	11.87ab	1591.0c	88.0ab	1502.8c
	2001	0.194b	95.33a	1.138b	107.93a	0.082ab	106.83a	1.107ab	116.80a	12.75a	2.06a	10.69a	1520.0bc	113.0bc	1394.8bc
	2002	0.172ab	92.98a	1.147b	106.43a	0.094b	102.65a	1.144b	116.25a	12.63a	1.85a	10.78ab	1473.8ab	125.5c	1348.3ab
	2003	0.162a	106.58a	1.194b	126.43a	0.071ab	92.63a	1.131b	103.33a	13.06a	1.81a	11.25ab	1387.9a	78.8a	1296.8ab

[a)]Ecological farming system; [b)]Integrated farming system; [c)]Values followed by the same letter within each column are not significantly different at $P < 0.05$; C_T, total organic carbon; C_L, labile carbon; C_{NL}, non-labile carbon; L_C, lability of soil organic carbon; LI_C, lability index of carbon; CPI, carbon pool index; CMI, carbon management index; N_T, total nitrogen; N_L, potentially mineralizable nitrogen, N_{NL}, non-labile nitrogen; L_N, lability of soil nitrogen; LI_N, lability index of nitrogen; NPI, nitrogen pool index; NMI, nitrogen management index

Nitrogen parameters in evaluation of SOM changes

The farming system and the fertilization had statistically significant influence on total nitrogen content (N_T). On average, the nitrogen content was higher in ES than in IS (about 149 mg kg^{-1}). Noticeable differences of N_T contents were also between the years. On average, the lowest N_T content was in 1999 (1,365 mg kg^{-1}) and the highest in 2000 (1,591 mg kg^{-1}). Higher percentage portions of potentially mineralizable nitrogen (N_L) from N_T were in IS than in ES. Their portions in control variants were higher, but the differences between spring and autumn sampling were not observed. Differences in their percentage portions were between the years. On average, the lowest value of N_L portion from N_T 5.9% was denoted in 2000. The measurement of potentially mineralizable carbon and nitrogen represents a bioassay of labile organic matter using the indigenous microbial community to release labile organic fractions of carbon and nitrogen. The mineralizable nitrogen is also an important indicator of soil capacity to supply the nitrogen for crop. It is concluded that individual labile organic matter fractions are sensitive to changes in soil management and have specific effects on soil function (Zaujec et al., 2005). According to Westerhof et al. (1998) NMI is a good indicator of N availability but it gives no information about the total amount of N. In land use system analysis, N_T and N_L can be used together as a simple and rapid tool for evaluation the nitrogen status of the soil. Nitrogen evaluation changes are also more sensitive through the lability of nitrogen (L_N), lability index of nitrogen (LI_N) or nitrogen pool index (NPI). L_N fluctuated from 0.046 to 0.107 in both farming systems. The lowest values were obtained in 2000 and the highest in 2002. Fissore et al. (2008) found that both soil organic matter quantity and quality decreased with increasing mean annual temperature. Soil moisture is also one of the key factors influencing soil microbial activity and SOM decomposition, but presence of plants can not be ignored in SOM decomposition studies (Dijkstra and Cheng, 2007). Crops with bigger root systems in topsoil were in 2000 than in 2002. Year 2000 was not only dry, but there were also mainly cereals, which decreased soil moisture. Higher value of L_N indicates higher amount of available nitrogen. Differences were also between years, with the highest value in 2002, and the lowest in 2000. In 2002, average annual temperature and annual sum of precipitation were the highest. It is interesting that marked differences were not observed between fertilized and control variants. Average values of L_N were higher in autumn than in spring. Parameter LI_N confirmed, that nitrogen organic substances were less resistant in ES than in IS. They were least stable in the dry year 2000. NMI pointed to the most intensive changes of nitrogen content just in year 2000, where this average value was the lowest. It means that in case of year 2000, the nitrogen organic substances were the least stable and they underlay the most intensive changes. More sensitive parameter of nitrogen content evaluation was nitrogen pool index (NPI). The amount of organic matter inputs statistically significantly influenced the parameters of CPI, CMI and NPI. Their amount was higher in control variant in ES and in fertilized variants in IS (Table 2).

Correlations between climatic changes and soil organic matter parameters

Statistical assessment (Table 3) showed that significant linear dependence was between precipitation and C_L, but not C_T. It can be the reason of the higher accumulation of organic matter in topsoil, but in lower part of soil profile stabilized organic substances are dominant. This also indicated that soil labile carbon was relatively more sensitive to environmental changes than soil organic carbon. CMI, CPI, NMI and NPI indexes were more suitable for comparison of SOM changes between individual years. It was probably the reaction on climatic changes (temperature and precipitation). In our experiment, the average temperatures in July and August influenced statistically significantly values of CPI and NPI (Table 3). Homann et al. (2007) recorded that the organic carbon pool is negatively related to a temperature/precipitation index in studied regions and negatively related to mean annual temperature. These relations are consistent with concepts of moisture and temperature controls on detrital production, differential effects of temperature on detrital production and decomposition, and stabilization of organic matter by clay and silt. In our study, the average annual temperature had statistically significant influence on C_L ($r = -0.79$, $P < 0.01$) and N_{NL} ($r = 0.76$, $P < 0.01$). Average temperatures in July and August significantly influenced C_L ($r = -0.50$, $P < 0.05$), C_{NL} ($r = -0.74$, $P < 0.01$) and CPI ($r = 0.61$, $P < 0.01$), NPI ($r = 0.63$, $P < 0.01$). Average temperatures from April to October had statistically significant influence on N_{NL} ($r = 0.63$, $P < 0.01$) and L_N ($r = -0.60$, $P < 0.01$). Annual sum of precipitation had statistically significant influence on CMI ($r = -0.58$, $P < 0.01$), N_L ($r = 0.72$, $P < 0.01$), L_N ($r = 0.61$, $P < 0.01$). Sum of precipitation in July and August significantly influenced C_L ($r = -0.50$, $P < 0.05$), N_{NL} ($r = -0.72$, $P < 0.01$), L_N ($r = 0.59$, $P < 0.01$). Sum of precipitation from April to October significantly influenced LI_C ($r = -0.54$, $P < 0.05$), N_L ($r = 0.72$, $P < 0.01$), N_{NL} ($r = -0.59$, $P < 0.01$), L_N ($r = 0.68$, $P < 0.01$), LI_N ($r = 0.57$, $P < 0.01$), NMI ($r = 0.58$, $P < 0.01$). Temperature and precipitation play important role in SOM changes. It is important not only for annual characteristics, but also their distribution during the year.

Table 3. Correlation coefficients between soil organic matter parameters and climatic conditions and variants of farming systems

	C_T	C_L	C_{NL}	L_C	LI_C	CPI	CMI
Year average (temperature)	–0.38	–0.79**	–0.25	–0.40	–0.04	–0.41	–0.46
Average temp. (April–October)	–0.34	–0.25	–0.31	0.10	0.15	–0.12	0.03
Average temp. (July–August)	–0.34	–0.50*	–0.74**	0.13	–0.30	0.61**	0.37
Year sum (precipitation)	0.12	0.16	0.10	0.01	–0.38	–0.18	–0.58**
Sum of precipitation (April–October)	–0.07	–0.25	–0.11	0.21	–0.54*	0.37	–0.15
Sum of precipitation (July–August)	0.41	–0.50*	0.35	0.02	–0.30	0.17	–0.15
IS – fertilized variant	0.39	–0.29	0.46*	–0.52*	0.24	0.83**	–0.64**
IS – control	–0.08	–0.06	–0.07	–0.05	–0.46*	–0.08	–0.54*
ES – fertilized variant	–0.68**	–0.41	–0.63**	0.19	–0.31	–0.13	–0.43
ES – control	–0.20	–0.41	–0.13	–0.32	–0.09	0.67**	0.63**
	N_T	N_L	N_{NL}	L_N	LI_N	NPI	NMI
Year average (temperature)	0.76**	0.01	0.78**	–0.28	–0.43	–0.20	–0.29
Temperature av. (April–October)	0.59**	–0.43	0.63**	–0.60**	–0.30	–0.15	–0.22
Temperature av. (July–August)	0.09	–0.16	0.07	0.01	–0.14	0.63**	0.31
Year sum (precipitation)	–0.03	0.72**	–0.12	0.61**	0.41	–0.00	0.24
Sum of precipitation (April–October)	–0.48*	0.72**	–0.59**	0.68**	0.57*	0.47	0.58**
Sum of precipitation (July–August)	–0.68**	0.39	–0.72**	0.59**	0.38	0.14	0.25
IS – fertilized variant	0.48*	0.12	0.53*	–0.22	–0.29	–0.67*	–0.53*
IS – control	0.02	0.73**	–0.08	0.64**	0.33	0.14	0.29
ES – fertilized variant	0.65**	0.09	0.81**	–0.21	–0.06	0.03	0.07
ES – control	–0.71**	–0.06	–0.70**	0.38	–0.17	0.64**	0.23

Sum of samples = 19, $*P < 0.456$; $**P < 0.575$

Conclusions

The results showed on the necessity of application, predominantly, of carbon and nitrogen fractions in the evaluation of soil organic matter quality and its losses. Because the changes in these fractions are observed in shorter time periods, it is possible to respond to them more flexibly and to assess together the quantity and quality of soil organic matter. In this case, longer time of dryness strongly influenced processes of soil organic matter transformation. It means that temperature and precipitation play important role in soil organic matter changes and it is important to monitor not only mean annual temperature and sum of precipitation, but also their distribution over the year.

According to statistical assessment, suitable parameters for sensitive response to changes of organic matter in agro-ecosystems are mainly parameters labile carbon, carbon lability and non-labile nitrogen. They are the most suitable for assessment of soil organic matter changes in conditions of different farming systems. New approach to the evaluation of contents and changes in soil organic matter presented possibilities in complex assessment of carbon and nitrogen forms, total and labile, not only for different ecosystems but also for farming systems.

According to total organic carbon content, higher values were in average in ecological than in integrated system. But according to carbon lability on average higher values were in IS than in ES, which indicates higher amount of active carbon in labile form. Carbon management index values were increasing more intensively in integrated than ecological system, which showed on higher intensity of carbon transformation and microorganism activity. Higher percentage portions of potentially mineralizable nitrogen from total nitrogen were in integrated than in ecological system. It means that higher soil organic matter sources are in ecological than integrated system, but according to parameters carbon lability, carbon management index, labile nitrogen from total nitrogen, more intensive changes in soil organic matter sources we can await in integrated than in ecological system.

Acknowledgement

This project was supported by the Scientific Grant Agency of the Ministry of Education of the Slovak Republic and the Slovak Academy of Sciences (No. 1/0092/08 and No. 1/0457/08).

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Vhodné parametre pre hodnotenie zmien v organickej hmote pôdy v agroekosystémoch

Súhrn

Vo vybraných agro-ekosystémoch (ES – ekologický systém hospodárenia, IS – integrovaný systém hospodárenia), ktoré boli založené v roku 1990 na experimentálnej báze SPU – Nitra, sme v rokoch 1999–2003 študovali vhodnosť nových ukazovateľov pre určenie zmien v organickej hmote pôdy. Zistili sme, že labilita uhlíka (L_C) v oboch systémoch hospodárenia bola vyššia na jar (0,183) ako na jeseň (0,158). Labilita dusíka (L_N) bola vyššia v IS (0,080) v porovnaní s ES (0,074). Hodnoty uhlíkového riadiaceho indexu (CMI) sa výraznejšie zvýšili v IS (z 108,7 do 118) ako v ES (z 109,3 do 113,3), čo poukazovalo na vyššiu intenzitu transformácie uhlíka. Vyššie percentuálne zastúpenie potenciálne mineralizovateľného dusíka z celkového dusíka bolo v IS ako v ES, čo znamená, že vyššie zdroje organickej hmoty pôdy sú v ES ako v IS. Na druhej strane na základe hodnôt L_C, CMI, L_N, intenzívnejšie zmeny v zdrojoch organickej hmoty pôdy môžeme očakávať v IS ako v ES. Vstupy organickej hmoty ovplyvnili tieto parametre: veľkosť zdroja uhlíka (CPI), CMI a veľkosť zdroja dusíka (NPI). Zvyšovanie ich priemerných hodnôt bolo výraznejšie v IS v porovnaní s ES počas celého sledovaného obdobia od jari do jesene. Zvýšenie hodnôt v období experimentu bolo od jari do jesene v priemere vyššie v IS ako v ES. To znamená, že zmeny v dynamike pôdnej organickej hmoty boli vyššie v IS, s jej nižším obsahom, teda reakcia na vstupy organickej hmoty bola oveľa citlivejšia. Zaznamenali sme vplyv priemernej ročnej teploty na parametre C_L (r = –0,79; *P < 0,01*), nelabilného dusíka (N_{NL}) (r = 0,76; *P < 0,01*), a taktiež vplyv ročného úhrnu zrážok na CMI (r = –0,58; *P < 0,01*), labilný dusík (N_L) (r = 0,72; *P < 0,01*) a L_N (r = 0,61; *P < 0,01*). Z pohľadu trvalej udržateľnosti agroekosystémov sa parametre labilného uhlíka (C_L), L_C a N_{NL} javia oveľa vhodnejšími pre hodnotenie zmien v pôdnej organickej hmote jednotlivých systémov hospodárenia.

Received April 9, 2009
Accepted May 19, 2009