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Precipitation, Fertilization, and Crop Rotation Effects on Organic Carbon Changes

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Abstract:

It is well known the effect of fertilizer applications in Haplic Luvisols after crop production, but long term changes in precipitation and soil organic carbon are not well documented. The present study aimed to determine the effect of precipitation and fertilization (NPKCaMg) on the changes in soil organic carbon (SOC) in a long-term field experiment set up in Nyírlugos (Nyírség region, Hungary: N: 47º 41' 60'' and E: 22º 2' 80'') on a Haplic Luvisol with popular rotation crops. Over the 40 year period, from 1962 to 2002, SOC pool values ranged between 2.32 and 3.36 mg kg-1. On the untreated control plots the values remained nearly constant (3.31 mg kg-1: ±0.29 mg kg-1 and 0.52 mg kg-1). In the 1st 20-year period, (1963–1982) there was a significant (P<0.001) decrease (16%) on all experimental plots, which may be due to the winter half year (WHY) precipitation (228 mm), summer half year (SHY) precipitation (288 mm), the NPKCaMg fertilizer application rate (64 kg ha-1), and the potato–rye–wheat–lupin–sunflower crop sequence. In the 2nd 20-year period (1983–2002) SOC pool values varied betweem 3.13 and 4.47 mg kg-1. The 16.9% significant (P<0.001) increase 16.9% could be attributed to the lower WHY (204 mm) precipitation, higher SHY (320 mm) precipitation, higher NPKCaMg fertilizer rate (213 kg ha-1), and the sunflower–grass–barley–tobacco–wheat–triticale cropping system. NPKCaMg fertilization resulted in a significant (P<0.001) decline (16.6%) in SOC in comparison to the control plots in the 1st 20-year interval, while in the 2nd 20-year period a significant (P<0.001) rise (up to 31.9%) was registered. During the 40 experimental years the seasonal correlations (R^2) among SOC (mg•kg-1), WHY and SHY precipitation (mm) ranged from 0.3343 to 0.9078 (on the P<0.001 significance level). The correlations (R^2) on the influence of NPKCaMg fertilization on SOC (mg•kg-1) and precipitation (mm) were significant (P<0.001): the means for WHY, SHY and over the 40 years were 0.4691, 0.6171 and 0.6582, respectively. Organic carbon reserves (mg kg-1) in soils decreased linearly as precipitation increased (from 3.22 to 7.27 mm yr-1). In case this trend – increasing precipitation caused by climate change reduces SOC in arable soils – will continue, and is aggravated by warming temperatures and a more altering climate (as predicted by climate change forecasts), the livelihoods of many Hungarian and European farmers may be substantially altered. Thus, farmers must take into consideration the climate (WHY and SHY precipitation), fertilization (NPKCaMg), and cropping (tuber–seed–tobacco–protein–oil–forage) changeability to optimize their SOC pool, soil carbon sequestration, soil sustainability and crop management in the nearest future.

Keywords: *Organic Carbon, Precipitation, Fertilization, Crop Rotation*

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Introduction

Organic carbon in arable soils (SOC) has a favourable effect on soil fertility, soil tilth, crop production (Burke *et al.* 1989; Jolánkai 2005), and overall soil sustainability, as soil biological activity, biodiversity and soil biological productivity (Houghton *et al.* 1983; Lal 1995; Lal *et al.* 1995; Lal *et al.* 1998; Kirschbaum *et al.* 2001). SOC regulates, partitions soil water and solute transports, and filters, buffers, degrades, immobilizes, detoxifies organic and inorganic materials, including industrial and municipal by-products and atmospheric deposition (Patron *et al.* 1987; Burke *et al.* 1989; Bajtes and Sombroek 1997; Lal 2002; Várallyay 1992, 1994, 2005). SOC stores and cycles nutrients (Voss *et al.* 1970; Walter 1973; Kádár 1992; Kádár and Szemes 1994; Várallay 1994; Horst 1995) and other elements in the biosphere. With a renewed interest in climate change (CC), soil quality and long-term sustainability interrelations, research on soil organic carbon (SOC) status has taken on new significance, nowadays (Várallyay 2005). This can be explained by the fact that SOC correlates quite well with climate (precipitation) and a number of important soil physical, chemical and microbiological changes as a consequence of fertilization (Adams *et al.* 1995; Marschner 1995; David *et al.* 1998; Németh *et al.* 1998; Barrow *et al.* 2000; Bryant *et al.* 2000; Kirschbaum *et al.* 2001; Rosenzweig and Iglesias 2003; Várallyay 2005; Lásztity 2006). The optimisation of agricultural management for SOC accumulation benefits the sequestration of atmospheric CO_2, thereby partially mitigates the current increase in atmospheric CO_2 (Houghton *et al.* 1983; Schlesinger and Andrews 2000; Lal 2001, 2002). In addition to the environmental benefits of soil carbon sequestration (SCS), consideration has also been given to the implementation of a carbon (C) credit trading system, which may provide economic incentives for C sequestration initiatives (Parton *et al.* 1987; Smith *et al.* 1997; Metting *et al.* 2001; Post *et al.* 2001).

Recently, there is a concern that increased precipitation caused by climate change (CC) may reduce SOC in arable soils (Le Houérou 1995; Graef and Haigis 2001; Lal 2002; Wang *et al.* 2005; Márton 2005, 2007), because of the increased rate of SOC decomposition, and SOC leaching from the upper soil layer to the lower (Trierweiler and Lindsay 1969; Várallyay 2005; Russel and Jennifer 1991). Furthermore, fertilizer input limits (e.g., nitrogen, phosphorus, potassium, etc.) for crops have been introduced in Europe to reduce pollution originating from agriculture (Von Blottnitz 2006). In some countries (Germany, Portugal and Spain), where fertilizer limits are applied, crop yields and residue returns are expected to decline, and hence in agricultural systems there may be a reduction in the potential SOC equilibrum (Kádár 1992; Ardö and Olsson 2003; Von Blottnitz 2006). Long-term experiments are ideal for evaluating the complex influences of climate change (CC) (as precipitation) and agricultural practices (as crop fertilization) on changes in soil organic carbon (SOC). As at the moment, little is known about the net-interrelations of the quantity and distribution of precipitation, and NPKCaMg fertilization on altering SOC in soil, the present study aimed to investigate this problem in a long-term field experiment in Hungary.

Materials and Methods

The interrelations among the quantity and distribution of precipitation, mineral fertilization (N, P_2O_5, K_2O, CaO, MgO) and the changes in SOC were studied in a long-term field experiment set up at the Experimental Station of the Research Institute for Soil Science and Agricultural Chemistry of the Hungarian Academy of Sciences in Nyírlugos (Hungary) in 1962 (Láng, 1973) on a Haplic Luvisol (sandy, acidic lessivated brown forest soil) with different indicator crops [rye (*Secale cereale* L.), potato (*Solanum tuberosum* L.), winter wheat (*Triticum aestivum* L.), lupin (*Lupinus albus* L.), sunflower (*Helianthus annuus* L.), grass, barley (*Hordeum vulgare* L.), tobacco (*Nicotiana tabacum* L.), triticale (*X Triticosecale* W.)] for a 40-year period (1962–2002).

The experimental station is located in the Debrecen and Nyíregyháza region, found in the East Northern–Eastern part of the country. The area – 160 m above sea level – is a typical lowland field with very poor mineral resources in the soil (Marosi and Szilárd 1967). There are no major differences in elevation within the region, but the climate is rather variable. The local climate is somewhat drier in the summer and a bit warmer in the winter than that of the surrounding Hungarian Great Plain. The total number of sunny hours is 1900–2000 per year. The min/max temperatures are about -25 ºC and +35 ºC. The annual mean temperature is 10–12 ºC. The area is very windy (SW and NE). It is one of the driest parts of Hungary (Márton 2005) with an annual precipitation of only 520–550 mm (Kádár and Szemes 1994). The distribution of precipitation is uneven and unpredictable. The site is extremely drought sensitive. This is one of the major constraints explaining why plant production is less successful. The groundwater table level is found at a depth of 2–3 m.

The initial soil properties at the beginning of the long-term experiment (in 1962) were as follows (Láng 1973): particle-size distribution in the 0–25 cm layer: sand (> 0.05 mm) 70–85%, loam (0.05-0.002 mm) 8–20%, clay (< 0.002 mm) 3–6%; clay in colloid accumulation layers: 10–18%; saturation percentage: 25–30; pH(H_2O) 5.4; pH(KCl) 4.3; organic matter 0.5–0.8%; CEC 3–5 meq·100 g^{-1}. The main chemical characteristics of the plowed (0–25 cm) soil layer in the untreated plots in 1962, 1983, 1988, 1998 and 2002 are presented in Table 1. From 1962 to 1980 the trial included 2 (crops)×2 (plough)×16 (fertilization)×8 (replications) = 512 plots and from 1980 to 2001 32 (fertilization)×4 (replications) = 128 plots in random block design. The treatments and their combinations are shown in Table 2. The gross plot size was 10×5 = 50 m². The fertilizers were applied in the form of Ca-ammonium nitrate (N: 25%), superphosphate (P_2O_5: 18%), muriate of potash (K_2O: 40%), powdered limestone ($CaCO_3$: 96%) and dolomite (MgO: 14%).

The production technology was based on rainfall condition. Additional irrigation had not been used. The crop sequence was potato (tuber)–rye (seed)–wheat (seed)–lupin (protein)–sunflower (oil) in the 1st 20-year period (1963–1983), and sunflower (oil)–grass (forage)–barley (seed)–tobacco (tobacco)–wheat (seed)–triticale (seed) in the 2nd 20-year interval (1983–2002). The 1st and 2nd 20-year crop yield average was 3.37 and 2.47 t ha^{-1}, respectively (mean 2.9 t ha^{-1}).

Table 1. Chemical soil properties in the plowed (0–30 cm) layer of the untreated control plots of the long-term fertilization experiment on sandy, acidic lessivated brown forest soil (Nyírlugos) in 1963, 1983, 1988, 1998 and 2002

Year	pH		Hydro-lytic acidity	hy_1	Humus	Total Nitrogen	AL-soluble	
	H_2O	KCl					P_2O_5	K_2O
					%	mg kg-1		
1963	5.9	4.7	8.4	0.3	0,7	34	43	60
1983		4.16			0.35		67	57
1988		4.40			0.54		59	90
1998		3.41			0.55		65	27
2002		4.1			0,56		54	72.8

Table 2. Fertilizer treatments in the long-term fertilization experiment on sandy, acidic lessivated brown forest soil (Nyírlugos) between 1962 and 2002

From 1962 to 1980, kg ha^{-1} yr^{-1}

Control		
$N_1 = 30$ $N_2 = 60$ $N_3 = 90$	P = 48 (P_2O_5) K = 80 (K_2O) Mg = 15 (MgO)	
N, P, K, Mg combinations		
Control		
N_1	N_2	N_3
N_1P	N_2P	N_3P
N_1K	N_2K	N_3K
N_1PK	N_2PK	N_3PK
N_1PKMg	N_2PKMg	N_3PKMg

From 1980, k ha^{-1} yr^{-1}

Level	N	P_2O_5	K_2O	$CaCO_3$	$MgCO_3$
Control	0	0	0	0	0
1	50	60	60	250	140
2	100	120	120	500	280
3	150	180	180	1000	0

Precipitation was collected in a BES-01 collector (collecting precipitation on a standard 200 cm² surface) at the Meteorological Station in Napkor. The average precipitation (mm) in the 1st 20-year period for the winter half year (WHY) (October–March), the summer half year (SHY) (April–September), and the total year (YT) (October–September) was 228, 288 and 516 mm, while in the 2nd 20-year interval these values were 204, 320 and 523 mm, respectively.

Composite soil samples (consisting of 20 cores drawn from the 0–30 cm layer; Ap horizon) were collected randomly from each plot in 1963, 1973, 1983, 1988, 1998 and 2002. After thorough manual root separation the soil samples of all plots were air-dried at 40 ºC, sieved through a 2 mm mesh and ground. For measuring pH (KCl) the suspension was made 1 M L^{-1} with respect to KCl and stirred. The chemical analysis were carried out on the basis of standard procedures: pH (KCl) (MSZ 08-0206-2, Baranyai *et al.* 1987); hydrolytic acidity (HA) and exchangeable acidity (hy_1) (MSZ-080206-1-78, Baranyai *et al.* 1987); total N (Bremner and Keeney 1966); phosphorus and potassium (Egnér *et al.* 1960). Phosphorus was determined by photometry, and potassium by Atomic Emission Spectrophotometry (AES). Soil organic matter (SOM), and soil organic carbon (SOC) contents were determined by the Tyurin method (Baranyai *et al.* 1987; MSZ-080210-77 protocol).

All of the experimental data matrixes were estimated by ANOVA and MANOVA (One and Multivariate Analysis of Variance) by SPSS test (SPSS Inc., 2000). Results are shown on the averaged level of the main effects (N, P, K, Ca, Mg, NP, NK, NPK, NPKCa, NPKMg, NPKCaMg) to enable the summing up of the principal experimental results from the 40-year database.

Results and Discussion

The dynamics, seasonal changes and mechanisms of SOC in arable soils are essential in understanding and mitigating global climate change in interrelation with crop nutrition. Thus, with a renewed interest in soil quality and long-term sustainability, research on soil organic carbon (SOC) status has taken on new significance. This can be explained by the fact that SOC correlates quite well with climate (as precipitation), and the changes in a number of important soil chemical properties as a consequence of fertilization. The effects of NPKCaMg fertilization on the soil organic carbon (SOC) pool (in mg· kg^{-1} and in M ha^{-1}) between 1963 and 2002 are presented in Table 3.

In the 1st 20-year period, from 1963 to 1982 SOC yields ranged from 2.32 mg kg^{-1} (1.05 Mg ha^{-1}) to 3.48 mg kg^{-1} (1.58 Mg ha^{-1}) over all treatments. On the control plots SOC changed between 3.02 mg kg^{-1} (1.37 Mg ha^{-1}) and 3.36 mg kg^{-1} (1.52 Mg ha^{-1}), and stabilized at 3.21 mg kg^{-1} (1.45 Mg ha^{-1}). In case of untreated plots and those receiving unfavorable N, NP and NK rates, there was a 10.1%, 31.0%, 11.9% and 13.7% decline in SOC, respectively. In the NPK, NPKCa, NPKMg and NPKCaMg treated plots SOC decreased by 11.9%, 13.7%, 22.3% and 13.7% ($P<0.001$ level of significance). In comparison to the control plots there was a 5.0%, 1.3%, 2.5%, 2.5%, 7.3%, 3.7% decrease in the values in the N, NP, NK, NPKCa, NPKMg and NPKCaMg treatments and a 1.6% increase in the NPK-treated plots. In the various treatments the mean SOC mass production was as follows: control: 3.21 mg kg^{-1} (1.45 Mg·ha^{-1}), N: 3.05 mg kg^{-1} (1.38 Mg ha^{-1}), NP: 3.17 mg kg^{-1} (1.45 Mg ha^{-1}), NK: 3.13 mg kg^{-1} (1.42 Mg ha^{-1}), NPK: 3.27 mg kg^{-1} (1.48 Mg ha^{-1}), NPKCa: 3.13 mg kg^{-1} (1.42 Mg ha^{-1}), NPKMg: 2.98 mg kg^{-1} (1.35 Mg ha^{-1}), NPKCaMg: 3.09 mg kg^{-1} (1.40 Mg ha^{-1}). It can be stated that in the 1st 20-year period of the trial SOC concentration decreased from 3.36 mg kg^{-1} to 2.82 mg kg^{-1}, and SOC yield from 1.52 Mg ha^{-1} to 1.28 Mg ha^{-1}, in general. The depression in SOC may be due to the higher WHY.

Table 3. The effects of fertilization on the soil organic carbon (SOC) pool (mg kg^{-1} and Mg ha^{-1}, soil bulk density: 0.15 Mg ha^{3-1}) between 1963 and 2002

(Long-term fertilization experiment on sandy, acidic lessivated brown forest soil, Nyírlugos)

Treatment	Sampling year						Average
	1963	1973	1983	1988	1998	2002	
	SOC, mg kg^{-1}						
Control	3.36	3.25	3.02	3.13	3.83	3.25	3.31
N	3.36	3.48	2.32	3.54	3.83	3.94	3.41
NP	3.36	3.19	2.96	4.18	4.35	4.06	3.68
NK	3.36	3.13	2.90	3.65	4.18	4.00	3.54
NPK	3.36	3.48	2.96	4.47	4.23	4.12	3.77
NPKCa	3.36	3.13	2.90	3.83	4.12	3.77	3.52
NPKMg	3.36	2.96	2.61	4.06	3.89	4.23	3.52
NPKCaMg	3.36	3.02	2.90	4.00	3.83	3.77	3.48
$LSD_{5\%}$	0.0	0.29	0.87	1.51	0.93	0.58	0.70
Average	3.36	3.21	2.82	3.86	4.03	3.89	3.53

SOC, Mg ha^{-1}							
Control	1.52	1.47	1.37	1.42	1.73	1.47	1.50
N	1.52	1.58	1.05	1.60	1.73	1.99	1.58
NP	1.52	1.45	1.34	1.89	1.97	1.84	1.67
NK	1.52	1.42	1.31	1.66	1.89	1.81	1.60
NPK	1.52	1.58	1.34	2.02	1.92	1.87	1.71
NPKCa	1.52	1.42	1.31	1.73	1.87	1.71	1.59
NPKMg	1.52	1.34	1.18	1.84	1.76	1.92	1.59
NPKCaMg	1.52	1.37	1.31	1.81	1.73	1.71	1.58
$LSD_{5\%}$	0.0	0.13	0.39	0.68	0.42	0.26	0.31
Average	1.52	1.45	1.28	1.75	1.83	1.79	1.60

(228 mm) precipitation, lower SHY (288 mm) precipitation, lower NPKCaMg fertilizer application rate (64 kg·ha^{-1}), and the potato–rye–wheat–lupin–sunflower crop sequence, respectively.

In the 2nd 20-year period (1983–2002) of the trial SOC sets changed from 3.13 mg kg^{-1} (1.42 Mg ha^{-1}) to 4.47 mg kg^{-1} (2.02 Mg ha^{-1}) in all treatments. In the untreated plots the SOC yields ranged between 3.13 mg kg^{-1} (1.42 Mg ha^{-1}) and 3.83 mg kg^{-1} (1.73 Mg ha^{-1}), and stabilized at 3.40 mg kg^{-1} (1.54 Mg ha^{-1}). Comparing the 1963 mean SOC pool with the 2nd 20-year period's SOC pool of the control, N, NP and NK treated plots, it can be seen that the SOC yield was expanded by 1.3%, 12.2%, 24.9% and 17.4%, respectively. In the NPK, NPKCa, NPKMg and NPKCaMg treated soils the SOC stocks significantly (P<0.001) increased by 27.2%, 16.3%, 20.8% and 15.1%. Parallelly, yields increased by 10.8%, 23.3%, 15.9%, 25.6%, 14.8%, 19.3% and 13.6% in the case of the control, N, NP, NK, NPK, NPKCa, NPKMg and NPKCaMg treatments. Results of the 2nd 20-year experimental term show that SOC concentration grew from 2.82 mg kg^{-1} to 3.89 mg kg^{-1}, and SOC yield from 1.28 Mg ha^{-1} to 1.79 Mg ha^{-1}. The increase in SOC could be attributed to the lower WHY (204 mm) precipitation, higher SHY (320 mm) precipitation, higher NPKCaMg fertilization rate (213 kg ha^{-1}), and the sunflower–grass–barley–tobacco–wheat–triticale cropping system.

Over the 40-year period, the minimum and maximum SOC mean yields were 3.31 mg kg^{-1} (1.50 Mg ha^{-1}) and 3.77 mg kg^{-1} (1.71 Mg ha^{-1}). Without mineral fertilization the SOC pool stabilized at the level of 3.31 mg kg^{-1} (1.50 Mg ha^{-1}). As compared to the untreated plots, the N, NP, NK and NPK treatments led to a significant (P<0.001) yield rise of 3.02%, 11.2%, 6.9% and 13.9%, respectively, while the NPKCa, NPKMg or NPKCaMg combinations resulted in an increase of 6.3%, 6.3% and 5.1%.

Table 4. Correlations (R^2) between precipitation (mm) of winter half years (WHY), summer half years (SHY), years total (YT), and soil organic carbon (SOC) stock (mg kg^{-1}) between 1963 and 2002

(Long-term fertilization experiment, sandy, acidic lessivated brown forest soil, Nyírlugos)

	Winter Half Year (October–March)	Summer Half Year (April–September)	Year Total (October–September)

	Precipitation, mm		
Minimum	111.5	301.7	353.0
Maximum	320.6	372.6	781.0
Average	216.1	337.2	567.0
	Soil Organic Carbon (SOC), mg kg^{-1}		
Minimum	-	-	2.32
Maximum	-	-	4.47
Average	-	-	3.40
	Precipitation and SOC Model		
Function	$Y'=-1205.5-7.7x+0.02x^2$	$Y'=1069.8+11.2x-0.02x^2$	$Y'=-4790.8-16.8x+0.02x^2$
n	160	160	160
R^2	0.7049 (P<0.001)	0.9204 (P<0.001)	0.6582 (P<0.001)

The correlations (R^2) between precipitation (mm) of the winter half years (WHY), summer half years (SHY), total years (TY) and soil organic carbon (SOC) stocks (mg kg^{-1}) between 1963 and 2002 are shown in Table 4. The main relationships are characterized mainly by polynominal correlations (winter-half year: R^2 = 0.7049 at P<0.001, summer-half year: R^2 = 0.9204 at P<0.001, year total: R^2 = 0.6582 at P<0.001). The total coefficients (R^2) among precipitation and SOC sink fluctuated from 0.65 to 0.92 at P<0.001 depending on the different precipitation (mm yr^{-1}), and the fertilization (kg ha^{-1} yr^{-1}) rates. The correlations (R^2) for the winter half years and years total were negative, while they were positive for the summer half years. SOC reserves in soils decreased linearly with increasing rainfall, from 322 to 727 mm yr^{-1}.

Summary and Conclusions

Summing up our findings, it can be stated that in the 1st 20-year period (from 1962 to 1983) of the trial SOC concentration decreased strongly (16%). The depression in SOC may be due to the higher WHY (228 mm) precipitation, lower SHY (288 mm) precipitation, lower NPKCaMg fertilization level (64 kg ha^{-1}), and the tuber–seed–seed–protein–oil crop sequence, respectively. This is particularly true ,when we are talking about Luvisols. The less than 15 cm “A” horizon and low organic matter content support eluviations processes. The eluviations of clay in organic and inorganic forms is the dominant process, where the leaching of carbonates is prerequisite before clay can translocate. When clay particles are dispersed in aqueous suspension, as effect of the seasonal precipitation, they are translocated from the “A” and “E” horizon under the influence of percolating water. The influence of organic matter as electron donor for reduction and solubilisation iron oxides causes the leaching of iron. The presence of organic acids destabilizes the soil micro-aggregates and produces dispersible leaching clays. Results of the 2nd 20-year experimental term (from 1983 to 2002) show that there was a 38% rise in SOC concentration, which can be attributed to the lower WHY (204 mm) precipitation, higher SHY (320 mm) precipitation, higher NPKCaMg fertilizer rate (213 kg ha^{-1}), and the oil–forage–seed–tobacco–seed–seed cropping system. The unpredictable moisture regime (because the variable precipitation) favors the declination of SOC, because the wetahering and translocation processes are supported by percolation water and the precipitation of translocated material by the erratic moisture regime.

Since the 1950s, there has been a significant expansion in the variability experienced by European and Hungarian farmers in term of soil organic carbon (SOC), seasonal precipitation, NPKCaMg fertilization, and cropping changeability has also increased over the same period. The dynamics, seasonal changes and mechanisms of SOC in arable soils are essential in understanding and mitigating global climate change in interrelation with crop nutrition. There is a concern that increasing precipitation as a result of climate change, and reduced fertilizer input may reduce SOC in arable soils, as stated by Le Houérou (1995), Wigley (1999), Graef and Haigis (2001), Lal (2002), Wang *et al.* (2005) and Márton (2007). If this trend continues, and is aggravated by warming temperatures and a more altering climate, as predicted by climate change forecasts, the livelihoods of many Hungarian and European farmers may be substantially altered. Thus, it should be emphasized that farmers must take into consideration the changeability of climate (WHY and SHY precipitation), fertilization (NPKCaMg), and cropping pattern (tuber–seed–tobacco–protein–oil–forage) to optimize their SOC pool, soil carbon sequestration, soil sustainability and crop management in the nearest future. Especially important fact the increased calcium content by fertilization, because it increases the exchangeable calcium content in the soil, which flocculates clay particles. The created particles are too large to be transported in suspension. The calcium-humate aggregate's komplex is not soluble and water resistent (it expands but not leaching).

The changes in the crop rotation also has a stabilizing effect on SOC. Crops like grass increase SOC in two ways. First, they contribute with additional organic matter into SOM. Second, illuviated materials are deposited (or block illuviaton) along the root channels instead on the surfaces of argillans from the deeper soil horizon.

However, the presented study demonstrated that the properly calibrated and tested long-term experiment-based models are capable of detecting SOC yield responses to climatic (at first winter half year, summer half year and year total precipitation) variations (closely corresponding with the findings of Jolánkai 2005 and Márton *et al.* 2007) in interaction with several nitrogen, phosphorus, potassium, calcium and magnesium fertilization systems for Hungary and on the European level under the changeable climate conditions.

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