A 40-YEAR RECORD OF SOIL ORGANIC CARBON (SOC) SEQUESTRATION IN AN INTENSIVE CROPPING SYSTEM IN HUNGARY

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1 INTRODUCTION

In recent years there has been growing concern that increased precipitation caused by climate change (CC) may reduce Soil Organic Carbon (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 to lower soil layers (Trierweiler and Lindsay 1969; Várallyay 2005; Russel and Jennifer 1991). Furthermore, new 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 SOC in soil, the present study aimed to investigate this problem in a long-term field experiment in Hungary.

2 MATERIALS AND METHODS

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}.

From 1962 to 1980 the trial included 2 (crops)×2 (plough)×16 (fertilization)×8 (replicats) = 512 plots and from 1980 to 2001 32 (fertilization)×4 (replicats) = 128 plots in random block design. The gross plot size was 10×5 = 50 m². The main chemical characteristics of the ploughed (0-25 cm) soil layer in the untreated plots in 1962, 1983, 1988, 1998 and 2002 are presented in TABLE 1. The treatments and their combinations are shown in TABLE 2.

TABLE 1 **Chemical soil properties in the ploughed (0–30 cm) layer of the untreated control plots of the long-term fertilization experiment on sandy, acidic leached 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 leached brown forest soil (Nyírlugos) between 1962 and 2002**

From 1962 to 1980, kg·ha^{-1}·yr^{-1}					
No Fertilization					
$N_1 = 30$			$P = 48$ (P_2O_5)		
$N_2 = 60$			$K = 80$ (K_2O)		
$N_3 = 90$			$Mg = 15$ (MgO)		
N, P, K, Mg combinations					
No Fertilization					
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, kg·ha^{-1}·yr^{-1}					
Code	**N**	**P_2O_5**	**K_2O**	**$CaCO_3$**	**$MgCO_3$**
0	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 averaged 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.

The average fertilizer rates in kg ha^{-1} year^{-1} were nitrogen 75, phosphorus 90 (P_2O_5), potassium 90 (K_2O), calcium 437.5 ($CaCO_3$) and magnesium 140 ($MgCO_3$). The fertilizers were applied in the form of calcium-ammonium nitrate (N: 25%), superphosphate (P_2O_5: 18%), muriate of potassium (K_2O: 40%), powdered limestone ($CaCO_3$: 96%) and dolomite (MgO: 14%). 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}).

3 RESULTS AND DISCUSSION

Soil organic carbon (SOC) has strong influence on soil fertility, and crops yield. Several studies shown that continuous cropping decreases soil organic carbon stocks rapidly in the initial years. 40 year soil database was evaluated to investigate the impact of intensive ray-potato-wheat-triticale cropping system on SOC sequestration in a Long Term Field Fertilization Experiment at Nyírlugos in North-Eastern Hungary (N: 47º 41’ 60’’ and E: 22º 2’ 80’’) on an acidic sandy soil from 1962 to 2002. Intensive fertilization and cropping resulted in a significant ($P<0.001$) decrease in SOC (16%) on all experimental plots in the 1st 20-year period, (1963–1982). In the 2nd 20-year period (1983–2002) SOC pool values were improved by 16.9%. The correlation (R^2) between precipitation sums for different periods of experimental years (Winter Half Year: WHY, Summer Half Year: SHY), and NPKCaMg fertilization on SOC (mg·kg^{-1}) contents were significant ($P<0.001$): the means for WHY, SHY over 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}). Therefore, in the case of a trend - for growing precipitation caused by climate change, there will be associated reduction in SOC in soils. This process probably will continue in the future. Thus, farmers must take into consideration the climate (WHY's and SHY's precipitation), fertilization (NPKCaMg), and cropping changeability to optimize their SOC pool and crop management.

4 CONCLUSIONS

Since the 1950s, there has been a significant increase 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. 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. 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 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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