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Carbon stocks, sequestration rate and efficiency over 50 years of increasing mineral N fertilization

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Abstract: Microbially mediated soil organic matter is an extremely sensitive pool that indicates subtle changes in the quality parameters. Calculation of different carbon pools (organic carbon – OC, labile carbon – PMC, light carbon – LFC and microbial carbon – MBC), their sequestration rate (Csr) and efficiency (Cse) as affected by 50 yrs. of mineral fertilization was done. C sequestration rate between the fertilized plots were not significantly different except for the control plot. The sensitivity index, which indicates the response of soil organic matter to changes in different carbon fractions, demonstrated a strong correlation with the amount of light-fraction organic matter (OM). Use of mineral N over 50 years resulted in increase of soil labile C, but not resulted in greater C sequestration efficiency. The results give a deeper insight into the behavior of carbon pools and can serve as a reliable basis for further researches focused on neutral carbon emissions and effective C sequestration.

Keywords: sequestration rate; carbon pools; labile carbon; microorganisms; mineral fertilization; nitrogen

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1. Introduction

Soil organic carbon (SOC) sequestration in agricultural soil is directly affected by anthropogenic activities and climate change; both can alter net primary production (NPP) and organic matter decomposition (Yan et al., 2010). Under the same climatic, soil and topographic conditions the biomass and activity of soil microorganisms are the main conductors of SOM mineralization and CO2 fluxes. Generally, long-term fertilization adversely affects soil microbial community (Huang et al. 2019; Koković et al., 2021). Microbially mediated soil organic matter is an extremely sensitive pool that indicates subtle changes in the quality parameters responsible for the soil's ecological and productive functions. However, accumulation of organic carbon in soil is a slow and reversible process. In contrast, the annual fresh plant litter decomposes during one growing season thus returning back organic carbon into atmosphere as a carbon dioxide. In Serbia, agricultural production is still largely based on traditional land management. In previous works, we outlined the effect of long-term application of synthetic fertilizers on various soil properties and parameters (Koković et al., 2021, Koković et al., 2022). In these studies, it was found that increasing dose of synthetic nitrogen naturally led to an increase in the yield, and thus also in the biomass of plant residues. The latter resulted that labile carbon pools also increased. The purpose of this work was to establish how increasing doses of synthetic nitrogen may or may not contribute to carbon sequestration.

2. Materials and methods

In a field experiment lasting more than 50 years, four variants of different doses of mineral fertilizers with increasing doses of nitrogen and equal doses of phosphorus and potassium fertilizers were selected and compared with a control that did not receive either synthetic or organic fertilizers. The detailed description of the study site and experimental design can be found in the Koković et al. (2021). The soil type was *Eutric Cambisol*, and the area is located in central Serbia (44°24′58″ N and 20°10′34″ E). The plots were arranged in a randomized block design in four replications.

Soil respiration was measured by alkali trap method under controlled laboratory conditions (temperature 28°C and soil moisture 50% WHC) at the following intervals: 3, 9, 16, 30, 44, 62, and 83 days for each treatment in four replications. The potentially mineralizable carbon (PMC) and mineralization rate constant (k) were calculated using the first-order kinetic model, (Exponential Rise to Maximum; SPSS Inc., Sigma Plot 14). The microbial biomass carbon (MBC) was determined by fumigation-incubation method (Jenkinson and Powlson, 1976). The light fraction C (LFC) was determined in CNS atomic analyzer after isolation by density with a NaI solution (Janzen et al., 1992).

Carbon stocks (Mg/ha) of SOC, LFC, PMC and MBC as well as carbon sequestration rate C_{SR} (Mg/ha/y) and the carbon sequestration efficiency C_{SE} (%) for each fraction of carbon were calculated as described in Xiang et al. (2022).

3. Results and discussion

In general, with an increase in the dose of mineral nitrogen, all the studied carbon pools increased accordingly (Table 1). A significant difference was observed between the control and all fertilized treatments, as well as between lower and higher doses of N. Higher doses of mineral nutrition produce higher plant biomass, both aboveground and belowground (Koković et al., 2021). Long term accumulation of crop residues as an easily available organic substrate resulted in greater accumulation of labile fractions of SOM under N120 and N150 treatments. Generally, prolonged use of synthetic fertilizer can adversely affect soil biota (Huang et al., 2019; Koković et al., 2021). However, when soil samples were placed in controlled conditions with optimal moisture and temperature, the microbes began to grow actively. This in turn led to high levels of labile carbon pools. In addition, autumn samples contain significantly more labile fractions of organic matter that return after harvesting.

Table 1. Labile fractions of soil organic matter.

Treatment	**Fertilizer**	**OC, %**	**LFC mg/kg**	**PMC, mg/kg**	**MBC, mg/kg**	***q*CO₂**
control	0	0.92b ± 0.02	332.44a	913.91a	188.31a	3.664a
N60	$N_{60}P_{51}K_{67}$	0.98b ± 0.02	589.55b	1287.95b	228.66b	4.562b
N90	$N_{90}P_{51}K_{67}$	1.08c ± 0.03	590.69b	1893.50c	295.91c	5.694c
N120	$N_{120}P_{51}K_{67}$	1.13c ± 0.03	650.16c	1840.94c	342.99d	4.743b
N150	$N_{150}P_{51}K_{67}$	1.14c ± 0.02	680.49c	2054.64c	352.14d	5.331c
t-test		**	**	***	***	**
		$p < 0.05$	$p < 0.05$	$p < 0.001$	$p < 0.001$	$p < 0.05$

Note: ** Significantly different at $p < 0.01$; values followed by the same letter in a column are not significantly different; OC—organic carbon; LFC – light fraction carbon; PMC – potentially mineralizable carbon; qCO_2 – microbial metabolic quotient.

In contrast to the concentrations of the labile C pools, their reserves did not differ significantly, except for the control and the lowest dose of N (N60) (Table 2). Hence, delta carbon stocks showed the same trend.

Table 2. Carbon stocks in different fractions.

treatment	**Carbon stock, t/ha**	**Δ carbon stock, t/ha**

	OC	PMC	LFC	MBC	OC	PMC	LFC	MBC
0	1.0585a	1.1058a	0.4023a	0.2279a				
N60P80K80	1.2110b	1.5584a	0.7134b	0.2767a	0.1524a	0.0355a	0.0247a	0.0037a
N90P80K80	1.2639b	2.2911b	0.7147b	0.3581ab	0.2054b	0.0959b	0.0253a	0.0105b
N120P80K80	1.2756b	2.2275b	0.7867b	0.4150b	0.2171b	0.0924b	0.0317ab	0.0154b
N150P80K80	1.2917b	2.4861b	0.8234b	0.4261b	0.2332b	0.1134b	0.0346ab	0.0163b

Note: values followed by the same letter in a column are not significantly different.

Calculations of the rate and efficiency of carbon sequestration for each carbon pools showed that, in general there was no significant difference between the treatments with increasing doses of mineral N (Table 3) for LFC and MBC, while OC and PMC showed less sequestration efficiency at the lowest dose (N60) of mineral N compared to N120 and N150.

Table 3. Carbon sequestration rate and efficiency.

treatment	**Csr, Mg/ha/yr**				**Cse**, %			
	OC	PMC	LFC	MBC	OC	PMC	LFC	MBC
N60P80K80	0.3049a	0.0710a	0.0494a	0.0075a	0.07664a	0.07848a	0.07934a	0.07680a
N90P80K80	0.4109a	0.1917b	0.0505a	0.0210b	0.05541ab	0.08088ab	0.08085a	0.08080a
N120P80K80	0.4343a	0.1848b	0.0634a	0.0309b	0.03822b	0.08237b	0.08241a	0.08252a
N150P80K80	0.4665ba	0.2268b	0.0693ba	0.0327b	0.03983b	0.08216b	0.08226a	0.08238a

Note: Csr – carbon sequestration rate, Mg/ha/year; Cse – carbon sequestration efficiency, %.

This study confirmed that long-term field experiments provide a highly reliable basis for setting realistic targets for carbon sequestration in traditionally managed agricultural landscapes. Although the addition of higher doses of mineral nitrogen has increased the concentration of labile carbon pools over 50 years, it has not been able to effectively sequester carbon. This research provides greater insight into the carbon cycle and sequestration potential of a traditional agricultural system that uses only synthetic fertilizers.

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References

1. Huang L, Riggins CW, Villamil MB, Rodríguez-Zas S, Zabaloy MC. Long-term N fertilization imbalances potential N acquisition and transformations by soil microbes. Sci. Total Environ. 2019. 691, 562–571, https://doi.org/10.1016/j.scitotenv.2019.07.154
2. Janzen HH, Compbell CA, Brandt SA, Lafond GP, Townley-Smith L. Light-fraction organic matter in soils from long-term crop rotation. Soil Sci. Soc. Am. J. 1992, 56, 1799–1806, https://doi.org/10.2136/sssaj1992.03615995005600060025x
3. Jenkinson DS, Powlson DS. The effect of biocidal treatments on metabolism in soil – V: A method for measuring soil biomass. Soil Biol. Biochem. 1976. 8, 209–213, https://doi.org/10.1016/0038-0717(76)90005-5.
4. Koković N, Jačimović G, Sikirić B, Čirić V, Ugrenović V, Zhapparova A, Saljnikov E. Changes in Eutric Cambisol due to long-term mineral fertilization: A case study in Serbia. Italian Journal of Agronomy. 2022; 17:2029; doi:10.4081/ija.2022.2029
5. Koković N, Saljnikov E, Eulenstein F, Čakmak D, Buntić A, Sikirić B, Ugrenović V. Changes in Soil Labile Organic Matter as Affected by 50 Years of Fertilization with Increasing Amounts of Nitrogen. Agronomy. 2021; 11(10):2026. https://doi.org/10.3390/agronomy11102026
6. Xiang Y, Cheng M, Wen Y, Darboux F. Soil Organic Carbon Sequestration under Long-Term Chemical and Manure Fertilization in a Cinnamon Soil, Northern China. Sustainability 2022, 14, 5109. https://doi.org/10.3390/su14095109
7. Yan X, Cai Z, Wang S, Smith P. Direct measurement of soil organic carbon content change in the croplands of China. Global Change Biol. 2010; 17, 1487–1496