Active carbon pool-size is enhanced by long-term manure application

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Abstract: We studied the dynamics of soil organic carbon (SOC)-pool mineralisation in agricultural soil. A laboratory incubation experiment was conducted using the soil from a long-term experiment involving the following fertilisation regimes: no fertilisation (CK); mineral (NPK); organic (M), and combined organic-inorganic fertilisers (MNPK). SOC mineralisation rate decreased as follows: MNPK > M > NPK > CK. Cumulative SOC mineralisation (C_m) ranged between 730.15 and 3 022.09 mg/kg in CK and MNPK, respectively; 8.81% (CK) to 20.45% (MNPK) of initial SOC was mineralised after a 360-day incubation. Soil C_m values were significantly higher under NPK, M, and MNPK compared to those under the CK treatment. Dynamic variation in C_m with incubation time fitted a double exponential model. Active carbon pools accounted for 2.06–6.51% of total SOC and the average mean resistant time (MRT_1) was 28.76 days, whereas slow carbon pools accounted for 93.49–97.94% of SOC, with an average MRT_2 of 8.53 years. The active carbon pool in fertilised soils was larger than in CK; furthermore, it was larger in M- and MNPK- than under NPK-treated plots. SOC decomposed more easily in long-term fertilised plots than in non-fertilised plots.

Keywords: macronutrient; land use management; decomposition; fluvo-aquic soil; long-term fertilisation; organic carbon mineralisation

Soil organic carbon (SOC) plays a critical role in maintaining crop productivity and yield stability. The proportion of SOC is the largest in global terrestrial carbon (C) pools (Pan et al. 2009). Approximately 1 500 Pg of C is present in soils of terrestrial ecosystems, which is two times higher than atmospheric C and three times higher than C in terrestrial vegetation. Soil organic matter (SOM) decomposition accounts for a large proportion of global CO_2 emissions (Zhao et al. 2020). Annual net C release from agriculture is estimated at 2.5 Pg (Smith 1999), and farmlands may act as carbon sources or sinks, depending on the specific land use and management method (Olesen and Bindi 2002).

Current crop production models largely rely on fertilisers, as these have significantly increased yields (Hou et al. 2015). However, fertilisers affect soil properties; thus, for example, fertilisers reportedly increased SOC and influenced SOC dynamics (Wang et al. 2016). In China, long-term fertilisation has led to increased topsoil SOC at rates of approximately 0.19 and 0.13 g/kg/year in paddy and highland soils, respectively. Wang et al. (2010) reported that the increase in SOC was more significant in

soils where organic/mineral compound fertilisers or organic fertilisers were used instead of mineral fertilisers. Furthermore, the mineralisation of C pools increased significantly and nutrients were released rapidly by organic fertiliser application (Ribeiro et al. 2010). Similarly, Mohanty et al. (2013) reported that potentially mineralisable soil organic carbon was significantly enhanced under a 41-year rice-rice rotation pattern with long-term mineral and organic compound fertiliser application in India. Similar results have been documented in an irrigated sandy soil in Germany (Bidisha et al. 2010) and a red-earth paddy soil in China (Zheng et al. 2012).

Based on relative susceptibility to biological decomposition, SOC is divided into two main fractions: active and slow SOC pools (McLauchlan and Hobbie 2004). As organic C mineralisation is mostly associated with active SOC pool decomposition, SOC mineralisation is significantly affected by changes in the proportions of active and slow SOC pools (Fang et al. 2005), which in turn are affected by changes in land use. Thus, the slow SOC fraction significantly increased when initial cropland use was replaced by permanent grassland over 77 years (Lopes de Gerenyu et al. 2008). Furthermore, the mineralisation rate constant was recently shown to increase from 0.032 to 0.047 with cow manure application; consequently, the half-life time ($T_{1/2}$) of the active SOC pool decreased from 21.7 to 14.8 days (Guo et al. 2019).

Since the early 1980s, the Government of China has recommended organic and balanced fertilisation to promote sustainable agriculture. To investigate the effects of organic and balanced fertilisation on crop yield, long-term fertilisation patterns have been established (Li et al. 2015), thereby providing an opportunity to explore the influence of fertilisation regimes and fertiliser types on SOC pools and their mineralisation patterns.

Herein, we report the results of a laboratory study in which soil samples from a 35-year fertilisation experiment set in the Huang-Huai-Hai Plain in China were incubated for 360 days. Then, using double exponential models, we evaluated the effects of different long-term fertilisation regimes on: (1) soil properties; (2) SOC mineralisation rate, and (3) SOC pool size and mean residence time (MRT).

MATERIAL AND METHODS

Site description. A long-term fertilisation experiment was established in 1980 in the fields of the Experimental Station at the Xuzhou Institute of Agricultural Sciences, in Xuhuai District (34°16'N; 117°17'E), Jiangsu province, China. The region is characterised by a warm, semi-humid, continental monsoon climate with an average annual temperature of 14 °C, and average annual precipitation and evaporation of 860 and 1 870 mm, respectively. The mean annual sunshine duration is 2 317 h and the frost-free period is 210 days. The soils at the site are fluvo-aquic sandy loams formed from alluvial parent material of the Yellow River. The initial (1980) concentrations of nutrients in the topsoil layer (0–20 cm) were: SOC – 6.26 g/kg; total soil nitrogen (TN) – 0.66 g/kg; total soil phosphorus (TP) – 0.74 g/kg; available soil phosphorus (AP) – 12.0 mg/kg; and available soil potassium (AK) – 63.0 mg/kg. Soil pH (1:2.5, *w*:*v*) was 8.01. At the beginning of the experiment, in 1980, a wheat-maize rotation system was established. Wheat was mechanically sown at a spacing of 15 cm between rows for a plant density of 3×10^6 plants/ha. In turn, maize was mechanically sown at a spacing of 60 cm between rows and 23 cm between seeds for a plant density of 72 000 plants/ha. In 2002, maize was substituted with sweet potato. Sweet potatoes were mechanically transplanted at a spacing of 80 cm between rows and 25 cm between seedlings for a plant density of 49 500 plants/ha. After the cultivation of cereals, the straw above the ground was removed and the root stubble was incorporated. However, sweet potato plants were harvested completely, leaving no root tubers or aboveground biomass in the field. Crop management followed conventional procedures in the region.

Experimental design. Treatments included: (1) CK – no fertiliser control; (2) NPK – 300, 66, and 178 kg/ha N, P, and K, respectively. Sources of NPK were urea (46% N), diammonium phosphate (15% N, 18.3% P), and potassium sulfate (41.5% K); (3) M – organic fertiliser (from 1980 to 1984: 75 t/ha horse manure; from 1985 to 2015: 37.5 t/ha cattle manure); and (4) MNPK – organic-inorganic fertiliser (from 1980 to 1984: 75 t/ha horse manure plus NPK treatment, and from 1985 to 2015: 37.5 t/ha cattle manure plus NPK treatment). Horse and cattle manures were gathered from a nearby dairy and composted for at least four months. Manure composition included 6.32, 2.24, and 6.09 g/kg N, P, and K, respectively. C:N ratio was 20.3:1. In the crop rotation system, the total fertiliser dose was divided into two equal portions and applied during winter wheat and summer maize or sweet potato

cultivation, respectively. For wheat and maize, 50% of the N fertiliser was applied basally and the rest as a topdressing, whereas P and K fertilisers, and manure were applied basally.

Four replicate plots were distributed in a randomised complete block design for each treatment; each plot was 33.6 m^2 (4.8 m × 7.0 m), with a 1.0-m concrete slab separating the plots to prevent cross-contamination.

Sample collection. Soil samples from the topsoil layer (0–20 cm) were collected in June 2015, after winter wheat harvest. Crop residues on the soil surface were carefully removed before sampling, and five soil cores (3.8 cm inner diameter) were obtained from each plot and mixed. Both roots and plant debris were removed and the remaining samples were air-dried and passed through a 2 mm sieve.

Soil chemical analysis and respiration measurement. SOC and TN concentrations were determined using the K_2CrO_7-oxidation method and the Kjeldahl digestion procedure, respectively. The concentration of TP was analysed using the molybdenum blue method after digesting the soil samples with $HClO_4$-H_2SO_4. The concentration of NO_3^--N and NH_4^+-N was analysed using a flow injection autoanalyser after extracting the samples with 2 mol/L KCl. Available P concentration was determined using the Olsen-P method. To estimate AK, samples were extracted with 1 mol/L NH_4OAc (pH 7.0) and analysed by flame photometry. The pH of a 1 : 2.5 soil-water suspension was measured using a glass electrode. All procedures were as described previously (Duan et al. 2015).

Soil respiration was measured using the alkali absorption method (Xu et al. 2014); 30-g soil samples were placed in 150 mL plastic bottles (3 cm diameter) and distilled water was added to 60% water-holding capacity. All samples were placed in the dark for one day (25 ± 1 °C). Subsequently, small beakers containing 25 mL of 0.4 mol/L NaOH (alkali absorption cups) were placed at the bottom of each bottle, and the whole units were sealed and placed in a dark incubator at 25 ± 1 °C. These alkali absorption cups were replaced on days 2, 4, and 7 during the first week, then, weekly during the following 8 weeks, biweekly during the following month, and monthly during the rest of the experimental period. CO_2 trapped inside the lye absorption cups was measured after adding 2 mL of 1 mol/L $BaCl_2$ solution and two drops of phenolphthalein and then titrating with 0.05 mol/L HCl to a colourless solution (calibrated with borax before each titration). SOC cumulative mineralisation was calculated based on the amount of CO_2 released from the soil samples during the incubation period. Cumulative C mineralisation (C_m) is expressed as CO_2-C mg/kg of soil.

Model description. The turnover time of SOC pools can be estimated using a double exponential model (Yang et al. 2006, Zhao et al. 2008), as per the following equation:

$$C_{mr}(\%) = a \times (1 - e^{-k_1 t}) + b \times (1 - e^{-k_2 t})$$

where: t – number of incubation days; C_{mr} – cumulative value of mineralised SOC at time t; a and b – portion of active C and slow C; k_1 and k_2 – mineralisation rate constants for active and slow SOC-pools, respectively (unit: per day).

This double decomposition equation for the two distinct C pools with different mineralisation rate constants was fitted with a non-linear regression model (SPSS 16.0) based on the Levenberg-Marquardt algorithm. An iterative process was performed to determine the parameters that minimised the residual sum of squares. The model with the least square error was considered the best model. To choose a model, all parameters should provide credible results in realistic situations; for example, the rate constant values should be positive, and the concentration of both active and slow C pools should be lower than the total SOC concentration.

Statistical analysis. ANOVA and the least significant difference (*LSD*) test were applied to analyse fertilisation effects using the SPSS 16.0 package (IBM Corp, Armonk, USA). Pearson linear regression was used to evaluate the relationships among parameters.

RESULTS

Soil chemical properties. Soil organic carbon, TN, C/N, TP, NO_3^--N, AP, and AK concentrations under the NPK, M, and MNPK treatments increased significantly relative to CK, but there was no significant effect on the NH_4^+-N concentration (Table 1). Compared with NPK, M, and MNPK treatments significantly increased SOC, TN, TP, AP, and AK concentrations. The prolonged use of fertilisers increased the C/N ratio, particularly under NPK and MNPK treatments. Additionally, fertilisation significantly reduced soil pH, from 8.08 (CK) to 7.71 (NPK).

Soil organic C mineralisation. The rate of CO_2-C evolution was highest in all treatments at the start of incubation, and then decreased progressively

Table 1. Soil chemical properties

Treatment	SOC	Total N	C/N	Total P	NO_3^--N	NH_4^+-N	Available P	Available K	pH_{H_2O}
	(g/kg)			(g/kg)	(mg/kg)				(2.5:1)
CK	8.43 ± 0.43[d]	0.77 ± 0.03[d]	10.96 ± 0.25[c]	0.62 ± 0.622[d]	6.75 ± 0.756[b]	5.84 ± 0.846[a]	4.12 ± 0.126[d]	46.84 ± 6.84[d]	8.08 ± 0.084[a]
NPK	11.41 ± 1.41[c]	0.94 ± 0.942[c]	12.18 ± 2.18[a]	0.98 ± 0.984[c]	15.36 ± 5.36[a]	6.54 ± 0.546[a]	15.04 ± 5.04[c]	75.25 ± 5.25[c]	7.71 ± 0.715[d]
M	14.42 ± 4.42[b]	1.27 ± 0.04[b]	11.34 ± 1.34[b]	1.25 ± 0.205[b]	17.58 ± 7.58[a]	8.44 ± 0.448[a]	62.51 ± 2.51[b]	79.43 ± 9.43[b]	7.94 ± 0.943[b]
MNPK	18.93 ± 8.93[a]	1.57 ± 0.574[a]	12.03 ± 2.03[a]	1.55 ± 0.554[a]	15.37 ± 5.37[a]	8.19 ± 0.197[a]	91.90 ± 1.90[a]	110.84 ± 10.8[a]	7.85 ± 0.858[c]

SOC – soil organic carbon; CK – no fertiliser; NPK – mineral fertiliser; M – organic fertiliser; MNPK – organic-inorganic fertiliser. Different letters within columns indicate significant differences ($P < 0.05$)

(Figure 1). Total SOC mineralised over the 360-day experimental period can be considered the potentially mineralisable C pool. In this study, this pool decreased considerably from days 1 to 35 and then remained at a low and relatively constant level. Daily SOC mineralisation rate decreased in the following order: MNPK > M > NPK > CK; the difference between M and NPK treatments was not significant up to day 300 of incubation. This pattern fitted a logarithmic function, with R^2 values ranging from 0.7097 (CK) to 0.8548 (MNPK) (Table 2).

The C_m increased with incubation time under all fertilisation regimes (Figure 2) and the differences among treatments gradually increased with the incubation period. Thus, C_m values ranged from 730.15 (CK) to 3 022.09 mg/kg (MNPK) after 360 days of incubation, with significant treatment differences. By the end of the incubation period, the C_m value estimated for NPK-, M-, and MNPK-treated soils had significantly increased by 117.79, 190.03, and 313.90% relative to CK treatment, respectively. Therefore, C_m values in soils subjected to long-term manure applications were higher than for soils under mineral fertilisation alone (NPK); furthermore, C_m values of the samples under MNPK treatment were significantly higher than under M treatment at most sampling time-points during the experimental period ($P < 0.05$).

After 360 days of incubation, C_{mr} ranged from 8.81% to 20.45%, with the highest values recorded under MNPK treatment (Figure 3). C_{mr} under all, NPK, M, and MNPK treatments were higher than under CK, with an increase of 95.04, 95.61, and 132.17%, respectively. The C_{mr} value under MNPK was higher than under M and NPK treatments (19.04% and 18.69%, respectively).
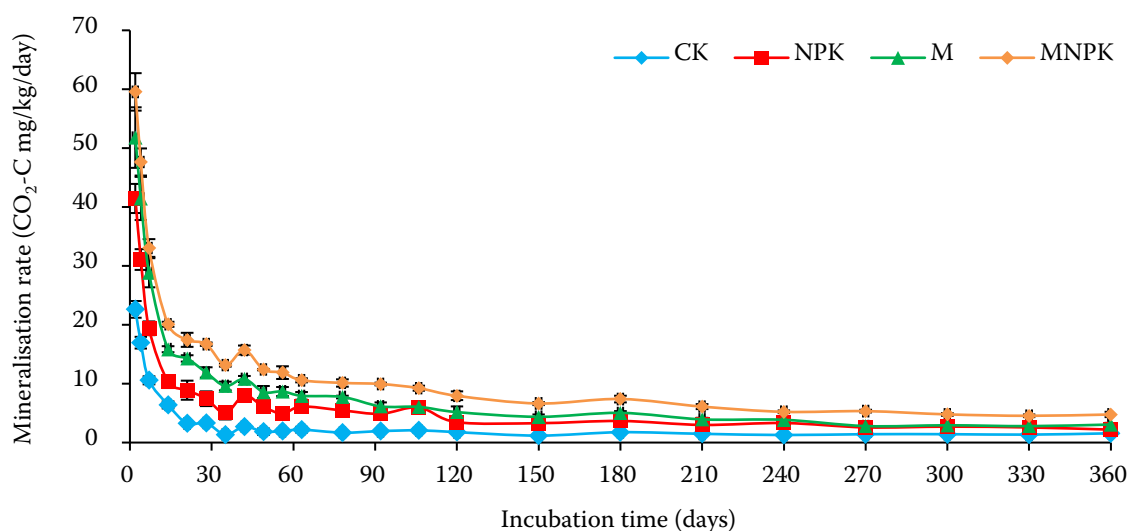

Figure 1. Mineralisation rate of soil organic carbon (SOC). Data for each time-point are means ± standard error. CK – no fertiliser; NPK – mineral fertiliser; M – organic fertiliser; MNPK – combined organic-inorganic fertiliser

Table 2. Regression equations of soil organic carbon mineralisation rates

Treatment	Regression equation	R^2
CK	$y = -3.207\ln(x) + 1732$	0.7097**
NPK	$y = -5.893\ln(x) + 32.636$	0.7646**
M	$y = -8.037\ln(x) + 44.589$	0.8372**
MNPK	$y = -9.01\ln(x) + 51.888$	0.8548**

CK – no fertiliser; NPK – mineral fertiliser; M – organic fertiliser; MNPK – organic-inorganic fertiliser; y – CO_2 production rate (mg/kg/day); x – incubation time (days). **$P < 0.01$

SOC mineralisation kinetics. The CO_2-C-release patterns were best described by the double exponential model across soil samples; R^2 values ranged from 0.994 to 0.997 (Table 3). Active SOC pool-size ranged from 2.06% to 6.51% and the highest values were recorded in M and MNPK-treated soils. Furthermore, the active SOC pool was higher in all NPK, M, and MNPK treatments than in CK. The k_1 value (i.e. the mineralisation rate constant of the active pool) decreased significantly in all fertilised soils, although no significant differences were detected among fertilisation treatments. The mean residence time (MRT_1) of this C fraction, which averaged 26.26 days for all four treatments, was significantly extended in the fertilised soils, particularly in those that received organic amendment (i.e. M and MNPK; 32.26 and 37.04 days, respectively).

Similarly, the size of the slow SOC-pools in soils with no manure was larger than in soils under manure treatments, but the difference between them was not significant (Table 3). k_2 values were 2–3 orders of magnitude lower than k_1, ranging from 2×10^{-4} to 4.6×10^{-4}, and they were higher in fertilised than in CK soils, with the maximum increase observed in MNPK-treated plots. MRT_2 was 8.63 years under all four treatments. MRT_2 of fertilised soils was lower than that of CK soils, and it was consistent with k_2 values; further, the lowest MRT_2 value was recorded in MNPK-treated plots.

Correlations between soil chemical properties and mineralisation parameters. Soil OC, TN, TP, C/N, NO_3^--N, AP, and AK contents showed significant positive correlations with C_m, C_{mr}, a, k_2, and MRT_1 values, and negative correlations with k_1, b, and MRT_2 (Table 4). NH_4^+-N showed a significant positive correlation with a and a significant negative correlation with b. Soil pH showed significant positive correlations with k_1 and MRT_2 and significant negative correlations with C_{mr}, k_2, and MRT_1.

DISCUSSION

The process of SOC mineralisation is crucial for soil functions, modulating atmospheric CO_2 feedback, and sustaining nutrient supply and soil structural stability; thus, SOC mineralisation contributes to biodiversity (Paterson and Sim 2013). Long-term application of mineral fertilisers reportedly increases the cumulative mineralised C and daily average mineralisation rate as it favours optimum growth environments for microbes by decreasing soil pH and improving soil
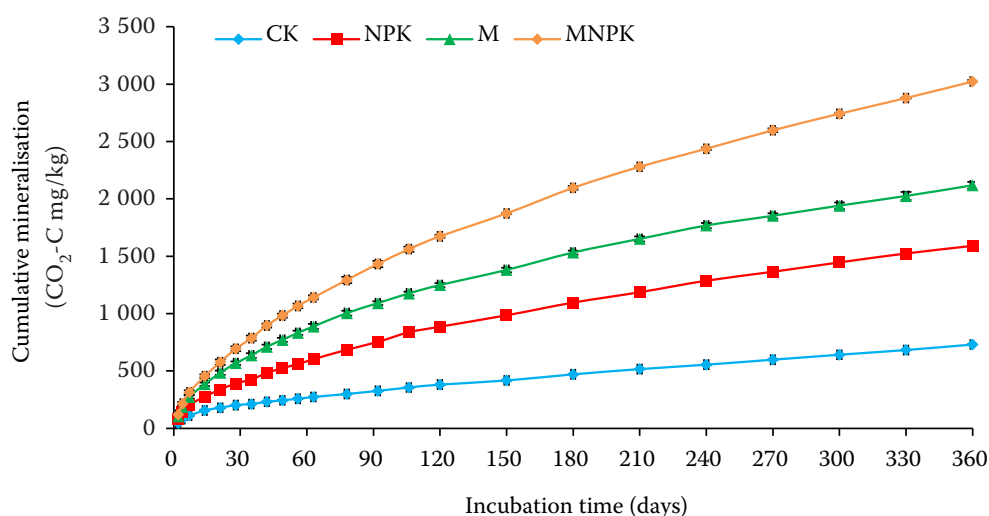

Figure 2. Cumulative mineralisation of soil organic carbon. Data at each time-point are means ± standard error. CK – no fertiliser; NPK – mineral fertiliser; M – organic fertiliser; MNPK – organic-inorganic combined fertiliser
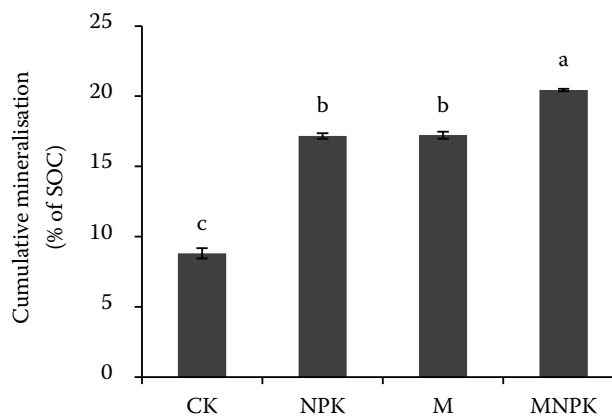
Figure 3. Cumulative mineralisation of soil organic carbon (SOC) after 360 days of incubation. Percentage of initial SOC concentration. Data are means ± standard error. Different lowercase letters indicate significant difference among treatments ($P < 0.05$). CK – no fertiliser; NPK – mineral fertiliser; M – organic fertiliser; MNPK – organic-inorganic combined fertiliser

properties (Wang et al. 2016). Additionally, effective C sources are another limiting factor for SOC mineralisation, as soil microbial activities are determined mainly by crop development (Li et al. 2010).

Here, soil samples obtained from cultivated plots managed under different long-term fertilisation regimes in Northern China were incubated for 360 days under the same temperature and humidity conditions such as to prevent their potential effects on C mineralisation rate, and thus be able to attribute any change in C mineralisation dynamics to fertilisation effects alone, unequivocally.

Cumulative mineralisation of OC in soils previously subjected to long-term fertilisation treatments was gen-erally higher than in non-fertilised soils; furthermore, it was greater in M- and MNPK- than in NPK-treated plots. Furthermore, differences in SOC mineralisation rate and cumulative mineralisation among soils under different treatments were significant. Total CO_2 released after 360 days of incubation was significantly higher in soils that received organic fertiliser (alone or combined with mineral fertiliser) than in soils that received only mineral fertiliser. These differences between the effects of organic and mineral fertilisers can be attributed to the central role of C input. Although the input of organic fertilisers directly increases SOC concentration, these fertilisers also promote plant growth. Organic C availability in soils receiving only mineral fertilisers relies solely on the decomposition of root residues and root exudates (Ribeiro et al. 2010).

The use of organic fertilisers may have resulted in higher C availability, which in turn enhanced microbial activity and accelerated mineralisation (Guo et al. 2019). Furthermore, the SOC mineralisation rate was relatively high early during the incubation period. This has been attributed to the higher amount of easily decomposable compounds including sugars, proteins, and other organic substances present in the soil, thus providing abundant C sources and nutrients for soil microorganisms and improving soil microbial activities (Lin et al. 2014). However, as the concentration of readily decomposable organic compounds decreased, SOC mineralisation rate also decreased gradually, with the lowest SOC mineralisation rate observed in the later stages of the incubation experiment, at which time, microbial activities might have been restricted, as SOM is mainly composed of cellulose and lignin (Guo et al. 2013), which are harder to decompose.

Table 3. Relative carbon pool-size and soil organic carbon kinetic mineralisation parameters

Treatment	Active C	Slow C	k_1	k_2	MRT$_1$ (day)	MRT$_2$ (year)	R^2
	(%)		(per day)				
CK	2.06 ± 0.17[c]	97.94 ± 0.17[a]	0.115 ± 0.018[a]	0.00020 ± 0.000010[d]	8.70 ± 1.34[c]	13.70 ± 0.69[a]	0.994
NPK	4.95 ± 0.12[b]	95.05 ± 0.12[b]	0.037 ± 0.003[b]	0.00040 ± 0.000005[b]	27.03 ± 2.46[b]	6.85 ± 0.08[c]	0.994
M	6.34 ± 0.09[a]	93.66 ± 0.09[c]	0.031 ± 0.003[b]	0.00036 ± 0.000005[c]	32.26 ± 2.94[a]	7.61 ± 0.26[b]	0.995
MNPK	6.51 ± 0.16[a]	93.49 ± 0.16[c]	0.027 ± 0.002[b]	0.00046 ± 0[a]	37.04 ± 3.10[a]	5.96 ± 0.11[d]	0.997

Data were obtained using a double exponential model; R^2 – coefficients of determination; CK – no fertiliser application; NPK – mineral fertiliser; M – organic fertiliser; MNPK – organic-inorganic fertiliser; active C – rapidly mineralisable C; slow C – slowly mineralisable C; k_1 – mineralisation rate constant of the active C pool; k_2 – mineralisation rate constant of the slow C pool; MRT$_1$ – mean residence time of the active C pool ($1/k_1$); MRT$_2$ – mean residence times of the slow C pool ($1/k_2$). Different lowercase letters within columns indicate significant differences ($P < 0.05$)

Table 4. Pearson correlation coefficients between soil chemical properties and mineralisation parameters

	Mineralisation parameter							
	C_m	C_{mr}	*a*	k_1	*b*	k_2	MRT_1	MRT_2
SOC	0.99**	0.88**	0.88**	−0.77**	−0.88**	0.84**	0.90**	−0.79**
TN	0.98**	0.84**	0.87**	−0.74**	−0.87**	0.78**	0.88**	−0.74**
TP	0.99**	0.92**	0.94**	−0.84**	−0.94**	0.88**	0.94**	−0.85**
C/N	0.59*	0.78**	0.59*	−0.72**	−0.59*	0.86**	0.65*	−0.82**
NO_3^--N	0.66*	0.79**	0.80**	−0.74**	−0.80**	0.75**	0.72**	−0.83**
NH_4^+-N	0.53	0.49	0.58*	−0.48	−0.58*	0.42	0.44	−0.45
AP	0.96**	0.79**	0.85**	−0.70**	−0.85**	0.73**	0.85**	−0.68**
AK	0.98**	0.94**	0.88**	−0.83**	−0.88**	0.93**	0.92**	−0.87**
pH	−0.43	−0.70**	−0.55	0.72**	0.55	−0.76**	−0.63*	0.78**

C_m – cumulative mineralisation of soil organic carbon (SOC); C_{mr} – cumulative value of mineralised SOC at day 360; *a* – active C; *b* – slow C; k_1 – mineralisation rate constant of the active C pool; k_2 – mineralisation rate constant of the slow C pool; MRT_1 – mean residence time of the active C pool ($1/k_1$); MRT_2 – mean residence times of the slow C pool ($1/k_2$); TN – total nitrogen; TP – total phosphorus; AP – available phosphorus; AK – available potassium; *$P < 0.05$; **$P < 0.01$

Consistently with reports by Ci et al. (2015) and Guo et al. (2019), in our study, the CO_2-release rate initially increased and then decreased during incubation; thus, the rate of SOC mineralisation followed a logarithmic function in relation to the incubation time.

Notably, most of the CO_2 released under short-term incubation is derived from active SOC pools, which are generally low in mineral soils. Despite their low proportions, such pools can contribute significantly to total soil respiration. Here, we found that 35 years of fertilisation using either mineral fertilisers (NPK), organic fertilisers (M), or a combination of the two, significantly affected *a*, *b*, and *k* values, estimated using a double exponential model. However, there were no significant differences between the M and MNPK treatments. k_1 and k_2 can reflect the relative mineralisation rate of the active- and slow SOC fractions, respectively (Reichstein et al. 2000). Manure application led to a decrease in k_1 from 0.115 to 0.031 and, consequently, to an increase in MRT_1, from 8.70 to 32.26 days (Table 3). Although the k_2 value was obviously lower than the k_1 value, the slow SOC pool size was considerably larger than that of the active SOC pool size. These findings improve our understanding of SOC mineralisation and provide a fundamental basis for soil C balance research. However, this study was conducted under a controlled environment. *In situ* research is necessary to verify our findings, as SOC mineralisation is significantly affected by temperature, water availability, and other environmental factors.

Long-term fertilisation changed soil properties and C mineralisation rates; further, the effects were more pronounced in soils under the sustained application of a combination of organic and inorganic fertilisers. C mineralisation dynamics fitted the double exponential model and that the kinetic parameters derived from this equation demonstrated positive and negative correlations with most soil chemical properties sensitive to their changes. Continuous organic-inorganic fertilisation significantly altered important chemical soil properties and increased organic C accumulation and mineralisation potential, along with the size of the active SOC pool, which is a crucial determinant of soil nutrient turnover.

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