Spatial distribution of soil organic matter and total nitrogen under relay strip intercropping system

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Abstract

Assessing the spatial distribution of organic matter and total nitrogen in soil is essential for management and optimum utilization of fertilizers in order to obtain better crop yield with minimum fertilizers cost. Subsequently, this field experiment has studied the impact of different planting patterns arrangements of maize and soybean strip relay intercropping on spatial distribution of soil total nitrogen and organic matter contents. The planting was arranged in a manner that soil sampling could be done from continuous maize/soybean relay strip intercropping (MS1), maize/soybean relay strip intercropping in rotations (MS2), Traditional maize/soybean intercropping (MS3), sole maize (M), sole soybean (S), and fallow land (FL) from 2018 to 2020. The results showed significant variations for soil organic matter and total nitrogen under different planting patterns of maize and soybean in intercropping. The highest soil organic matter (29.19 g/kg) and total nitrogen (10.19 g/kg) were MS2. In contrast the minimum organic matter (1.69 g/kg) and total nitrogen (0.64 g/kg) were FL. Soil organic matter and total nitrogen in MS2 increased by 186.45% and 164.06%, respectively, compared with FL. Furthermore, under MS2, the spatial distribution of soil organic matter was higher in both maize and soybean crop rows as compared with other cropping patterns, whereas the soil total nitrogen was higher under soybean rows as compared with maize in all other treatment. However, the correlation analysis of the treatments showed variations for organic matter. It can be concluded that different planting patterns can have other effects on soil organic matter and total nitrogen distribution under intercropping. Moreover, it is recommended from this study that MS2 is a better planting pattern for strip intercropping, that can increase spatial distribution of soil organic matter and total nitrogen, consequently it can improving the soil fertility and C:N ratio.

1. Introduction

China feeds approximately 20 percent of the world's population, with less than 9 percent of the world's arable land[1]. The world's population is increasing rapidly. Therefore, it must produce more from the limited arable land to meet the needs of the growing population[2, 3]. Strengthening the utilize of chemical fertilizer is an essential step in expanding crop yields[4, 5], nevertheless, the indiscriminate use of fertilizers has led to raised soil nutrients imbalance in various regions of the world, notably many Asian countries[6, 7]. In economically developed areas of China, a markedly disproportionate dose of fertilizers is being administered. That is averaging 339kg/hm^2, which was 1.29 times the national average of 262kg/hm^2, while in economically underdeveloped areas, the fertilizing amount was only 178kg /hm^2[8, 9]. Additionally, in soil organic matter areas, the limited fertilizer resources are markedly wasted and lead to environmental pollution[10]. Regarding the limited utilization of fertilizer resources, China adopted the concept of ecological agriculture in the last century[11, 12]. In this regard, a lot of research on soil nutrient status has been carried out. Similarly, intercropping of different crops was one of the priorities. Intercropping is a cropping pattern in which two or more crops are cultivated simultaneously on the same piece of farmland[13], which proved to be economically, ecologically, and socially profitable[14, 15]. According to statistics, the universal intercropping area is more than 1,109 hm^2, which is about 3% of the total cultivated area[16, 17]. The common intercropping patterns principally comprise intercropping or relay strip intercropping, and strip intercropping refers to growing two or more crops, strips within a specific bandwidth allowing alternate planting of different crops. It is determined by intercropping and relay intercropping. The main difference between intercropping and strip intercropping is: In strip intercropping, different kinds of crops are not grown in a single row, but two or more rows of the same crop are grown together, the one crop is formed "Strip" and interval cultivated with another "Strip" of crop, having relatively fixed line number, line spacing and strip width (bandwidth), which can make full use of the limited land resources, improve the nutrient absorption and utilization efficiency of crops, and improve soil fertility and quality[18, 19].

Soil organic matter and total nitrogen are important indexes to evaluate soil fertility and soil quality. They are essential sources and sinks of the global carbon cycle and have become one of the research hotspots in soil and environmental sciences[14, 20]. Although they only account for a small part of the total soil volume, they play a vital role balancing the soil fertility, environmental protection, and sustainable agricultural development[21]. Under intercropping, soil organic matter and total nitrogen, like other soil characteristics, have high spatial variability in various regions. Similarly in China, there are significant differences in soil organic matter and nitrogen contents at different spatial locations at the same time[22, 23]. The changes of SOM and TN are dependent on farming practices such as fertilization, incorporation of crop residues, crop rotations, soil utilization, and tillage method[24]. The Tillage method had a great influence on soil organic matter and total nitrogen content. It was discovered that intercropping could enhance the distribution and content of soil organic matter and total nitrogen[24]. Cereal/legume intercropping is widely recognized as a sustainable agricultural production system, and it can improve the symbiotic nitrogen fixation of legumes and reduce the input of chemical fertilizers[25] Intercropping of maize and soybean represents a new cereal/legume pattern that farmers are rapidly adopting in Southwest of China[25]. However, there is no available literature on soil organic matter and total nitrogen spatial distribution in the maize/soybean relay strip-intercropping system. Whereas, information is needed to identify better management practices that can optimize land use efficiency and to understand the mechanism underlying the increased soil fertility under maize/soybean relay strip intercropping systems, especially Southwest China and similar areas. Furthermore, The main objectives of this three-year study were to quantify the relationship between soil organic matter and total nitrogen content and planting patterns in a maize/soybean strip relay intercropping system. We speculate that maize/soybean relay strip intercropping systems can improve soil organic matter and total nitrogen content with planting patterns in maize/soybean relay strip intercropping system.

2. Materials And Methods

2.1. Experimental location

Field experiments were conducted from 2018 to 2020 at the teaching and research farm of Sichuan Agricultural University site in Ya'an city, and the site is located in Southwest Sichuan Province of China

(101°56'26"E, 28°51'10"N). This region has hilly and mountainous mainly (Fig. 1). The climate is humid subtropical monsoon, with the average annual temperature of 16.2°C, rainfall 1250 to1750 mm, sunshine duration 1005 hours, and frost-free period of 300 days. The soil type is Gley soils according to FAO-UNESCO 1988[26] having pH 6.6, organic matter 29.8 $g \cdot kg^{-1}$, total nitrogen 1.6$g \cdot kg^{-1}$, total phosphorus $g \cdot kg^{-1}$, and total potassium 14.28$g \cdot kg^{-1}$.

2.2. Experimental design and treatments

The experimental design was a randomized block design with three replications (Fig. 2). In this experiment, maize variety Denghai-605(Shandong Denghai Seeds Co., Ltd)and soybean variety Nandou-12(Nanchong Academy of Agricultural Sciences) were used. Treatments were arranged as MS1= continuous maize/soybean relay strip intercropping, MS2= maize-soybean relay strip intercropping in rotations, MS3 = Traditional maize/soybean intercropping (MS3: A conventional planting method in Southwest of China), M = Sole maize, S = Sole soybean, FL= Fallow land. The size of the experimental plots under MS1, MS2, MS3, M, and S was 6×6 (36m^2), whereas the plot size for FL was 2×6 (12m^2). The total bandwidth of MS1 and MS2 was “160 cm + 40 cm” maize wide-narrow-row sowing, i.e., the relay intercropping combination of two crop strips with a total width of 200 cm, consisting of two rows of maize and two rows of soybean with a 40-cm row width for maize and soybean, and 60-cm spacing between the adjacent rows of maize and soybean. Traditional intercropping (MS3) has a total bandwidth of 100cm with a 1:1 row ratio and distance between maize/soybean rows of 50 cm. Insole planting of maize and soybean, the distance between two rows was 100 cm for maize and 50 cm for soybean, respectively (Note: The difference between MS2 treatment and MS1 treatment is that the maize belt and soybean belt will be rotated in MS2 means that maize belts turn into soybean, soybean belts turn into maize each year.).

The fertilizers were used as Urea (including 46% N), Calcium superphosphate (including 14% P_2O_5), and Potassium chloride (including 52% K_2O), all fertilizers for maize and soybean were used as basal fertilizers. Maize was fertilized with pure nitrogen at 120 kg/ha, P_2O_5 105 kg/ha, and K_2O 135 kg/ha, soybean was fertilized with pure nitrogen at 60 kg/ha, P_2O_5 63 kg/ha and K_2O 52.5 kg/ha in 2018, 2019, and 2020. Maize crop was sown on 24th March, 23rd March, and 29th March, in 2018, 2019, and 2020, respectively, and harvested on 25th July, 6th August, and 8th August in 2018, 2019, and 2020, respectively. Soybeans were sown on 7th June, 8th June, and 13th June, in 2018, 2019, and 2020, respectively, and harvested on 30th October, 23rd October, and 22nd October 22 in 2018, 2019, and 2020, respectively.

2.3. Sampling and measurements

In this experiment, the soil samples from all the cropping patterns were collected after soybean harvesting. For soil sampling, the fixed-point sampling procedure was adopted to collect the soil sample from 0-20 cm soil layer (Fig. 3). To collect the piece, the soil core was inserted vertically into the ground. All the collected soil samples were mixed, and approximately 1kg of soil was taken for further analysis.

The undisturbed soil samples were placed in the tray and stored in a clean indoor ventilation area for natural air drying. After drying, samples were put into a sample bag for determination of soil organic matter and total nitrogen. All the sample bags were labeled with a number, sampling place, soil type, sampling depth, sampling date, and time.

A maize-soybean relay strip intercropping (Continuous and rotation cropping), B Traditional maize-soybean intercropping; C maize monoculture, D soybean monoculture, E fallow land. M maize, S soybean, ·soil sample sites;● For the soil sample collection point.

2.3.1. Soil organic matter and total nitrogen content determination

The Soil organic matter(SOM as abbreviation) determination was done by potassium dichromate volumetric method - external heating method[27].

$$SOM = c\frac{(v_0 - v)\times 0.003\times 10724\times 1.1}{m\times k}\times 100\% \quad (1)$$

Where c (mol/L) is the molar concentration of consuming ferrous sulfate, V0 is the volume (ml) of consuming ferrous sulfate in blank test, V is the volume (ml) of consuming ferrous sulfate in titrating soil sample, 0.003 is ¼ mmol/grams of carbon, 10172 is the conversion coefficient from soil organic carbon to organic matter, 1.1 is correction factor (The oxidation rate in this method is 90%), m (g) is air dry soil quality, k is the coefficient of drying soil to drying soil.

The total nitrogen(TN as abbreviation) was determined by the Kjeldahl method[28].

$$TN = \frac{(v_0 - v)\times c\times 14\times 10^{-3}}{w}\times 10^{3} \quad (2)$$

Where V0 is the volume (mL) of standard acid used for titrating the sample, V is the volume (mL) of normal acid used for titrating the blank, C is normal acid concentration (mol/L), 14 is N molar mass (g/mol), W is the sample weight (g).

2.3.2. Soil organic matter and total nitrogen reference standards

At present, there are many soil nutrient grading standards in China, and each of them has soil nutrient grading standard[27]. The results of this experiment mainly refer to the national soil nutrient classification standard (Table 1). Chinese soil nutrient classification standard divides soil organic matter and soil nutrient into six grades from 1 to 6. Soil organic matter and soil nutrient are the highest in grade 1, and the most minor in grade 6[28]. Furthermore, the spatial variation of soil organic matter and nutrient availability in China is relatively high. For example, soil organic matter in China can be as high as 200g/kg or more, and as low as 5g/kg or less, and the total nitrogen content can be as high as 35g/kg and as low as 5g/kg[29]. Therefore, further refinement of soil organic matter and soil nutrient grade is needed to compare differences in soil nutrient grade in China[30].

Table 1. Nation soil nutrient standard grade

Standard grade[a]	Nutrient elements	
	Organic matter (g/kg)	Total nitrogen (g/kg)
1	>40.0	>2.00
2	30.1-40.0	1.51-2.00
3	20.1-30.0	1.01-1.50
4	10.1-20.0	0.76-1.00
5	6.0-10.0	0.50-0.75
6	<6.0	<0.50

[a] 1, 2, 3, 4, 5, 6 represent the First standard, Second standard, Third standard, Fourth standard, Fifth standard, Sixth standard, respectively.

The classification of coefficient of variation: coefficient of variation is considered weak under <10%, moderate variation between 10% and 100%, and strong variation when it is > 100%[31,32] .

2.4. Statistical analyses

All the experimental data were managed by Microsoft Excel 2016, and the figures were constructed with Origin Pro 2018. Differences between intercropping systems and soil organic matter and total nitrogen content were identified by analyzing variance (ANOVA) using SPSS 22.0 software (SPSS Inc., Chicago, IL, USA). The mean values were compared with a least significant difference (LSD) test at the $P < 0.01$ significance level. Linear regression techniques were used to describe the relationships between soil organic matter and total nitrogen. The effectiveness of cropping patterns was determined by regression equations analysis with P-values (Tukey's test) and the coefficient of determination (R^2).

3. Results

3.1. Soil organic matter content and spatial distribution

The planting pattern shows significant ($P < 0.01$) variations for soil organic matter content of both maize and soybean at all sampling times across the three years of this experiment (Table 2 and Fig. 4). On average, during the three years, the average value of each treatment is MS2(Maize-soybean relay strip intercropping in rotations) > MS1(Continuous maize/soybean relay strip intercropping)>MS3(Traditional maize/soybean intercropping) > S(Sole soybean) > M(Sole maize) > FL(Fallow land), where the smallest average value was found in FL (10.19g/kg), and the most significant value was found in MS2 (29.19g/kg)(Table 2 and Fig. 4). Furthermore, it was observed that the maximum soil organic matter (39.72 g kg^{-1}) was recorded in MS2, whereas the minimum soil organic matter (8.71 g kg^{-1}) was recorded in FL(Table 2 and Fig. 4), and soil organic matter in MS2 increased by 186.45% compared with FL. Overall, there were more significant variations in soil organic matter under MS2, as compared with other planting patterns. The results implied that there were differences in soil organic matter content among different treatments, which might be related to different planting methods and crop types. At the same time, the spatial distribution of MS2 organic matter in maize and soybean rows was most dense. This phenomenon may be due to different planting patterns and crop residues of maize and soybean in the field.The results showed that the MS2 planting pattern was most beneficial to soil organic matter accumulation.

The obtained results were also graded by the coefficient of variation, where we find that MS1, MS2, MS3, M, and S have moderate variations when compared, while FL shows weak variation, and overall MS2 shows the most significant variations(Table 2). This result might be due to the multi-year rotation of maize and soybean, and increased organic matter over the time.

Table 2
Soil organic matter content under different planting methods of maize and soybean in 2018–2020

Treatment[a]	Number of samples	Content range (g/kg)	Average (g/kg)	Coefficient of variation (%)
MS1	45	15.33–36.54	27.02 ± 7.98b[b]	29.53
MS2	45	15.51–39.72	29.19 ± 9.36a	32.06
MS3	27	14.79–34.19	25.07 ± 5.74c	22.91
M	18	17.68–24.65	20.42 ± 2.45e	12.02
S	18	14.79–27.89	22.07 ± 3.95d	17.90
FL	9	8.71–11.46	10.19 ± 0.71f	6.97

[a]MS1, MS2, MS3, M, S, FL represent the Continuous planting of maize/soybean relay strip inter-cropping, Planting of maize/soybean relay strip inter-cropping in rotation, Traditional maize/soybean inter-cropping, Sole maize planting, Sole soybean planting, Fallow land, respectively.

[b]Values followed by a different letter within the same column are significantly different at $P < 0.01$.

3.2. Total soil nitrogen content and spatial distribution

Across all treatments, the soil nitrogen content of the maize/soybean intercropping systems, MS2 has more significant variation in total soil nitrogen (Table 3 and Fig. 5). On average, MS2(Maize-soybean relay strip intercropping in rotations) > MS1(Continuous maize/soybean relay strip intercropping)>MS3(Traditional maize/soybean intercropping) > S(Sole soybean) > M(Sole maize) > FL(Fallow land), The treatment shows that the minimum soil nitrogen content was under FL (0.64g/kg), and the maximum soil nitrogen content was recorded under MS2 (1.69g/kg)(Table 3 and Fig. 5).

However, under MS2, the spatial distribution of soil total nitrogen under soybean rows was higher in soybean rows, as compared with maize rows (Table 3 and Fig. 5). As shown in Table 3, the maximum total soil nitrogen (2.47 g kg^{-1}) was recorded in MS2, and the minimum total soil nitrogen (0.55g kg^{-1}) was recorded in S and FL, and total nitrogen in MS2 increased by164.06% compared with FL. Under all planting patterns, the spatial distribution of soil total nitrogen in maize rows was lower as compared with soybean rows, however, the average maximum and minimum total nitrogen and organic matter was almost identical under various planting patterns. Therefore, it can be speculated that organic matter and total nitrogen have a strong correlation to each other.The results showed that MS2 planting pattern was most beneficial to soil total nitrogen accumulation.

According to correlation analysis there was moderate variation in soil total nitrogen under MS1, MS2, MS3, M, and S, weak variation in FL, and the most significant variation were observed under MS2 (R^2 = 0.96). It can be concluded that the interpretation of total nitrogen is the same as organic matter, which indicates that the high correlation between organic matter and total soil nitrogen. Furthermore, these results shows that the intercropping of maize/soybean can improve the organic matter and total nitrogen content in soil.

Table 3
Total nitrogen content under different planting methods of maize and soybean in 2018–2020

Treatment[a]	**Number of samples**	**Content range (g/kg)**	**Average (g/kg)**	**Coefficient of variation (%)**
MS1	45	0.96–2.46	1.48 ± 0.37b[b]	25.05
MS2	45	0.87–2.47	1.69 ± 0.53a	31.35
MS3	27	0.69–1.81	1.23 ± 0.29c	23.73
M	18	0.62–0.99	0.78 ± 0.13e	16.07
S	18	0.55–1.21	0.98 ± 0.17d	17.21
FL	9	0.55–0.71	0.64 ± 0.04f	6.35

[a]MS1, MS2, MS3, M, S, FL represent the Continuous planting of maize/soybean relay strip inter-cropping, Planting of maize/soybean relay strip inter-cropping in rotation, Traditional maize/soybean inter-cropping, Sole maize planting, Sole soybean planting, Fallow land, respectively.

[b]Values followed by a different letter within the same column are significantly different at P < 0.01.

3.3. Correlation between soil organic matter and total nitrogen

According to the contents of soil organic matter and total nitrogen in the six treated soils, the correlation equation and correlation coefficient between them can be obtained from Table 4 and Fig. 6.The relationship between soil organic matter (X) and total nitrogen (Y) was unevenly linear. Six linear regression equations of soil organic matter and total nitrogen and their correlation coefficients were obtained respectively (Table 4), the regression equation was y = 0.06x-0.08, and the correlation coefficient was R^2 = 0.87. Furthermore, the correlation between all treatments (planting patterns) for soil organic matter and total nitrogen was significant, where correlation of MS1, MS2, MS3, and FL were closer to 1. These results indicated that the correlation between soil organic matter and total nitrogen in different planting methods was significant and positively correlated.

Table 4
Soil organic matter and total nitrogen correlation

Treatment[a]	Sample number	Linear regression	Correlation coefficient (R^2)	Significance[b]
Whole test area	162	y = 0.06x-0.08	0.87	Very significant
MS1	45	y = 0.05x + 0.25	0.96	Very significant
MS2	45	y = 0.06x + 0.07	0.96	Very significant
MS3	27	y = 0.05x-0.01	0.94	Very significant
M	18	y = 0.04x-0.01	0.58	Very significant
S	18	y = 0.03x + 0.25	0.60	Very significant
FL	9	y = 0.06x + 0.07	0.97	Very significant

[a]Whole test area, MS1, MS2, MS3, M, S, FL represent the all experiment treatments(MS1 + MS2 + MS3 + M + S+ FL), Continuous planting of maize/soybean relay strip inter-cropping, Planting of maize/soybean relay strip inter-cropping in rotation, Traditional maize/soybean inter-cropping, Sole maize planting, Sole soybean planting, Fallow land, respectively.

[b]content followed by a different letter within the same column are significantly different at $P < 0.01$.

4. Discussion

4.1. Variations in soil organic matter

Soil organic matter is one of the vital soils fertilities materials[34]. Soil organic matter not only provides nutrients for vegetative growth but is also an important factor affecting soil structure formation and nutrient bioavailability [35, 36]. The soil organic matter content is mainly influenced by land-use management, especially, the management of different vegetation to the soil. The percentage of organic matter in a shrub, grassland, and forest soil with 20 cm in the soil layer with 1m depth respectively was 33%, 42%, and 50%, that was significantly correlated with type of vegetation[36, 37]. Similarly, in this study, there were differences in soil organic matter content between maize and soybean planting patterns. This might be due to the phenomenon related of increased crop residues such leaves and roots stubbles of maize and soybean in the field. Usually, the soil organic matter is determined by the balance between soil organic matter input and mineralization rates of different organic matter types[38]. Different land-use patterns lead to different soil cultivation, soil physical, chemical properties, and soil fertility. These variations directly affect the decomposition and transformation of soil organic matter in different soils [39, 40]. Furthermore, increased organic matter contents under different treatments of this study reported that, soil organic matter plays a vital role in soil fertility, especially under relay strip intercropping.

4.2. Variations in soil total nitrogen

The soil total nitrogen content reflects the soil potential capacity to provide nutrients for vegetation, which, together with soil organic matter and its dynamic balance, constitute an essential index of soil fertility[41]. Soil nitrogen content is influenced by natural factors (climate, topography, and vegetation) and agricultural practices (fertilization, tillage, irrigation, and land-use practices)[42–44]. Nitrogen is considered blood for crop growth and development because its absorption and utilization can promote crop growth and increase crop yield[45]. The nitrogen competition among crop species was significantly, however, in the cereal/legumes intercropping system it can be promoted by the nitrogen fixation mechanism of legumes, that can increase the nitrogen availably for absorption and utilization by cereals. Ta and Faris[46] found that clover increased the nitrogen absorption and utilization for cereals by 25% under intercropping. Broadbent et al.[47] reported that white clover improved the nitrogen for ryegrass absorption and utilization by 80% under. Du et al., and Raza et al. (2019)[48, 49]found that in the maize and soybean intercropping system, the nitrogen uptake of maize was increased by 17–21%, that was mainly attributed to soybean nitrogen fixation. Similarly, this study finds that soil total nitrogen in maize/soybean strip intercropping was higher than sole cropping. It might be soybean nitrogen fixation and increased total organic matter. Furthermore, this study showed that when legumes and non-legumes are intercropped, legumes' nitrogen fixation can benefit non-legumes in nitrogen absorption and uptake, thus, promoting the growth and development of non-leguminous crops. However, the amount of nitrogen fixation depends upon the different legumes and non-legumes intercropping combinations and different crop varieties, planting patterns, and growth habits of various crops. The biological nitrogen fixation of legumes can not only improve the nitrogen absorption and utilization of non-legumes, but it can also promote growth and development, reduce crops dependence on non-renewable resources, increase land equivalent ratio and land interest rate[50, 7]. Similarly, this study reported that maize/soybean relay strip intercropping has a positive effect on soil total nitrogen contents.

4.3. Relationship between soil organic matter and soil total nitrogen

The soil C/N plays a vital role in soil organic matter decomposition, and it is an essential factor of soil quality evaluation, because it determines the organic matter effectiveness that improves the soil structure and enhances the carbon fixation, and increase the soil potential as a "source/sink" of atmospheric CO_2 and nitrogen regulation[51, 52]. It is generally believed that during the initial stage of mineralization, organic matter having C/N > 30 cannot produce nitrogen. If organic matter have C/N < 15, at the beginning of mineralization, the amount of adequate nitrogen will exceed microorganisms assimilation in the soil. Thus can make it possible for plants to obtain an adequate nitrogen from organic matter mineralization[53, 54].

Our result shows that the variation coefficient of organic matter and total nitrogen in each treatment was moderate. This might be due to the difference between organic matter and total nitrogen content. Furthermore, that can also be influenced by 1. The contrast of parent material and soil texture at the experimental site; 2. The particularity of remote terrain in the field; 3. Impact of crops vegetation; and 4. Climatic factors. Meanwhile, the contents of organic matter and total nitrogen in soil samples were compared, and it was found that the spatial difference of organic matter and total nitrogen was significant, and there was a significant positive correlation between organic matter and total nitrogen. According to the content level and spatial distribution of organic matter and total nitrogen in the soil of the test area, it can guide the rational fertilization in agricultural production, make the proportion of nutrients in the fertilizer structure appropriate, improve the utilization rate of nutrients, make the medium and low yield soil get high yield, and make the high yield soil keep stable and high yield.

5. Conclusions

In this study, it was found that in different planting patterns of maize and soybean intercropping affected nitrogen availability and total nitrogen content in soil. Under maize/soybean relay strip intercropping system, the spatial distribution of soil organic matter and total nitrogen content were significantly increased, and the increase in soil organic matter and total nitrogen will increase the C:N ration. Furthermore, these results indicated that spatial distribution of soil organic matter and total nitrogen input and uptake can be increased with help of cereal/legumes intercropping. Therefore, it can be concluded that different planting patterns have different effects on soil organic matter and total nitrogen. Moreover, it can also be concluded that increase in soil organic matter can not only improve soil quality, but also improves the soil fertility.

At the same time, there are still shortcomings in this study. The content and distribution of soil organic matter and total nitrogen in the surface layer (0-20cm) under different planting patterns were only studied, and the changes of soil organic matter and total nitrogen in different tillage layers were not involved.

Declarations

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Author Contributions

X.T. and W.Y.Y. conceived and designed the research. M.J.H., C.K.S., X.J.H., M.N.A. and A.S.conducted the experiments. X.T. and C.K.S. evaluated the data. X.J.H., M.N.A., and S.A.provided different chemical reagents and experimental material. Paper writing was completed by X.T.,W.Y.Y., M.J.H., and C.K.S.reviewed and edited the manuscript.

Data availability statement

All data generated or analysed during this study are included in this published paper.

Additional Information

1.A statement on guidelines as Experimental research and field studies on plants, including the collection of plant material, comply with relevant institutional, national, and international guidelines and legislation.

2.All authors fully agree that there exists no commercial or financial conflict of interest.

References

1. Guo JH, Liu XJ, Zhang Y, Shen JL, Han WX, Zhang WF, Christie P, Goulding KWT, Vitousek PM, Zhang FS. Significant Acidification in Major Chinese Croplands. Science 327,1008–1010(2010).
2. Altieri MA. The ecological role of biodiversity in agroecosystems. AGR ECOSYST ENVIRON 74,19–31(1999).
3. Fan M, Shen J, Yuan L, Jiang R, Zhang F. Improving crop productivity and resource use efficiency to ensure food security and environmental quality in China.Journal of experimental biology 63,13–24(2019).
4. Hassanein A, Mesbah E, Soliman F, El-Aidy T. Effect of Nitrogen Rates, Biofertilizers and Foliar Urea Application on Yield and Yield Components of Maize (Zea mays, L.). INT J PLANT PROD 10,53–58(2019).
5. Mohamed AA, Younis SM, Ibrahim MM. EFFECTS OF DIFFERENT TILLAGE METHODS AND FERTILIZER ON SOIL CARBON, EMISSION OF CO2, AND MAIZE YIELD. Plant Archives 20, 9265–9276(2020).
6. Wang PP, Han YJ, Zhang Y. Characteristics of change and influencing factors of the technical efficiency of chemical fertilizer use for agricultural production in China. Resources Science 42,1764–

1776(2020).

7. Zhou L, Fu ZD, Du Q, Chen P, Yang WY, Yong TW. Effects of reduced N fertilization on crop N uptake, soil ammonia oxidation and denitrification bacteria diversity in maize/soybean relay strip intercropping system. S AGR SINI 50,1076–1087(2017).
8. Cho SE. Effects of spatial variability of soil properties on slope stability. Engineering Geology 92:97–109(2007).
9. Zhang ZZ, Qin SJ, Na LI, Guo LW, Ning TY, Chen GQ. Effects of subsoiling and N fertilizer application on dry matter accumulation,nitrogen use efficiency and yield of summer maize. J PLANT NUTR 19,790–798(2013).
10. Zhang Zhifeng, Zhang Weifeng. The situation and trend of fertilizer application in China. P COMPOUND FERT 23,9–12(2008).
11. Shao Y, Chen Z, Xiao H, Zhu Z, Li B. Integrating environmental parameters and economic benefits to analyze the ecological agriculture (EA) application in the mountain rice paddy system of Chongqing, China. ENVIRON SCI EUR31, 1–10(2019).
12. Tourn SN, Videla CC, Studdert GA. Ecological agriculture intensification through crop-pasture rotations does improve aggregation of Southeastern-Pampas Mollisols. SOIL TILL RES 195,104411(2019).
13. Godfray HC, Beddington JR, Crute IR, Haddad L, Lawrence D, Muir JF, Pretty J, Robinson S, Thomas SM, Toulmin C. Food security: the challenge of feeding 9 billion people. Science (New York, N.Y.) 327,812–818(2010).
14. A JWMP, A PS, B BM, A JEO. Legacy effects of soil fertility management on cereal dry matter and nitrogen grain yield of organic arable cropping systems - ScienceDirect. EUR J AGRON 122,126169(2020).
15. Gitari HI, Nyawade SO, Kamau S, Karanja NN, Schulte-Geldermann E. Revisiting intercropping indices with respect to potato-legume intercropping systems. FIELD CROP RES 258,107957(2020).
16. Gautam P, Lal B, Rana R. Intercropping: An Alternative Pathway for Sustainable Agriculture Alternative Pathway for Sustainable Agriculture. Popular Kheti 1,216–220(2014).
17. Li L, Li SM, Sun JH, Zhou LL, Bao XG, Zhang HG, Zhang FS. Diversity enhances agricultural productivity via rhizosphere phosphorus facilitation on phosphorus-deficient soils. P. China Basic Science 104,11192–11196(2007).
18. Ahmed A, Aftab S, Hussain S, Cheema HN, Yang W. Nutrient Accumulation and Distribution Assessment in Response to Potassium Application under Maize–Soybean Intercropping System. Agronomy 10,725(2020).
19. Zhang M, Wang N, Zhang J, Hu Y, Sun G. Soil Physicochemical Properties and the Rhizosphere Soil Fungal Community in a Mulberry (Morus alba L.)/Alfalfa (Medicago sativa L.) Intercropping System. Forests 10,167(2019).
20. Boselli R, Fiorini A, Santelli S, Ardenti F, Tabaglio V. Cover crops during transition to no-till maintain yield and enhance soil fertility in intensive agro-ecosystems. FIELD CROP RES 255,107871(2020).

21. Struijk Marijke, Whitmore Andrew P, Mortimer Simon R., Sizmur Tom. Obtaining more benefits from crop residues as soil amendments by application as chemically heterogeneous mixtures. Soil 6,1–22(2020).
22. Yao X, Yu K, Deng Y, Liu J, Lai Z. Spatial variability of soil organic carbon and total nitrogen in the hilly red soil region of Southern China. J. FORESTRY RES 31,2385–2394(2019).
23. Wenjie Liu, Yongzhong Su, Rong Yang, Qiu Yang, Guiping Fan.Temporal and spatial variability of soil organic matter and total nitrogen in a typical oasis cropland ecosystem in arid region of Northwest China[J]. ENVIRON EARTH SCI, 64(8),2247–2257(2011).
24. Biao Huang, Weixia Sun, Yongcun Zhao, Jing Zhu, Rongqing Yang, Zhong Zou, Feng Ding, Jianping Su. Temporal and spatial variability of soil organic matter and total nitrogen in an agricultural ecosystem as affected by farming practices[J]. Geoderma,139(3–4),336–345(2007).
25. Leonard Rusinamhodzi, Marc Corbeels, Justice Nyamangara, Ken E. Giller.Maize-grain legume intercropping is an attractive option for ecological intensification that reduces climatic risk for smallholder farmers incentral Mozambique[J].FIELD CROP RES, 136,12–22(2012).
26. Rolf Sommer,Eddy de Pauw.Organic carbon in soils of Central Asia—status quo and potentials for sequestration[J]. PLANT SOIL,338(1/2),273–288(2011).
27. Zengchao Geng, Dai Wei. 2020. Soil science. Beijing: science press,30–32(2020).
28. Wu Lishu. Soil fertility. Beijing: China Agriculture Press 95–96(2004).
29. Zhang FS, Wang Ji Qing, Zhang Wei Feng, Cui Zhen Ling, Ma Wenqi, Chen Xin Ping, Jiang Rong Feng. Present situation of fertilizer utilization rate of main grain crops in China and improve ways. ACTA CARDIOL SIN 5,915–924(2008).
30. Yan Xiang, Jin Jiyun, Liang Mingzao. Fertilizer Use Efficiencies and Yield-increasing Rates of Grain Crops in China. Soils 49,1067–1077(2017).
31. Duan Jiannan. Soil variation and its process simulation on the Loess Plateau. Beijing: China Agriculture Press,90–91(2000).
32. Zhang Shu Juan, He Yong, Fang Hui. Spatial variability of soil properties in the field based on GPS and GIS. Transactions of the CSAE 19,39–44(2003).
33. Zhao Z, Zhao Z, Fu B, Wang J, Tang W. Characteristics of soil organic carbon fractions under different land use patterns in a tropical area. J. Soil. Sediment,1–9(2020).
34. Demir Y, Mrc ME. EFFECT OF LAND USE AND TOPOGRAPHIC FACTORS ON SOIL ORGANIC CARBON CONTENT AND MAPPING OF ORGANIC CARBON DISTRIBUTION USING REGRESSION KRIGING METHOD. Carpath J. EARTH AND ENVIRONMENTAL SCIENCE TRANSACTIONS 15:311–322(2020).
35. Mishra G, Sarkar A, Das J. Changes in soil organic carbon lability along the altitudinal variations in three land use types of Meghalaya, India. ENV SUST 3,325–331(2020).
36. Eghdami H, Azhdari G, Lebailly P, Azadi H. Impact of Land Use Changes on Soil and Vegetation Characteristics in Fereydan, Iran. Agriculture 9,58(2019).

37. Yeasmin S, Jahan E, Molla MA, Islam AKMM, Chungopast S. Effect of Land Use on Organic Carbon Storage Potential of Soils with Contrasting Native Organic Matter Content. International Journal of Agronomy 2020:1–9.
38. Segura JH, Nilsson MB, Sparrman T, Serk H, Öquist MG. Boreal tree species affect soil organic matter composition and saprotrophic mineralization rates. PLANT SOIL 441,173–190(2019).
39. Lai Z, Zhang Y, Liu J, Wu B, Qin S, Fa K. Fine-root distribution, production, decomposition, and effect on soil organic carbon of three revegetation shrub species in northwest China. FOREST ECOL MANAG 359,381–388(2016).
40. Liu M, Liu M, Li P, Yang J, Chang Q. Variations in soil organic carbon decompositions of different land use patterns on the tableland of Loess Plateau. Environ. Sci. Pollut. R. 27,1–16(2020).
41. Meng Tingting. Effects of Tillage Methods on Soil Organic Carbon and Total Nitrogen Content in the Loess Plateau. Asian Agricultural Research 12,29–31(2020).
42. Alhaj Hamoud Y, Guo X, Wang Z, Shaghaleh H, Chen S, Hassan A, Bakour A. Effects of irrigation regime and soil clay content and their interaction on the biological yield, nitrogen uptake and nitrogen-use efficiency of rice grown in southern China. AGR WATER MANAGE 213,934–946(2019).
43. Dai L, Fu R, Guo X, Du Y, Cao G.Long-term grazing exclusion greatly improve carbon and nitrogen store in an alpine meadow on the northern Qinghai-Tibet Plateau. Catena 197, 104955(2020).
44. Li Z, Zeng Z, Tian D, Wang J, Fu Z, Zhang F, Zhang R, Chen W, Luo Y, Niu S. Global patterns and controlling factors of soil nitrification rate. GCB BIOENERGY 26(2020).
45. Hua W, Luo P, An N, Cai F, Han X. Manure application increased crop yields by promoting nitrogen use efficiency in the soils of 40-year soybean-maize rotation. Sci Rep-Uk 10,14882(2020).
46. Ta T, Faris M. Species variation in the fixation and transfer of nitrogen from legumes to associated grasses. PLANT SOIL 98,265–274(1987).
47. Broadbent FE. Methodology for nitrogen transformation and balance in soil. PLANT SOIL 58,383–399(1981).
48. Du Q, Zhou L, Chen P, Liu X, Yong T. Relay-intercropping soybean with maize maintains soil fertility and increases nitrogen recovery efficiency by reducing nitrogen input. The Crop Journal 8,1–22(2019).
49. Raza MA, Feng LY, Werf WVD, Iqbal N, Xi ZJ. Optimum leaf defoliation: A new agronomic approach for increasing nutrient uptake and land equivalent ratio of maize soybean relay intercropping system. FIELD CROP RES 244:107647(2019).
50. Chen P, Song C, Liu XM, Zhou L, Yang H, Zhang X, Zhou Y, Du Q, Pang T, Fu ZD. Yield advantage and nitrogen fate in an additive maize/soybean relay intercropping system. SCI TOTAL ENVIRON 657,987–999(2019).
51. Bewket W, Stroosnijder L. Effects of agroecological land use succession on soil properties in Chemoga watershed, Blue Nile basin, Ethiopia. Geoderma 111,85–98(2003).

52. Hagedorn F, Spinnler D, Bundt M, Blaser P, Siegwolf R. The input and fate of new C in two forest soils under elevated CO2. Global Change Biol. 9,862–872(2010).
53. Sun Y, Wang C, Chen HYH, Ruan H. Responses of C:N stoichiometry in plants, soil, and microorganisms to nitrogen addition. Plant & Soil 456:1–11(2020).
54. Veronika Jílková A, Petra Straková B C, Jan Frouz A D. Foliage C:N ratio, stage of organic matter decomposition and interaction with soil affect microbial respiration and its response to C and N addition more than C:N changes during decomposition. APPL SOIL ECOL 152,103568(2020).

Figures

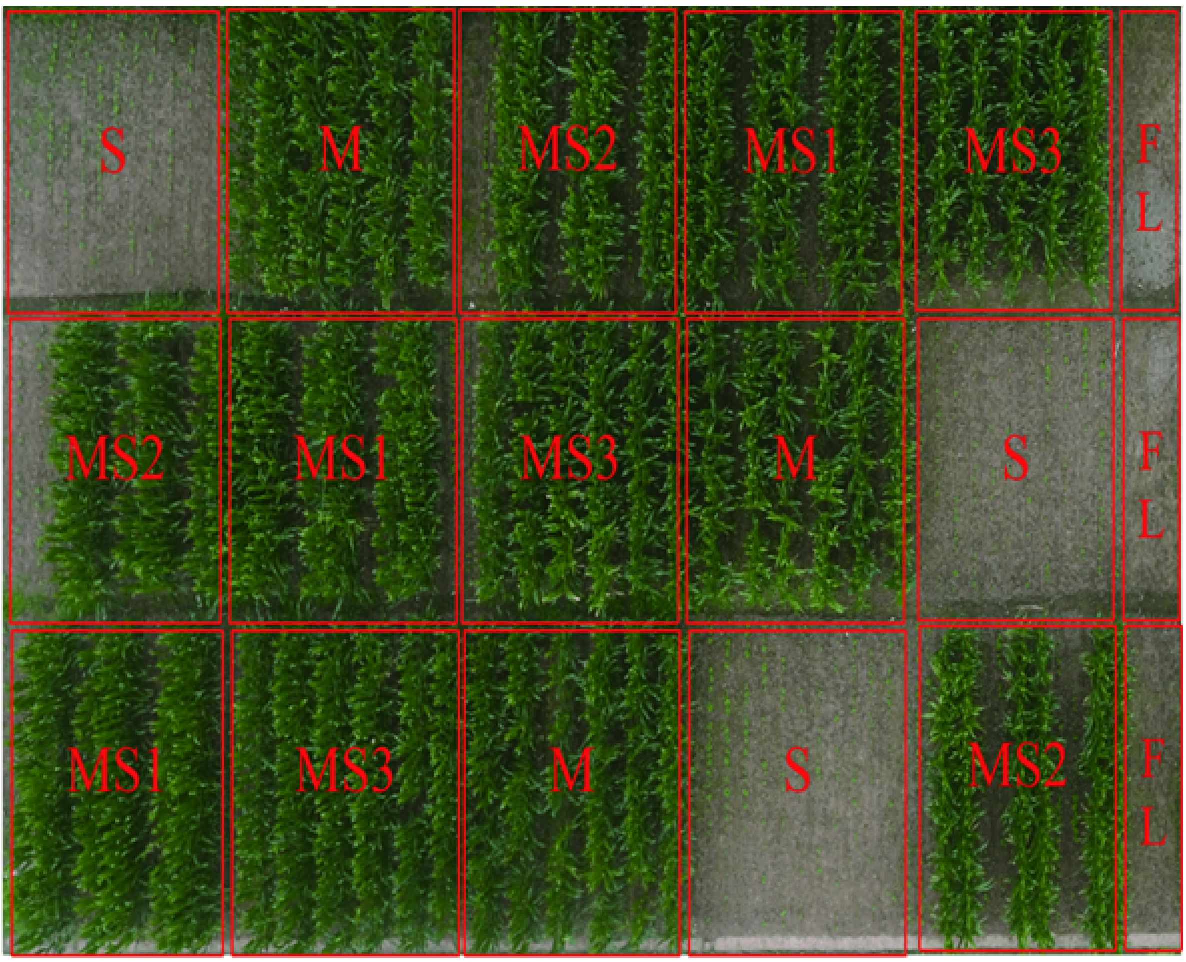

Figure 1

Aerial view of the experimental location.MS1, Continuous planting of maize/soybean relay strip intercropping; MS2, Planting of maize/soybean relay strip intercropping in rotation; MS3, Traditional maize/soybean intercropping; M, Sole maize planting; S, Sole soybean planting; FL, Fallow land. Repeat 3 times.

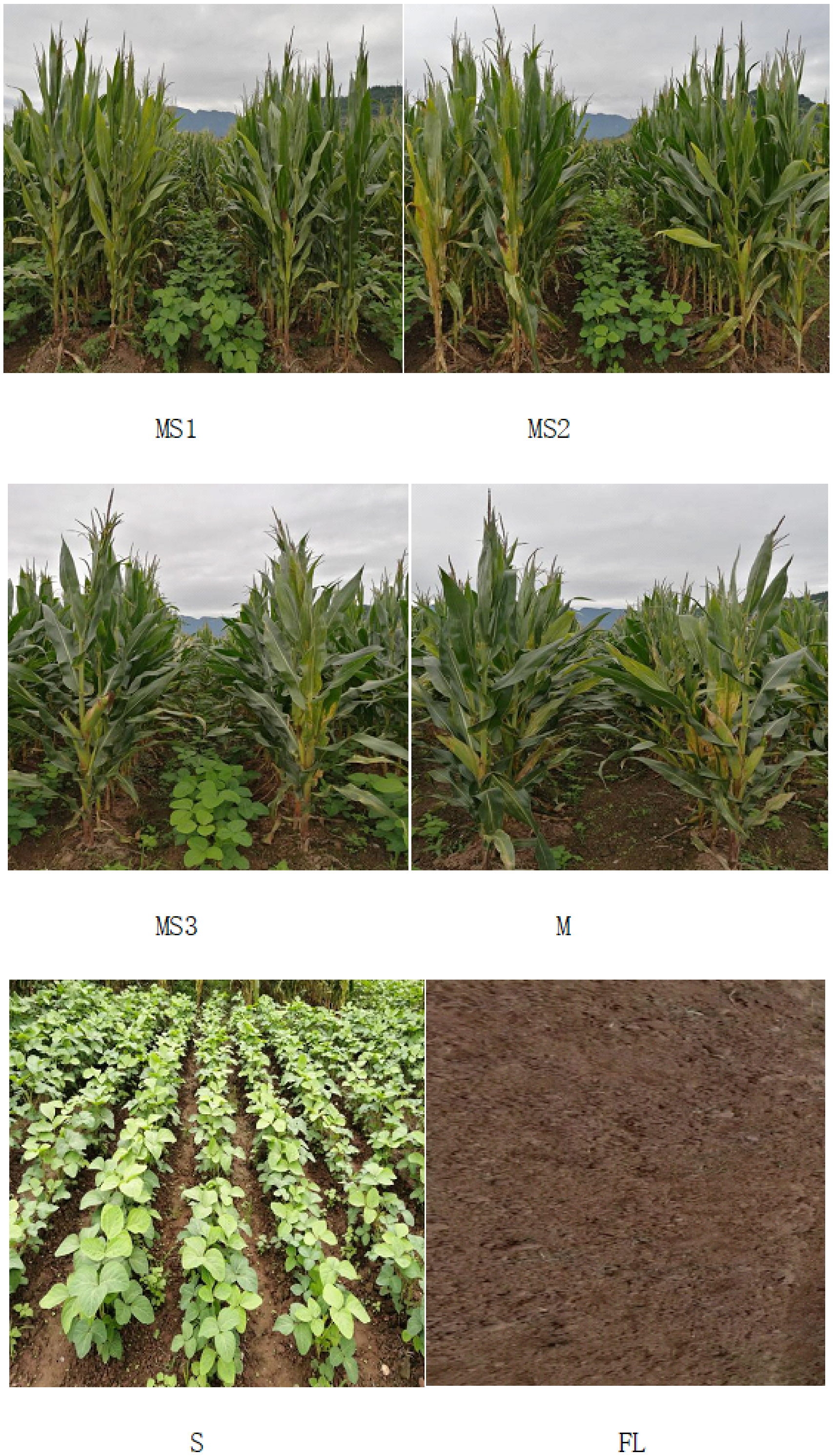

Figure 2

Different planting patterns.T1=MS1, Continuous planting of maize/soybean relay strip intercropping; T2=MS2, Planting of maize/soybean relay strip intercropping in rotation; T3= MS3, Traditional maize/soybean intercropping; T4= M, Sole maize planting; T5= S, Sole soybean planting; T6=FL, Fallow land.

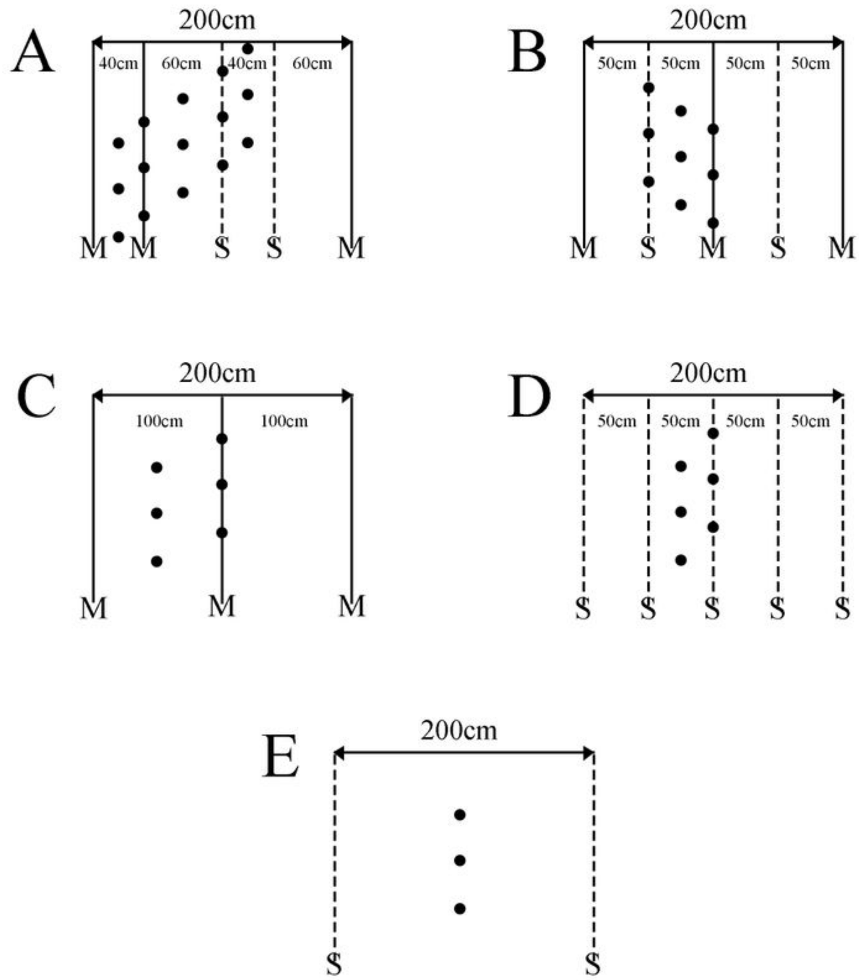

Figure 3

Spatial distribution of soil sample sites in different cropping patterns. A, B, C, D, and E represents the maize/soybean relay strip intercropping (continuous planting and rotation), traditional maize/soybean intercropping, sole maize, sole soybean, and fallow land plots. M represents maize, S representssoybean. ● represents soil sample sites.

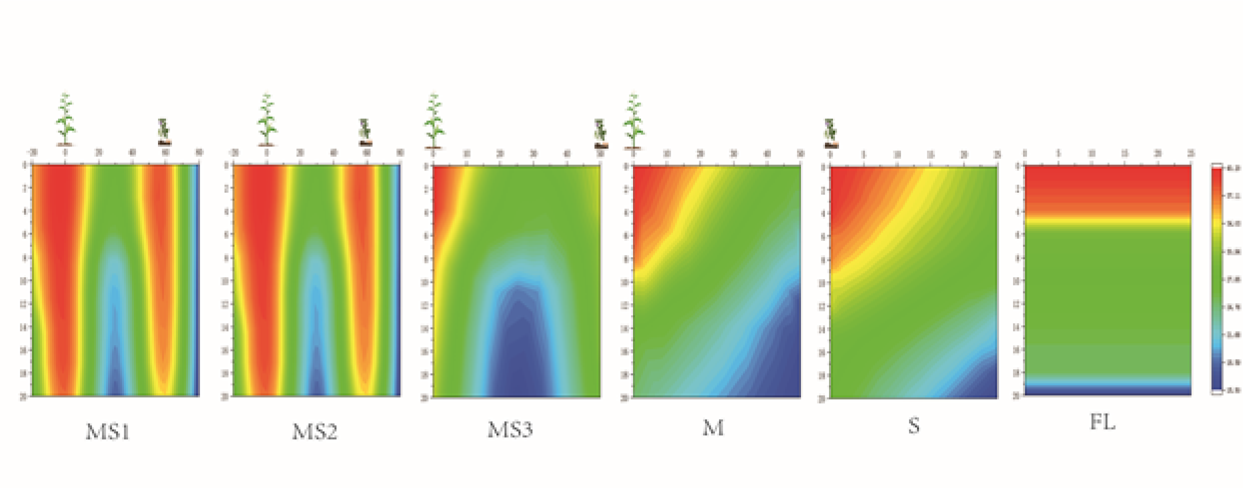

Figure 4

Spatial distribution of soil organic matter under different planting patterns of maize and soybean, SOM(g/kg).

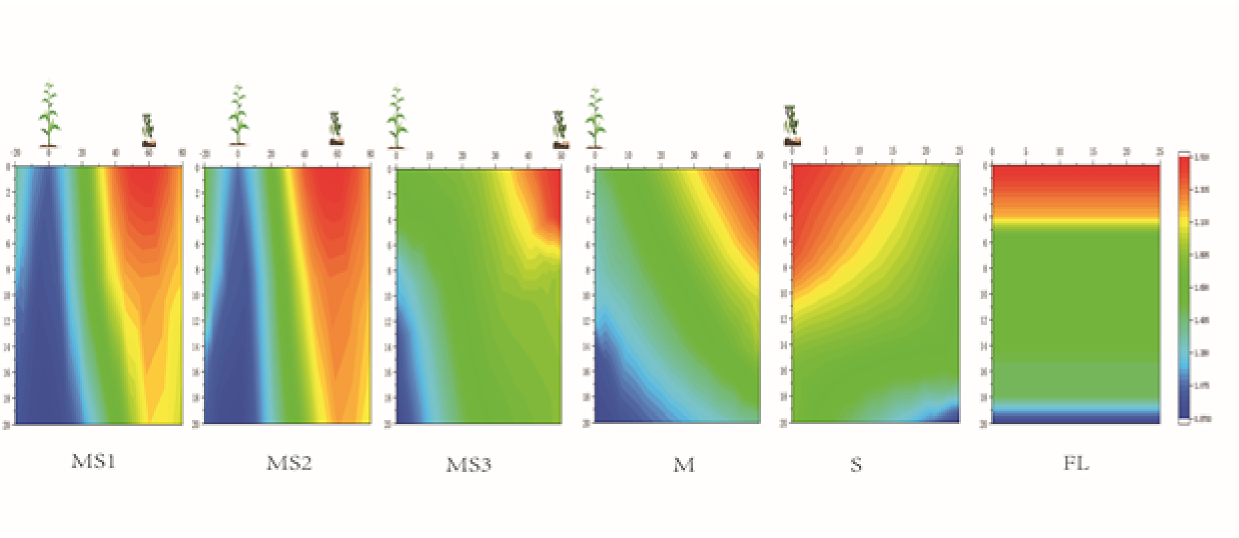

Figure 5

 Spatial distribution of soil nitrogen content under different planting patterns of maize and soybean, TN(g/kg).

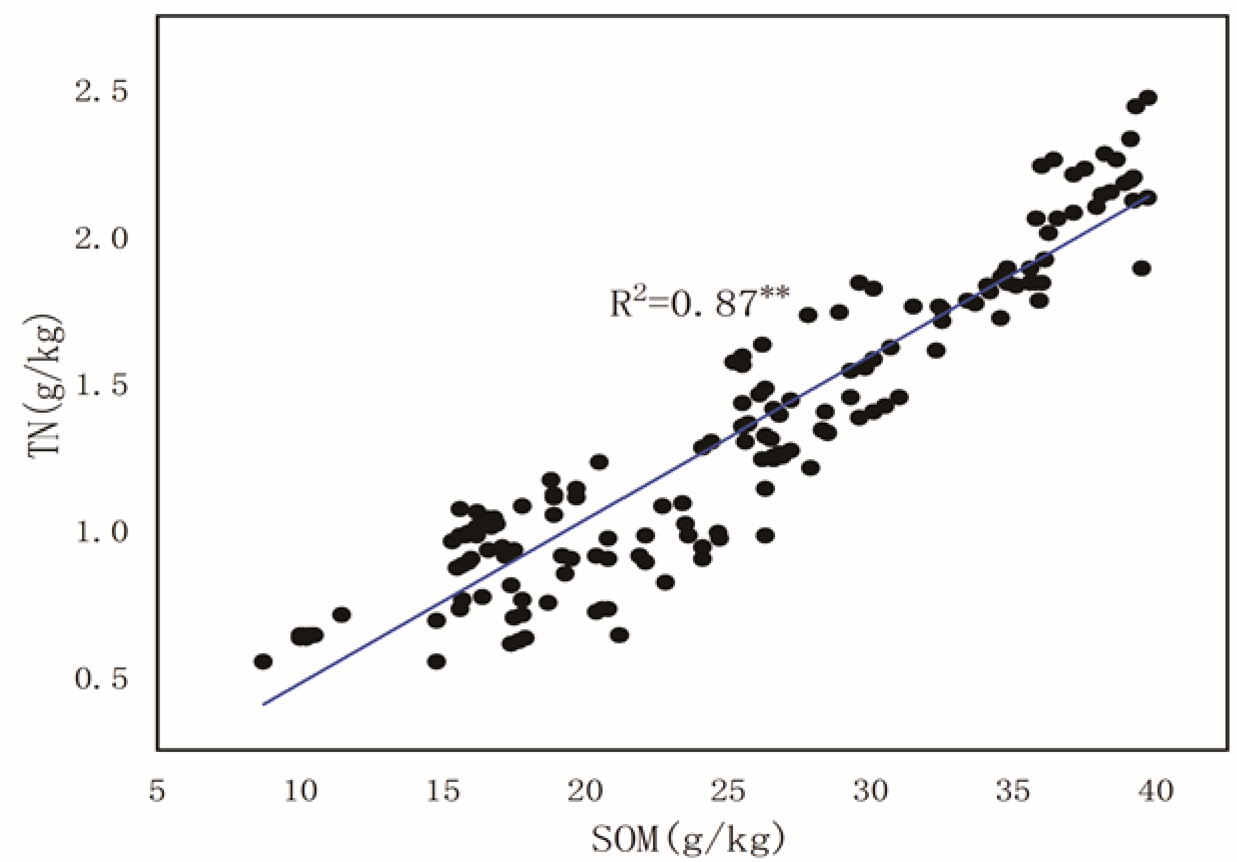

Figure 6

Soil organic matter (x) and soil total nitrogen (y) relations

Supplementary Files

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