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ARTICLE

Analysis of the Effects of Different Tillage Methods on Soil Water Holding Characteristics and Organic Carbon Storage in Farmland

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ABSTRACT

Analyze the impact of tillage on soil carbon storage, define scientific farming methods in Chengdu Plain, China, and provide the basis for regional optimization of farming models and soil improvement. Based on 4 location experiments, two tillage treatments, conventional tillage (CT) and no tillage (NT), were selected to analyze the difference of the impact of tillage on organic carbon. Due to different crop types and soil properties, there are regional differences in the impact of no tillage on soil organic carbon storage, which can significantly improve the surface soil organic carbon storage in various regions. In general, no tillage conservation tillage technology is an effective way to improve surface organic carbon storage.

1. Introduction

Soil is the largest carbon pool of the terrestrial ecosystem [1], which has a great impact on global terrestrial carbon cycle. Farming measures will change the physical properties of soil, affect the decomposition and transformation of organic carbon, and then affect the storage of organic carbon. Many studies show that conservation tillage can increase the content of organic carbon and enhance the effect of soil carbon sequestration. However, the potential of soil carbon sequestration is affected by many factors, such as soil texture, farming methods, planting systems and so on [2]. Carry out comparative networking research on the physical properties of soil in different regions by farming methods will help to understand the differences in the impact of different tillage on soil organic carbon storage, and provide a basis for the promotion of conservation tillage technology in the future [3-5]. Most of the existing studies focus on a single experimental site,

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and the relationship between soil physical properties and organic carbon in different regions and different tillage methods is still unclear [6,7]. In this study, farmland soils in four long-term pilot sites were used as the research object to explore the impact of different regional tillage on organic carbon storage and its driving factors, so as to provide a scientific basis for evaluating the carbon sequestration effect of conservation tillage on farmland soils in different regions. The conclusions of the test results are of universal significance.

2. Materials and Methods

2.1 Overview of the Study Area

GZL, SSY, HLF and SLF test points are selected for the test, which are located in the Chengdu Plain of China and are important areas for the promotion and application of conservation tillage in China. The basic information of each test point is shown in Table 1.

2.2 Experimental Design

The field management of each experimental site was carried out according to local customs, but the amount of straw returned to the field and the amount of fertilizer applied were different. A randomized block design was adopted in the experiment. Conventional tillage (CT) and no tillage (NT) were selected as test treatments, and each treatment was repeated 3 times. Traditional tillage (CT): After harvest, remove the crop straw from the field, use agricultural machinery such as rotary tiller and seeder to plow and sow, and apply fertilizer before sowing; No tillage (NT): Return the harvested crop straw to the field, use the no tillage planter to sow, and at the same time, deeply apply chemical fertilizer on the side of the sowing line. For soil sampling, after the crops are harvested, use the multi-point mixed sampling method to drill 0-10, 10-20, 20-40, 40-60 and 60-80 cm soil samples in the four test sites. Use the section digging method to collect the ring knife samples. All soil samples are put into polyethylene bags and taken back to the room for analysis and determination.

2.3 Index Measurement and Data Processing

Soil compactness: The compactness of 0-45 cm soil layer is measured in the field plot by using the compactness meter (SC900 type). The soil compactness meter automatically counts with the change of soil depth, and reads a value every 2.5 cm, with a horizontal spacing of 10 cm and 9 repetitions [8-10].

Volume weight of soil: ring knife method. Place the ring knife sample in the oven, bake it at 105 °C for 8 h, take it out and place it in the dryer, cool it and weigh it.

Total porosity of soil (%)=(1-soil bulk density/soil density) × 100; The soil density is 2.65 $g \cdot cm^{-3}$.

Soil organic carbon: Vario MACRO cube CHN element analyzer. Pass the air-dried soil sample through a 0.15 mm sieve, remove the carbonate with 1 $mol \cdot L^{-1}$ hydrochloric acid, and then dry it for determination on the machine [11-13].

2.4 Data analysis

Excel 2010 was used for data processing, Sigmaplot14.0 was used to make charts, and the data measurement results were all expressed as mean ± standard deviation. SAS9.1 software was used for one-way ANOVA and two-way ANOVA, LSD method was used for multiple comparisons between different treatments, and t-test was conducted between two treatments at a single test point ($P < 0.05$) [14,15].

Table 1. Basic of the four experimental site.

Site	Annual average temperature (°C)	Annual precipitation (mm)	Crop	Soil type	Soil particle composition (%)		
					Clay (0-0.002 mm)	Silt (0.002-0.05 mm)	Sand (0.05-2 mm)
GZL	5.6	594.8	Spring corn	Cinnamon soil	5.3	59.9	39.1
SSY	7.4	461.8	Spring corn	Cinnamon soil	5.6	63.9	30.5
HLF	11.9	550.0	Winter wheat -Spring corn	Fluvo-aquic soil	4.1	51.4	44.5
SLF	10.7	555.0	Winter wheat	Loessal soil	5.2	73.9	20.9

3. Results

3.1 Effects of Different Tillage Methods on Soil Physical Properties

3.1.1 Soil Bulk Density and Porosity

Different tillage treatments affect soil bulk density, but the degree of influence is different in four test points (Table 2). The soil bulk density of NT treatment group at GZL test site increased by 12.1% compared with that of CT treatment group ($P < 0.05$); The soil bulk density of NT treatment group in SSY test site was significantly lower than that of CT treatment group ($P < 0.05$), decreased by 8.2%. There was no significant difference in soil bulk density between CT and NT treatment groups at HLF and SLF test sites ($P > 0.05$). Compared with soil bulk density, the changing trend of soil total porosity is opposite. The soil porosity of CT treatment group in GZL test site was higher than that of NT treatment group, with a significant difference ($P < 0.05$). The soil porosity of NT treatment group in SSY test site was 49.4%, which was significantly different from that of CT treatment group ($P < 0.05$). There was no significant difference between CT and NT treatment groups at HLF and SLF test points ($P > 0.05$).

Table 2. Soil bulk density and total porosity in 0-10 cm depth under different tillage.

Site	Treatment	Bulk density ($g \cdot cm^{-3}$)	Total porosity (%)
GZL	CT	1.33 ± 0.03	0.49 ± 0.01
	NT	1.49 ± 0.13	0.44 ± 0.05
SSY	CT	1.46 ± 0.02	0.45 ± 0.01
	NT	1.34 ± 0.07	0.49 ± 0.03
HLF	CT	1.46 ± 0.06	0.45 ± 0.02
	NT	1.47 ± 0.01	0.44 ± 0.01
SLF	CT	1.38 ± 0.10	0.47 ± 0.04
	NT	1.36 ± 0.06	0.49 ± 0.02

3.1.2 Soil Compactness

The effects of different tillage treatments on soil compactness at the four test sites were different (Figure 1). The soil compactness of NT treatment group in the whole soil profile of GZL test site was higher than that of CT treatment group in varying degrees; The soil compactness of 0-5 cm topsoil, SSY, HLF and SLF test sites under different tillage treatments had no significant difference ($P > 0.05$). At 5-25 cm, the soil compactness of NT treatment group at SSY and SLF test sites was significantly higher than that of CT treatment group ($P < 0.05$), while that of NT treatment group at HLF test sites was higher than that of CT treatment group, with no significant difference ($P > 0.05$). 25-45 cm, the soil compactness of SSY test site CT>NT ($P < 0.05$), and the soil compactness of HLF and SLF test sites had no significant difference ($P > 0.05$).

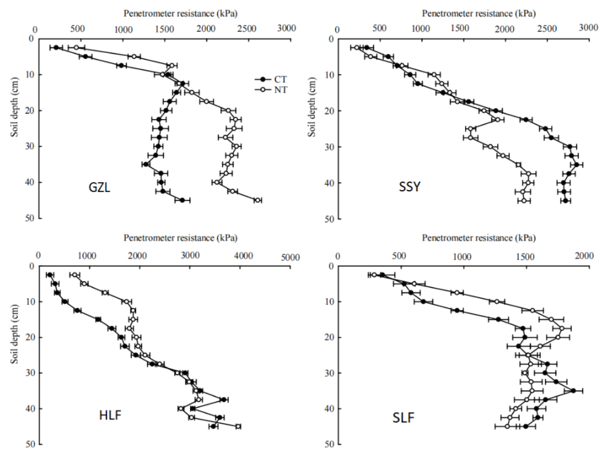

Figure 1. Penetrometer resistance under different tillage.

3.2 Effects of Different Tillage Methods on Soil Organic Carbon

3.2.1 Soil Organic Carbon Content

The content of soil organic carbon under the two tillage treatments decreased with the deepening of soil layers, and the decreasing trend was gradual. There are differences in soil organic carbon content under different tillage treatments in four test sites (Figure 2).

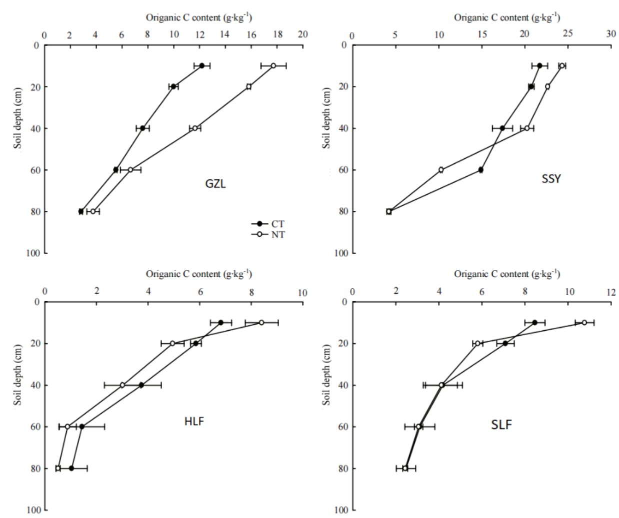

Figure 2. Soil organic carbon contents under different tillage.

The soil organic carbon content of NT treatment group in different soil layers at GZL test site was significantly higher than that of CT treatment group ($P < 0.05$). In SSY test site, no tillage significantly increased soil organic carbon content in 0-40 cm soil layer (P > 0.05), and organic carbon content in soil layer below 40 cm in CT treatment group was higher than that in NT treatment group. In SLF test site, NT treatment group increased the carbon content of 0-10 cm tillage layer, the organic carbon content of 10-20 cm soil layer CT > NT, and the organic carbon content of soil layer below 40cm had no significant difference (P > 0.05). Compared with other test sites, the soil organic carbon content of HLF test site under different treatments was significantly different (P < 0.05), and the soil organic carbon content of NT treatment group was only higher than that of CT treatment group in the 0-10 cm soil surface layer.

3.2.2 Soil Organic Carbon Storage

According to the two-factor variance analysis, it was found that tillage mode had a very significant impact on soil organic carbon storage (P < 0.01), and the experimental site had a significant impact on soil organic carbon storage (P < 0.05). Soil organic carbon storage was less affected by the interaction of site and tillage mode (P > 0.05). Table 3 shows that the effects of tillage methods on the organic carbon storage of 0-80 cm soil layers at different test sites are different. Compared with the CT treatment group, the NT treatment group increased the organic carbon storage of surface farmland soil. Among them, the organic carbon reserves in 0-10 and 10-20 cm soil layers and the total organic carbon reserves in 0-80 cm soil layers of GZL test site in NT treatment group were significantly higher than those in CT treatment group (P < 0.05), with an increase of 45.4%, 58.5% and 7.2% respectively. At SSY test site, the organic carbon storage of 0-10 and 10-20 cm soil layers in NT treatment group increased by 11.9% and 9.2% respectively compared with CT treatment group, but the total organic carbon storage of 0-80 cm soil layers decreased by 26.8%. At SLF test site, the organic carbon storage of NT treatment group in 0-10 cm soil layer was 23.1% higher than that of CT treatment group, and the organic carbon storage of NT treatment group in 0-80 cm soil layer was significantly lower than that of CT treatment group, with a decrease of 31.3%. At SLF test site, the organic carbon storage of 0-10 cm soil layer in NT treatment group increased by 27.2% compared with CT treatment group, and the total organic carbon storage of other soil layers and 0-80 cm soil layer decreased, of which the total organic carbon storage decreased by 23.5%, with significant difference (P < 0.05).

Table 3. Soil Organic carbon storage under different tillage.

Site	Treatment	Organic carbon storage($t\cdot hm^{-2}$)					
		0-10 cm	Increased than CT (%)	10-20 cm	Increased than CT (%)	20-40 cm	Increased than CT (%)
GZL	CT	19.04 ± 0.96	45.4	15.99 ± 0.56	58.5	23.21 ± 0.02	–16.5
	NT	27.69 ± 1.52		24.71 ± 0.19		19.37 ± 0.72	
SSY	CT	28.41 ± 1.19	11.9	27.12 ± 0.42	9.2	56.55 ± 4.89	–56.7
	NT	31.81 ± 0.52		29.62 ± 0.14		24.49 ± 1.66	
HLF	CT	10.56 ± 0.63	23.1	9.06 ± 0.32	–15.5	12.14 ± 2.48	–59.1
	NT	12.99 ± 0.99		7.66 ± 0.69		4.96 ± 1.16	
SLF	CT	12.02 ± 0.67	27.2	10.07 ± 0.58	–18.1	12.32 ± 2.67	–49.2
	NT	15.29 ± 0.62		8.25 ± 0.33		6.26 ± 1.12	
GZL	CT	16.87 ± 0.28	–34.4	8.61 ± 0.36	–27.5	83.33 ± 0.89	7.2
	NT	11.07 ± 1.79		6.24 ± 0.81		89.32 ± 0.21	
SSY	CT	28.68 ± 0.28	–26.9	11.69 ± 0.69	–49.4	154.09 ± 3.57	–26.8
	NT	20.97 ± 0.14		5.92 ± 0.09		112.84 ± 1.81	
HLF	CT	3.04 ± 0.31	–52.3	3.36 ± 1.96	–74.7	39.85 ± 1.75	–31.3
	NT	1.45 ± 0.55		0.85 ± 0.14		27.37 ± 2.81	
SLF	CT	9.18 ± 2.06	–49.3	7.28 ± 1.32	–49.1	50.22 ± 4.06	–23.5
	NT	4.65 ± 0.29		3.71 ± 0.17		38.42 ± 0.45	

3.3 Correlation between Climate Factors, Soil Factors and Organic Carbon

There is a correlation between climate factors, soil factors and organic carbon storage under long-term different tillage measures in the four test sites (Table 4). Soil organic carbon storage was significantly positively correlated with saturated water content ($P < 0.01$), significantly negatively correlated with annual average temperature and annual precipitation ($P < 0.01$), and significantly negatively correlated with compactness ($P < 0.05$), but not significantly correlated with bulk density, clay content, silt content, and sand content. At the same time, the saturated water content has a very significant correlation with the annual precipitation and unit weight ($P < 0.01$), and the compactness has a very significant correlation with the silt content and sand content ($P < 0.01$).

Table 4. Correlation coefficients between climate factors, soil factors and organic carbon.

	Annual average temperature	Annual precipitation	Bulk density	Clay	Silt	Sand	Saturated moisture	Penetrometer moisture	Organic C storage
Annual average temperature	1								
Annual precipitation	0.126	1							
Bulk density	0.149	0.106	1						
Clay	–0.132	0.101	–0.389	1					
Silt	–0.368	0.023	–0.321	0.902**	1				
Sand	0.337	–0.035	0.335	–0.928**	–0.998**	1			
Saturated moisture	–0.381	–0.589**	–0.524**	0.381	0.317	–0.315	1		
Penetrometer moisture	–0.337	0.298	0.084	–0.308	–0.544**	0.538**	–0.154	1	
Organic C storage	–0.731**	–0.708**	–0.88	0.46	0.218	–0.194	0.627**	–0.538**	1

4. Conclusions

The effects of no tillage on soil bulk density and compactness were different in different regions. No tillage increased soil bulk density and compactness at GZL test site and HLF test site, and decreased soil bulk density at SLF test site and SSY test site.

Compared with traditional tillage, no tillage significantly increased the surface organic carbon storage of 0-10 cm in four experimental sites. Among them, the organic carbon reserves at GZL test point increased by 45.4%, SSY test point increased by 11.9%, HLF test point increased by 23.1%, and SLF test point increased by 27.2% [16-18].

The influence of tillage on the total organic carbon storage in different regions of 0-80 cm soil layer is significantly different. Under no tillage, the organic carbon storage in GZL test site increased by 7.2%, while that in SSY test site, HLF test site and SLF test site decreased by 26.8%, 31.3% and 23.5% respectively.

Long term tillage can affect soil organic carbon storage by adjusting soil water holding capacity and compactness, but the influence degree is different in different regions [19-20]. In general, no tillage is an important measure to improve the topsoil organic carbon storage.

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Conflict of Interest

There is no conflict of interest.

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