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Temporal and Spatial Variation Characteristics of Soil Organic Carbon Content in Cultivated Land of Black Soil Region in Liaoning Province

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Abstract [**Objectives**] To study the temporal and spatial variation of SOC content in cultivated land in black soil region in Liaoning Province. [**Methods**] Through the evaluation and analysis of the research data of this project and the data of the second national soil census, and using GIS technology, this paper studied the temporal and spatial variation characteristics of SOC in the black soil region of Liaoning Province, and provided a basis for improving cultivated land carbon storage and soil organic matter content. [**Results**] Since 1980, the SOC content in cultivated land in the black soil region in Liaoning Province has generally declined, and the spatial distribution difference has gradually decreased. From 1980 to 2018, the homogeneity of SOC distribution weakened, and the variation in a small range strengthened. The SOC content generally showed the characteristics of increase and decrease, and the changes in the area were scattered. [**Conclusions**] This study is of great significance to the sustainable utilization of land resources.

Key words Black soil region in Liaoning Province, Cultivated land, SOC, Temporal and spatial variation

1 Introduction

The growth of living things depends on soil, and only there is soil, may there be grain. Cultivated land is a precious resource, and black soil is the most scarce resource in the world. Black soil is a type of soil with good properties and high fertility, very suitable for plant growth. However, under the long-term traditional agricultural farming methods, the emphasis is placed on the use of resources and the predatory management, which has led to many problems, such as serious degradation of black soil, reduction of soil organic matter, thinning of soil layer, imbalance of soil nutrients in cultivated land, weak soil fertility and other problems, which affect the improvement of grain production capacity and the sustainable development of agriculture in Liaoning Province. SOC is an important indicator in soil quality evaluation and sustainable land use management. Therefore, it is of great significance for the sustainable utilization of land resources to study the temporal and spatial variation of SOC in the black soil region of Liaoning Province.

2 Overview of the study area

The black soil region Liaoning is located in the central and eastern part of Liaoning Province. This region includes all of Shenyang, Liaoyang, and Tieling cities and some counties and districts of Anshan, Fushun, Benxi, and Dandong cities (as indicated in Fig. 1). The total population of this region has reached 20.059 million in the study period, accounting for 45.8% of the total population of Liaoning Province; the total area of cultivated land was 1.867 million ha. The main crops are maize and rice. The main soil types in the black soil region of Liaoning Province are: brown soil, meadow soil, cinnamon soil, paddy soil, lessive soil, alkaline soil, and aeolian soil.

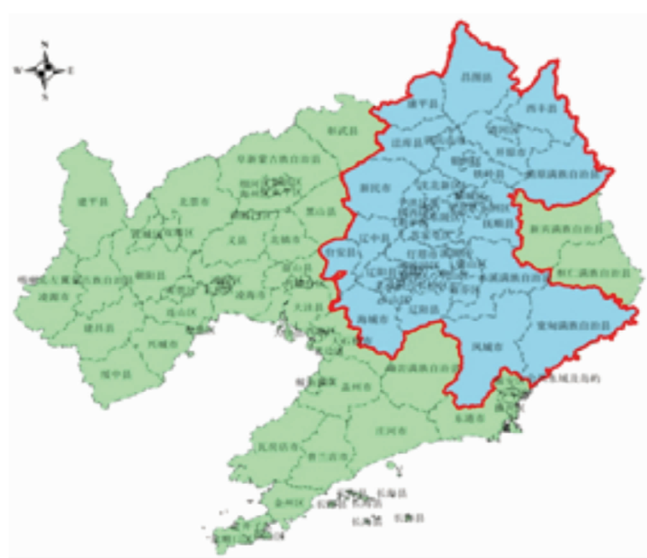

Fig. 1 Distribution of black soil region in Liaoning Province

3 Data sources and research methods

In this study, we used the Matheron's Theory of Regionalised Variables, the Semi-variogram model and the Kriging interpolation method to evaluate and analyze the research data and the data of

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the second national soil census (1980). The number of sample points in 1980 was 887, and the number of sample points in 2018 was 7 826.

4 Results and analysis

4.1 SOC content of cultivated land Table 1 shows the classification and area statistics of SOC content in the black soil region in Liaoning Province. It can be seen that in 1980, the soil organic carbon (SOC) content was 8.93 – 28.37 g/kg, with an average of 14.08 g/kg and a coefficient of variation of 18.99% (Table 2, Fig.2 and Fig.3). The organic carbon content in the medium level (11.60 – 17.40 g/kg) took up the largest proportion, accounting for 58.82%, and the smallest proportion was the quite abundant level, only 0.90% (Table 1). In 2018, the SOC content of cultivated land was distributed in the range of 6.09 – 23.26 g/kg, and its average content was 11.95 g/kg, which was 17.82% lower than that in 1980, and the coefficient of variation was 23.20% (Table 2, Fig.2 and Fig.3). The relatively deficient level (5.80 – 11.60 g/kg) took upthe largest proportion, accounting for 58.92%, while the quite abundant level was the lowest and accounted for only 0.04% (Table 1). On the whole, the SOC content in the two periods showed a normal distribution and reached a very significant level. The samples with decreased organic carbon content accounted for 88.78%, and the samples with increased content accounted for 11.22%.

Table 1 Area and level of SOC content in the black soil region in Liaoning

SOC content // g/kg	Level	Area of black soil region in 1980 // ha	Proportion to total cultivated land // %	Area of black soil region in 2018 // ha	Proportion to total cultivated land // %
≥ 23.20	Quite abundant	16 800.04	0.90	746.67	0.04
17.40 – 23.20	Abundant	194 693.75	10.43	106 026.89	5.68
11.60 – 17.40	Medium	1 097 975.69	58.82	660 054.75	35.36
5.80 – 11.60	Relatively deficient	557 201.20	29.85	1 099 842.37	58.92
3.48 – 5.80	Deficient	0	0	0	0
<3.48	Quite deficient	0	0	0	0

Table 2 Characteristics of SOC content in different periods of black soil region in Liaoning

Year	Statistical value		
	Average content // g/kg	Standard deviation	Coefficient of variation // %
1980	14.08	2.673 90	18.99
2018	11.95	2.772 35	23.20

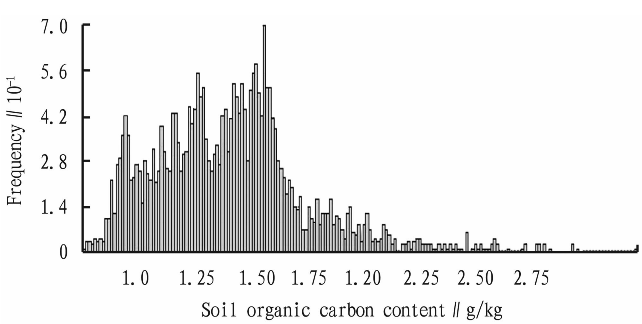


Fig.2 Frequency distribution of SOC content in 1980

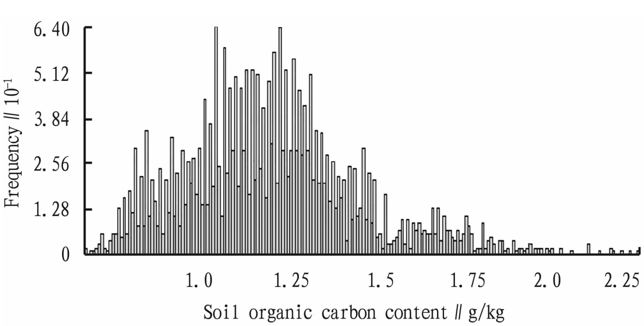


Fig.3 Frequency distribution of SOC content in 2018

4.2 Spatial variation analysis of SOC content in cultivated land Fig.4 and Fig.5 are the theoretical models of the optimal semivariance function drawn by fitting. It can be seen that the semi-variance value of SOC increases with the increase of the step size, and the step size is larger, and the spatial correlation degree gradually decrease. This shows that, on a large scale, there is a spatial autocorrelation of SOC in the black soil region of Liaoning, and when the point-pair distance is greater than the step size, the spatial independence is maintained. From Table 3, it can be seen that the semivariance changes of SOC content in 1980 and 2018 can be fitted by the exponential model, and the fitting degree is very high.

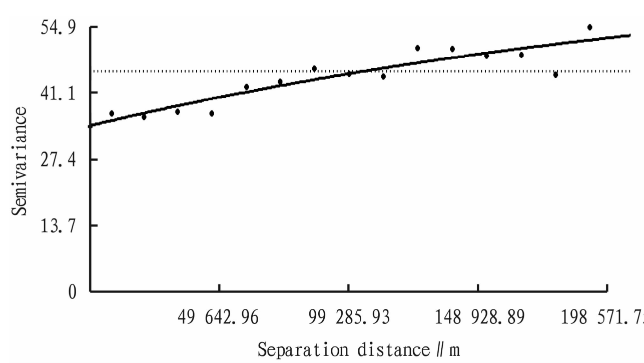


Fig.4 SOC semivariogram and exponential model fitting in 1980

The nugget value (*Co*)/nugget value (*Co*) + Sill (*C*) reflects the degree of spatial autocorrelation of variables, and is also an important indicator to distinguish the sources of spatial heterogeneity of variables. Structural factors (natural factors such as climate, parent material, topography, biology, time, *etc.*) may lead to strong spatial autocorrelation of soil nutrients, while random factors (man-made activities such as fertilization, tillage measures, planting systems, *etc.*) may weaken the autocorrelation of soil nutrients and develop towards a homogenization. In the black soil region of Liaoning, the nugget value (Co)/nugget value (Co) + Sill (C) of organic carbon in 1980 was 49.99%, and the nugget value (Co)/nugget value(Co) + Sill (C) of organic carbon in 2018 was 49.97%, which belongs to medium level of spatial autocorrelation, which is related to the strong influence of organic carbon itself structural factors (such as parent material).

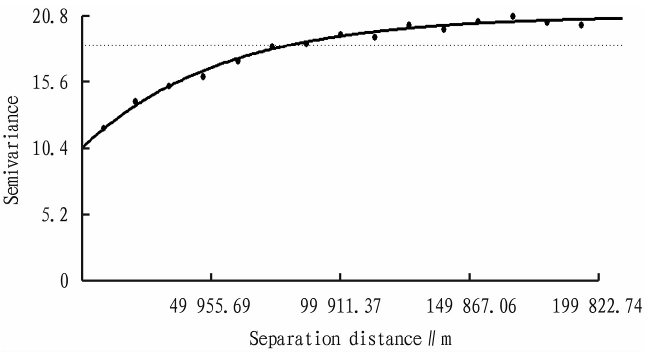
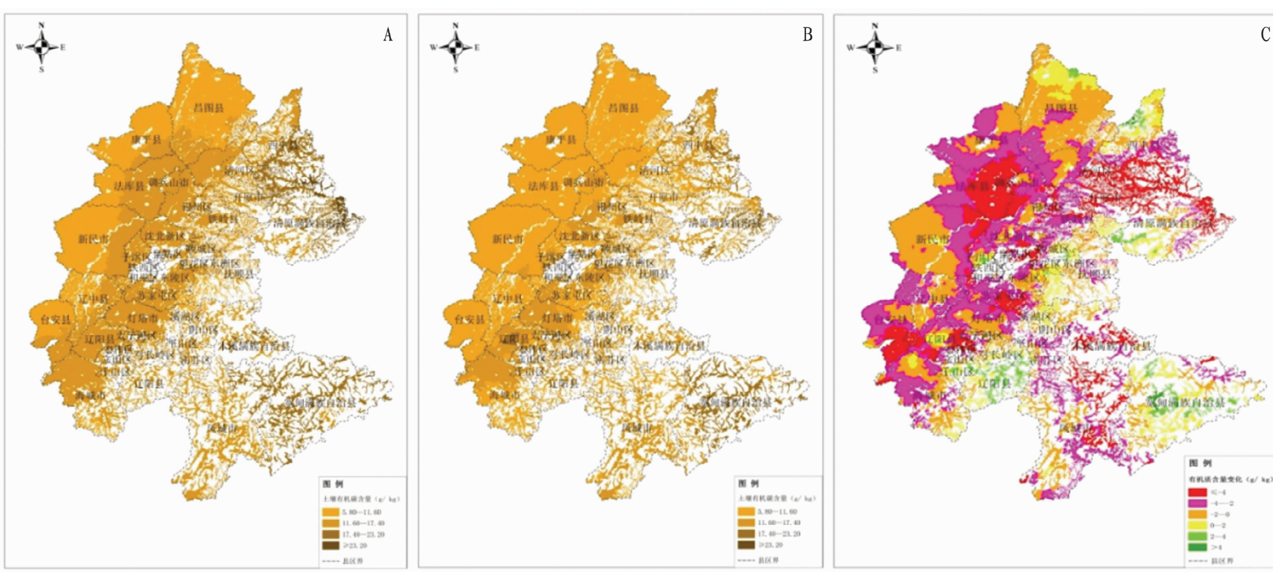


Fig. 5 SOC semivariogram and exponential model fitting in 2018

4.3 Spatial distribution and variation characteristics of SOC content in cultivated land of black soil region From Fig. 6A, it can be seen that the distribution of SOC content in the black soil region of Liaoning Province is uneven, and the overall trend is gradually decreasing from the northwest to the southeast. The areas with higher organic carbon content in the black soil region were mainly distributed in Qingyuan County, Xifeng County and Kuandian Manchu Autonomous County in the eastern region. Among them, Qingyuan County had the highest average SOC content, reaching 20.47 g/kg; the areas with low organic carbon content were mainly distributed in Kangping County, Changtu County, Xinmin City and Liaozhong County. Among them, the average SOC content in Kangping County was the lowest, only 10.88 g/kg.

The overall trend of the distribution of organic carbon content in cultivated land of black soil region in 2018 was the same as that in 1980. From Fig. 6B, it can be seen that the areas with higher organic carbon content in the black soil region were mainly distributed in Kuandian County, Qingyuan County and Xifeng County in the eastern region. Among them, the average SOC content in Kuandian County was the highest, reaching 18.19 g/kg; the areas with low organic carbon content were mainly distributed in Faku County, Kangping County, Tai'an County and Xinmin City. Specifically, the average SOC content in Faku County was the lowest, only 7.70 g/kg.

Fig. 6C shows the changes in SOC. It can be seen that the content of SOC in the black soil region of Liaoning had both increase and decrease, and the decrease areas were mainly in parts of Shenyang, Tieling and Anshan cities. The proportion of reducing 0 – 2 g/kg was 34.70%, and the proportion of reducing 2 – 4 g/kg was 36.49%; in Kuandian Manchu Autonomous County, parts of Liaoyang County, Gongchangling District, Dongzhou District, and Xinfu District, the increase was larger. The proportion of increase of 0 – 2 g/kg accounted for 8.68%, and the proportion of increase of more than 2 g/kg accounted for only 2.54%.



Note: A. 1980, B. 2018, C. 1980 – 2018.

Fig. 6 Spatial distribution of SOC content in black soil region of Liaoning Province

5 Conclusions

In order to study the temporal and spatial variation of SOC content in cultivated land in black soil region in Liaoning Province, we conducted the evaluation and analysis of the research data of this project and the data of the second national soil census. Using GIS technology, we analyzed the temporal and spatial variation characteristics of SOC in the black soil region of Liaoning Province, and provided a basis for improving cultivated land carbon storage and soil organic matter content. We found that since 1980, the SOC content in cultivated land in the black soil region in Liaoning Province has generally declined, and the spatial distribution difference has gradually decreased. From 1980 to 2018, the homogeneity of SOC distribution weakened, and the variation in a small range strengthened. The SOC content generally showed the characteristics of increase and decrease, and the changes in the area were scattered. It is expected to provide a certain research value and reference for sustainable utilization of land resources.

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(From page 6)

3 Conclusions

The six tobacco loading methods can meet the needs of baking. The tobacco loading methods of loose leaf stacking, loose leaf binding and inserting, loose leaf inserting, loose leaf net basket and loose leaf grid have changed the traditional tobacco loading methods and increased the amount of tobacco loading. The cost of dry tobacco loading equipment for hanging pole and loose leaf stacking is low, and the cost of loose leaf net basket is the highest. The labor cost for direct stacking of loose leaves to bake dry tobacco is the lowest, and the labor cost for binding and inserting loose leaves is the highest. The energy consumption cost of dry tobacco cured with loose leaf grid is the lowest, and that of bulk cured with loose leaf is the highest. From the perspective of baking income, loose leaf inserting is the lowest, while net basket is the highest, followed by grid and loose leaf binding and inserting. The one-time capital investment of the net basket is large, which is difficult to promote. According to comprehensive analysis, loose leaf binding and inserting and loose leaf grid baking are worth popularizing.

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