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The Quantified and Major Influencing Factors on Spatial Distribution of Soil Organic Matter in Provincial-Scale Farmland—A Case Study of Shandong Province in Eastern China

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Abstract: Soil organic matter (SOM) is an important component of soil and plays an important role in improving the soil's physical and chemical properties. Ascertaining the spatial distribution of soil organic matter and its main controlling factors in the context of provincial scale farming is of important guiding significance for soil carbon sequestration, emission reduction and sustainable utilization. Using 257 soil profiles from the second soil survey in Shandong Province, GIS, we applied geostatistical methods to study the spatial distribution characteristics of SOM in topsoil. In addition, correlation and regression analyses were used to explore the main controlling factors over the spatial variation of SOM. The results showed that the mean amount of SOM in Shandong province ranged from 1.20–74.90 $g \cdot kg^{-1}$, with a coefficient of variation of 73.52%, which is a medium level of variation. The distribution of SOM in the study area was patchy, with higher levels of organic matter in the central, eastern, and northern parts, and lower levels of organic matter in the south-west. The comprehensive explanatory ability of all factors reached 52.30%. Soil type and parent material were the main controlling factors for the spatial variability of SOM in the Shandong Province, followed by soil texture and land use type, with topography and climatic factors having relatively little influence.

Keywords: soil organic matter; spatial variation; regression analysis; main controlling factors; provincial scale

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Citation: Zhao, X.; Zhang, Z.; Zhao, M.; Song, X.; Liu, X.; Zhang, X. The Quantified and Major Influencing Factors on Spatial Distribution of Soil Organic Matter in Provincial-Scale Farmland—A Case Study of Shandong Province in Eastern China. *Appl. Sci.* **2023**, *13*, 3738. https://doi.org/10.3390/app13063738

Academic Editor: José A. González-Pérez

Received: 6 February 2023
Revised: 9 March 2023
Accepted: 10 March 2023
Published: 15 March 2023

1. Introduction

Soil organic matter (SOM) is the basis of soil fertility, and not only reflects the quality and health of the soil but also plays an important role in improving the soil's physical and chemical properties, in addition to plant growth [1]. The content and spatial distribution pattern of soil organic matter is affected by both natural factors and human factors, which have certain spatial variability regardless of scale. Natural factors include soil type, landform, meteorological climate, parent material type, soil texture, etc., while human factors include land use methods, tillage management measures, etc. [2–4]. Because of the high heterogeneity in soil organic matter, studying the spatial variability of SOM and its influencing factors can effectively elucidate the current spatial distribution of SOM in the region, which is of great significance for improving soil fertility, environmental protection, and sustainable agricultural development.

At present, most of the research on the spatial variation of soil organic matter has focused on only a certain type of influencing factor, and most of them only focusing on a small scale. However, soil organic matter is affected by many factors, and the influence of all factors on organic matter content is scale dependent. In this present study, our spatial scales covered different ranges, including county, province, regional scales [5–7] (such as hilly red soil region in the Songliao Plain of China, or the small watershed of Loess Plateau), in addition to national scales, etc. There are many studies based on the county scale. For example, slope has been found to be the main controlling factor of the spatial distribution of organic matter on the Loess Plateau in Hengshan county [8]. In some counties of eastern China, it has been found that topographic factors such as elevation and slope direction have the most significant influence on the spatial distribution of organic matter [9,10]. Hu et al. found that the main controlling factors of soil organic matter in the Pinggu County of Beijing were terrain, soil type, texture, and land use type, but that texture and tillage methods had more significant effects at the township scale [11]. In Huzhu County, Qinghai Province, it was found that soil type, average annual precipitation, and altitude each play a leading role in the formation of organic matter spatial distribution [12]. There are few studies on the spatial distribution of soil organic matter at provincial scale in China [13–15].

At larger regional scales, topographic factors and climate seem to have more influence on organic matter. For example, the influence of climatic factors on soil organic matter is very obvious in dryland soil of the north-east region [16]. The SOM variation between different geographical regions in China is controlled by temperature, precipitation, and altitude, with the level of variance ranging from 41.5% to 56.2% [17]. At the national scale, studies have shown that 45% of the variation in soil organic carbon in the Spanish peninsula can be explained by climate variables and land use [18]. In Irish grassland soils, precipitation is the main controlling factor upon soil organic matter [19].

In summary, the main controlling factors affecting the spatial distribution of SOM vary from region to region, due to different geographical and environmental conditions. Most of therecent studies have focused on a limited range influencing variables or factors on SOM content in small and medium scales, such as City and County. In particular, there are few studies that comprehensively consider the effects of numerous natural and human factors at large scales, such as the provincial scale and beyond. The factors influencing SOM are different at different scales, so the different types of influencing factors should be considered comprehensively. Shandong Province is a major agricultural province in eastern China and has a significant role in the whole country. Its SOM content and distribution directly affect agricultural production. However, neither the characteristics of the spatial variation of SOM in the Shandong Province, nor the degree of influence various types of influencing factors have on the spatial variation of SOM, have been clearly or systematically ascertained. Therefore, it is necessary to further study these spatial distribution characteristics, and quantify the influencing factors on the spatial variation of SOM.

The innovation of this research is to study the spatial distribution characteristics of SOM on a provincial scale, which has been rarely studied up to now, and to do so by means of geostatistics. In addition to a comprehensive analysis of the effects that soil texture, parent material, land use type and soil type, topography, and climate factors have upon the spatial variation of soil organic matter, the stepwise regression analysis method was used to quantify the influence of each factor, in order to fully understand the spatial distribution characteristics and main controlling factors of soil organic matter at a provincial scale.

2. Materials and Methods

2.1. Site Description

Shandong Province is located in the eastern coast of China and is the northernmost province of East China (Figure 1). Its geographical location lies between 114°19′–122°43′ E and 34°22′–38°23′ N. The total land area is 157,000 km^2. The terrain is complex, with the central and southern part being the low hills of the Luzhong district, sloping from the middle to the surrounding area, with an average altitude of 500–1000 m. The eastern part comprises the low hills of the Jiaodong district, with an average altitude of less than 400 m, and covers the main part of Shandong Peninsula. The north-western part comprises the

North-west Plain of Shandong Province, with an altitude of less than 50 m, which is formed from the alluvial deposits of the Yellow River; in addition, this area is part of the North China Plain. The climate of Shandong Province is warm-temperate monsoonal, with annual precipitation of 550–950 mm, with 60–70% of the annual precipitation occurring in summer. The mean annual temperature is between 11 °C and 14 °C. There are many soil types in Shandong Province, the main soil types being brown soil, cinnamon soil, alluvial soil, Lime concretion black soil, skeleton soil, and Coastal Saline soil.

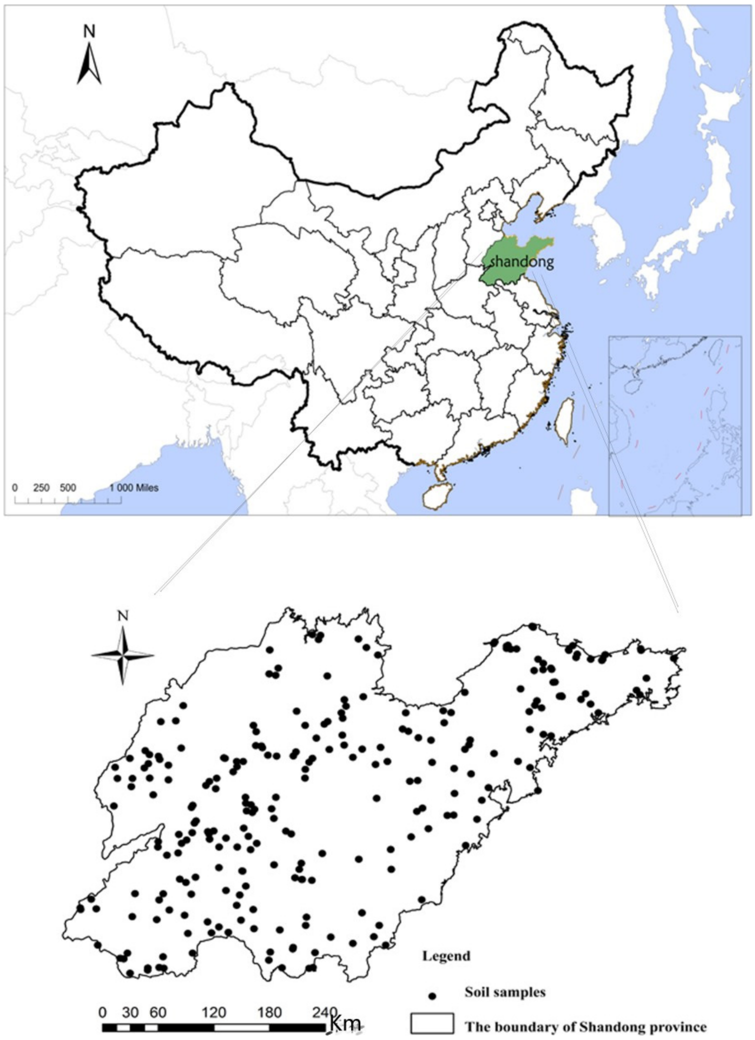

Figure 1. Location of study area.

2.2. Data and Methods

The data used for this study are from typical soil profiles recorded during China second national soil survey, including the Shandong Soil Species Records. 257 samples were collected from these records. According to the Chinese Soil Genetic Classification System, these soil profiles belong to 15 soil groups, 36 subgroups, 85 soil genera, and 257 soil species. The soil profile information mainly includes the sampling location, soil parent material, land use pattern, and the soil's physical and chemical properties. In this study, the SOM content of surface soils (those within a depth of 0–20 cm) was used as the research object. SOM content was determined using a potassium-dichromate-oxidation-based external heating method [20].

The data for the average annual temperature and average annual rainfall were obtained from the 1 km grid data of Resources and Environmental Science and Data Center, which documented the annual average from 1980 to 1999. DEM was obtained from the geospatial data cloud. Based on the DEM, topographic factors such as slope and slope direction were calculated using ArcGIS. Finally, the annual average temperature, annual rainfall, and topographic data of these various points were then extracted from the raster data.

All the statistical analyses were performed with SPSS software 13.0. The effects of soil type, soil texture, soil parent material and land use type on organic matter were studied using variance analysis. Correlation analysis was used to study the effects of terrain and climate variables on organic matter. Using the geostatistical analysis module of ArcGIS 10.3 and ordinary Kriging interpolation, the spatial distribution of soil organic matter was mapped. The main influencing factors of the spatial distribution of soil organic matter were quantitatively studied using a stepwise regression method.

3. Results

3.1. Descriptive Statistics of SOM Content

The summary statistics of SOM data are reported in Table 1. A total of 257 soil samples were obtained in the study area, and the SOM content ranged from 1.20 to 74.90 g·kg^{-1}, with a mean value of 10.78 g·kg^{-1}. According to the nutrient content grading standard of the second national soil census, the level of SOM content in the study area was at the fourth level, which is a medium to lower level [21]. The SOM had a high CV (73.36%), which may be due to the great heterogeneity of land use and in fertilization patterns between different regions. The coefficients of skewness and kurtosis were 4.86 and 33.46, which means that the statistical distribution of the raw data is positively skewed and has a sharp peak. The geostatistical analysis requires the data to meet the normal distribution, otherwise the semi-variance function may have proportional effect, and the experimental semi-variance function will produce distortion, affecting the accuracy of the statistical results. The original data were of a skewed distribution, conforming to the normal distribution after undergoing log transformation.

Table 1. Descriptive Statistics characteristic of SOM content.

Indicators	Min	Max	Mean	Standard Deviation	Coefficient of Variation	Skewness	Kurtosis	*p*-Value
SOM (g·kg^{-1})	1.20	74.90	10.78	7.91	73.36	4.86	33.46	0.00
Log-transformation						0.001	−0.106	1.00

3.2. Spatial Distribution Characteristics of SOM

As can be seen from the map (Figure 2), the interpolation results for SOM content in the study area ranged from 1.20 to 74.90 g·kg^{-1}, with the area in which SOM content was between 5.00 and 15.00 g·kg^{-1} being the largest. Overall, spatial distribution of SOM shows a trend of being high in the middle, and relatively low in the surrounding areas. From the spatial distribution map of SOM content, it is not difficult to see that SOM values are higher in the central and southern mountainous areas of Shandong Province, while it is lower in the south-west and north-west plain areas of Shandong Province, which is related to the topography and land utilization of the study area. Areas with high SOM content are mainly low hills, such as those which border the plains and are susceptible to influxes of surface water and groundwater. These hydrogeological conditions are favorable for the input of organic matter, and also suitable for vegetation growth. The output of organic matter is mainly derived from the decomposition of organic matter by soil microorganisms. Organic matter in these areas decomposes slowly because of their high elevation, low temperature, and sufficient moisture. In addition, the area is distributed with many types of soil, such as cinnamon soil, alluvial soil, and Lime concretion black soil. Some of them have an increased maturity and are relatively rich in SOM content due to a long history of tillage. Lower values were found in the south-western part of Shandong Province. This is because these areas are mainly located in the Yellow River alluvial plain, where the soil texture is mainly sandy or has poor water retention, and thus easily undergoes nutrient loss. The accumulation of organic matter can also be affected by uneven precipitation levels.

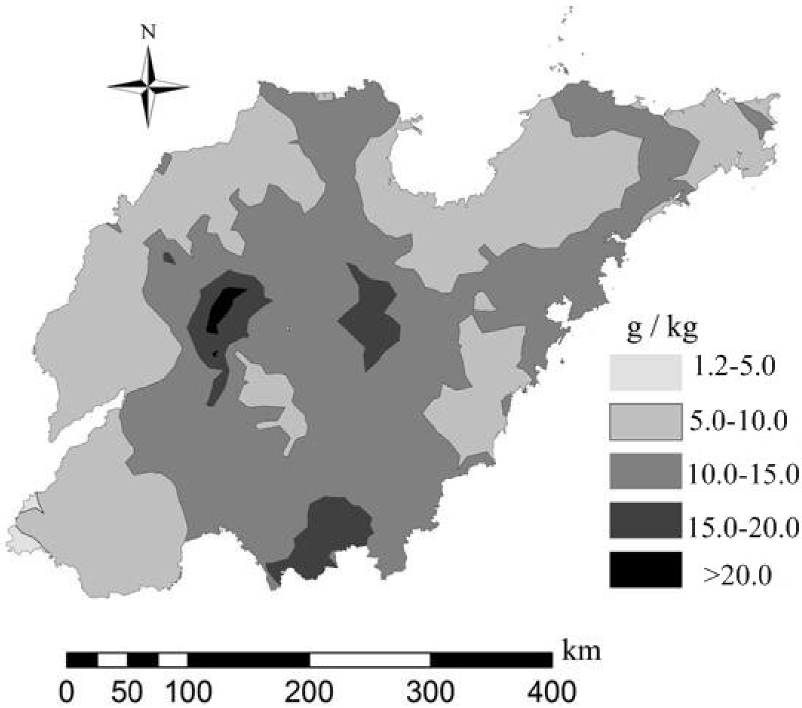

Figure 2. Spatial distribution map of SOM content in Shandong Province.

In addition, the north-west of Shandong is located in the hinterland of the Yellow River alluvial plain, and the soil is loam tidal soil. The soil is seriously short of *p* and has even less N. The soil is also heavily salinized, with less organic matter content. The spatial distribution of organic matter is different in other regions. In the southern part of the central plain of Jiangsu Province, which is close to Shandong Province, soil organic matter content decreased from north-east to south-west [22]. The amount of organic matter in the southern region is relatively low, which is mainly due to the difference in regional soil-forming environments. The alluvium of the Yangtze River is mainly distributed in the southern region, with light texture, high sand content and lack of adsorption stability mechanisms, none of which is conducive to the accumulation of organic matter. The level of soil organic matter increased gradually from north-west to south-east in Shanxi Province [23]. The north comprises the Loess Plateau, having both a higher altitude and less rain, and consequently soil organic matter content was the lowest here. The south-east has the highest organic matter content because it is mainly brown soil with high precipitation. The central region is mostly tidal soil, which has good fertilizer-retention performance, so its organic matter content was relatively high. In Guangxi Province of southern China, soil organic matter was lower in the south and higher in the north [13]. In northern Guangxi, karst peak cluster depression is the main vegetation type, comprising mostly forest and shrubland. The altitude is relatively high, and the temperature is relatively low. The decomposition of organic matter is slow while the input of litters is large, and the accumulation of soil organic matter is large. The southern Guangxi is mainly cultivated plains, and the input of organic matter is relatively low. Meanwhile, due to the high temperature, the decomposition of organic matter is accelerated, so the accumulation of soil organic matter is small. It can be seen that the spatial distributions of soil organic matter in different regions are obviously different, and is closely tied to the actual situation of the study area.

3.3. Analysis of Factors Affecting SOM Content

In general, the accumulation and decomposition of SOM is affected by a combination of various natural and human factors, such as topographical factors, hydrogeological conditions, temperature, and anthropogenic agricultural activities. In order to further clarify the factors affecting the spatial distribution of SOM, we extracted the data of land use pattern, soil texture, parent material, soil type, as well as climatic and topography factors to study the effects of these various factors on the spatial distribution of SOM content (Figure 3). Land use pattern, soil texture, soil parent material and soil type were categorical variables, which were analyzed using ANOVA to determine whether each factor had a significant effect on SOM content. Climatic and topographic factors are numerical variables, so correlation analysis was conducted between elevation, slope, MAP, MAT, and SOM content to determine whether they were statistically significantly correlated. The results (Table 2) showed that all the categorical variables had significant effects on the spatial variability of SOM ($p < 0.05$).

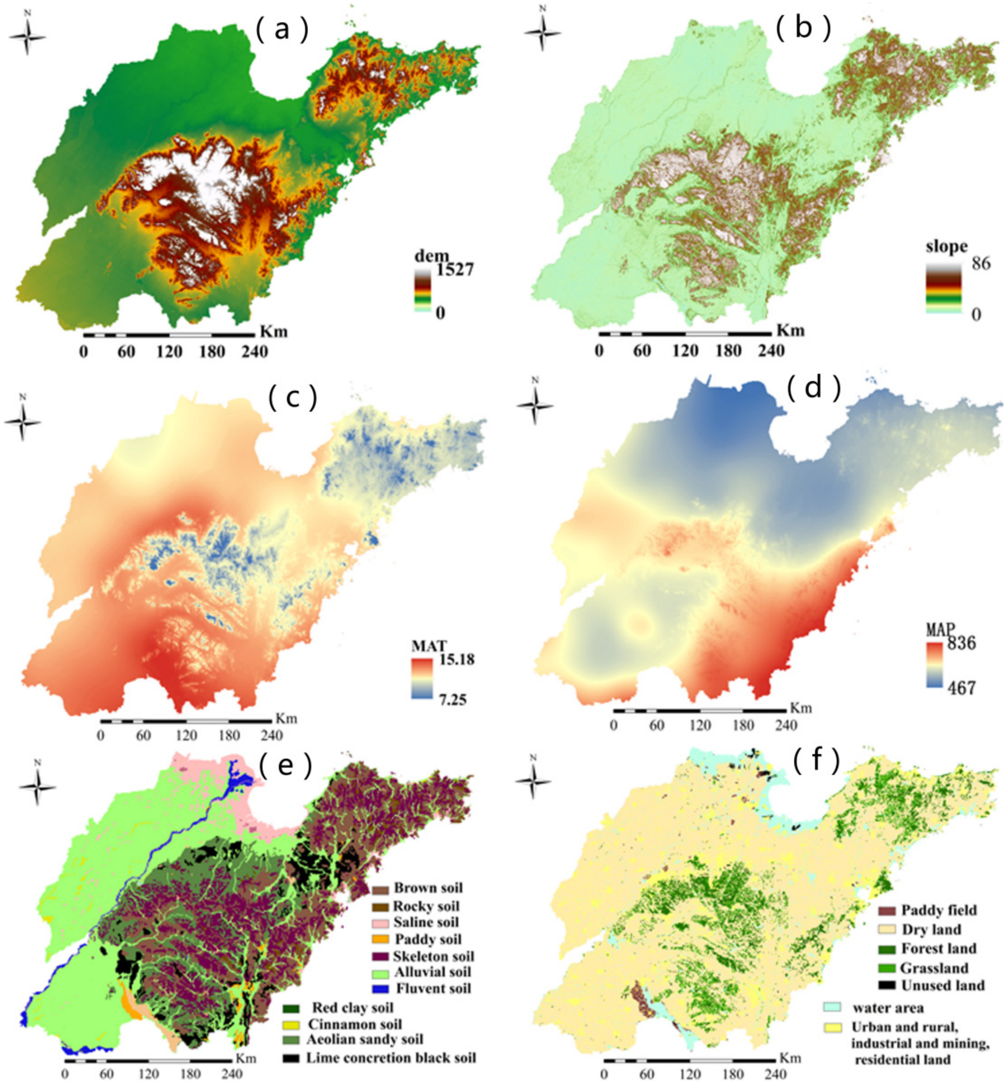

Figure 3. Spatial distribution map of SOM content in Shandong Province. Note: (**a**) DEM, (**b**) slope, (**c**) MAT, (**d**) MAP, (**e**) soil type, (**f**) land use pattern.

Table 2. ANOVA results for each factor affecting SOM.

Impact Factor	Sum of Squares	df	Mean Square	F	*p*-Value
Land use pattern	2237.82	4	584.45	10.76	0.000
Soil texture	1281.42	8	160.18	2.70	0.007
Parent material	1162.17	7	166.02	2.78	0.008
Soil type	1625.06	10	162.51	2.78	0.003

3.3.1. Difference of SOM Content under Different Parent Material

There are eight main types of soil parent materials in the area studied, and the SOM content of different soil-forming parent materials in sequence are: lacustrine deposits > aeolian deposits > deluvium > littoral sediment > diluvial deposit > residual deposits > loess parent material > river alluvium. The highest SOM level was found in the soils developed from lacustrine deposits (17.63 $g{\cdot}kg^{-1}$), followed by soils from the aeolian deposited (11.75 $g{\cdot}kg^{-1}$), deluvium (11.72 $g{\cdot}kg^{-1}$), and littoral sediment (11.71 $g{\cdot}kg^{-1}$). Soils developed from river alluvium and loess parent material had the lowest SOM content, at 9.08 $g{\cdot}kg^{-1}$ and 9.22 $g{\cdot}kg^{-1}$, respectively. The variation coefficient of the SOM content in different types of parent material ranged from 23.92% to 112.18%. With the exception of lacustrine deposits and deluvium, the SOM content in other types of parent material showed a moderate degree of variation (Table 3).

Table 3. Analysis of the SOM content of different soil-forming parent materials.

	N	Min/($g{\cdot}kg^{-1}$)	Max/($g{\cdot}kg^{-1}$)	Mean/($g{\cdot}kg^{-1}$)	CV/(%)
deluvium	44	3.50	74.30	11.72	98.60
diluvial deposit	57	6.60	20.53	10.42	23.92
river alluvium	96	2.40	32.70	9.08	45.02
Lacustrine deposits	11	4.89	74.90	17.63	112.18
aeolian deposit	12	1.20	32.42	11.75	79.91
Loess parent material	6	2.40	18.13	9.22	55.65
Littoral sediment	24	2.30	33.66	11.71	53.65
Residual deposits	7	4.83	17.56	10.16	47.65

3.3.2. Difference in SOM Content under Different Soil Textures

Soil texture reflects intrinsic fertility characteristics and is an important influence factor on SOM content. The results of variance analysis showed significant differences in SOM content between different soil textures, so multiple comparisons were made, the results of which are shown in Figure 4. There are significant differences between loamy clay soils and sandy soils, and such differences were also found between loamy clay and loamy sand soils. The general trend was clay > loam > sandy, and similar research results were found in Taiyuan City and Jiangsu Province (both located in China) [14,24]. Among them (Table 4), the SOM content of loamy clay soils was 15.32 $g{\cdot}kg^{-1}$, which was significantly higher than the others. The sandy soils had the lowest content, at only 3.07 $g{\cdot}kg^{-1}$, which may be due to the lapsed SOM induced by lighter texture and good aeration conditions. These results are similar to the studies in south-east areas of Chongqing City [25]. Sandy loam and sandy clay loam had the highest coefficient of variation, while the rest had moderate, with loamy sandy soil having the lowest coefficient of variation.

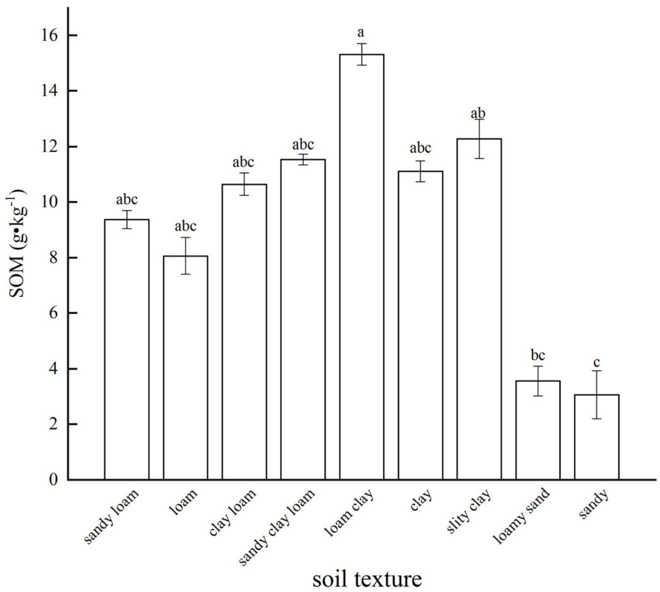

Figure 4. SOM content of different soil textures. Notes: The maximum mean value is marked with the letter a; the letter b represents the mean value that significantly different from the mean value marked with the letter a; the letter c represents the mean value that significantly different from the mean value marked with the letter b; data with the same letter are not significant at 0.05 level.

Table 4. Analysis of SOM content in different soil textures.

	N	Min/(g·kg^{-1})	Max/(g·kg^{-1})	Mean/(g·kg^{-1})	CV/(%)
Sandy loam	64	2.40	74.30	8.78	110.60
Loam	13	5.30	13.60	8.06	29.37
Clay loam	77	3.50	22.40	10.68	32.81
Sandy clay loam	56	5.20	74.90	11.36	80.60
Loam clay	30	6.15	33.66	15.32	49.68
clay	6	6.90	17.09	11.11	30.28
Silty clay	4	8.80	20.30	12.28	43.95
Loamy sand	3	2.50	4.10	3.57	25.90
Sandy soil	4	1.20	5.27	3.07	56.82

3.3.3. Differences in SOM Content across Different Soil Types

Different soil types have different soil forming conditions and nutrient sources, so their SOM level is different. The study area includes 11 main types of soil. The ANOVA shows that SOM content was significantly different in different soil types. Comparison of SOM between soil samples from different soils was conducted, with the results shown in Table 5. The mean SOM content of the Lime concretion black soil was the highest at 15.94 g·kg^{-1}, followed by paddy soil, cinnamon soil, rocky soil, skeleton soil, brown soil, alluvial soil, red clay soil, saline soil, and fluvent soil. The lowest average SOM level, 6.43 g·kg^{-1}, was found in aeolian sandy soils. The variation coefficients for all soil types ranged from 11.69% to 100.31%, with red clay soil having the smallest coefficient of variability at 11.69%, indicating that this soil type has a stable SOM content and is conducive to SOM accumulation. The variation coefficient was the largest in Lime concretion black soil, indicating that the SOM content varied greatly in this soil type.

Table 5. Analysis of SOM content in different soil types.

	N	Min/(g·kg^{-1})	Max/(g·kg^{-1})	Mean/(g·kg^{-1})	CV/(%)
Brown soil	40	4.89	30.40	10.03	44.67
Cinnamon soil	63	2.40	30.80	11.90	39.58
Lime concretion black soil	16	7.70	73.30	15.94	100.31
Alluvial soil	78	2.40	74.90	9.88	81.38
Saline soil	18	2.30	20.30	7.38	62.33
Paddy soil	10	6.81	33.70	15.77	63.28
Rocky soil	5	4.80	17.60	11.09	48.33
Aeolian sandy soil	5	1.20	17.00	6.43	95.02
Skeleton soil	16	3.50	32.40	10.79	80.07
Red clay soil	3	7.62	9.40	8.81	11.69
Fluvent soil	3	4.30	11.10	6.67	56.82

3.3.4. Difference of SOM Content across Different Land Use Patterns

Land use patterns are an important anthropogenic factor that influence the variability of SOM. Soil properties will change with the changing of land use patterns. The main land use patterns in this study area are forest land, grassland, dry land, paddy field and unused land. As shown in Figure 5, SOM content could be ranked as follows: grassland > forest land > paddy field > dry land > unused land. The maximum (21.71 g·kg^{-1}) was found in grassland, with a possible reason being the high litter yield and low decomposition on the surface of grassland. The minimum (8.38 g·kg^{-1}) was found in unused land, with the former being 2.6 times higher than the latter. As shown in Table 6, SOM has different coefficients under different land use patterns. The variation coefficient of grassland reached 97.29%, which is 1.7 times higher than that of dry land and falls under the strong variability type, while all other land use patterns had moderate degrees of variation.

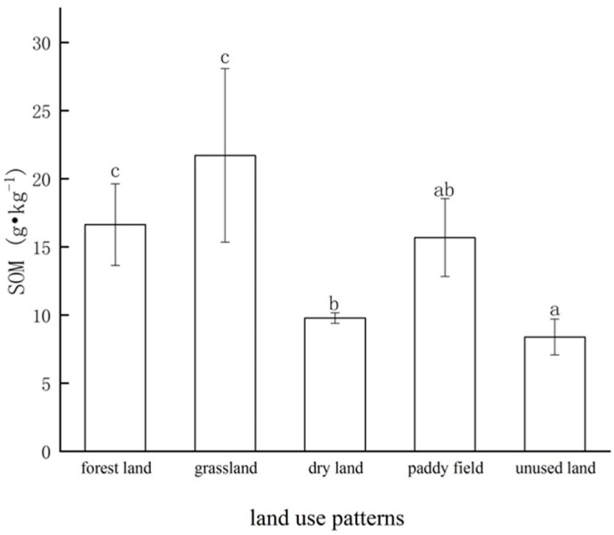

Figure 5. Difference in SOM content across different land use patterns. Notes: The letters a, b, and c correspond to the same meanings as in Figure 4.

Table 6. SOM content across different land use patterns.

	N	Min/(g·kg^{-1})	Max/(g·kg^{-1})	Mean/(g·kg^{-1})	CV/(%)
Forest land	13	1.20	32.42	16.63	65.11
Grassland	11	2.40	74.3	21.71	97.29
Dry land	203	2.40	74.90	9.78	57.23
Paddy field	11	6.81	33.66	15.68	60.39
Unused land	19	2.30	25.74	8.38	68.55

3.3.5. Difference of the Influence of Topography and Climate on Organic Matter

As topographic, meteorological, and climatic factors are numerical variables, we conducted correlation analysis between these numerical variables and SOM content. According to the results shown in Table 7, among all topographic variables, elevation and slope had significant positive correlations with SOM, while aspect had no significant correlation with it. This indicates that SOM levels increased in conjunction with elevation and slope, which is consistent with studies from the Guizhou and Hubei Provinces in China, and those conducted in the Spanish Peninsula [18,26,27]. Climate variables are positively correlated with SOM, which indicates that SOM content increases with the increase in precipitation and temperature levels [28,29].

Table 7. Correlation between topographic/climatic factors and SOM.

Indicators	Elevation	Slope	Aspect	MAT	MAP
SOM content	0.36 **	0.47 **	0.02	0.15 *	0.13 **

Notes: * indicates significant correlation at the 0.05 level, ** indicates highly significant correlation at the 0.01 level.

3.3.6. Dominant Factors Controlling Variability in SOM

The above sections provide a semi-quantitative analysis of the influence of each factor on SOM, but the magnitude of their influence cannot be accurately quantified. In this research, land use pattern, soil type, soil parent material, soil texture, as well as topographic and climatic factors were taken as explanatory variables for stepwise regression analysis, with SOM content taken as the target variable. The comprehensive explanatory ability of each factor on the spatial variation of SOM content, and the influence of each factor on the spatial variation of SOM, were each quantitatively studied. Before regression analysis, it was necessary to assign values to categorical variables, such as land use pattern, soil texture, soil parent material, and soil type [30].

The corrected determination coefficients in the regression equations reflect the independent explanatory ability of each influencing factor on the variability of SOM. For each impact factor shown in Table 8, the smaller the characteristic parameter R^2 is, or the larger ΔR^2 or $R^2_{§}$ are, the greater the relative importance of that factor. R^2_{adj} is the comprehensive explanatory ability of all independent variables in the regression equation, to explain the variability of dependent variables [31].

Table 8. Results of the regression analysis of the variance between the factors upon SOM.

Impact Factor	R^2	ΔR^2	$R^2_{§}$	R^2_{adj}
All factors				0.523
Land use pattern	0.541	0.049	0.091	
Soil type	0.453	0.137	0.250	
Parent material	0.498	0.092	0.183	
Soil texture	0.542	0.048	0.105	
Slope	0.582	0.008	0.019	
Elevation	0.587	0.003	0.007	
Precipitation	0.589	0.001	0.002	
Temperature	0.586	0.004	0.009	

Notes: R^2 is the determination coefficient of SOM stepwise regression for all other variables except this variable; ΔR^2 is the increment of the determination coefficient of the regression equation when this variable is added to the other variables; $R^2_{§}$ is the bias determination coefficient, which refers to the proportion of what can be explained by the new variable in the regression equation, compared to what cannot be explained by the regression equation in its absence.

Among the models, the inclusion of the soil type variable has the largest ΔR^2 value, which indicating that soil type has the greatest influence on the spatial distribution of SOM in Shandong province. Without considering soil type, the R^2 of the model was 0.453, which indicated that the remaining seven factors explained 45.30% of the variability in SOM.

With the addition of soil type, the model ΔR^2 value was 0.137, indicating that the addition of soil type increased the explanatory ability of the model by 13.70%. According to the R^2 value, the influence of soil type was much larger than the other factors. The second most influential variable on the spatial distribution of SOM was parent material (9.20%), followed by land use pattern (4.90%) and soil texture (4.80%). The remaining variables in order of influence are slope, temperature, elevation, and precipitation, with the combined explanatory ability of these variables being less than 1.00%. Therefore, it can be concluded that soil type and parent material are the main controlling factors of the spatial variability of SOM in Shandong Province. The comprehensive explanatory ability of the eight factors on the variability of SOM can reach 52.30%.

4. Discussion

4.1. Analysis of Factors Affecting SOM Content

There are five natural soil-forming factors, and the influence that three major soil-forming factors (parent material, climate, and topography) had on SOM content was analyzed in this study. Soil parent material is the basis for soil formation, and soils developed under different parent materials have different material bases [32]. The SOM content of different parent materials in the study area was ordered as follows: lacustrine deposits > aeolian deposits > deluvium > littoral sediment > diluvial deposits > residual deposits > loess parent material > river alluvium. Soils developed from lacustrine deposits were mainly distributed in the north-west Shandong Plain, the Yellow River alluvial plain, and the southern shore of Laizhou Bay, where the richness of organic matter brought about by lake deposition has led to the highest SOM content. In addition, wind transported nutrients also leave rich organic matter. The SOM content of deluvium and diluvial deposits were higher than that of residual deposits [25]. This is because deluvium deposits tend to accumulate nutrient-rich weathered material that has moved down from higher elevations, and diluvial deposits can collect clay particles during the transportation of running water. While residual deposits migrate very little and accumulate products in situ, flowing water can weather away certain soils and easily cause nutrient loss, so the resulting level of organic matter is relatively low.

Topography influences the process of soil formation by redistributing surface material and energy. Elevation and slope affect microclimates by influencing the water andsoil balance of microtopography and solar radiation, which leads to differences in SOM levels. Correlation analysis showed that SOM was positively correlated with elevation and slope. Higher elevation and slopes are less affected by human activities, and the vegetation was dense, so the soil surface was easily enriched with organic matter. The organic matter level is lower in areas with low elevation and slope, which is due to the fact that these areas are greatly influenced by human farming activities and high-intensity land use. This is consistent with results of small watershed scale research in the Dabie Mountains and the south-western Yunnan province (in China) [33,34].

Climate factors, such as temperature and precipitation, are affected by topography and also have a certain impact on soil organic matter, but their explanatory ability was less than 1%. The influence of climate variables on organic matter has two parts. Firstly, the microbial decomposition of SOM is temperature dependent, as the complex molecular structure of SOM is sensitive to temperature [35]. The SOM content in this area increased slightly with the increasing MAT. This was similar to resultsin agricultural fields in the Bavaria region of Germany. This is probably related to the intensive utilization of farmland soil that makes up for the adverse climate conditions and balances out the loss of organic matter caused by high-temperature decomposition. Earlier studies suggested that climate had a greater impact on organic matter in soils with a high intensity of management [36]. Secondly, the sensitivity of SOC to temperature is related to precipitation [37]. Precipitation as an important climate-related component, controlling the above (ANPP) and belowground (BNPP) net primary productivity, and thus influencing the input of organic matter into the soil. However, ANPP and BNPP are also influenced by irrigation condition, fertilization, the type of crop, etc., which collectively reduce the impact of precipitation on organic matter [36].

4.2. Influence of Soil Texture, Soil Type and Land Use Patterns on SOM Content

The variation of SOM content is affected not only by parent material, topography, and climate, but also by other factors, such as soil texture, soil type, and land use patterns. Soil texture is a comprehensive indicator of the soil's physical and chemical properties. There are differences in soil structure and fertilizer retention capacity between different soil textures, which also have an important influence on the SOM content. Previous studies have shown that loam and clay soils have high SOM content. Clay and slit have a strong ability to preserve water and fertilizer, so soils with high clay and silt content have a high organic matter content [28,38]. In contrast, soils with high sand content have weak protective mechanisms, and therefore have a rapid decomposition of organic matter mineralization. The soils in the study area are predominantly clay loam soil, which consists of mostly clay particles. The clay particles combine with organic matter to form an organic-inorganic complex that ensures the stable uptake of SOM by reducing the mobility of SOM, and promotes the accumulation of SOM by reducing the rate of mineralization.

Different types of soil have different soil-forming processes, soil development level, tillage-management measures, and fertilizer supply capacity, which result in differences in soil properties between different soil types. Studies have found that Lime concretion black soil and paddy soil have the highest SOM content. This is because their topsoil had more clay particles, which have strong ability to retain mineral nutrients [39]. In addition, soil-forming conditions also have a certain effect on the SOM content of Lime concretion black soils. The areas where Lime concretion black soils are distributed are flat and low-lying, and groundwater drainage is blocked. These environmental conditions allow a variety of wet and aquatic herbaceous plants to flourish, thus providing the formation of humus in the black soil layer. Paddy soils have different physio-chemical and biological properties compared with dry land soils, due to differences in water conditions and human management. Rice cultivation can increase SOM content more than dry land cultivation. The decomposition of SOM in water-saturated soils is faster than in well-aerated soils due to the input of crop residues. The high input of organic matter also makes paddy soils more susceptible to carbon sequestration [40–42]. However, Aeolian sand soil and Fluvent soil are coarser in texture, both having little clay content and easily losing organic matter, and thus their SOM levels are relatively low.

Compared with soil textures and soil types, land use pattern is more easily influenced by human activities. Therefore, the influence of land use patterns on SOM is also important. There were differences in soil organic matter content among different land use types. In this research, the SOM content of grassland and forest land was significantly higher than that of dry land and paddy fields. There is relatively little human activity in grassland and forest land, and the soil surface is covered with a large amount of fallen leaves, which accelerates the accumulation of organic matter [43]. Long-term tillage and intensive tillage can also lead to organic matter loss; as a result, the SOM content of dry land and paddy fields is relatively low [8,19,44]. SOM content is higher in paddy fields than in dry land, which is mainly because paddy fields are generally in flat areas and have favorable conditions for the accumulation of SOM. In addition, the waterlogging conditions in paddy fields create a relatively humid environment, which reduces the activity of microorganisms. The mineralization of organic matter in paddy fields was inhibited, and the rate of organic matter decomposition decreased. As a result, the SOM content of paddy fields is higher than that of dry land.

4.3. The Differences of Influence Factors on SOM Content

The study area is rich in soil types and parent material types. Different types of soil develop from different parent materials, and have some attributes of their parent materials, thus there is a certain correlation between parent materials and soil types. The spatial variation of SOM content in Shandong Province was predominantly controlled by soil type and parent material, which is similar to results in Guangxi Province and Huzhu County of Qinghai Province (both located in China) [12,13]. The effects of soil texture and land use pattern on the spatial variation of SOM are less than those of soil type and parent material. The difference in the effect of soil texture on SOM was reflected in both parent material and soil type; likewise, parent material, soil type, and soil texture exhibited great influences on land use pattern. Compared with the above factors, climatic and topographic factors are less able to influence the spatial variation of organic matter.

The topography of the study area is mainly hilly and plain, with little topographic relief or variation in climate factors, which is not enough to play a significant role in the spatial distribution of organic matter. Similar results were shown in many areas, such as northern Jiangsu Province and the Hebei Province (in China), and North Central Iowa [15,38,39]. In some areas with large undulating topographic and rich landscape types, the spatial variation of organic matter was mainly determined by topography and climate factors, which was confirmed by many researches. For example, the combination of temperature, precipitation, and elevation could explain 41.5–56.2% of the variation in SOM for different geographical regions. Temperature and precipitation variables determined surface SOM concentration in northern, north-eastern and north-western China, while precipitation and elevation were the main factors controlling SOM concentration in eastern and southern China [17]. Studies have shown that SOC density is more sensitive to temperature in Northeast China. Temperature alone can explain 35.6% of the organic carbon distribution, while the explanatory ability of temperature and precipitation reached 42.7% [16,45]. In the Luzhou tobacco farming area of south-eastern Sichuan Province, where the topography is dominated by mountains and hills, elevation was the most influential factor for SOM variation, which can independently explain 31.3% of SOM variation [46]. In general, compared with climate factors, topographical factors had a greater impact in this study area.

In this area, climates factors have little explanatory ability compared with other factors, but the influence of temperature on the spatial variation of SOM was slightly greater than that of precipitation, which may have been due to the fact that irrigation can reduce the effect of MAP on SOM variation. Similar results were found in areas such as the Yunnan–Guizhou–Guangxi regions and the Jiangsu province (in China) [14,31]. However, in some other countries, such as Spain [18] and India [47], precipitation has a greater impact on organic matter than temperature. Therefore, there are differences in the effect of climate variables on SOM content in different regions.

4.4. Scale Effect Analysis of Influence Factors

The spatial distribution of organic matter is obviously different at different research scales, which is due to the comprehensive effect of different types of influencing factors. Provincial scale can effectively reflect the spatial distribution of organic matter in a large spatial range. In this study, it was found that soil type and parent material were the main controlling factors of spatial variation of soil organic matter in the Shandong Province, followed by soil texture and land use type. The influence of terrain and climate factors was relatively small, and human activities overshadowed the influence of climate, to a certain extent. In other provinces of China, such as Guangxi Province [13], soil type was the most important influencing factor, independently explaining 36.0% of the variation, followed by parent material and elevation. Jiangsu Province is located in the humid area of eastern China and the terrain is flat; there, soil texture was the main factor affecting the variation of organic matter content [14]. In North China's Hebei Province, soil type and land use mode have great influence on the spatial distribution of soil organic matter. The lower the soil classification level, the greater the ability to reflect the spatial variation of soil organic carbon density [15]. It can be seen that, at similar provincial scales, the influence factors of different regions will also differ due to the different physical and geographical environments.

For the smaller spatial scale, the influence of topography and soil type was relatively large, but the influence of temperature and precipitation was relatively small. In some areas at the county scale, such as Hengshan County on the Loess Plateau and eastern China, topographic factors such as elevation and slope direction had significant effects on organic matter [8–10]. The main factors of soil organic matter distribution in Pinggu County were terrain, soil type, texture, and land use type. At the township scale, texture and tillage methods were dominant factors [11]. In Huzhu County, north-east Qinghai Province, the three main factors affecting soil organic matter variation were soil type, average annual precipitation, and altitude [12].

For some larger scales, it is mainly the topographic climate that plays a prominent role. For example, some studies found that 41.50% to 56.20% of SOM changes in different geographical areas in China were predominated affected by temperature, precipitation, and altitude [17]. On a national scale, many studies have shown that climate variables and land use are the most significant influences on soil organic matter change [18,19].

These studies further indicate that the relationship between environmental factors and organic matter content is different at different scales and in different regional environmental conditions. Therefore, it is necessary to constantly summarize the spatial variation information among various scales in future research to strive for the accuracy of the research.

5. Conclusions

The SOM content in Shandong Province ranged from 1.20–74.90 $g \cdot kg^{-1}$, with a mean value of 10.78 $g \cdot kg^{-1}$. According to the nutrient content standard of the second soil census, the typical level of SOM content in this region belonged to the fourth class, which is a moderate to low level. The coefficient of variation was 73.36%, which is moderate variability. According to the spatial distribution map of SOM, the organic matter in Shandong Province showed a tendency to be high in the middle and relatively low around. The SOM content was higher in the central and southern mountainous areas of Shandong Province, while being relatively lower in the south-west and north-west plain of Shandong Province.

It is considered that the spatial variation of organic matter is not influenced by any one single factor, but rather the result of multi-factor interaction. In this study, the common influence of various factors was comprehensively analyzed, and these influence factors have been quantitatively analyzed using a stepwise regression method. The results showed that the effects of soil type, soil texture, parent material type, and land use type on organic matter were significantly different. Furthermore, the elevation, slope, average annual temperature, and average annual precipitation are all related to organic matter. Stepwise regression analysis showed that soil type and parent material were the most important dominant factors for the spatial variation of organic matter in this type of region, and the distribution of organic matter was dominated by these two factors together. The spatial variation of organic matter was also significantly influenced by soil texture and land use type. Topography and climatic factors had very little effect relatively, which may be because the change of climate change in the study area is not obvious.

Author Contributions: Conceptualization, X.Z. (Xin Zhao); data curation, X.Z. (Xin Zhao) and Z.Z.; formal analysis, X.Z. (Xin Zhao); funding acquisition, X.S., X.L. and X.Z. (Xiaoguang Zhang); investigation, X.S. and X.L.; methodology, Z.Z. and X.Z. (Xiaoguang Zhang); project administration, X.Z. (Xiaoguang Zhang); resources, X.Z. (Xiaoguang Zhang); software, X.Z. (Xin Zhao); supervision, X.S. and X.Z. (Xiaoguang Zhang); validation, M.Z.; visualization, M.Z.; writing—original draft, X.Z. (Xin Zhao); writing—review and editing, Z.Z. All authors have read and agreed to the published version of the manuscript.

Funding: This research was funded by the National Key Research and Development Program of China [grant number 2021YFD1900902]; the Key Research and Development Program of Shandong Province, China [grant number 2021CXGC010801, 2021CXGC010804]; the National Natural Science Foundation of China [grant number 41601211].

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Acknowledgments: The authors acknowledge all the funds that provided funding during the writing process of the paper.

Conflicts of Interest: The authors declare no conflict of interest.

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