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Spatial Characteristic Analysis and Variation Research of Cultivated Land Soil Based on GIS

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Abstract: Revealing the characteristics of soil nutrient space and studying the variation characteristics of soil nutrient space can provide a reliable theoretical basis for the precise management of soil nutrients. The purpose of this paper is to study the spatial characteristics analysis and changes of cultivated soil based on GIS. A spatial database was established and kriging interpolation was analyzed. To study the characteristics of the spatial variation of soil nutrients in the M area, select the optimal theoretical model, and conduct a detailed theoretical analysis of the spatial variation of the soil in the study area on the basis of ArcGIS 10.2 data. The contents of soil organic matter, total nitrogen, alkali-hydrolyzed nitrogen, available phosphorus and available potassium were profoundly affected by external factors; under anisotropy, the spatial correlation of each nutrient content hardly increased. The soil nutrients are generally higher in the north and lower in the south, and higher in the west and lower in the east. The distribution trend of available potassium in the region is not obvious, and there are high-value areas under different landforms.

1. Introduction

Soil is a continuum, which is formed by long-term temporal and spatial changes of parent material. The spatial differences are not only affected by structural factors such as parent material, topography, climate, hydrology, vegetation, and geology, but also by random factors such as human farming management and fertilization. Accurate analysis of the spatial distribution of soil nutrients is not only the basis for rational management of soil nutrients, but also has important implications for environmental protection and governance [3-4].

Soil properties are critical to crop health and their yields, and therefore to agriculture. Soil properties are spatially variable, so soil resources should be managed according to site-specific requirements. Mehra M conducted a comprehensive spatial analysis of soil resources in the Mewat area to identify soil resource management zones to develop site-specific soil management plans that may lead to sustained and improved crop yields. Spatial analysis of soil resources was performed by simulating soil fertility and erosion that determine crop productivity in the region [5]. Budhathoki S used X-ray computed tomography (CT) and image analysis to quantify the spatiotemporal variability of 3D soil macropore structure in a 0.40-hectare pasture. Thirty-six undisturbed soil pillars, 150 mm in diameter and 500 mm in length, were collected from a ranch in Alabama, USA. Image analysis was performed to quantify the spatial and temporal variability of soil macroporous characteristics. Macroporous features differed significantly between different topographic locations and sampling seasons, especially at surface (0–100 mm) depths. Soil macropores at downslope locations are sparsely distributed in the topsoil [6]. Therefore, it is of practical significance to study the spatial characteristics analysis and changes of cultivated soil based on GIS [7-8].

By sorting out the research progress on cultivated land quality at home and abroad, this paper takes cultivated land in M area as the research object, and with the support of the annual cultivated land quality update achievement database in M area, the spatial difference characteristics of cultivated land quality in the study area are analyzed. In order to apply the research results in the division of cultivated land protection zones and the differential protection of regional cultivated land quality.

2. Spatial Characteristic Analysis and Variation Research of Cultivated Land Soil Based on GIS

2.1 Establishment of Spatial Database

(1) Image preprocessing

Graph preprocessing can reduce some tedious mechanical repetitions in the vectorization process and greatly improve the efficiency of mechanization [9]. The preprocessing is carried out according to a certain digitization method, which mainly includes the scanning of the drawings and the correction of the drawings. The drawings are scanned as images in a 1:1 ratio, with a resolution of 300 dpi and saved in black and white TIFF format [10].

(2) Digitization of drawings

The steps of the raster vectorization method are shown in Figure 1:

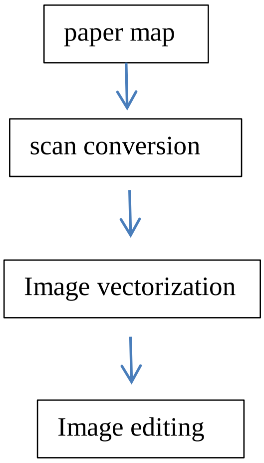

Figure 1. Raster-vector method steps

The data conversion method is to use the existing digital data and use software to convert it into the *.shp format required for this research. The data format of MapGIS is used, and ArcGIS is simpler than MapGIS in graphic editing, data inspection and modification. Therefore, To utilize the file conversion function of MapGIS, convert the data in *.wp/*.wl/*.wt format to *.shp format [11-12].

(3) Graphic editing

Since the update time of the soil map and the current land use map are often different, the boundaries of the two maps may be inconsistent. At this time, the two maps can be edited to make the boundaries of the soil map and the current land use map basically consistent [13-14]. At the same time, it is necessary to revise the soil map, merge the soil map with the county boundary, and use the spatial query function of ArcGIS software to select and delete the part of the soil map beyond the county boundary. For a small area without attributes, it can be considered that it is consistent with the attributes of adjacent areas, and the final soil map can be obtained [15-16].

2.2 Kriging Interpolation

The investigation of soil nutrient status is achieved by soil sampling surveys in typical and representative areas. The estimation of unmeasured points is absolutely necessary, and the values of non-sampling points can be obtained by spatial interpolation. Interpolation methods include kriging interpolation, inverse distance weighted interpolation, and polynomial interpolation. Kriging interpolation can provide the best linear unbiased estimates and is the most widely used optimal interpolation method in geostatistics [17-18].

At the heart of kriging interpolation is the semivariance function, which uses known point data to estimate the value of an unknown point (X0). The estimated value Zv#(x) is the estimated or estimated block part within the influence range of the points obtained by the linear combination of n valid sample values Z(Xi)(i=1,2,3...n), the formula is as follows :

$$Zv^{\#}(x)=\sum_{i=1}^{n}\lambda_i Z_v(x_i) \qquad (1)$$

In the formula, Zv#(x) is the interpolated estimated value at the unobserved point x, and Zv(x) is the measured value obtained at several observation points near the point x. The estimated variance can be found from the following equation:

$$\sigma^2 E=b^T\begin{pmatrix}\lambda\\ \mu\end{pmatrix} \qquad (2)$$

In the formula, b is the semi-variance matrix between the estimated point and other points, bT is the permutation matrix of the b matrix, and μ is the Lagrangian parameter.

3. Investigation and Research on Spatial Characteristic Analysis and Change of Cultivated Land Soil Based on GIS

3.1 Data Acquisition

(1) Vector data of basic geographic elements in M area: including provinces, cities, counties, administrative boundaries at all levels, roads, rivers, and topographic maps.

(2) Meteorological data: data from meteorological stations in Northwest China, including years of precipitation, accumulated temperature, etc.

(3) Soil sampling points: The attribute data of soil sampling points in this study come from the

cultivated land quality protection project of the Ministry of Agriculture, and the summary evaluation of cultivated land fertility in M area. The content of the sampling point attribute fields includes: the longitude and latitude of the sampling point, and the name of the province, city and county to which the sampling point belongs, sampling year, altitude, landform type, annual precipitation, irrigation method, soil texture, soil pH value, organic matter, total nitrogen, alkali-hydrolyzed nitrogen, straw returning method, mulching method, etc.

3.2 Data Processing

(1) Build the semivariance function fitting model and parameters in GS+9.0, and select the optimal model.

(2) Generate a digital ground elevation model (DEM) in ArcGIS 10.2, extract influence factors such as elevation and slope; draw a spatial distribution map of soil organic matter; use ordinary kriging interpolation to copy the sampling point attributes to the surface; map registration and digitization, attribute database, grid calculation, feature statistics, spatial distribution map making, editing and output of result map, etc.

(3) Treatment of abnormal values of soil organic matter: The Laida criterion is adopted in this paper, that is, normal values are distributed in the interval of plus or minus three standard deviations of the mean, and outliers are outliers and need to be eliminated. A total of 2,564 sampling points were counted in this study, of which 112 outliers were excluded. Therefore, a total of 2,452 sampling points participated in statistical analysis and spatial variation analysis.

4. Analysis and Research of Spatial Characteristics and Changes of Cultivated Soil Based on GIS

4.1 Spatial Differences in Soil Physical and Chemical Properties

After using GIS software for spatial interpolation, the spatial difference characteristics of soil physical and chemical properties in M area were analyzed. From the different attribute values of various types, the difference of the average bulk density of dry land, irrigated land and paddy field in M area was the smallest, which were 1.12, 1.02, 1.88: followed by pH, the average pH values of dry land, irrigated land, and paddy field were 5.62, 5.66, and 5.82, respectively; the differences of the remaining index values were large: the average values of slow-acting potassium and pH of different land types were all at the top. The levels of organic matter, total nitrogen, available phosphorus, available potassium, and bulk density were slightly lower. In addition, judging from the average value of the different attributes of soil physical and chemical properties of the cultivated land in each township, the research and analysis showed that the attribute values of the cultivated land in the townships in the M region were quite different. The organic matter content of town s was the highest at 32.5/kg, and the content of organic matter in town d was the lowest at 11.6/kg, as shown in Figure 2. The levels of total nitrogen, available phosphorus, and available potassium in the soils of each township were above medium, and the levels of soil slowly available potassium and soil bulk density were relatively high. See Table 1 for details:

Table 1. Statistical results of average soil physical and chemical properties of cultivated land in each township

M area	organic matter	total nitrogen	Available phosphorus	fast-acting potassium	slow-acting potassium	Test weight	pH
b town	15.3	1.5	10.3	155	485	1.2	7.2
c town	20.5	1.2	21.5	162	926	1.5	5.1
d town	11.6	1.1	18.8	131	887	1.8	5.5
s town	32.5	1.3	30.1	142	624	1.4	6.1

In order to more intuitively understand the specific conditions of the various indicators of the soil physical and chemical properties of the cultivated land in the M area, based on the collected data of the various indicators, the soil physical and chemical properties of the cultivated land in the M area are classified into grades. Research and analyze its spatial distribution. The specific classification is shown in Table 2 below:

Table 2. Classification of soil physical and chemical properties

index	Level 1	Level 2	Level 3	Level 4	Level 5
organic matter	>31	21-30	11-20	6-10	<6
total nitrogen	>2.1	1.6-2	1.1-1.5	0.6-1	<0.5
Available Phosphorus, Available Potassium	>25	21-25	16-20	11-15	<10
slow-acting potassium	>250	201-250	151-200	101-150	<100
Test weight	<1	1.1-1.5	1.6-2	2.1-2.5	2.5>
pH	<5	5.1-6	6.1-6.5	6.6-7	>7

4.2 Spatial Variation Characteristics of Soil Organic Matter in Cultivated Land in M Area

Using the GS+10.0 software, the theoretical model of the semi-variance function of organic matter in the cultivated soil in the M area was fitted, and the obtained model structure parameters are shown in Figure 2.

In this study, the spatial heterogeneity analysis was carried out on multiple sampling points evenly distributed in the M area, the data was imported into the GS+10.0 software, and the semivariance function simulation model tool was selected to calculate the optimal theoretical model. The results of each parameter are as follows: shown in Table 3.

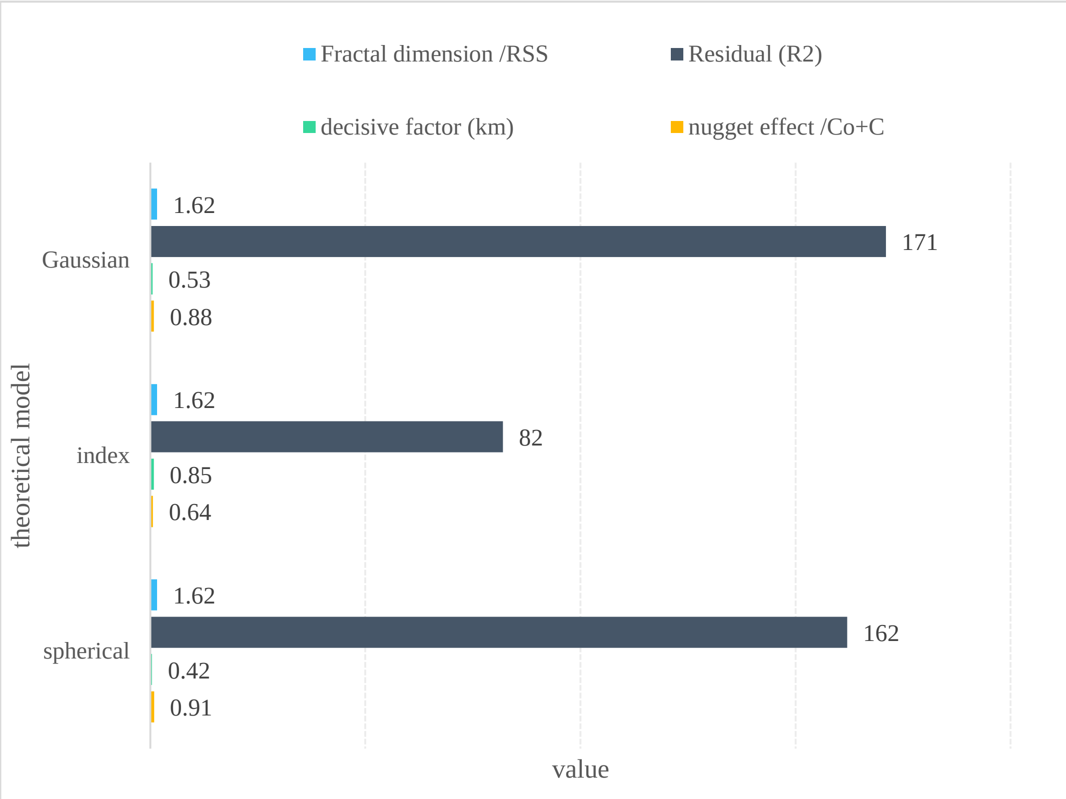

Figure 2. Results of each parameter

Table 3. Theoretical model and parameters of soil organic matter semivariance function

theoretical model	nugget effect /Co+C	decisive factor (km)	Residual (R^2)	Fractal dimension /RSS
spherical	0.91	0.42	162	1.62
index	0.64	0.85	82	1.62
Gaussian	0.88	0.53	171	1.62

It can be seen from Table 3 that the coefficient of determination of the exponential model reaches 0.85, the coefficient of determination of the Gaussian model reaches 0.53, and the coefficient of determination of the spherical model reaches 0.42. It can be seen that the coefficient of determination of the exponential model is the highest, and the residual values of the three models are The exponential model is 82, the spherical model and the Gaussian model are 162 and 171 respectively, and the exponential model tends to be 1, indicating that the optimal fitting effect of the semi-variance function of soil organic matter is the exponential model, which can objectively reflect its existence in the region. Spatial heterogeneity.

The nugget effect Co/(C+Co) of the three models is in the order of spherical model 0.91 > Gaussian model 0.64 > exponential model 0.88, and the nugget effect index is lower, indicating that the spatial variation of soil organic matter in this area is mainly caused by the structure. It is caused by sexual factors, and less than half is caused by random factors. Except for the exponential model, which has a moderate spatial correlation, the other two models have very weak spatial correlations. Within the region, it is less affected by human factors, such as fertilization, farming, and planting systems, and is more likely to be affected by landform types, soil texture, soil pH levels, etc.

5.Conclusions

It is of great practical significance to grasp the changes between the quality and quantity of cultivated land resources in a timely manner, to be able to utilize cultivated land, to promote the management and protection of cultivated land in my country, and to improve the structural adjustment of agricultural industry and the sustainable development of agriculture in a timely manner. This paper takes GoeData and GIS platform as technical support, analyzes the quality of cultivated land statistically, and more accurately describes the spatial distribution characteristics and differentiation law of cultivated land quality in the M area through the output of correlation maps and tables. The optimal model for spatial variation of soil organic matter content in cultivated land in M area is an exponential model. At super-large scales, the autocorrelation range of soil organic matter content and distribution is large.

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