REASONABLE SAMPLING SCALE OF MACROPORE BASED ON GEOSTATISTIC THEORY

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Abstract: Spatial scale of soil character is forefront in soil-scientific research, and the analysis of macropore reasonable sampling size becomes significant in studyinig on soil spatial variability. From the micro-structure of the soil, using digital image preparation and analysis technology, this paper described the soil macropore with rations, discussed the spatial structure of soil macropore on both the vertical and horizontal directions by geologic geostatistic theory , analysed by the base value of variation function C0, structure variance C, variable function, model test parameter I and model accuracy rate of change k and so on. The results showed that the reasonable sampling interval of vertical depth was 20 mm, and the economic reasonable sampling diameter on horizontal was about 90 ~ 100 mm. The production has very important significance to ensuring the scientific of the soil macropore research, saving study time, and reducing the human and financial resources in the trial.

Keywords: digital image; soil macropore degree; geostatistic theory; scale sample

1. INTRODUCTION

Soil is a kind of uneven and variational continuum, its spatial scale problem is in the forefront of soil-scientific research. In the pedology, configuration and variability of many regional variables usually exist in different scales, some structure just show under fixed observational measure, meanwhile, some observational measure just reveal relevant change rule or structural characteristic, the effect of spatial variability differs during different scales (Li Zizhong et at., 2001). Sampling is the first step in all macropore research, its scale effect can directly impact spatial variability rule of soil.

Geostatistical theory is a risingly fringe subject founded and developed in lately thirty years (Hou Jingru et at., 1982; Wang Renduo et at.,1988). Since it was taken into the spatial analysis of soil characteristic, geostatistical theory had largely applied to many fields, such as soil-water science, hydrology, and so on (Li Weiping et at., 2004; Shi Haibin et at.,1994).However, this theory was almostly used to study some characteristic and crop information in field scale presently. The depth of research was stressly about the spatial insert number and related interval of some soil characteristic and crop information, then drew isoline figure. Practical research showed that, in order to reflect macropore distributing in soil completely, the research of macropore spatial variability in both microcosmic and macrocosmic had become a necessarily solving problem, as the gradual development of macropore research.

Optimal sampling scale means mortal sampling scope、very tittle sampling interval and sampling volume (Westerna A W et at., 1999), but in fact, this is very difficult to achieve. This paper took geostatistical theory into microcosmic domain to research macropore distributing, analysis the spatial structural characteristic, obtain the reasonable sampling size of macropore study, accurately obtain macropore distributing rule, provide instruction for soil moisture, solute movement regulation and setting up exact predictive model for cropland moisture.

2. GEOSTATISTICAL THEORY

Geostatistical theory is based on regional variables、random function and balanced supposes, consider semi-variance function as its basic tool, studies the natural phenomena that both randomicity and configuration in the spatial distributing (Hou Jingru et at., 1993). Semi-variation function is the core during calculating regional variables, usually take following formula which Matheron commended:

$$\gamma(h) = \frac{1}{2N(h)} \sum_{i=1}^{N(h)} \left[Z(x_i) - Z(x_i + h) \right]^2 \quad (1)$$

where $N(h)$ is experimentation logarithm at a distance of h on x axis; h is sampling interval; $\gamma(h)$ is the result of semi-variation function; $Z(x_i)$, $Z(x_i+h)$ is realization of observation value $Z(x)$, $Z(x+h)$.

3. MATERIAL AND METHOD OF EXPERIMENT

3.1 Prepare and dispose the soil column

The experiment took original soil as object, and the fetching soil containers included two kinds of UPVC pipe, that is: (1) Diameter 11cm, pipe thickness 3mm, length 60cm; (2) Diameter 20cm, pipe thickness 4mm, length 25cm. It fetched soil from the field, and original soil should avoid been disturbed during the whole process.

The original soil was then dried in nature air, took impregnant to marinate the soil columniation next, it must be slowly and separately immitted, to the greatest extent to be immerged into soil macropore. When there was 0.5cm impregnant higher than soil surface in the pipe, just stopped immerging and placed until impregnant completely solidified. The last step was skived the soil with electromotion thin grinding wheel, obtained many real multicolor surface every other 5mm by scanner。

3.2 Obtain digital images

Used the large-scale image disposal software ImageSys and Photoshop to pick-up macropore area (based on the precision of this experimental investigation and data processing level , considered the hole that larger than 100μm as macropore). The final data were following series macroporous degrees:(1) 600mm underground depth, diameter scope 104mm , every other 5mm interval ; (2) 230mm underground depth, diameter scope 25mm、40mm、60mm、80mm、100mm、125mm、150mm、 175mm, every other 10mm interval.

4. RESULTS AND ANALYSIS

4.1 Semi-variance analysis

4.1.1 Model choice

Semi-variance function was the foundation of spatial variability explaining by geostatistical theory. It was usually expressed by experimental semi-variogram. These curves can be fitted by curve equation. These curve equations were called of semi-variance function. There were spherical model, Gaussian model, the index model and the linear model. The theoretical model of choice depended on the specific cases. According to the studies of predecessors, theoretical variogram model of soil properties were generally the spherical model of transition (Masaru Hoshiya, 1995; Gotway C A. R B Ferguson,1996). When selecting the semi-variance model, first of all, used the equation (1) to calculate $\gamma(h)$ scatter plot, then fitted the curves with spherical model, that was :

$$\gamma(h)=\begin{cases}0 & h=0\\ C_0+C\left(\frac{3}{2}\frac{h}{a}-\frac{1}{2}\frac{h^3}{a^3}\right) & 0<h\leq a\\ C_0+C & h>a\end{cases} \qquad (2)$$

Where C_0 was the value for the block, meaned semi-variance when distance approached zero. It was the variability caused by random factors such as experimental error; C was structure variance. It was the variability caused by non-human factors such as soil parent material, terrain and so on.; a was the related socpe of the observation points.

4.1.2 Test of model precision

In order to make sure the theoretical models of semi-variance really describe the law of the changes, it must do the optimal test. The tests were usually cross-examination, the estimated variance test and *I* value test. The cross-examination was the theoretical variogram model of "the square of decrease between kriging estimates and measured value was minimum". The estimated variance test was the method which do the test through the ratio of the practical variance and theoretical estimated variance. If the theoretical variation function properly fitted, then $\overline{(z^*-z)^2/(s^*)^2}$ should be fluctuated around 1. *I* value test integrated the above two indicators into a unified theory (Hou Jingru et at., 1982) , formula was as follows:

$$I = \overline{\left(z^* - z\right)^2} \times \left[P \times \left| 1 - \frac{1}{\left[\left(z^* - z\right)/s^*\right]^2} \right| + \left(1 - P\right) \right] \quad (3)$$

Where P was parameters for the empirical.When $0 \le \overline{\left(z^* - z\right)^2} < 100$, P was 0.1. When $100 \le \overline{\left(z^* - z\right)^2}$, P was 0.2.The smaller I value, the higher fitted precision of variation function model. Three methods were used to test the model. The results were shown in Table1 and Table2. The corresponding map of semi-variogram was as Fig. 1.

In order to quantificationally describe how scale change impact model precision , change rate of model precision was introduced, that was:

$$k\ (‰) = \left| (I_2 - I_1) \right| / \delta * 1000 \quad (4)$$

The results were shown in Fig .2 and Fig.4.

Table 1. Theoretical model and model testing parameters of macroporous degree under the condition of the differernt minimum step

Minimum Step (mm)	C_0 (%)	C (%)	$\frac{C_0}{(C + C_0)}$ (%)	Variable a (mm)	$\overline{\left(z^* - z\right)^2}$	$\overline{\left(\left(z^* - z\right)/s^*\right)^*}$	P	I
5	0.23	0.43	34.8	201.6	0.0027	0.97	0.1	0.0025
10	0.29	0.47	38.2	199.8	0.0041	1.05	0.1	0.0037
15	0.40	0.35	53.3	202.7	0.0052	1.00	0.1	0.0047
20	0.42	0.48	46.7	199.1	0.0025	1.09	0.1	0.0048
25	0.59	0.47	55.7	210.8	0.0038	0.99	0.1	0.0058
30	0.55	0.55	50.0	231.6	0.0042	1.02	0.1	0.0055

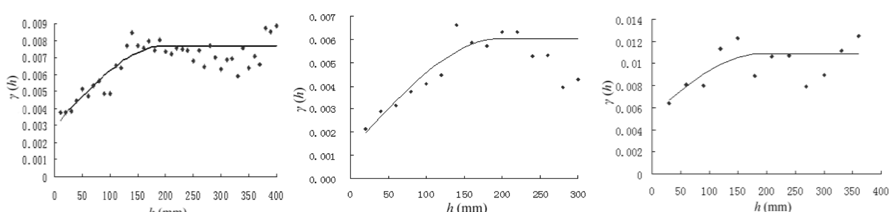

Fig.1: Semi-variogram when the minimum step was 10、20 and 30mm

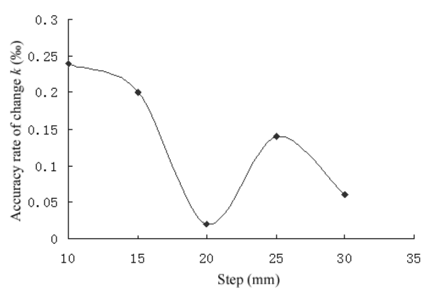

Fig.2 : Relationship between change rate of model accuracy and step

Table 2. Theoretical model and model testing parameters s of macroporous degree under the condition of differeent sampling diameter

Sampling Diameter (Mm)	C_0 (%)	C (%)	$\frac{C_0}{(C+C_0)}$ (%)	Variable a(mm)	$\overline{(z^*-z)^2}$	$\overline{((z^*-z)/s^*)^*}$	P	I
25	2.12	0.66	76.3	47.9	0.0268	0.96	0.1	0.0243
40	1.36	0.83	62.1	32.5	0.0237	0.94	0.1	0.0296
60	1.55	0.67	69.8	61.8	0.0197	1.02	0.1	0.0159
80	0.59	1.86	24.1	94.05	0.0128	1.19	0.1	0.0117
100	0.11	1.96	5.31	97.70	0.0084	1.28	0.1	0.008
125	0.28	3.95	6.62	93.24	0.0146	1.06	0.1	0.0132
150	0.10	2.41	3.98	89.44	0.0099	1.13	0.1	0.0093
175	0.02	1.54	1.28	97.92	0.0047	1.15	0.1	0.0044

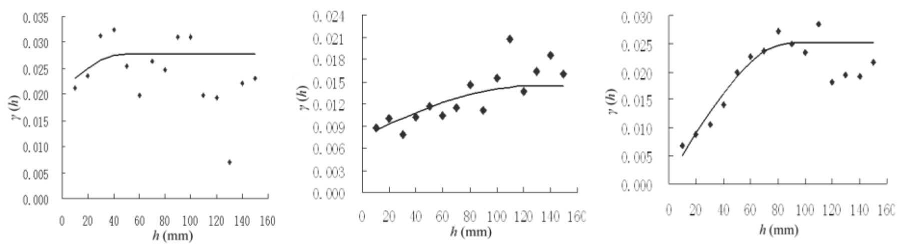

Fig. 3: Semi-variogram when the sampling diameter was 25、60、150mm

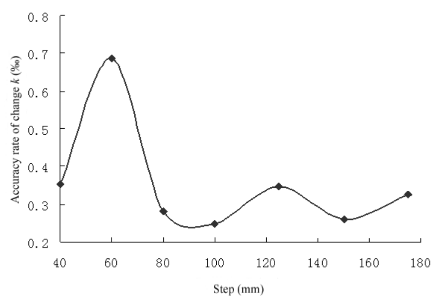

Fig.4: Rrelationship between change rate of model accuracy and sampling diameter

4.2 Reasonable scale analysis

From Table 1. and Fig.1~4**,** it can be found that the precision change rate gradually decreased between 10mm and 20mm step. The precision varied larger with these step. When the step achived 20 mm, the rate of model precision achieved smallest. And then it had tend to stabilize ups and downs. 20mm could be considered the critical step. But $\overline{(z^*-z)^2}$ and *I* increased along with the minimum step increased. For example ***I*** value increased from 0.0051 to 0.0025. It showed that sampling interval can not be too large. Because even if sample spacing increased, the workload reduced, and at the same time it caused academic model would not primely describe variable characteristics and special structure of macropore degree in soil. And the accuracy of estimates and simulation would also reduce.

Table 2. and Fig.5~8 said that when the sampling diameter was between 40 mm and 80 mm, model precision varied from 0.28‰ to 0.685‰, changed distinctly. Model precision change rate reached the smallest between 80mm and 100mm. In the context, the model precision achieved the highest point of local and then changed in the steady state. *I* value slightly reduced with the sampling increaced, concretely minished from 0.00243 to 0.0044(<10%). The larger the sampling diameter, the higher simulation accuracy of calculation and of variogram were. The sampling diameter went bigger, it could reflect the nature of the porosity more. But this would spend a significant amount of manpower, material. It said that 80~100mm could be taken for reasonable sample diameter.

5. CONCLUSION

This paper took geostatistical theory into microcosmic domain to research macropore distributing, analysis the spatial structural characteristic, broadened the application of goestatistical theory. It had two conclusions as follows:

(1) Used digital image analysis technology to visually describe the number of the soil macropore, size and other characteristics. It said that the macropore degree had roughly the same trend in different soil column. Max value basically concentrated lied underground 12cm to 18cm, that was cultivation layer. The maximum of macropore area changed little. But the maximum of macropore perimeter fluctuated in the apparent trend. This showed in the vertical section, the difference of macropore spatial distribution structure was different.

(2) Used geostatistical theory to research the spatial structure of the macropore of soil. Analysised the spatial structure of macropore on both vertical and horizontal directions. Through the parameters such as C_0, C, Variable, I, model precision change rate k and so on, it showed that 20mm was reasonable sampling interval in the vertical depth. 80～100mm was the economically reasonable sampling diameter in the level. This provided instruction for soil moisture, solute movement regulation and setting up exact predictive model for cropland moisture.

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