Journal of Agricultural Science; Vol. 5, No. 2; 2013
ISSN 1916-9752 E-ISSN 1916-9760
Published by Canadian Center of Science and Education

Trend Effect and an Isotropy of Soil Particle Composition in the Chengdu Plain

Li, Wen-Hong[1], WANG, Chang-quan[1], YANG, Mei[1], WANG, Lei[1] & Li, Bing[1]

[1] College of Resources and Environment, Sichuan Agricultural University, Chengdu, Sichuan, PR China

Correspondence: WANG, Chang-quan, College of Resources and Environment, Sichuan Agricultural University, Chengdu, Sichuan, PR China. Tel: 86-136-0826-9831. E-mail: w.changquan@163.com

Received: April 1, 2012 Accepted: April 27, 2012 Online Published: January 15, 2013

doi:10.5539/jas.v5n2p56 URL: http://dx.doi.org/10.5539/jas.v5n2p56

Abstract

This paper studies the spatial variation characteristics of soil particle composition on both sides of Qingbaijiang River (Chengdu Xin Du District of Sichuan province) by using the geostatistical component of ArcGIS and GS software. The results have shown that the trends of sand contents in the east-west direction and the north-south direction were first order and second order, respectively. And the trends of both silt particle and clay particle contents were first order in the east-west direction, and second order in the north-south direction. The anisotropy semi variance models of sand particle content showed that the ranges in the long axis direction were 718.77 m and 677.01 m and the ranges in the short axis direction were 273.78 m and 276.63 m with first order and second order. The results showed that the difference between the ranges in the short axis direction and the ranges in long axis direction changed little, while the anisotropy semi variance model had longer ranges than the isotropy model with the trend parameters of first order. From the error analysis and the result that reflect regional and local trend, it indicated that Kriging interpolation method considering the study about soil particle composition along Qingbaijiang River with the second order trend effect was the best, comparing the contour maps of sand particle content under different trend effects and anisotropy parameters.

Keywords: soil particle composition, variation functions, kriging interpolation, trend effect, anisotropy

1. Introduction

Soil is a variant of space-time continuum which has a high degree of spatial heterogeneity. Whether in the observation on with large scale or small scale, the spatial heterogeneity of soil still exist (Wang, 2004). Spatial variability of soil particle composition is an important basis for farmers to determine the dosage and period of fertilizer. In the regional study, it appears obvious characteristics of the local anisotropy by the influence of soil parent material. This characteristic was called directional influence in geostatistics, and it attracts great attention of researchers of precision agriculture (Wang, 1999; Sharmasarkar et al., 1999; Wingle et al., 1999). In recent 10 years, with the rapid development of information technology, it promotes the broad rise of precision agriculture research in China. And the researchers pay more and more attention on the spatial variability of regional farm crops, fertilizer management and production of soil properties (Jin & Bai, 2001; Nyam Angara et al., 2000; Ettema et al., 1998; Guo et al., 2000). In fact, in addition to the soil properties and soil formation conditions, in the region of large-scale study, the management measures about irrigation, fertilization and tillage will also produce directional difference in a way. This is one of the main reason that leads to the difficulty on quantitative modeling of part of the agricultural engineering measures (Canarache et al., 2000; Oliver et al., 2001; Roose & Barthes, 2001).

The directional influence of the regional soil properties is made up by global trends and random processes anisotropy composition (ESR, 2001; Burrough & Rachael, 1998). In the study area, the global trend can be expressed by physical process or mathematical formula. While the anisotropy can not be expressed by the same way, it can only as a random error when modeling. The incorporate of this stochastic process is: the research object has higher autocorrelation coefficient in a particular direction than it in the other direction. The regional soil properties present a certain degree of directional effects and difficult to satisfy the quasi second-order of steady assumption, therefore, it is more difficult to model directly by using geostatistics.

Qingbaijiang River is located in Xindu area of Chengdu Plain, soil particles on both sides of the river has an obvious trend effect and anisotropy. This is closely related to complex soil particle composition which caused by seasonal fluctuation in water levels and the change in river course change. Therefore, this article tries to use ArcGIS Geostatistical components and the GS software to explore the influence that the trend effect and anisotropy have on variogram modeling and kriging prediction.

2. The Condition of the Surveying Region and Methods

2.1 Regional Situation

Xin Du District lies in the northern suburb of Chengdu, and it is located in the hinterland of Western Sichuan Plain called "Land of Abundance". It is known as "the pearl" and "Sweet city". The entire district covers over an area of 496 square kilometers, of which five-sixths is plains, and the rest one-sixth is alow hill. Qingbaijiang River flows through the popedom. The study mainly focuses on the both sides of Qingbaijiang River, located at 103.97 to 104.03 degree east longitude and from 30.90 to 31.02 degree north latitude. About 80% of the study area has a subtropical monsoon climate which is beneficial to the development of agriculture. The main soil type is paddy soil which is developed from gray-brown or grey alluvial deposits.

2.2 Sample Processing and Analysis

2.2.1 Sample Collection

According to the basic situation of Xin Du District, after comprehensive consideration of changes in the regional, social economic conditions, distribution of water system, topography and human activities, etc., we adopted a uniform sampling method. Each soil sample was taken the sampling points as the center, takes 5 to 8 samples of 0~20 cm top soil within the radius of ten meters, then mixed them. At the same time, recorded the center position by using GPS (Garmin 72). We collected 104 samples of grey alluvial deposits paddy soil on both sides of Qingbaijiang River, among them sample XD001 to XD048 were collected from the north bank of Qingbaijiang River, sample XD049 to XD104 were collected from the south bank.This is shown in Figure 1.

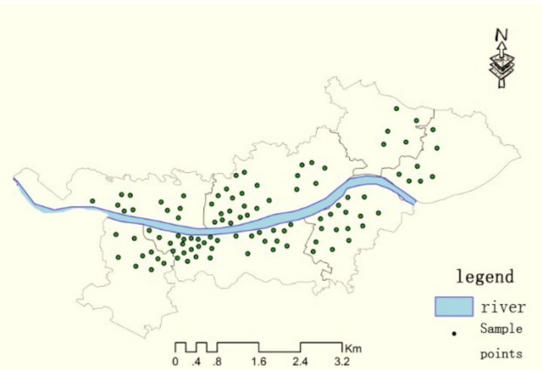

Figure 1. Distribution map of soil sampling points

2.2.2 The Processing and Analysis of Samples

The soil samples were placed on a kraft in the room, dried naturally after eliminating the plant debris and gravel. Taking the quarter by using quarter-separated method, then mulled through nylon sieve of 100 mesh, these samples were used for physicochemical property analysis. In this experiment, 15% of the sample parallel, the National Institute of Standards of the sample GBW07405 and reagent blank as a quality control. The physical properties of the sampling soils is shown in Table 1, the details of determining methods can be found in “Analysis of soil characteristics” (Bao, 1999).

Table 1. Physical properties of the sampling soils

Soil	pH	Organic matter (g/kg)	CEC (cmol/kg)	Sand (g/kg)	Silt (g/kg)	Clay (g/kg)
paddy soil	5.95±0.52	24.88±6.49	14.12±3.72	525.91±89.11	332.98±68.40	141.40±44.12

Note: numerical value= mean value±root-mean-square deviation.

This article uses the ArcGIS 9.0 Geostatistics components and the GS software to statistics the basic characteristics of soil particles on both sides of Qingbaijiang Rriver. On this basis, we conducted the regional soil particle composition analysis, global trend analysis, the anisotropy analysis, variogram modeling and kriging analysis.

2.3.1 Trend Effect and the Selection of the Anisotropy Parameter

Using the trend analysis tools of the Geostatistics, components of ArcGIS 9.0 to obtain the change trend of regional soil particle composition in different directions, and provide the suitable trend parameters for Variogram modeling and kriging interpolation. The processing method of trend effect in ArcGIS is as follows: before the Variogram modeling, remove the trend according to the trend analysis results; compound the trend in automatically when in the kriging interpolation. In the geostatistical component of ArcGIS9.0, the trend effect was divided into three parts, they were zero order (no trend effect), first order (regionalized variable changes straightly in a certain direction) and second or multi order (regionalized variable present's polynomial change in a certain direction).

2.3.2 Error Analysis

The test methods of errors in Variogram modeling and kriging interpolation are cross-validation method or Jacknife method, respectively. Using this method to calculate the hypothetical point which is not determined, according to the selected model, the value of this point can obtain from the data of other N-1 measuring points with specific Kriging method. Assume that the measured value of the measuring point is $Z(x_i)$, the predictive value is $Z'(x_i)$, the standardized values are $Z_1(x_i)$ and $Z_2(xi)$. Therefore, the mathematical expressions of the various types of errors are as follows:

$$ME = \frac{1}{N}\sum_{i=1}^{N}[Z(X_i) - Z'(X_i)]$$

$$MSE = \frac{1}{N}\sum_{i=1}^{N}[Z_1(X_i) - Z_2(X_i)]$$

$$ASE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}[Z'(X_i) - (Z'(X_i))/N]^2}$$

$$RMSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}[Z(X_i) - Z'(X_i)]^2}$$

$$RMSSE = \sqrt{\frac{1}{N}\sum_{i=1}^{N}[Z_1(X_i) - Z_2(X_i)]^2}$$

The standards of the evaluation model and its parameters is appropriate or the suitable degree are as follows: 1) The Mean Error is most close to zero; 2) The Mean Standardized Error is most close to zero; 3) The Average Standard Error is most close to Root-Mean-Square Error; 4) The Root-Mean-Square Standardized Error is most close to onestandardized error of the RM SSE is closest to 1.

3. Results and the Analysis

3.1 The Statistical Characteristics of Soil Particle Composition on Both Sides of Qingbaijiang River

Table 2 is the basic statistical characteristics of sand, silt and clay that were sorted by American system. The size of variation coefficient shows that the variation coefficient of sand is 17.02%, it belongs to variation coefficient of low intensity; but the variation coefficients of clay and silt were 31.29% and 20.64%, respectively, they belong to the project of medium variations. It indicated that the content has been affected to different extent by various factors, so the distribution of the contents is not uniform. In the study area, although the variation coefficient of sand isrelatively small, there still exists a certain change (Table 2). The content of clay particle was affected by the variation coefficient of sand and silt.

Table 2. Statistical features of soil particle composition

Item	Mean	Min.	Max.	S.D.	C.V.(%)	Skewness	Kurtosis	Distribution type
sand	525.91	360.60	786.70	89.51	17.02	0.95	0.18	Normal
silt	332.98	113.70	476.10	68.74	20.64	-0.82	1.02	Normal
clay	141.40	40.00	242.80	44.25	31.29	-0.30	-0.69	Normal

The analysis result shows that the modulus of skewness and kurtosis of soil particle obey the range that required by normal distribution. In addition, the difference between the minimum and maximum of soil particle on both sides of Qingbaijiang River was great, it indicated that its range was widely distributed in the area, so the spatial distribution characteristics need to be further discussed.

3.2 Regional Trend Analysis about Soil Particle Composition on Both Sides of Qingbaijiang River

In the spatial variability study about farm plot or soil particle composition on small scales, because the area is limited, the particle content mostly presents a obvious normal distribution or logarithmic normal distribution directly. When in kriging interpolation or calculate the variation functions, we can do it without analyzing the trend effect or ignore the trend effect in a way. But in the study of regional soil particle concentration, it is easy to observed the trend effect (Figure 2) though inspection results of skewness and kurtosis present a obvious normal distribution. In Figure 1, axis X refers to the east direction, axis Y refers to the north direction and axis Z refers to the size of the measured data of each point; the dark-coloured line on the left back of projection plane refers to the change of the overall trend effect in east-west direction, and the light-coloured line on the right back of projection plane refers to overall trend effect in south-north direction.

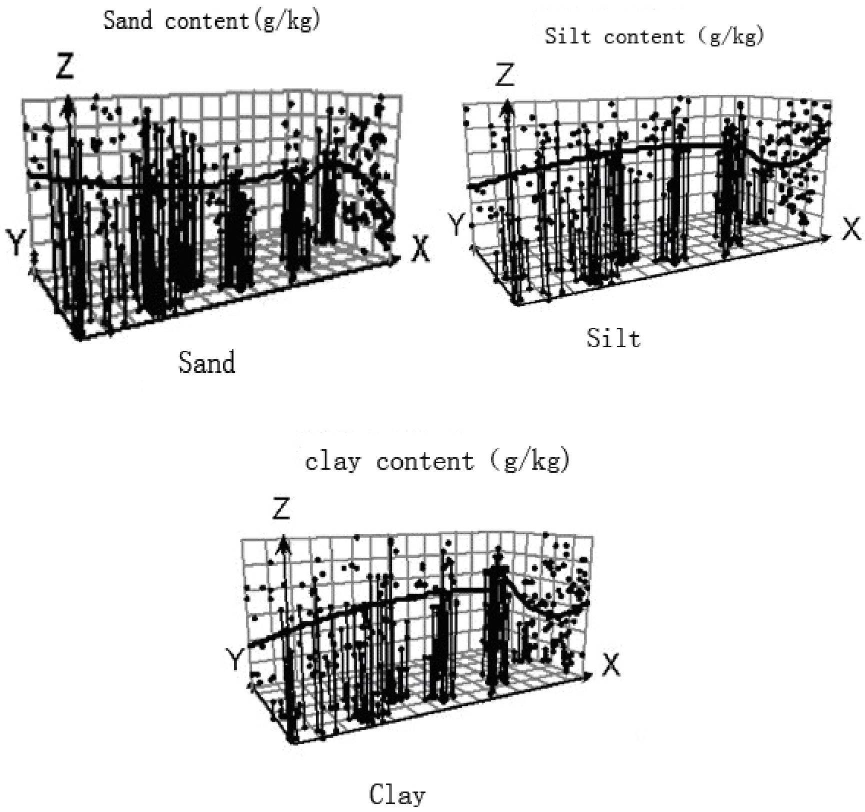

Figure 2. Trend analysis of soil particle contents in the region

In the geostatistical component of ArcGIS9.0, the trend effect were divided into three parts, they were zero order (no trend effect), first order (regionalized variable changes straightly in a certain direction and second or multi order (regionalized variable presents polynomial change in a certain direction). If the projective line approximate a straight line, the trend is one order; if the projective line presents a U-shape, it indicates that the trend presents polynomial change. All these provide a basis for selecting the variation trend when making the interpolation figures. A high trend order need more parameters when in Kriging interpolation, but these would cause errors. So in order to reduce the errors, low order or simple effect should be chosen for estimating and evaluating as the order of trend effect is in between or multiple.

From Figure 2 we can know that the content of sand present the change with one order approximately from east to west; the content of sand increased from east to west, but the trend presents U-shape polynomial change from south to north. The content of sand in middle part is higher than the North and South, so it has both a linear trend effect with first order and U-shape trend effect with second order. We can also know that the content of silt and clay present the change with one order approximately from east to west, but the content reduced from east to west; the trend also presents U-shape polynomial change from south to north, but the content of silt and clay in middle part is lower than the North and South.Combined with the sampling points of the study, stationing on both sides of Qingbaijiang River. Its content characteristics obey the geological evolution characteristics that the closer the soil to the river, the particles will be thicker. Conversely, the farther the soil from the river, the particles will be thinner.

3.3 Anisotropy Analysis about the Soil Particle Composition on Both Sides of Qingbaijiang River

Take the sand grain content for example, observed the effect that anisotropy have on Variation functions modeling or on the prediction results (Table 3). According to the front trend effect analysis results, using the geostatistical component of ArcGIS9.0 can find out the azimuth angles of long axis with first order and second order (the A1 and A2 in Table 3), they were 85.20 degree and 84.60 degree, respectively. The anisotropy semi variance models of these two trend parameters showed that the ranges in the long axis direction were 718.77 m and 677.01 m and the ranges in the short axis direction were 273.78 m and 276.63 m with first order and second order. The codomain of isotropy (A3) in the long axis were obviously shorter when compared with the front two, only 366.26 m.

Table 3. Semivariance models of soil sand particle content

method	Semivariance model	Trend order	Range/m		Long axis azimuth	C0	C+C0	C/(C0+C)（%）	R2	RSS
			Long axis	Short axis	（°）					
A1	Globular	First order	718.77	273.78	85.20	777.68	15323.68	94.92	0.345	2.16E+09
A2	Globular	Second order	677.01	276.63	84.60	1502.80	13644.80	88.99	0.287	1.98E+09
A3	Globular	First order	366.26			1594.60	14629.60	89.10	0.641	8.31E+07

On this basis, directional variogram of soil particle composition after analysed by GS+7.0 software is shown in Figure 3. In Figure 3, the nugget value (C0) refers to the random variance which is caused by less than sampling unit or analytical error, C refers to the structural variance caused by structural factors, the sill value(C0 +C) refers to the maximum variance of data sequence. The structure effect value {C/(C0 + C)} refers to the ratio of structural variance to total variance, that is the structure effect of data sequence, it reflects the spatial correlation of soil properties.Generally speaking, it means the spatial correlation is very strong when the value of C/(C0 + C) greater than 75, its spatial heterogeneity is mainly caused by space structural factors; it may has a medium spatial correlation when the value of C/(C0+C) in 25 to 75; it means the spatial correlation is relatively weak when the value of C/(C0+C) less than 25. The range is refers to the corresponding distance from variation functions to the sill value,namely spatial auto-correlation distance of soil elements, the change of range also reflects the main variation process of soil elements. The sampling point may be spatial autocorrelative when its interval less than the range, if not, it may be spatial uncorrelated. Choosing models depends on the five fitting parameter values of the theoretical model of variation functions, consider the determination coefficient (R2) first; second, the residual (RSS); then the sill value and the size of range. Based on this theory principle, we chosed the spherical model for the study of different particle composition at last after comprehensive comparison of linea model, gaussian model, spherical model and index model. Because the data in Table 3 haven't been dealed with normalization, so the unit of nugget effect and sill value is consistent with the project. The values of all items were greater than zero, this indicated that this model has various positive substrate-effects caused by short-range variation,Sampling error or analysis. In this study, the values of C/(C0+C) soil about particle composition with anisotropy on both sides of Qingbaijiang River, were 94.92,88.99 and 89.10, respectively. That means the spatial correlation is very strong, this may because that the sampling points were focused on both sides of Qingbaijiang River in Xindu district, the river have a greater effect on soil particle composition, so the great differ of soil particle composition may be caused by the different distance to the river.

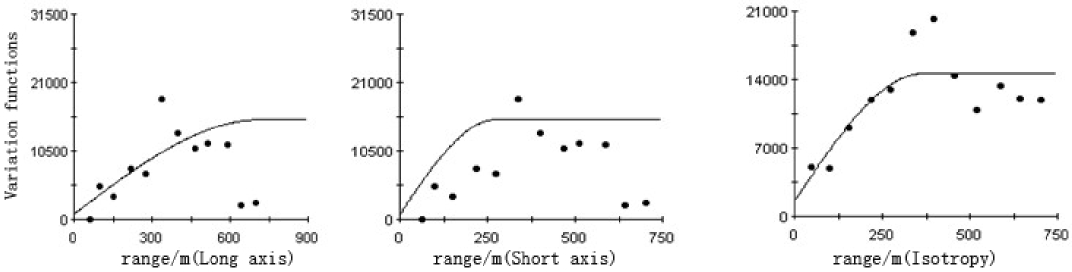

Figure 3. Directional variogram of sand particle content after removing trend with one order

3.4 Analysis about the Contour Map of Soil Particle Composition on Both Sides of Qingbaijiang River

Because the soil particlescomposition on both sides of Qingbaijiang River obey the normal distribution, so as to ensure the effectiveness of kriging interpolation. The accuracy of all kinds of modeling method can be analyzed by forecasting the size of error and analysing the comprehensive reaction effect that reflect regional and local trend. The contour maps can reflect the size of error as well as incarnate a method that reflect regional total and local trend. Figure 3 is the contour maps of sand particle under different trend effects and anisotropy parameters. Their variation functions fitting are spherical model, and the patial interpolation method are all ordinary kriging method. Figure 4 is the interpolation contour maps of trend effect parameters with first order and second order or isotropy.

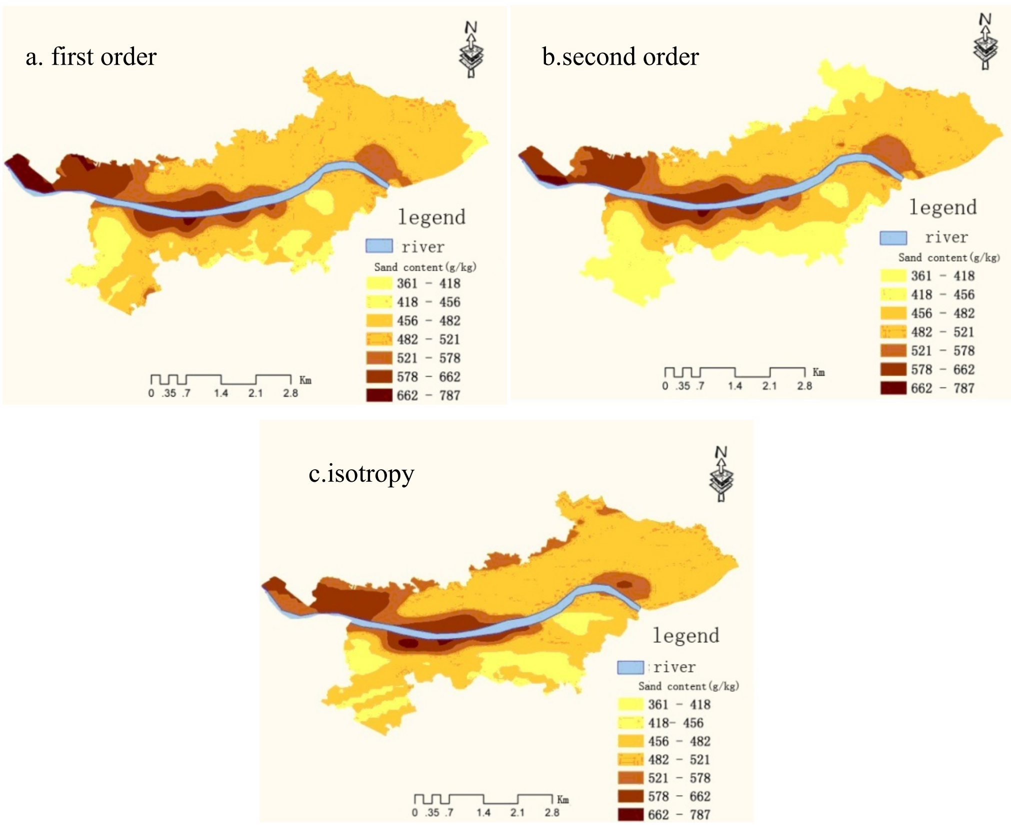

Figure 4. Analyzed results with different trend parameters for sand particle content(g/kg)

The standards of Figure 4 whether evaluation model and its parameters is appropriate or the suitable degree are mentioned in the second part (Error Analysis). From Table 4 we can be known that among Figure 4 the Mean Standardized Error value of isotropy is 0.0123, it is higher than second order (the value is 0.0030) and first order (the value is 0.0109). At the same time, it reflected the holistic trend of samples worse than the other two. Therefore, in the study of Geostatistics applied to large scale area, regarding the area as isotropy or ignore the processing method of trend effect may be difficult to reflect the regional characteristics of soil properties.

Table 4. Comparison of prediction error

method	interpolation	ME	RMSE	ASE	MSE	RMSSE
First order	Ordinary kriging	1.1750	62.88	84.69	0.0109	0.775
Second order	Ordinary kriging	0.2704	64.94	82.40	0.0030	0.812
isotropy	Ordinary kriging	1.3430	61.26	80.80	0.0123	0.807

From Table 4, the analysis about the size of error shows that we obtained the minimum Mean Error and the minimum Mean Standardized Error by using the interpolation method of second order trend effect, we also got the results that the Root- Mean-Square Error is most close to Average Standard Error and the Root-Mean-Square Standardized Error is most close to one by using the interpolation method of second order trend effect. Considering the interpolation error of anisotropy, trend effect and sampling of study area, after comprehensive analysis about evaluation error of each model, it indicated that Kriging interpolation method considering the study about soil particle composition along Qingbaijiang River with the second order trend effect was better than the other two interpolation methods.

4. Discussion and Conclusion

This article using the geostatis-tical component of ArcGIS and GS software which has fast trend analysis function and automatic search function for anisotropy in the long axis. Before the variant function modeling, remove the trend according to the trend analysis results.

Compound the trend automatically when in the Kriging interpolation. And this component can search best long axis direction automatically during anisotropy analysis. At the same time, it is more simple and reliable when GS is in the calculation of the variograms model.

Combining the two can better reflect the anisotropy of soil properties, it is a kind of geostatistcs statistics analysis tool, and its function is relatively perfect among the present similar software. And it is particularly applicable to analysis the spatial variation characteristics of regional soil properties.

Because of various forming factor (The purpose of this study is to rivers), the soil particle composition of study area often presents obvious trend effect and anisotropy characteristic. It shall also consider its influence when the variant function modeling or in the Kriging interpolation. Only doing corresponding processing analysis can better reflect the regional characteristics and change of soil properties.

The Kriging interpolation results about silt particle on both sides of Qing baijiang River in Sichuan Chengdu Xin Du District indicated that there were large errors if we regard both sides of the area along the river as isotropy or ignore the processing method of trend effect. And it is difficult to reflect the regional structure change characteristics of silt particle. In anisotropic conditions, all kinds of error is relatively small if we choose the secend order trend effect. Considering the interpolation error of anisotropy, trend effect and sampling of study area, after comprehensive analysis about evaluation error of each model, it indicated that Kriging interpolation method considering the study about soil particle composition along Qingbaijiang River with the second order trend effect was the best.

References

Bao, S. D. (1999). *Soil and Agricultural Chemistry Analysis*. Beijing: China Agriculture Press.

Burrough, P. A., & Rachael, A. M. (1998). *Principles of geographical information system* (pp. 108-120). Oxford: Oxford University press.

Canarache, A., Horn, R., & Colibas, I. (2000). Compressibility of soils in a long term field experiment with intensive deep ripping in Romania. *Soil & Tillage Research, 56*(3/4), 185-196. http://dx.doi.org/10.1016/S0167-1987(00)00143-4

ESR, I. (2001). Using ArcGIS geostatistical analyst (pp. 50-87). RedLands: ESRI Press.

Ettema, C. H., Coleman, D. C., & Vellidis, G. (1998). Spatio temporal distributions of bacterivorous nematodes and soil resources in a restored riparian. *Wetland Ecology, 79*(8), 2721-2734.

Guo, X. D., Fu, B. J., & Ma, K. M. (2000). Soil nutrient space mutation features study based on GIS and the geostatistics-Zun Hua in hebei province as an example. *Chinese Journal of Applied Ecology, 11*(4), 557-563.

Jin, J. Y., & Bai, Y. L. (2001). *Precision agriculture and soil nutrient management* (pp. 16-84). Beijing, China: The Earth Press.

Nyam, A. J., Mugwira, L. M., & Mpofu, S. E. (2000). Soil fertility status in the communal areas of Zimbabwe in relation to sustainable crop production. *Journal of Sustainable Agrure, 16*(2), 15-29.

Oliver, M. A., Frogbrook, Z. L., & Ellis, R. H. (2001). Exploring the spatial variation in wheat quality using geostatistics. *Aspects of Applied Biology,* (64), 207-208.

Roose, E., & Barthes, B. (2001). Organic matter management for soil conservation and productivity restoration in Africa: a contribution from Francophone research. *Nutrient Cycling in Agroecosystems, 61*(1/2), 159-170. http://dx.doi.org/10.1023/A:1013349731671

Sharmasarkar, F. C., Shankar, S. A., & Zhang, R. D. (1999). Micro-spatial variability of soil nitrate following nitrogen fertilization and drip irrigation. *Water, Air, and Soil Pollution, 11*(3-4), 605-619. http://dx.doi.org/10.1023/A:1005188827642

Wang Z. Q. (1999). Geostatistics and application in ecology. Beijing: science press.

Wang Z. Q. (2004). *Geostatistics and application in ecology*. Beijing: Science Press.

Wingle, W. L., Poeter, E. P., & M cKenna, S. A. (1999). Geostatistics, uncertainty analysis and applied to groundwaterflow and contaminant transport modeling. *Computers and Geosciences, 25*(4), 365-376. http://dx.doi.org/10.1016/S0098-3004(98)00140-X