Study on the Differences of Village-level Spatial Variability of Agricultural Soil Available K in the Typical Black Soil Regions of Northeast China

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Abstract. The spatial variability of soil nutrient is very important to the application of fertilizer, the sampling density of precision agriculture, and the sub-area of residence management of precision agriculture etc. With the examples of the agricultural soils of No.13 Village of Gongpeng Town and Xiguan Village of Enyu Town in Yushu City which are the typical black soil regions of Northeast China, applying semi-variance model and spatial autocorrelation model combined with GIS technology, a research on the differences of village-level spatial variability of agricultural soil available K is carried out in the thesis, which shows that the differences of averages and coefficients of variation in the same village are small, but large between different villages. The values of nugget and sill are close to the maximum ranges in No. 13 Village, but they are relatively different between different villages. The spatial autocorrelation of No. 3 and No. 7 lands in No. 13 Village are stronger than that of Xiguan Village.

Key Words: Available K; Spatial Variability; Village-level Differences; Black Soil Regions of Northeast China; Precision Agriculture

Researches on spatial availability of soil nutrient and management technology of precision agriculture have been very hot and have progressed rapidly in recent years [1]. With the putting forward and development of precision agriculture, the research on

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spatial variability of soil nutrient has already become one of the hotspot concerning modern soil sciences [2, 3]. The spatial variability of soil nutrient is very important to the application of fertilizer, the sampling density of precision agriculture, and the sub-area of residence management of precision agriculture, which is the most primary and foremost issue for the research of precision agriculture and has a great scientific meaning and research value. There are fairly a number of researches on spatial variability of soil nutrient related to small-scale lands of plot-level and large-scale lands (e.g. county-level) [2, 4 -15], but rather few related to the lands of village-level [12], and even fewer related to the lands under the same natural conditions both at home and abroad. Taking the spatial variability of soil available K as an example, by applying statistical analysis technique and geographic information system (GIS) technology, the differences of village-level spatial variability of agricultural soil nutrients are researched which supplies a scientific basis for the management and rational fertilizing of precision agriculture, meanwhile, the research on the spatial-temporal variability of soil available K lays a foundation for the scientific management of soil available K and rational fertilizing [16].

Through the spatial statistical analysis which takes sampling point as basic information resource, a theoretical optimized soil sampling density is put forward, and then, combined with an economic and rational consideration, a feasible soil sampling density will be made, which is one of the effective methods for designing a soil sampling plan [17]. Geo-statistics is a relatively good method to study the spatial variability characteristics of soil property, and has been widely applied in recent years [18]. An analysis combined by applying GIS can further clarify the situation of soil available K of the land, reflect the law of spatial variability of soil available K, and offer necessary means to explain the spatial distribution characteristics of soil available K.

1. Research Regions and Methods

1.1 An Introduction to the Region

Yushu City is a typical black soil region of Northeast China, which, thus, is selected as the research region in the thesis. Yushu City lies in the North Central Jilin Province, which is the center of the triangle district formed by three big cities: Changchun, Jilin and Harbin, with 30 towns, 4 sub-district offices, 388 villages, a population of 122 ten thousand, a total area of 4722 km^2, and an agricultural acreage of 290,700 hm^2 covering 68% of the area of the whole city, and is a typical black soil region.

Three agricultural plots in Gongpeng Town and Enyu Town of Yushu City are taken as research objects (Figure 1). Gongpeng and Enyu towns are two neighboring towns which have similar natural conditions. The research regions belong to the temperate zone which is sub-humid and mild, with clear four seasons, sufficient sunlight (percentage of sunlight amounts to 60%) and an average annual sunshine of

2800h, an effective accumulated temperature of 2800℃, the annual lead wind direction of southwest with a maximum speed of 3m/s, and an average annual rainfall of 620mm, which offer preferable weather conditions to the growth of crops and cash crops.

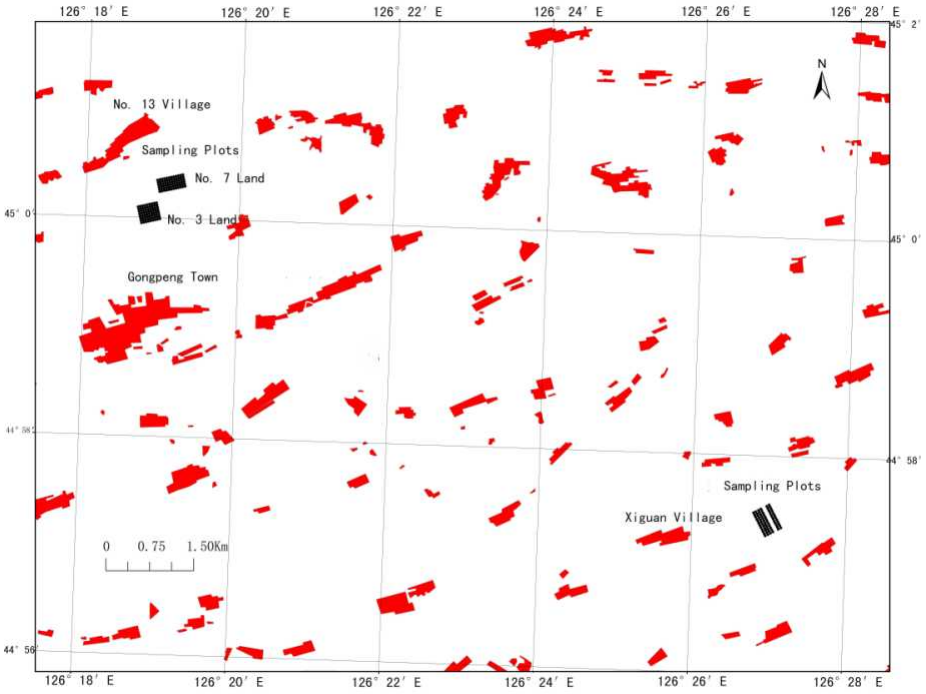

Figure 1 Location Diagram of Research Regions

1.2 Research Methods

Sampling is carried out in No. 3 and No. 7 lands of No. 13 Village in Gongpeng Town and in No. 9 Land of Enyu Town in the thesis (Figure 1), and the sampling interval is 40m× 40m, according to Quincunx Sampling Method, 72 samples are taken from each land (12 rows time 6 columns), and there are 216 samples taken in total. And then, extractions with the help of ammonium acetate—flame photometry will be applied to test the content of available K in these samples. A routine statistical analysis will be made on the data of soil available K of each plot through SPSS15.0, the semi-variance model of each plot will be worked out by applying GS+ software, and then a contrastive analysis will be carried out, with the help of GeoDa software, the overall Moran’ s I index of soil available K of all plots will be figured out and then be checked.

2. Results and Analyses

2.1 Analysis of the Characteristics of Descriptive Statistics

A descriptive statistical analysis is carried on towards the soil available K of each plot by applying SPSS15.0 in the thesis (Table 1).

Table 1 Descriptive Statistical Analysis of Each Plot

Item	No. 9	No. 3	No. 7
No.of Samples	72	72	72
Max	295.3	167	171
Min	215.8	136	137
Mean	253.943	152.36	157.22
Std.D	19.3104	6.488	6.059
Skew.	0.29	-0.378	-1.147
Kur.	-0.105	-0.45	1.899
C.V.	0.076	0.043	0.039

(Std.D: Standard Difference; Skew:Measure of Skewness; C.V.: Coefficient of Variation)

The average value of soil available K changes a lot between different plots, but the average value of No. 3 Land is not much different from that of No. 7 Land in No. 13 Village, but there is a great difference between these two averages and that of No. 9 Land of Xiguan Village. The variation coefficient reflects the relative degree of variation of the variable quantity, which is small between No. 3 Land and No. 7 Land in No. 13 Village, but there is a great difference between them and that of No. 9 Land of Xiguan Village. Soil belongs to a natural continuum, and spatial variability is a kind of natural attribute of it [19]. The variation degree of soil depends on its forming process and its balance between time and space. Due to the influences of some factors like human activities, soil available K has the nature of spatial variability. For the reason that peasants still fertilize according to their experience, and the peasants in the same area, due to the influence of primary farming experience, fertilize the same quantity and type of fertilizer in the same land, which leads a relatively great difference between different villages.

2.2 Selection and Analysis on Semi-variance Model

The semi-variance model of each plot is worked out by applying GS$^+$ software (Table 2, Figure 2).

Table 2 Semi-variance Model and Its Fitted Parameters

Plot	Model	Nug	Sill	Nug.	Max(m)	R^2	RSS
No. 3	Glo.	13.7	46.98	0.29	199.3	0.984	10.25
No. 7	Exp.	9.42	34.71	0.27	139.8	0.837	20.5
No. 9	Lin.	299.8	430.22	0.70	396.13	0.558	8987

(Glo.: Globular; Exp.: Exponential; Lin.: Linearity; Nug.:Nugget ; Nug.S:Nugget/Sill)

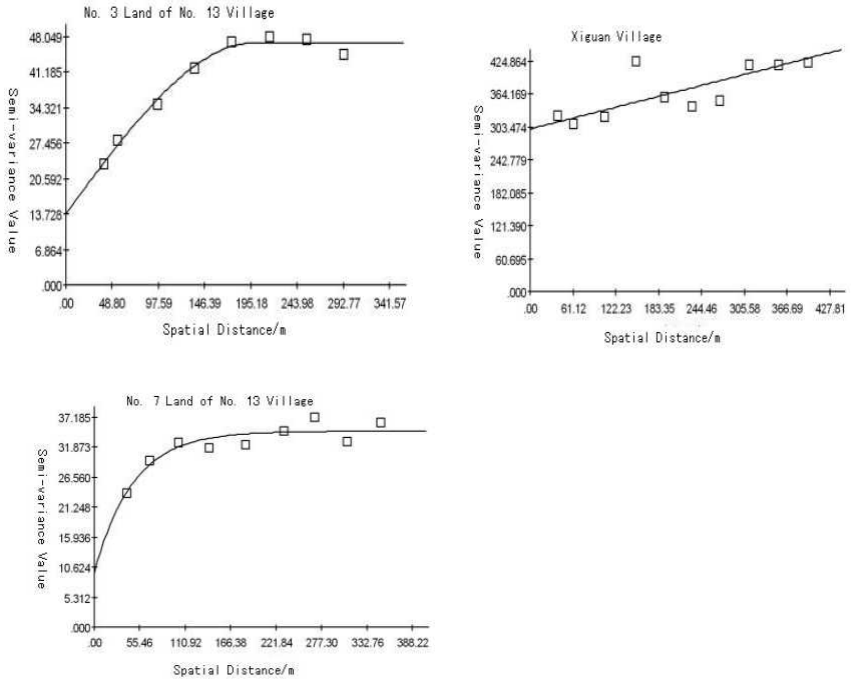

Figure 2 Diagram of Semi-variance Model

By adopting the semi-variance structure of soil available K calculated through GS$^+$ software, and analyzing on the residual errors of all models, we finally choose the optimal one to further launch an analysis on spatial variability. With respect to the determination coefficient (Table 2), those of the two mentioned lands in No. 13 Village are much larger than that of No. 9 Land of Xiguan Village. The ratio between

nugget and sill indicates the degree of spatial variability, and if the ratio is high, the degree of spatial variability caused by the stochastic part is relatively great; otherwise, the degree of spatial variability caused by spatial autocorrelation part is relatively great [1]. The relatively high ratio between nugget and sill in Xiguan Village illustrates that the degree of spatial variability caused by the stochastic part is relatively great, which shows that human factors play a leading role in the influences on the spatial variability of soil available K; while, the relatively low ratios between nugget and sill of No. 3 Land and No. 7 Land in No. 13 Village illustrate that the degree of spatial variability caused by spatial autocorrelation part is relatively great, and natural factors have much greater effects on No. 13 Village. The maximum correlation, namely distance refers to the variable function; from which we can see that the models of No. 3 Land and No. 7 Land in No. 13 Village are relatively close to each other, while the range of Xiguan Village is relatively different from those of the two lands in No. 13 Village.

2.3 Spatial Autocorrelation

The spatial autocorrelation characteristics of each plot are figured out by applying GeoDa software (Table 3). It can be seen from Table 3 that the significant levels of spatial overall autocorrelations of the two mentioned lands in No. 13 Village are higher than that of Xiguan Village, which demonstrates that the constitutive property of No. 13 Village is relatively stronger, but the randomness of Xiguan Village is relatively stronger. It can be also seen that, the two mentioned lands of No. 13 Village takes high-high aggregations as the main, aggregate type, while those in Xiguan Village are comparatively well-distributed, which indicates that the differences within a same village are small, but large between villages.

Comparisons are made between spatial autocorrelation of various soil available K, the d uniformity degree of soil available K between regions and between plots is fairly different. The spatial distribution of soil available K is directly related to the peasants' fertilizing habits, types of crops and management level. When the sampling interval does not surpass the maximum range of spatial autocorrelation of available K, the sampling and analysis towards various available K are relatively reliable and can be taken as the foundation for precision fertilizing.

Table 3 Spatial Autocorrelation and Its Aggregate Type

Sap.	Sig.	Moran' I	H-H	L-H	L-L	H-L
No. 9	0.02	0.1011	22	17	19	13
No. 3	0.001	0.3830	32	11	20	7
No. 7	0.005	0.1555	33	12	12	15

(Sap.:Sampling Plot ;Sig.:Significant Level ;H-H: High-high Aggregation ;L-H :Low-high Aggregation ;L-L :Low-low Aggregation ;H-L: High-low Aggregation)

3. Conclusion

With the example of spatial variability of soil available K, through comparing the differences between averages, coefficients of variation, ratios of nugget and sill, maximum ranges, spatial autocorrelations and aggregate types of soil available K of the plots in the same village and between different villages, the differences of village-level spatial variability of agricultural soil nutrients are studied, which shows that, through the long-term human influences on farmland, the difference of available K between the two mentioned lands of No. 13 Village is small, while, the difference of soil available K between No. 13 Village and Xiguan Village is relatively larger, which illustrates that human activities have changed the natural differences of soil of No. 13 Village, but have not changed those of soil between different villages.

In the past researches, only changes of soil nutrients in the same plot or village have been considered, while, the differences of soil nutrients between different villages had not been taken into account. The research on spatial variability degree of soil available K in the thesis and the research on spatial variability of soil available K through collecting and analyzing soil samples can effectively supply practical assistance for the fertilizing of precision agriculture, and further ensure smooth agricultural production. Because the sample-taken areas are only selected plots in two villages, the number of sampling data is small; while only the character of data themselves is considered during the process of selecting models instead of the essential character of the matter, therefore, other software would be selected to solve similar problems in future researches.

References

1. Jiang C.: Research on the Law of Spatial Variability of Soil Available K and Its Management Technology under Different Operative Mechanism.D. Graduate Institute of Chinese Academy of Agricultural Sciences. Jun,(2000)
2. Haneklaus S, Ruehling I, Schroder D, Schnug E.: Studies on the Variability of Soil and Crop Fertility Parameters and Yields in DifferentLandscapes of Northern Germany.A. In 1stEuropean Con.f Precision Agriculture, Stafford, J.V., Eds.; BIOS Scientific PublishersLtd., UK: Braunschweig, Germany, Vo.l II,; 785--792(1997)
3. Jin J.Y.:Precision Agriculture and Its Application Prospects in China.J. Plant Nutrition and Fertilizers Science. 4 , 1--7(1998)
4. Mallarino A P. :Spatial Variability Patterns of Phosphorus and Potassium in No- tilled Soils for Two Sampling Scales .J. Soil Sc.i Soc. Am. J. 60, 1473--1481(1996)
5. Hu Z.Y, Silvia Haneklaus, Liu Q, Cheng K, Cao Z.H, Ewald Schnug.:Small-scale spatial variability of phosphorus in a paddy soil.J.Communications in soil Science and PlantAnalysis.34, 2791--2801(2003)
6. Wang X.F, Zhang H.:Spatial Variability of Soil Organic Matter.J. Soils. 27 , 85-89(1995)
7. Zhou H.Z, Gong Z.T, Lamp J.: Research on Spatial Variability of Soils .J. Acta Pedologica Sinica. l, 33 ,232--241(1996)
8. Li J.M, Li S.X.: Spatial Variability of Some Nutrients in Soil .J. Research on Agriculture of Arid Region.16, 58--64(1998)
9. Hu K.L, Li B.G, Lin Q.M, etc.:Characteristics of Spatial Variability of Farmland Nutrients .J. Agricultural Engineering Journal.15 ,33--38(1999)

10. Yang Y.L, Tian C.Y, Sheng J.D, etc.:Anthropogenic-alluvial Soil Organic Matter, A Primary Exploration on Spatial Variability of Full Dose N, P and K .J. Research on Agriculture of Arid Region. 20 , 26—30(2003)
11. Yang L.P, Jiang C, Jin J.Y.: A Primary Exploration on Precision Management towards Cotton Field Nutrients.J. Scientia Agricultura Sinica. 33 , 67--72(2000)
12. Bai Y.L, Jin J.Y, Yang L.P.: Characteristics and Management of Soil Nutrients Variability of Different Scales .A. Jin Jiyun, Bai Youlu. Precision Agriculture and Management of Soil Nutrients .C. Beijing, Land Publisher of China. 51--57(2001)
13.Zhang Y.S, Lin Q.M, Qin Y.D. :Quantified Analysis on Spatial Variability of Soil Nutrients in Large-scale Region.J. Acta Agriculturae Boreali-Sinica. 13 , 122--128(1998)
14. Guo X.D, Fu B.J, Ma Keming. Research on Characteristics of Spatial Variability of Soil Nutrients Based on GIS and Geo-statistics—Taking Zunhua City of Hebei Province as an Example.J. Chinese Journal of Applied Ecology.11 , 557--663(2000)
15. Huang S.W, Jin J.Y, Yang L.P, etc.: Spatial Variability of County-level Grain Field Nutrients .J. Chinese Journal of Soil Science. 33 , 188--193(2002)
16. Gao Y.M, Tong Y.A, Hu Z.Y, etc.:Research on the Characteristics of Spatial Variability of Village-level Agricultural Soil Nutrients in Yellow Soil Region .J. Acta Pedologica Sinica. 37 ,1--6(2006)
17. Q i W.H, Xie G.D, Ding X.Z.:Research on Soil Sampling Density of Precision Agriculture—Taking Test and Demonstration Base of Shanghai Precision Agriculture as an Example. J. Chinese Journal of Eco-Agriculture. 11, 48--52(2003)
18. Peng Z.L, Ze Y, Li Z.Y, etc.:The Characteristics of Spatial Variability of Agricultural Soil Available K of Karst Mountainous Areas under Village-scale .J. Guizhou Agricultural Sciences. 36 ,81--84(2008)
19. Yang Y.L, Shi X.Z, Yu D.S, etc.: Research on Spatial Variability of Region-scale Soil Nutrients and Its Influencing Factors.J. Geographical Science.28,788--792(2008)