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Study on spatial distribution of soil available microelement in Qujing tobacco farming area, China

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Abstract

Descriptive analysis characteristics and spatial variation characteristics of soil available microelements were studied based on SPSS and GIS　Soil available microelements spatial distribution maps were created with ordinary Kriging method. The results indicate that, 7 available microelements in tobacco soil obey lognormal distribution, all the available microelements were intermediate variability; Anisotropic structure of available microelements of tobacco soil varies evidently, spatial variability of available B was mainly caused by random factors, and others' spatial variability were caused by structural factors and random factors; Spatial distribution maps show that, available B was widely deficient in tobacco soil of Qujing farming area, 'lower level' and 'low level' taken 7.74% and 68.20%, respectively　available Zn distribution was moderate, only 1.32% of the area lack of Zn, available Cu, available Fe and available Mn were extremely high in the whole extension, available Mo was deficient in part of the region with 28.38%, water soluble Cl was higher than critical value(30mg·kg-1)in the most of Qujing farming area, which taken 38.86%.

Keywords: Tobacco soil, Available microelements, Geostatistics, ArcGIS, Spatial distribution, Qujing

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1. introduction

Soil is one of the important sources of available microelements needed by tobacco. Either shortage or surplus would make an effect on growth of tobacco, as well as yield, quality and disease resistance [1-3]. Apply microelements fertilizer on soil that lack of microelements, could significantly promote the growth of tobacco, and improve quality of tobacco leaf[4-6]. Tobacco requires less microelement, unsuitable application of microelement likely to cause intoxication on tobacco plants, and soil pollution. 1970s, researchers began to study the spatial variability of soil properties [7]. Since 1980s, application of geostatistics on soil nutrient studies proved that soil nutrients was of spatial correlation, and studied spatial distribution soil nutrients base on Kring method[8,9]. Geostatistics has been proved to be one of the most effective methods of analyzing the spatial variability of soil features [10]. Spatial variability of soil major elements and secondary elements have been studied by many researchers [11, 12]. In recent years, study of spatial distribution of soil available microelements has been attracted more and more attentions [13, 14]. The study investigated the spatial distribution of soil available microelements content in Qujing tobacco farming area and generated the contour map base on geostatistics. The result will provide a theoretical basis for the scientific and effective divisional management of soil microelements and soil environmental protection in Qujing.

2. Materials and methods

2.1. study area

Qujing is located in eastern Yunnan, China (102 ° 42 '~ 104 ° 50'E, 24°19 '~ 27°03'N), which covers the area of 28,904km^2(Fig.1). The altitude of this region takes a range of 563 ~ 3675m.The annual temperature is 14.24 . The annual precipitation is 800~ 1700mm. The annual sunshine hours are 1584~ 2195h.The frost-free period is 204~ 282days each year. The total arable land area is 7.29×10^5 ha; suitable for planting tobacco in the area is 5.63×10^5 ha. Main tobacco farming soil types are red soil, purple soil, yellow soil and paddy soil.

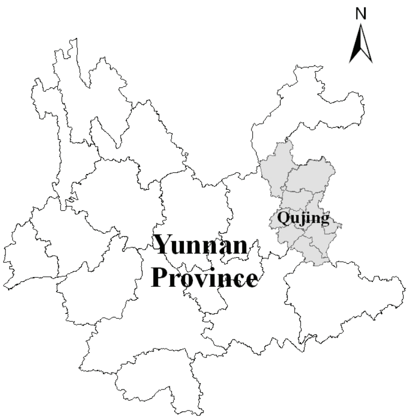

Fig.1. Location of the study area

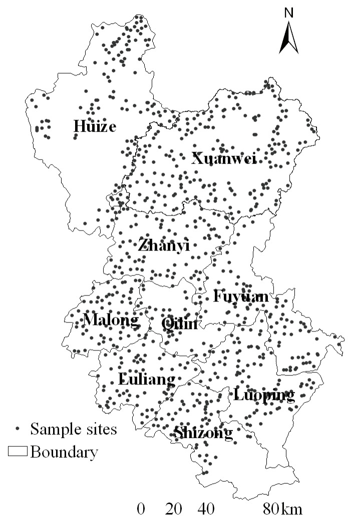

Fig.2. Distribution of soil sample sites

2.2. sample collection analysis

2088 soil samples were collected from the surface of the soil (0-20 cm deepth) in April 2008 with no rainfall for at least 7 days, and preserved by using the methods of soil analysis [15](Fig.2). The geographical coordinates of each sampling location were recorded using global positioning system (GPS).From each sampling point, 10 soil samples were gathered and mixed properly to obtain a composite sample mixture. A total of 1 kg of soil per sampling site was taken from the mixed samples to perform chemical analysis based on the quartile method. Soil samples were processed by air-drying, wood hammer crushing, and sieving. Each soil samples were saved in cellophane bags [16], labeled then taken to the laboratory for pre-treatment and analysis.

Flame atomic absorption spectrophotometry was used to determine the contents of Fe, Mn, Cu, B and Zn elements, after extraction with Diethylene triamine pentaacetic acid(DTPA). Polarographic method was used to determine content of Mo. Method of potentiometric titration with $AgNO_3$ was used to determine Water soluble Cl[17].

2.3. Data Analysis

Descriptive analysis and Kolmogorov-Smimov (KS) test were carried out on SPSS17.0. Calculation of experimental semivariogram, model fitting and map drawing were completed on ArcGIS 9.3 software. Before geostatistical analysis, values that greater than means+3C.V or less than means-3C.V were regard as exceptional value, and were instead by the maximum and minimum of normal.

3. Results and discussion

3.1. Content of available microelement in soil

Table 1 Summary statistics of soil microelement contents(2088 samples) ($mg\cdot kg^{-1}$)

Elements	Mean	S.D	C.V	Min.	Max.	Skewness	Kurtosis	Distribution
Available Cu	3.91	3.34	85.56	0.23	18.95	1.65	2.64	LN
Available Zn	3.95	3.67	93.08	0.1	24.95	2.92	11.05	LN
Available Fe	57.36	42.71	74.46	2.45	224.62	1.82	3.76	LN
Available Mn	57.82	36.32	62.81	0.32	247.00	1.19	1.82	LN
AvailableB	0.43	0.23	54.00	0.02	1.34	1.39	2.84	LN
Available Mo	0.23	0.21	92.76	0.00	1.23	2.60	8.09	LN
Water Soluble Cl	27.41	19.37	70.68	0.00	97.15	1.18	1.89	LN

Notes: LN, log-normal distribution; S.D, standard deviation; C.V, coefficient of variation.

As shown in Table 1, Soil available microelement present lognormal distribution, showed moderate variability with C.V from 54.00% to 93.08%.According to the standard of soil classified available microelement contents in Qujing(Table 2).Available Cu is abundant in study area, with a mean value of 3.91 $mg\cdot kg^{-1}$; Part of the soil lack of available Zn, with a mean value of 3.95 $mg\cdot kg^{-1}$; Available Fe is abundant in study area, with a mean value of 57.36$mg\cdot kg^{-1}$;Only a little soil lack of available Mn, with a mean value of 57.82 $mg\cdot kg^{-1}$; Available B is extreme shortage, with an mean value of 0.43 $mg\cdot kg^{-1}$; Only a little soil lack of Mo, with a mean value of 0.23 $mg\cdot kg^{-1}$; Only a little soil water soluble Cl is critical values, with a mean value of 27.41 $mg\cdot kg^{-1}$.

Table 2 Classified standard of the soil available microelement contents in Qujing(mg·kg-1)

Microelements	Very low	Low	Middle	High	Very high	Critical values
Available Cu	<0.10	0.10~0.20	0.20~1.00	1.00~1.80	>1.80	0.20
Available Zn	<1.00	1.00~1.50	1.50~3.00	3.00~5.00	>5.00	1.50
Available Fe	<1.50	1.50~2.50	2.50~4.50	4.50~10.0	>10.0	2.50
Available Mn	<3.00	3.00~5.00	5.00~10.0	10.0~15.0	>15.0	5.00
AvailableB	<0.25	0.25~0.50	0.50~1.00	1.00~2.00	>2.00	0.50
Available Mo	<0.10	0.10~0.15	0.15~0.20	0.20~0.30	>0.30	0.15
Water Soluble Cl						30

Notes: Based on the classification standards of soil available microelement contents of Qujing City in the second soil survey of China

3.2. Spatial structure analysis

The selection of theoretical semi-variance models and the cross-validation of model parameters can refer to the relevant literature[18,19],and the results are shown in Table 3. Except for the available B in subsoil, the ratios of nugget to sill of other microelements were all between 25-75 , which demonstrated that the spatial heterogeneity was owing to both structural factors(natural factors) and random factors(anthropic factors), and the spatial heterogeneity of available B mainly owing to random factors. Anisotropic ratio(major range to minor range ratio) of all available microelements were greater than 1, which demonstrated that distribution of them were of anisotropy[20,21].

Table 3 The semivariogram models of soil available microelements and corresponding parameters

Microelements	model	Nugget (C_0)	Sill (C_0+C)	Nugget / Sill	Major range(km)	Minor range(km)	Anisotropic ratio	MSE	RMSSE
Available Cu	Exponential	6.195	12.999	47.65	2.517	1.258	2.000	0.004	0.937
Available Zn	Spherical	5.428	18.092	30.00	2.517	1.609	1.564	0.005	0.999
Available Fe	Exponential	977.090	1851.590	52.77	0.258	0.115	2.253	-0.003	0.955
Available Mn	Exponential	909.380	1510.390	60.21	2.517	1.700	1.480	0.003	0.956
AvailableB	Exponential	0.042	0.056	76.44	2.517	0.699	3.602	0.001	0.915
Available Mo	Exponential	0.026	0.049	52.58	2.517	0.944	2.666	0.006	0.937
Water Soluble Cl	Exponential	146.680	388.290	37.78	2.353	0.835	2.818	0.002	1.034

3.3. Spatial distribution

To understand the spatial distribution of soil microelements in the study area, spatial distribution map of soil available microelements were created with ordinary Kriging based on the theoretical model of semi-variance (Fig.3). Mean Standardized errors (MSE) are approximate to 0. Root Mean Square Standardized errors (RMSSE) are approximate to 1(Tab.3). Both indices indicate that the predicted maps of soil microelements from Kriging are reliable in this study[22].As shown in Fig 3, soil available microelements show significant regional differences and certain trend. Distribution of soil available Cu high in east and low in west, the minimum area is in Luliang County, the highest value patch is in the east and north of study area; Soil available Zn high in north and low in south, and the minimum is in Luliang County and Fuyuan County, the highest value patch Mainly in the north; There was no obvious trend of spatial distribution of soil available Fe, the highest value patch is mainly distributed in the central of study area; Distribution of soil available Mn is high in north and low in south, the lowest patch is in central south areas, the highest patch is in the north; Distribution of soil available B is high in southwest and low in Northeast. There was no obvious trend of spatial distribution of soil available Mo, the lowest patch is in the central of study area; There was no obvious trend of spatial distribution of soil water-soluble Cl, the lowest patch is in the northeast of study area, and its distribution trend of patch boundaries roughly coincides with the county boundaries, possibly connected with regional fertilization habits.

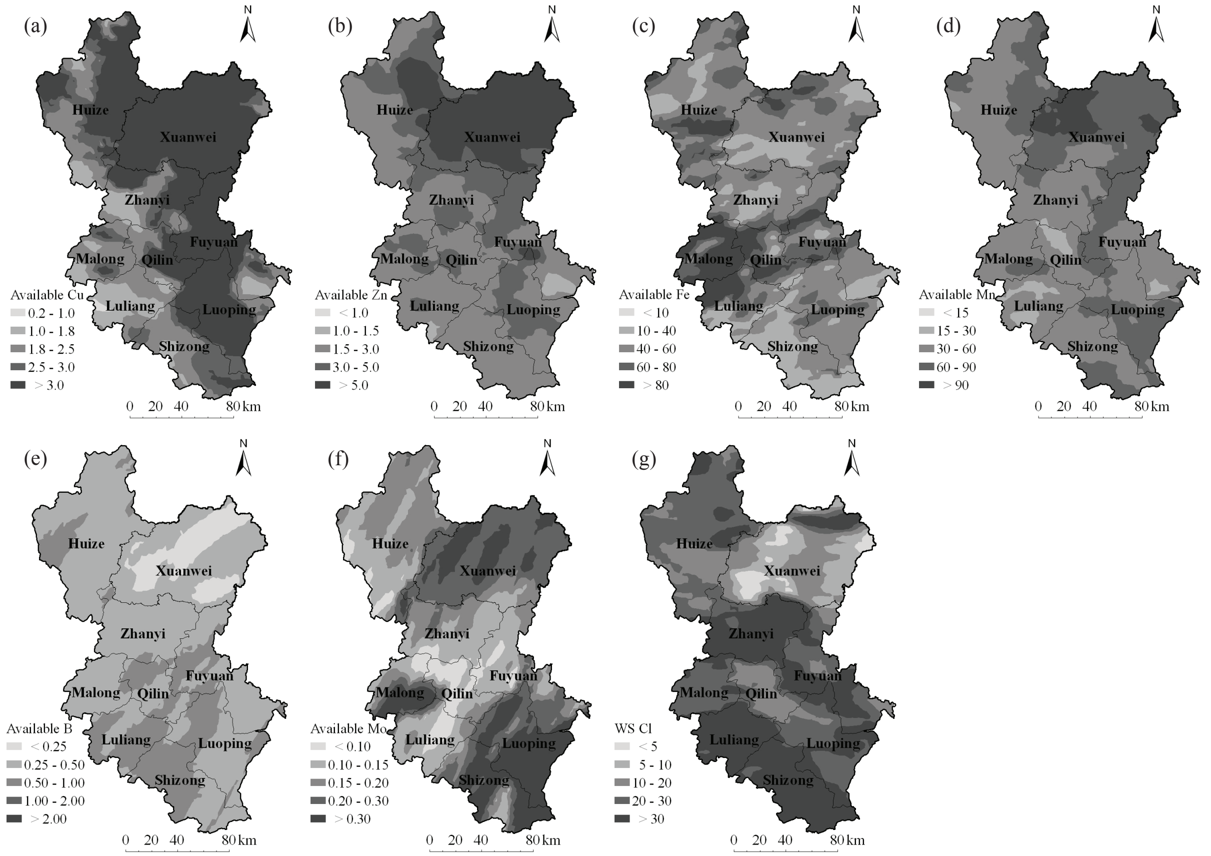

Fig.3 Spatial distribution of soil available Cu (a), available Zn (b); available Fe (c); available Mn (d); available B (e); available Mo (f) and water Soluble Cl (g)

Patch area of different categories of available microelements were calculating of spatial distribution map base on MapInfo. As shown in Tab. 4, Soil available Cu is of very high in most area, which take a percent of 90.48% of the total area. Middle grade(1.5~3.0 mg·kg^{-1}) of soil available Zn accounted for 48.56% of the total area, and 1.32% for low grade(1.00~1.5 mg·kg^{-1}). Soil available Fe is above 10mg kg-1(very high grade) in whole area, and 40 ~ 60 mg kg-1 accounted for 46.96%. Soil available Mn is above 15mg kg-1(very high grade) in whole area, and 30~60 mg·kg^{-1} accounted for 54.03% of the total area. Low grade(0.25~0.50 mg·kg^{-1}) and very low grade(<0.25 mg·kg^{-1}) of soil available B accounted for

68.15% and 7.75% of the total area, respectively. Low grade(0.10~0.15 mg·kg^{-1}) and very low grade(<0.10 mg·kg^{-1}) of soil available Mo accounted for 25.69% and 6.55% of the total area, respectively. There is 38.85% of the total area's Soil water-soluble Cl is beyond the critical value (> 30 mg·kg^{-1}).

Table 4 Area proportions of soil available microelements of each categories

Elements		Area proportions %				
Available Cu	Categories	<0.10	0.10~0.20	0.20~1.00	1.00~1.80	>1.80
	Proportion (%)	0	0	0.23	9.29	90.48
Available Zn	Categories	<1.00	1.00~1.50	1.50~3.00	3.00~5.00	>5.00
	Proportion (%)	0	1.32	48.56	27.43	22.69
Available B	Categories	<0.25	0.25~0.50	0.50~1.00	1.00~2.00	>2.00
	Proportion (%)	7.75	68.15	24.10	0	0
Available Mo	Categories	<0.10	0.10~0.15	0.15~0.20	0.20~0.30	>0.30
	Proportion (%)	6.55	25.69	22.91	24.62	20.22
Available Fe	Categories	<10	10~40	40~60	60~80	>80
	Proportion (%)	0	19.67	46.96	21.82	11.55
Available Mn	Categories	<15	15~30	30~60	60~90	>90
	Proportion (%)	0	3.09	54.03	37.88	4.99
Available Cl	Categories	<5.0	5~10.0	10.0~20.0	20~30	>30
	Proportion (%)	2.32	7.97	18.14	32.72	38.85

4. Conclusions

Soil available microelement showed moderate variability and performance anisotropy distribution. Spatial heterogeneity of available B was mainly owing to random factors, while others' were owing to both structural factors and random factors. Available Cu, Fe and Mn was abundant in study area, 1.23% of the total area lack of available Zn. Available B was deficiency in study area, Very low grade (< 0.25mg·kg^{-1})and low grade (0.25~0.50 mg·kg^{-1}) accounted for 7.74% and 68.20%, respectively. Very low grade (<0.10 mg·kg^{-1}) and low grade (0.10~0.15 mg·kg^{-1})of soil available Mo accounted for 6.55% and 25.69%, respectively. 38.85% of the total area's soil water-soluble Cl was beyond the critical value (> 30 mg·kg^{-1}) .

According to the spatial distribution of soil available microelement, boric fertilizer should be applied on soil in whole tobacco-planting area, molybdenum fertilizer should be applied on soil in central region and northern region, zinc fertilizer should be applied on soil in small part of the region, fertilizers containing Cl should be strictly prohibited in central and southwest region, fertilizers containing Cu, Mn and Fe should be prohibited in whole region, as well.

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