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Defining Agricultural Management Zones Using Gis Techniques: Case Study of Drip-irrigated Cotton Fields

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Abstract: Fuzzy c-means clustering was used to define soil-nutrient management zones. soil sampling data was tested to identify which data source was the best for partitioning optimum zones, using a geographical information system and various statistical techniques. The study area was a region of large-scale drip-irrigated cotton cultivation in China. For soil data sources, the area was portioned into three zones. To confirm the resulting zones, the coefficient of variation of the nutrient index was calculated for the soil data. The least spatial variation in soil nutrient content was found within the same management zones, with larger variation between zones. The degree of conformity (84.40%) with zones derived using actual cotton production data was found for the management zones defined using the combination of soil data. The method proposed here, using fuzzy c-means clustering and soil sampling data, can be useful in determining zones for optimal fertilizer application and resource management in cotton systems.

Key words: GIS, geostatistics, management zones, drip irrigation, cotton field

INTRODUCTION

Precision agriculture, has matured over the past decade, with advances in many types of technology. However, the effects of precision agriculture on environmental improvement and economic returns have not been fully clarified. One way to optimize resource use and protect environmental resources is by defining management zones (Koch *et al*., 2004; Doerge, 1999). Recent studies have examined precision agriculture in terms of spatial and temporal variations in soil and crops and have focused on accurately determining management zones for variable fertilizer inputs (Liu *et al*., 2004; Li *et al*., 2005; Zhu *et al*., 2006). A management-zone approach can improve the efficiency of soil nutrient utilization, there by protecting agricultural resources and environmental quality (Zhao, 1997; Bai *et al*., 2001).

In China, researchers has used various types od data and methods to determine management zones. Such studies have tended to focus on relatively small scale and to use a regular grid to define field management zones. For example: Baiyoulu *et al*. developed a regional soil nutrient zone management model that could be used to estimate fertilizer needs (Bai *et al*., 2001); and studied a drip-irrigated cotton field and used soil organic matter, total nitrogen, rapid available phosphorus and total salt contents as data sources for estimating precise zones for soil nutrient management (Wang *et al*., 2011). Applied the fuzzy c-means method of clustering and used salinity and crop output data to examine precision zone management in the Haituwei area (Li *et al*., 2007).

The Xinjiang Production and Construction Corps is a important producer cotton and other agricultural products. The company is under centralized management and operates farms of large size with high levels of mechanization, Climatic conditions are similar among the farms and techniques such as large-scale drip irrigation under plastic film are utilized (Lai, 2005). However, the company has made some blind investments and continues to increase agricultural inputs (such as chemical fertilizer inputs) to achieve high cotton yield This results in a low agricultural resource use ratio In addition, variable fertilization rates are difficult to achieve in such large fields.

Typically, variable fertilization is conducted on small scale grids.Understanding of the spatial variation in farmland soil nutrient characteristics and obtaining

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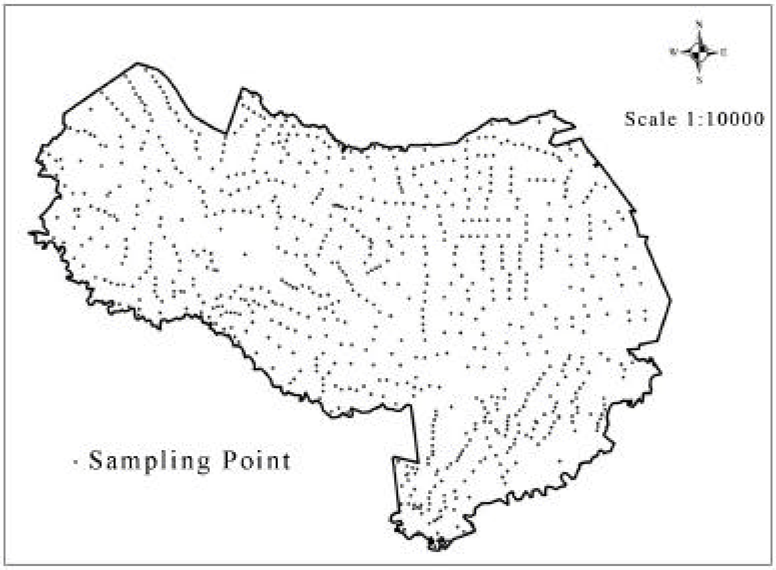

Fig. 1: Distribution map of sampling points in corps 81 Agricultural Construction Partition

consistent working units for individual nutrients for variable rate fertilization management are important both in theory and practice (Wang *et al*., 2010). Previous studies have used Remote Sensing (RS) data and soil-nutrient data to define variable rate fertilization management zones. However, the results have been incomplete and more research is needed.

This study focused on drip-irrigated cotton crop 81 in the 5th agriculture partition of the Xinjiang Production and Construction Corps.Referring to studies and research.The results provide a reference for differential zonal management of crops. In addition, the method presented, using soil sampling data, can be used to accurately define zones based on fertilization requirements in large-scale agricultural plots.

STUDY AREA AND DATA ANALYSIS

Study area: The study area is selected at Crop 81 in the 5th agriculture, it's partition of the Xinjiang Production and Construction Corps was located at 82°38'30"-82°24'49"E, 44°42'17"-44°48'52" N in the northwest of BoLe City, Xinjiang Uygur Autonomous Region, China, on the western edge of the Junggar Basin. The total area of the research region was 6533.3 ha. The sunshine and heat conditions, the large evaporation capacity and a frost-free period of 160-180 d make the region suitable for cotton production. Record-level cotton yields have been achieved many times in the northern Xinjiang region.

Soil data: Soil samples were taken at irregular intervals after the autumn cotton crop had been harvested in 2010. A Global Positioning System device was used to pinpoint the locations of the sampling sites which were situated near the centers of bar-shaped fields and are shown in Fig. 1. In total, 729 soil samples were obtained. The soil nutrient index was determined by soil agro-chemistry analysis (Bao, 2000).

Method of partitioning zones and confirmation of the appropriate number of zones: Fuzzy c-means is an unsupervised clustering method that has been used to classify various types of data, including soil, landform and RS data. The approach can also be used to classify natural phenomena with continuous variation. In this study, the fuzzy c-mean approach was used to delineate zones for soil-nutrient management. The optimal value obtained after repeated combinations, as proposed by McBratney and Moore (1985), was used to confirm the appropriate number of zones. That is, using a derivation function related to φ-[($\delta J/\delta\varphi$)c0.5], we optimized the choice of the minimum c value of the peak and the location of the maximum peak, after the c value had been selected (Tan *et al*., 2006; McBratney and Moore, 1985).

Data processing and analysis: The fuzzy c-mean clustering was conducted using Matlab 7.0 programming. We also used SPSS 17.0, GS +7.0 and ArcGIS 10.1 for analyses of statistics, spatial variability and fuzzy membership, as well as for semi-variogram calculation, matching of the theoretical model and graphic plotting of the kriging interpolation.

RESULTS AND DISCUSSION

Role of climate factors on soil wind erosion: Table 1 show the soil nutrient index obtained from soil test of the study area, Using this information, we calculated descriptive statistics

Table 1 show that, according to grading standards of the second general survey nationwide, organic matter and alkali-hydrolyzable nitrogen in study area were at the standard level or lower; rapidly available phosphorus, available Zn and manganese were at the moderate level; rapidly available potassium and available Cu were present in very high levels; and available Fe was in deficiency. The soil nutrient index variation coefficient was between 34.17% and 91.41%. The soil therefore complied with the management zone and we implemented variable rate fertilization because each index displayed medium spatial variation.

Method of partitioning zones: We obtained related matrix information from cotton yield data, obtained from yield monitor, soil property and making related analysis (Table 2).

Table 2 shows that each index correlated strongly with a soil property and there was significant positive correlation between major elements and microelements. However, a negative correlation was foundbetween total salt and soil nutrients, indicating that salinization is a main obstacle to improving soil fertility in the region. On the basis of the above results, we selected soil data had good correlations with crop output (organic matter, alkali-hydrolyzable nitrogen, rapid available P, total salt) .We chose four factors and used them as evaluation criteria for partitioning management zones. In the soil data approach, we used only soil nutrient data (organic matter, alkali-hydrolyzable nitrogen, rapid available P, total salt) and adopted the FCM method to divide the management zones.

Management zone partition: We adopted FCM to analyze the soil data. We set the maximum number of iterations as 300 and the convergence domain value as 0.001. The fuzzy weighted index number φ was set as 1.2-2.0, the fuzzy category number was selected between 2 and 10 for fuzzy clustering and there were three sub-zones in a cluster. The resultant management map is shown in Fig. 2.

Table 1: Soil nutrients of descriptive statistics

Name	Minimum	Maximum	Mean	S.D	C.V (%)
OM	2.00	48.02	13.7982	5.21019	37.76
AN	11.00	167.38	72.1121	30.27736	41.99
AP	1.68	30.56	11.3934	5.48272	48.12
AK	94.69	713.00	246.0395	105.58577	42.91
ACu	0.19	2.45	1.1297	0.38608	34.17
AFe	0.79	8.50	3.9725	1.48951	37.50
AZn	0.08	4.57	0.7155	0.60326	84.31
AB	0.08	4.57	1.1343	1.03690	91.41
AMn	1.35	20.94	7.6769	3.40569	44.36
Total salt	0.13	0.81	0.39	0.14	35.42
Yield	1507.29	8009.24	4973.8984	1806.22872	36.31

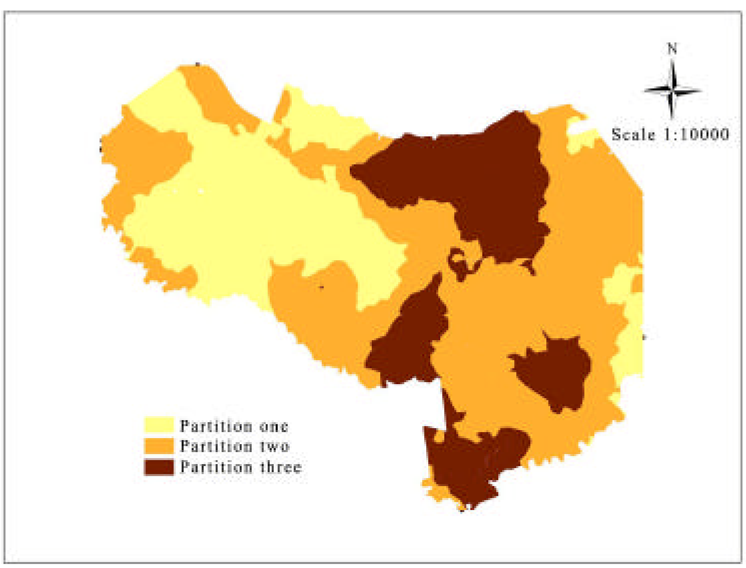

Fig. 2: Management map based on the cluster analysis

Table 2: Study area of soil properties and crop yield, vegetation index correlation coefficient matrix

	OM	AN	AP	AK	ACu	AFe	AZn	AB	AMn	T-salt	Yield
OM	1.0000	0.434**	0.378**	0.393*	0.402**	0.338**	0.277**	0.117**	0.421**	-0.182**	0.540**
AN	0.4340**	1.000	0.397**	0.359**	0.571**	0.691**	0.107**	-0.002	0.811**	-0.107**	0.441**
AP	0.3780**	0.397**	1.000	0.327**	0.249**	0.183**	0.145**	-0.052	0.221**	-0.027	0.382**
AK	0.3930*	0.359**	0.327**	1.000	0.251**	0.031	0.386**	0.519**	-0.263**	-0.100**	0.115
ACu	0.402**	0.571**	0.249**	0.251**	1.000	0.794**	0.491**	0.488**	0.474**	-0.159**	0.244*
AFe	0.338**	0.691**	0.183**	0.031	0.794**	1.000	0.358**	0.232**	0.703**	-0.195**	0. 218**
AZn	0.277**	0.107**	0.145**	0.386**	0.491**	0.358**	1.000	0.428**	0.065	-0.247**	0.067
AB	0.117**	-0.002	-0.052	0.519**	0.488**	0.232**	0.428**	1.000	-0.180**	-0.098**	0.055
AMn	0.421**	0.811**	0.221**	-0.263**	0.474**	0.703**	0.065	-0.180**	1.000	-0.098**	0.204**
T-salt	-0.282**	-0.107**	-0.027	-0.100**	-0.159**	-0.195**	-0.247**	-0.098**	-0.098**	1.000	-0.401**
Yield	0.540**	0.441**	0.382**	0.115	0.244*	0. 218**	0.067	0.055	0.204**	-0.401**	1.000

Table 3: Zoning statistics for soil properties and LSD test

		OM		AN		AP		T-salt	
	Sampling point Number	Mean value (g/kg)	Variable coefficient (%)	Mean value (g/kg)	Variable coefficient (%)	Mean value (mg/kg)	Variable coefficient (%)	Mean value (%)	Variable coefficient (%)
Zone 1	251	12.64bB	22.21	64.10bB	30.58	9.75bB	37.29	0.38bB	25.65
Zone 2	266	11.56cC	22.89	57.50cC	38.62	9.10cC	43.93	0.52aA	21.77
Zone 3	212	17.97aA	33.80	99.96aA	31.05	16.23aA	36.26	0.28cC	28.98

*Letters after the means indicate significant difference at 5% and 1% level, respectively

Management zone evaluation: Scientifically defined farmland management zones should have small variations within a specific management zone and larger differences among different management zones (Song *et al*., 2007).We calculated conventional statistics for soil data. The methods giving the least significant ranges and significance tests were conducted in each zone. Table 3 presents the result Table 3 shows that when only the soil data were used to divide management zones, the mean values and nutrient content were highest in partition 3 and the soil fertility was highest in partition 1, but the mean value and nutrient content were the lowest in partition 2 which also had low soil fertility. The soil fertility in partition 1 was in between those of partition 2 and partition 3. For soil organic matter, available nitrogen, rapidly available P, total salt and RVI, the LSD test showed that all values were significantly different ($p<0.01$).

In partitions 1, 2 and 3, NDVI differed significantly between partitions 2 and 3 ($p<0.01$); however, the NDVI difference was not significant between partition 1 and either partition 2 or 3 ($p>0.05$).In general, when useing soil data resources to separate management zones, the variation in nutrient content was smaller within the same partition after dividing the zones but larger between the divided partitions. Variable rates of fertilization can be applied based on the differences between the zones. The management zones obtained using soil data as data sources of partitioning had higher correspondence, i.e. the soil fertility in partition 1 was more than partition 1 and partition 1 is more than partition 2, It is therefore necessary to determine the appropriate data source for management zone partitioning.

Management zone precision check: The 'volume of production variation' reflects the soil nutrients, crop condition, various additional factors and their interactions. We conducted a single factor interpolation of actual output data for cotton at the test site in 2011. The output data were obtained from the Agricultural Production Management Decision section and were analyzed to obtain information on the spatial variation in production in the management zones. For convenience, we divided production into three categories of high (©ƒ6000 kg/ha2), middle (5250-6000 kg/ha2) and low (©,5250 kg/ha2), mapped in Figure 3. We used this map to check the rationality and accuracy of the management partitions obtained from the different data sources presented above.

We used separate fields for soil nutrients and actual cotton production output as data sources. Through this method we developed a management partition vector diagram which was imported into ArcGIS10.1 and then converted the vector data into raster data, with a raster set resolution of 100×100 m, 126 rows, 165 Columns and a total raster number of 126×165 = 20790. We used a classified shader to classify the raster data while keeping the correspondence between the raster images and the vector management zone map.We then used reclassified function under the spatial analysis mode, to assign new values for the raster data, specifically three categories with default values of 1, 2, and 3. Finally, the management zones, estimated using the soil data sources was shown as gray-scale images (following Fig. 4), statistics each category raster number covered, then statistics result show as following Table 4. Figure 4 shows the resulting management raster gray-scale image from the soil data

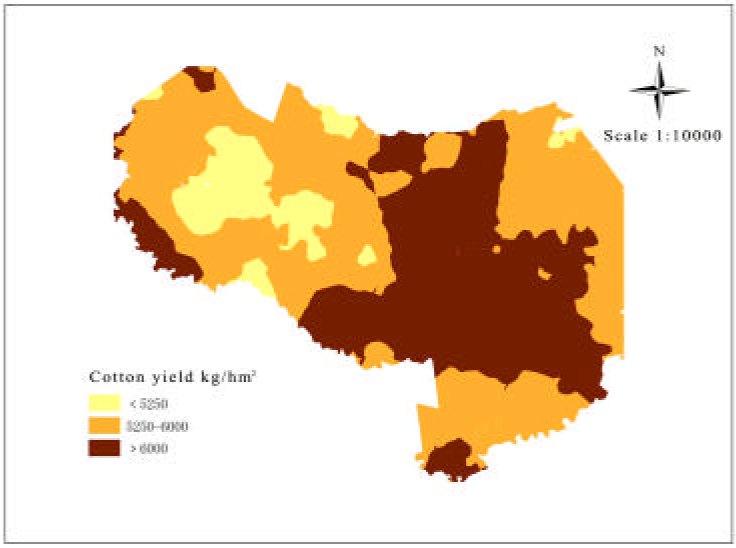

Fig. 3: Precise management zones map Based on the yield

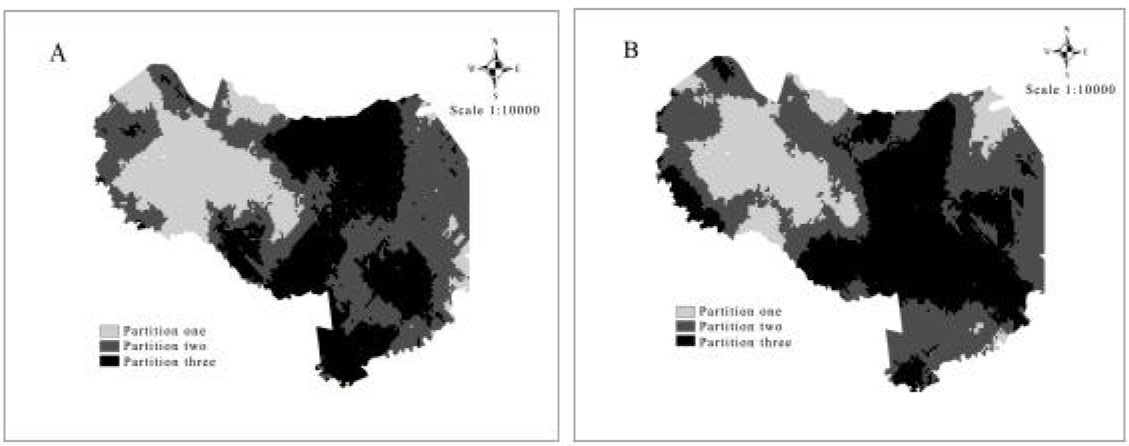

Fig. 4: Management raster image based on different data source, A- soil data ;B-actual yield as data sources

Table 4: Management partition grid number statistics of different data source partition

	Grid number			
Data source	Zone1	Zone2	Zone3	Total
Soil data	5430	8208	7152	20790
Actual output	3789	11451	5550	20790

sources (Fig. 3a) and agrees with the management zone gray-scale image (3-B) obtained from the actual output classification.However from the image only it is difficult to determine which method is preferable. Therefore, we developed a raster to calculate the statistics (Table 4) required to test the precision of management zones based on actual production rates in each region Table 5 shows that the partitions obtained using the soil data had 84.40% conformity with those obtained using the actual cotton production values.Indicate that the result of management zone which was divided by soil nutrient for precision management zone is more reasonable and more high-precision than only take soil nutrients as data for dividing management and which can better explain distribution of soil fertility.

Table 5:Results of grid computing statistical

	Grid No. of conformity with actual yield					
Data source	Zone1	Zone2	Zone3	Total	Grid number	Conformity
Soil data	3789	8208	5550	17547	20790	84.40%

CONCLUSION

In this study, we used soil nutrient data, as data resources and applied FCM to determine management zones, The study area was then divided into three zones for precision nutrient management zones with small partition overlap and clear distinction. To confirm the reasonableness of the partitions, we applied various statistics and methods of analysis of the mean nutrient values in each management partition, and used the LSD method for making significance testing. Generally, after dividing the management zones, the nutrient content index of the variable coefficient in each partition decreased to varying degrees and the spatial distribution was generally similar. There were obvious differences between different management partitions and smaller differences in nutrient contents within a given partition. To optimize nutrient management, the same fertilizer application rate should be used within a single management partition but different rates should be used among different partitions in fertilizer management zones. Soil data sources were also used for quantitative statistical analysis of the management zones obtained from d actual cotton crop output data. Using soil nutrient data as the basis for dividing management zones gave the second highest conformity of 84.40%. Consequently, the method using a combination of soil data is recommended for precise partitioning of management zones in areas of large fields.

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REFERENCES

Bai, Y.L., J.Y. Jin, L.P. Yan and M.Z. Liang, 2001. Research on the subarea management model of soil nutrients by GIS. Sci. Agric. Sinica, 34: 46-50.

Bao, S.D., 2000. Soil and Agricultural Chemistry Analysis. China Agricultural Press, Beijing, China.

Doerge, T., 1999. Defining management zones for precision farming. Crop Insights, 8: 1-5.

Koch, B., R. Khosla, W.M. Frasier, D.G. Westfall and D. Inman, 2004. Economic feasibility of variable-rate nitrogen application utilizing site-specific management zones. Agron. J., 96: 1572-1580.

Lai, X.Q., 2005. Oasis Agriculture of China. China Agricultural Press, Beijing, China.

Li, X., Y.C. Pan C.J. Zhao, J.H. Wang, Y.S. Bao, L. Liu and J. Wang, 2005. Delineating precision agriculture management zones based on spatial contiguous clustering algorithm. Trans. CSAE, 21: 78-82.

Li, Y., Z. Shi and C.F. Wu, 2007. Classification of management zones for precision farming in saline soil based on multi data sources to characterize spatial variability of soil properties. Trans. CSAE, 23: 84-89.

Liu, F.C., X.Z. Shi and D.S. Yu, 2004. Mapping soil properties of the typical area of Taihu Lake watershed by geostatistics and geographic information systems: A case study of total nitrogen in topsoil. Acta Pedologica Sinica, 41: 20-27.

McBratney, A.B. and A.W. Moore, 1985. Application of fuzzy sets to climatic classification. Agric. For. Meteorol., 35: 165-185.

Song, X.Y., J.H. Wang, L.Y. Liu, W.J. Huang, T. Shen and Z.Z. Yu, 2007. Research of management zones generating based on quickbird imagery. Sci. Agric. Sinica, 40: 1996-2006.

Tan, M.Z., J. Chen and F.M. Xu, 2006. Spatial prediction of soil heavy metal pollution based on fuzzy set theory. Acta Pedologica Sinica, 43: 389-396.

Wang, H.J., J. Cui, Y. Chen and X. Lu, 2010. Classification of management zones for soil nutrients in cotton land based on fuzzy clustering analysis. Cotton Sci., 22: 339-346.

Wang, H.J., T. Peng, X. Lv and Y. Chen, 2011. Study on management zones of small-scale based on soil nutrients in drip irrigation cotton field. Soil Fertil. Sci. China, 3: 78-82.

Zhao, Q.G., 1997. Problems challenging the development of modern agriculture of China. Acta Pedologica Sinica, 34: 1-9.

Zhu, J., B. Huang, W.X. Sun, R.Q. Yang and Z. Zou *et al*., 2006. Tempo-spatial variation of soil organic matter of farmland and its affecting factors in a typical area of the Yangtze River Delta Region. Soils, 38: 158-165.