Research and Application of Space-Time Evolution of Soil Fertility Data Mining Based on Visualization*

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Abstract. Soil fertility is a comprehensive reflection of soil properties, and its variation has been a central issue in the field of soil science. Most of current research on Variation of the soil fertility are most for a single time and place, and using expertise, simple mathematical model approach that can not effectively simulate the temporal and spatial variation of soil nutrients law. Therefore, this paper presents a spatial fuzzy clustering mining algorithms based on visualization to investigate the law of spatial and temporal evolution of soil fertility mining.

Keywords: soil fertility, spatial fuzzy clustering, temporal GIS, visualization, space-time evolution.

1 Introduction

Soil fertility is a comprehensive reflection of soil properties, it is changing in a vary period of time and space, it can fully reflect the natural factors and impacts of human activities on soil, and plays an important role on crops growth[1]. However, the interaction of the water, fertilizer, gas, heat and urbanization, environmental pollution and other man-made factors constitute complex space objects and relationships between the soil fertility itself and the corresponding the environment that hinders people's precise control to the soil spatial and temporal evolution fertility comprehensive, systematic analysis and intuitive [2-3]. Therefore, investigate the temporal and spatial variation of soil fertility is significance on the division of the farm management area, the implementation of variable rate fertilization and other precision agriculture technology.

Over the years, there are a lot of researches on soil fertility. Yu Yang etc[4] conducted a typical analysis about spatial variation of soil nutrient factors on black

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soil areas in Northeast ; Zhou Xu etc[5] proposed a approach of " based on GIS and AHP evaluation of arable soil fertility fuzzy", and has been applied in Pu an County, Gui zhou Province .Liling etc[6]take the long-term experiment in 1980-2006 which made by Hei long jiang Academy of Agricultural Sciences as a platform to compare the affect of different fertilization system on soil fertility of black soil region; Zougui Mei etc[7] suggests that urbanization is not only changes the land and geographical space, but also changes the soil fertility. Most of these researchers above focus on the soil itself, or only on single time or space relationship, mainly using the expertise or the simple mathematical model of data mining and conventional methods can not meet the vast amounts of spatial data, and then causes an inefficient procedure and large bias result. Comprehensive consideration of various factors study is very rare, and can not generate an accurate and effective simulation of space-time evolution of the law of soil fertility [8-9].

Thus, this paper integrates data mining, temporal GIS and visualization technology to study the evolution of soil fertility for many years, and improve the accuracy and efficiency of data mining and provide a reliable basis for the effective analysis and evaluation of soil fertility and fertilization of corn accurater decision- making. The result has been applied in the implementation of the national "863" project, "corn precise operating system research and application", the variable rate fertilization improves spatial diversity of soil fertility and enhances the ability of the agricultural management for agricultural production capacity which receives significant economic and social benefits.

2 Materials and Methods

2.1 Study Area

The experimental site is the national "863" model town , the No.3 13th District, Gong peng Village Yu shu City, locates northwest of Yu shu City and 26km from the city, in 126.315738-126.317017 longitude and latitudes between the 44.999859-45.002761. As a semi-humid temperature mild climate zone, the annual average temperature is 4℃, frost-free period has 135 days or so, the average annual precipitation is 500-700 mm. Plots of the total area of approximately 375 acres, the main crops are maize.

2.2 Data Acquisition and Processing

In this study, using GPS, GIS, RS technologies to obtain information of experimental corn cropland. Useing DGPS to divide the cropland into 40m×40m grid cell, A1~L10 as the sampling points. In this grid sampling unit, sampling depth is 25 cm, the sampling method is five-point plum sampling approach, which takes the four corners and centers of the grid on the soil samples mixture as the grid soil samples [10], shows in Figure 1. The experiment collects maize soil organic matter, available nitrogen, available phosphorus and potassium and other nutrient content data, production data and other related information, laboratory tests on soil samples to obtain a number of attribute data for analysis then acquire on the field of knowledge.

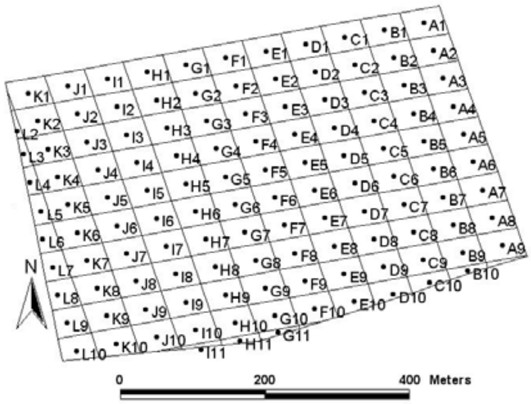

Fig. 1. Fertilization trellis

2.3 Method Description

2.3.1 Spatial Interpolation and VTK

Spatial interpolation is the procedure to estimate the value of other points from the known points. Commonly used spatial interpolation methods include Thiessen polygon method, Kriging method, the triangle method, Sibson natural neighbor method, inverse distance function method and so on. Kriging method becomes the preferred method of spatial interpolation, because of its compatible on integrity and locality[11]. In this paper, using the Kriging method to map the spatial variation of soil nutrient. The result can be displayed by the visualization toolkit VTK(Visualization Toolkit) as three-dimensional visualization.

VTK is an open source software system that includes computer graphics, image processing and visualization all in one and provides strong support to visual development tool for the study [12]. VTK uses pipeline mechanism to achieve visual process,and according to obtain the original data and the result to display to choose the appropriate algorithm . Source is the beginning of line by reading the source data files, etc. to produce source data. Filter handles a number of input data, and produces a number of output data and transform data various. Mapper is the interface between the visualization pipeline and the graphics model that converts processed Filter data into graphics data . Actor is the entity in the display window to receive the data attributes delivered from Mapper. Then Renderer window shows the results come out in[13-14].

2.3.2 Algorithm for Mining Fuzzy Weighted Space

Weighted spatial fuzzy clustering analysis includes determining the weight coefficient and the establishment of the weighted fuzzy clustering model two aspects [15]. Main steps as shown in Figure 2.

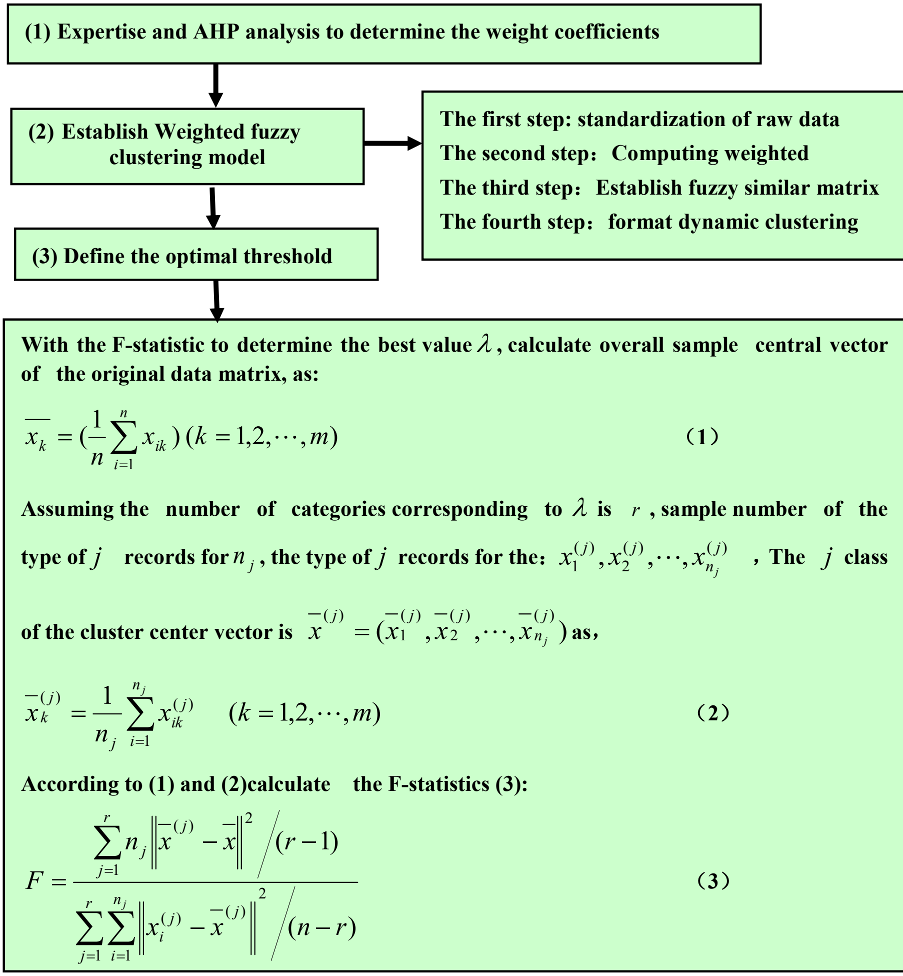

Fig. 2. Flow chart of the weighted fuzzy clustering

2.3.3 Temporal GIS Technology

Temporal GIS (T-GIS) was first proposed by Thrift in 1977, it indicates that time can be regarded as an external independent dimension apart from two-dimensional or three-dimensional space. Temporal GIS is also known as 4D-GIS, which means the three-Dimensional pace plus time dimension. Since the 1990s, With the further development of GIS applications, cadastral management, resource management, environmental monitoring, underground engineering, geology, mining, marine and other applications, temporal GIS has become a central research issue [16]. Temporal GIS technology can truly effectively manage the time of spatial data(reconstruction of historical status, track changes, predict the future, etc.), display the evolution of temporal and spatial data's variation , implementation historical and trend analysis of the different periods to achieve the purpose of dynamic monitoring.

3 Results and Analysis

3.1 Three-Dimensional Spatial Variation of Soil Nutrient Spatial Map

Takes soil available phosphorus of experimental base as an example three-dimensional spatial variability of soil nutrient map generation process.

(1) Convert the attribute information of soil available phosphorus in 2003 and 2008 into spatial information, using the Kriging method of interpolation them to form a raster layer. Then employ the VTK system to calculate the three-dimensional space within the area of each point of the element values with Kriging interpolation as VTK points data source, using VTKDelaunay2D function to generate DEM, which is VTK Unstructure Grid, use VTKdemreader to read the DEM, using VTKImage Shrink3D render three-dimensional effects and VTKElevationFilter set the output of z-axis, until adopted rule voxel model VTKPoly-Data Mapper that you can draw three-dimensional spatial variability of soil available P (Figure 3, Figure 4).

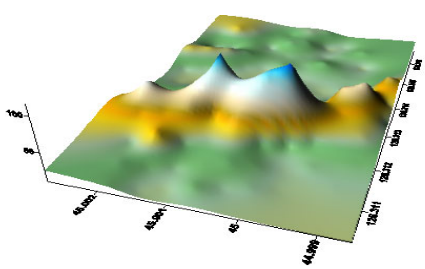

Fig. 3. Three-dimensional spatial variability map of Available P 2003

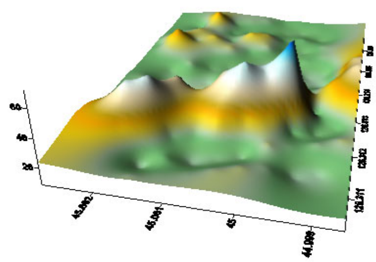

Fig. 4. Three-dimensional spatial variability map of Available P 2008

Size of the z-axis data of the available phosphorus in the three-dimensional spatial variability map can fully demonstrate in 2003 (the year before fertilization variable z is the range of 50ppm-100ppm) and significant effect of variable fertilization in 2008 (the first five-year variable-rate fertilization range of zis20ppm-60 ppm) that contribute to the proper evaluation of soil fertility. While the three-dimensional spatial variability map for arbitrary translation, rotation, subdivision, extract isosurface and other operations to help us dig out the hidden rules behind the data.

(2) Analyze the soil organic matter, available nitrogen, available phosphorus and potassium 4 planting of 2008 combined with GIS data to obtain the three-dimensional

spatial soil nutrients variability map of nitrogen, phosphorus, potassium No. 3 region in 2008 (Figure 5), according to historical data for acquiring soil nutrient spatial evolution of history, provide an objective, image, reliable decision support tools to verify the result of variable rate fertilization process and prediction.

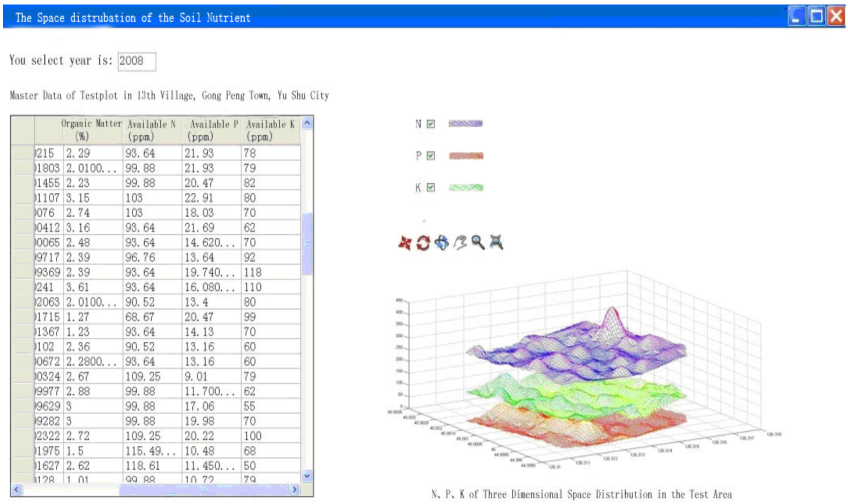

Fig. 5. Nitrogen, phosphorus and potassium distribution of three-dimensional space in 2008

3.2 Visualization of Spatial Data Mining

(1) Based on the principle of Weighted spatial fuzzy clustering algorithm, respectively, process the soil nutrient such as: the year before variable rate fertilization (2003), consecutive two-year variable rate fertilization(2005), consecutive 5-year variable rate fertilization (2008) and for seven consecutive years (2010) soil organic matter, available nitrogen, available phosphorus and potassium data, the first use of expertise and AHP to determine the weight coefficients to obtained weight in soil organic matter, available nitrogen, available phosphorus and potassium respectively are 0.1053, 0.2105, 0.1579, 0.5263; then establishing the weighted fuzzy clustering model; Finally, according to the results of clustering to determine the best threshold calculate F-distribution value to determine the optimum number of categories, F value is greater, indicating the distance between classes large categories, the better.

(2) According to the spatial relationship of the grid, clustering results will then be analyzed in a GIS then visualization. (Figure6).

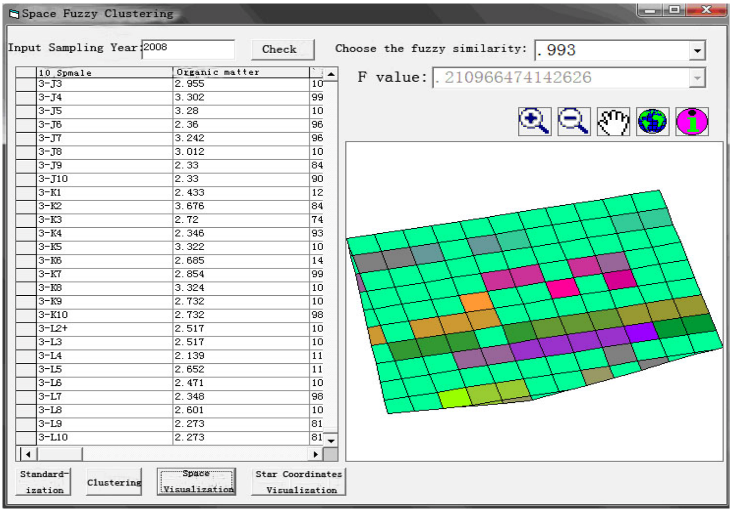

Fig. 6. Maize field soil nutrient spatial fuzzy clustering map in 2008

3.3 Space-Time Evolution of Soil Fertility

Temporal GIS technology add in the time dimension on the basis of the traditional relational model ,to expand the relational mode and relational algebra to handle temporal data, which directly or indirectly support spatial and temporal data storage, representation and processing based on the relational model . Based on this idea, this paper extends the traditional relationship model to achieve dynamic display the spatial and temporal evolution of soil fertility.

Analysis and determine the soil fertility dynamic evolution of spatial fuzzy clustering of the basic spatial pattern is the basic idea of this model which is spatial variation in soil fertility as background information, then follow the appropriate time step to map soil fertility clustering results of the state of each time slice data. Also expressed as: F (Si, T)-F (Si+1-i, T); which (S) for the space system (T) for the time system. Consists of two parts: (1) obtain the same region of the same type of clustering data over different time periods; (2) display continuous segment that the difference between the nutrient. Use the index to resolve the object description space objects and their properties in the time information retrieval, display and overlay, better perform dynamic presentation and analysis of spatial information between the query and visualization, easy, fast access to soil fertility dynamics simulation of the dynamic evolution of the information, and seize its essential character and the law (Figure 7).

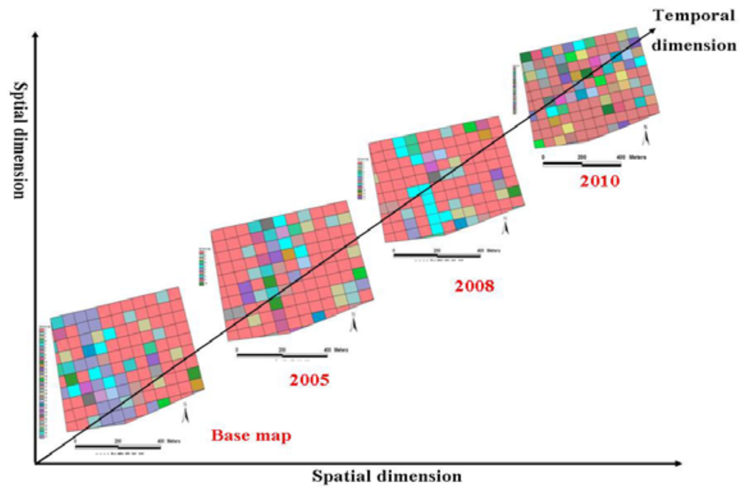

Fig. 7. Map of clustering variation

Figure 7 shows

(1) Accumulate the soil nutrients gradually through the continuous variable-rate fertilization, the entire block of soil organic matter, available nitrogen, available phosphorus and potassium, indicating differences in the overall decrease year by year, the similarity increase year by year.

(2) The results show that variable rate fertilization on soil nutrient spatial differences in a significant improved over years, indicating the temporal GIS model is able to describe the dynamics of the spatial variation of soil fertility.

4 Conclusion and Discussion

This paper discusses the use of spatial data mining, temporal GIS technology combined with visualization competent for many years of comprehensive analysis and comparison of soil fertility and effective evaluation of spatial and temporal evolution of fertility.

(1) Employ VTK and Kriging interpolation method to map three-dimensional distribution of soil nutrients is more natural, clear and intuitive than the traditional two-dimensional graph to represent the data variation.

(2) By visualization of mining weighted spatial fuzzy clustering algorithm applied comprehensive cluster to soil available nitrogen, available phosphorus, potassium and organic matter on 2003, 2005, 2008 and 2010, from the data analysis results, the continuous variables in the same block fertilization on soil nutrient spatial differences could obtain a significant improvement. Mainly reflected in: With the continuous increase in the year variable rate fertilization, differences in soil nutrients gradually reduce the overall data, data distribution is more concentrated and integrated similarity increased every year.

(3) Using the temporal GIS technology to display the weighted spatial fuzzy clustering results which can dynamic descript the spatial time variation of the variable

fertilization on soil nutrient, and indicating that the temporal GIS technology is a good new method for the soil fertility evaluation .

The effect of variable rate fertilization is a function that closely integrated with time and space, the text analysises the data of time and space in only 7 years , so the evaluation of the effect of variable rate fertilization is only a preliminary, It needs continuous research in order to obtain variable rate fertilization of economic and ecological benefits of a comprehensive evaluation.

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