

Arable Land Quality Assessment System Development and Its Application Based on ArcGIS Engine

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Abstract—The arable land quality assessment system is developed with Visual C++ coupled with ArcGIS engine. The system can provide basic functions of geographic information system, for example, map browsing, overlay analysis, and spatial interpolation. The program has both single-factor evaluation module and comprehensive evaluation module, which evaluate the land quality by field sampling data and other relevant information. In this paper, Xiping county in Henan province (China) is chosen as a sample area, fuzzy evaluation method and analytic hierarchy process are used to determine the membership function and the weight of evaluation factors respectively. Field sampling data, land use, soil type and administrative map are used as the supporting data. Using this program, the spatial distribution and areas of three level of farmland quality are obtained..

Index Terms—Arable land, quality assessment, GIS, ArcGIS Engine

I. INTRODUCTION

Arable land is the most valuable factor of agriculture, and also material basis for maintaining a national grain security. To keep effectively a national grain security, it is necessary to enforce the classification management of arable land. The premise of classification management is to evaluate and grade the arable land. Besides, evaluating and grading land resource has important significance: 1) It provides exact land quality information for farmers and agricultural management departments and guides farmers fertilization and field management moderately. 2) It offers accurate land grade information for arable land requisition-compensation balance and prevents occupying the good farmland but supplying the poor farmland. 3) It is beneficial to establish rational land price system and provides scientific information for the circulation of

farmland. 4) It is useful to discover the problems of land and provide scientific foundation for agricultural eco-environmental protection [1].

A geographic information system (GIS) is a computer system for capturing, storing, querying, analyzing, and displaying geospatial data, it is widely used in arable land resource evaluation and management [2]. Along with the development of geographical calculation and analysis, GIS software is becoming stronger in function and more expensive in price, however most functions of GIS software are redundant for most users. The component GIS that has core functions of GIS software and lower price has become a trend, meanwhile users can customize and develop the functions of application GIS according to their own needs under the less cost.

ArcGIS Engine is the component library and tool kit in embedded GIS, that is developed by ESRI company, it has been widely applied to develop the GIS procedure that run independently without ArcGIS Desktop [3,4].

In order to realize the quality evaluation and gradation management of arable land, authors have developed the arable land quality evaluation system using ArcGIS Engine and Visual C++ according to the actual condition in study area [5,6,7,8]. The system has been applied into practice.

II. SYSTEM TARGET AND ANALYSIS

The system has been set up by the component technology - ArcGIS Engine 9.2 (AE for short), general programming software and the Object-Oriented visual development tool - Visual C++, which has realized the scientific management of arable land resource and related fundamental geographic information data, and has basic functions of data input, inquiry, spatial analysis, etc. It can also be used to classify and map for arable land on the basis of physicochemical properties of sampling point and other relevant information.

III. SYSTEM DESIGN

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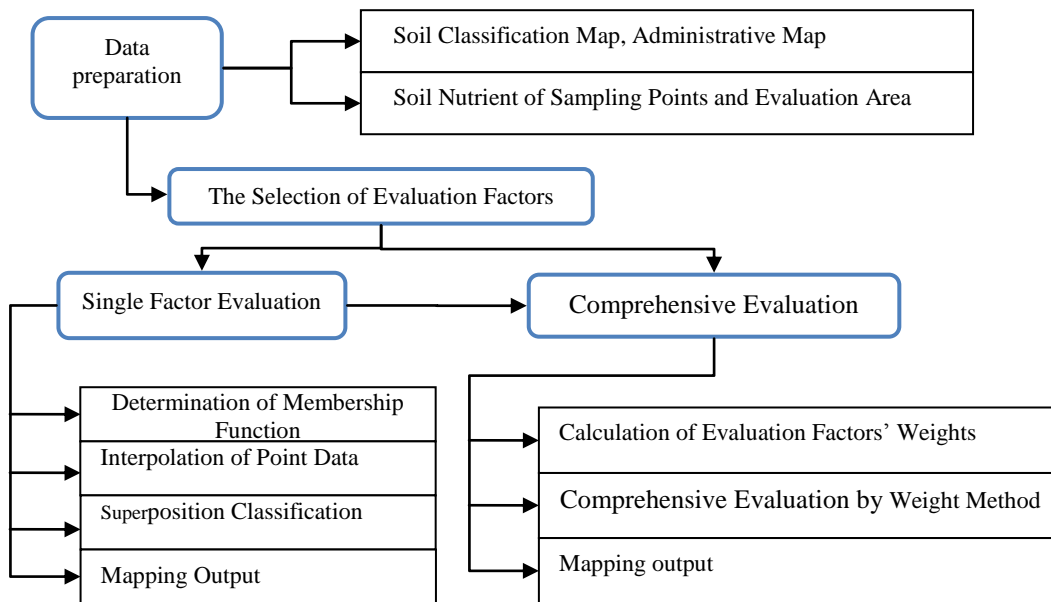


Figure 1. Diagram of land quality evaluation

A. The design and analysis of general function

The process of arable land quality evaluation includes three parts: (1) Data preparation. The part implements the collection and collation of land use data, soil data, environmental and social economic data of study area. (2) Single-factor evaluation. It includes the determination of membership function, interpolation processing of points data, re-classification, gradation and rendering. (3) Multi-factors evaluation. Its functions are mainly selection of evaluation factors, calculation of different factor weight, and comprehensive evaluation values based on the results of single-factor and weight sum. The evaluation flow diagram is shown as follows (Figure 1):

B. Development and runtime environment

Hardware environment: The system uses high grade PC, 2G memory, CPU2.0, the capacity of hard disk $\geq 40G$ and equips with scanner and printer.

Software environment: Windows XP or the more advanced conditions, Microsoft Visual studio C++ 6.0 and GIS development component - ArcGIS Engine Developer Kit, which is the development-oriented embedded GIS product that based on ArcObjects of ESRI. ArcGIS Engine Developer Kit is unrelated with platform, it could call core ArcObjects component through programming interface and establish GIS application.

Runtime environment: Windows XP and ArcGIS Engine Runtime, ArcGIS Engine Runtime is the core component of ArcObjects that terminal user could use.

C. The system interface design

A) The construction of main interface

The system uses Map control and Page Layout control to manage map function, and utilizes VC to realize the basic functions such as zoom in, zoom out and roam, etc.

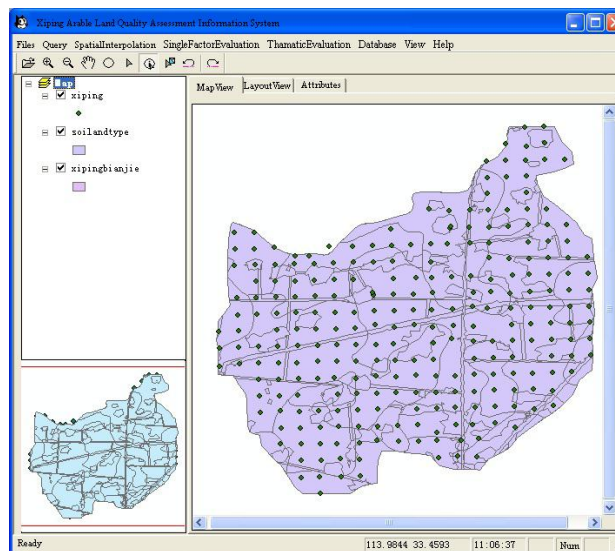


Figure 2. The main interface of the system

Based on main form application, the system has added AE control such as map control, TOC control and page layout control into the application. Meanwhile, corresponding component library of AE have been introduced into head file stdafx.h. For example, the key component - MapControl.ocx encapsulated having the mapping operation interface of IMapControlPtr has been introduced into the main window, the key codes of the process are as follows:

```

    #import "c:\Program Files\ArcGIS\bin\
    MapControl.ocx" raw_interfaces_only,
    raw_native_types, no_namespace, named_guids.
  
```

Meanwhile, # import statement has been used to add component library files, for example TOCControl.ocx, esriCatalog.olb, esriCartoUI.olb, esriCatalogUI.olb, esriCarto.olb, esriSystem.olb, esriSystemUI.olb,

esriFrameWork.olb, esriGeometry.olb, esriDisplay.olb, esriGeoDataBase.olb, esriOutput.olb, ArcReaderControl.ocx, esriDataSourcesFile.olb, esriDataSourcesGDB.olb, esriDataSourcesRaster.olb, PageLayoutControl.ocx, esriGeoAnalyst.olb.

All the properties and interface needed by the system have encapsulated into the files.

B) Connecting map control and core class interface

The dialog box-Class Wizard has been used to add m_MapControl variable to MapControl view class. The two interfaces variables have been defined and the following codes have been added into HngdView.h,

```
IMapPtr m_ipMap,
```

```
IMapControl2Ptr m_ipMapControl;
```

The corresponding function OnInitialUpdate() of OnInitialUpdate has been added to view class, the following codes connect the interfaces between IMap and MapControl .

```
CWnd *pWndCal=m_MapDlg.GetDlgItem  
(IDC_MAPCONTROL1);
```

```
LPUNKNOWN pUnk=pWndCal->
```

```
GetControlUnknown();
```

```
pUnk->QueryInterface(IID_IMapControl2,
```

```
(LPVOID*)&m_ipMapControl);
```

```
m_ipMapControl->get_Map(&m_ipMap);
```

TOCControl and PageLayoutControl have been correlated with the corresponding core class, and the interface ITOCControl has been used to connect TOCControl, MapControl and PageLayoutControl. A problem should be noticed is that association must be done in Tab Control. In this way, MapControl and PageLayout Control could associate with TOC Control, respectively.

C) The realization of eagle eye function

The system has put MapControl, TOC control and Tab control into the document view, utilized Tab Control to realize the linkage between MapControl and PageLayout control. The system has added MapControl and PageLayout Control into a new dialog box, and put this dialog box into the Tab Control, set the size of the control in OnSize to keep the relative position stable. Meanwhile, the system has used the graphic element interface IGraphicsContainer to set the control and passed it the view scope of the main control, then refreshed it to realize this function. In addition, the eagle eye function also has been used to drag by the left button and to draw the rectangular frame by the right button, to display the view scope of the rectangular frame in the main control.

D) Drawing the toolbars

The tool buttons have been drawn manually, such as opening the image, zoom in, zoom out, roam, click, selection, cancel and undo.

IV. SYSTEM FUNCTION

A . The basic functions of GIS

The system has realized various spatial data management functions, such as open, browse, and query attributes of a map.

A) Opening a map

AE supports various data types, for instance, raster data - Shapefile, ArcInfo Coverage, DXF and DWG and grid data - BMP, JPG, GRID and IMG. The system also realized the function of adding Shapefile, img, grid and mxd, the process is as follows,

The system opens the dialog box CFileDialog in VC to read the file path, and utilizes AddShapeFile and LoadMxFile of the interface IMapControl to open Shapefile and mxd files, then uses CreateFromFilePath of the interface MapControl to open img and grid files of MapControl. If ArcGIS has been installed, user could call IGXDialog interface to open more kinds of files. The interface is intelligent, it could open various map files of Geodatabase and filter the point, line and area files.

B) Map browsing

The toolbars can be used to zoom in, zoom out, roam, global view, click and query, essential selection, cancel and undo. The user can change the view scope by clicking or drawing the rectangular frame. It's realization required the interface IEnvelope and used Expand to change the value of IEnvelope. The value is determined by Expand() and the key codes of zoom out are as follows:

```
d=(width * height) /((XMax-XMin)*(YMax-YMin));
```

```
// the scope varies with the selection of frame.
```

```
ipEnvelope->Expand(0.8*d,0.8*d, VARIANT_
```

```
TRUE);
```

```
ipActiveView -> put_Extent(ipEnvelope);
```

The query function by click has realized using the dialog box of VC, its main method is acquiring the locations of element that you click and judging that the element are raster or feature, if the elements are feature class, this system would use IRowIdentifyObject to acquire the elements' field value and put them in the List control and tree control; if they are raster, this system would use the IRasterIdentifyObj2 to read raster's attribute value and put them into controls.

B. The function of spatial analysis

Spatial analysis is the general technology that related to analyzing spatial data. According to the property of data, these functions have been divided into several kinds: one function based on spatial graphic data, second function based on non-spatial attributes and the third function based on spatial and non-spatial data[9]. According to the functional requirement of data analysis in land resource quality evaluation, the system has realized functions of spatial interpolation, overlay analysis, spatial query and buffer analysis, etc.

A) Spatial interpolation

The system also has realized Kriging and IDW interpolation. Kriging interpolation is also known as spatial auto-covariance optimum interpolation, and it has been used to evaluate the best, linear, and unbiased

estimator. The technology uses variogram (semi-variance) model to represent the functions that varies with distance, and to evaluate the coefficient of variation under the conditions of unbiased and minimum estimation and to determine the weight coefficient of sampling points, then to calculate estimated value of points using the weight method[10]. IDW is also called the square method of inverse distance, it is a weighted average interpolation and could interpolate in an exact or slipper way. The interpolation has been realized with related parameters and the interpolation algorithm has been encapsulated into the interface IInterpolationOp2 in AE. The interpolation function of Kriging is as follows,

```
HRESULT Kriging ( IGeoDataset* geoData,
    esriGeoAnalysisSemiVariogramEnum
    semiVariogramType,
    IRasterRadius* radius,
    VARIANT_BOOL outSemiVariance,
    VARIANT* barrier,
    IGeoDataset** interpolatedRaster );
```

Where HRESULT is return type, if the result is 0, it means success; otherwise, it is false; GeoData is input dot file; SemiVariogramType is appointing different variation model; Radius is set the searching radius of input point; outSemiVariance, if it is true, creating semi-variance predictive value for each mesh; barrier is interpolation scope; interpolatedRaster is the result map.

B) Overlay analysis

Overlay analysis has divided into four types: overlay between different visual information, points and polygons, lines and polygons and the overlay between different polygons[11]. Overlay analysis is the operation of overlaying different data layers to create a new layer, which would have all the properties of the original layers. The system has various functions, such as clipping, intersection and matching. These functions are mainly used to overlay different layers of evaluation factors. The realization of these functions is mainly depended on Clip, Intersect and Union of the interface IBasicGeoprocessor. These three functions have the same parameters, Union is been taken for instance, its function prototype is as follows,

```
HRESULT Union
{ ITable* inputTable,
  VARIANT_BOOL useSelectedInput,
  ITable* overlayTable,
  VARIANT_BOOL useSelectedOverlay,
  double Tolerance,
  IFeatureClassName* outputName,
  IFeatureClass** resultFC };
```

Where inputTable means input attributes of layer; useSelectedInput means deciding whether to summarize overlay layers with the element subsets of input layers, it has two attributes, one is VARIANT_TRUE, it means using the selection set; the other is VARIANT_FALSE, it means ignoring the selection set; overlayTable means the

attributes of overlay layer; useSelectedOverlay means the selection area of overlay layers; Tolerance means tolerance value, it's default value is 1/10000 of data space domain; outputName means the type of output layer; resultFC means saving the result map.

C) Spatial query

The program also has querying spatial location by setting requirements for feature. The function has been realized by SelectFeatures of interface IFeatureSelection. The original function of SelectFeatures is as follows:

```
HRESULT SelectFeatures(IQueryFilter* Filter,
    esriSelectionResultEnum Method,
    VARIANT_BOOL justOne );
```

Where IQueryFilter is object model of interface, Filter is the object method of interface IQueryFilter. QueryFilter appoints a filter that based on attributes, and this filter can be used to find the data set that satisfies the conditions. By the interface of IQueryFilter, the attribute query is realized when SQL query language of BSTR type is introduced to put_WhereClause (BSTR WhereClause) .

As the CComBSTR has encapsulated BSTR, this query language could be converted into CComBSTR directly if it is CString. The esriSelectionResultEnum has been used to set options, and the value range of method is 0~4. If the value of esriSelectionResultNew is 0, it means create a new option set; if the value is 1, it will be added to the current option set; if the value is 2, it means delete from the current set; if value is 3, it will select from the current set; if value is 4, it will run the XOR operation. The justOne belongs to the VARIANT_BOOL type, if it is true, it means stop search when the system finds the coincident elements; if it is false, the system searches all the elements.

Using the searching methods provided by the system and inputting SQL statement in edit box, the system will execute the query sentences and display the corresponding results after SQL sentences has been put and applied.

D) Buffer analysis

This system can set buffer by the function interface of ITopologicalOperator. This interface provides space topological operator of geometric figure and can be used to create a new graphic on the basis of current graphic. It's prototype is HRESULT Buffer (double distance, IGeometry** outBuffer), where distance is the distance of buffer and outBuffer is the buffer graphic after buffer calculation. When the buffer has been created, the system uses AddGeometry method of IGeometryCollection interface to save the buffer graphic, and utilizes ConstrucUnion method of ITopologicalOperator interface to merge the buffer polygon.

C. The thematic evaluation of arable land quality

The thematic evaluation is one of the most important parts of the system. It consists of the determination of membership function, single-factor and multi-factors evaluation. This function has been realized by calling the spatial analysis function on the basis of deciding evaluation factors, weights, and methods.

A) The selection of evaluation factors

This system uses Access database to select, delete and modify soil property factors, natural environment factors and social economic factors. The function mainly uses two DataGrid controls to connect with data table, to choose factors from candidates and utilizes ">>" to read data into the table or use "<<" to delete data.

B) Single-factor evaluation

The single-factor evaluation is the foundation of the comprehensive evaluation. Its main function is the normalization of membership function. Due to the difference of dimension between indexes, it's necessary to normalize original data, such as transform different indexes to the interval {0, 1}. This evaluation system uses the membership function of fuzzy mathematics to normalize evaluation factors. In order to establish membership function, the factors should be quantified by specialist first, then using SPSS to fit curve.

C) Multi-factor evaluation

Based on the result of single-factor evaluation, multi-factors evaluation determines each factor's weight and utilizes accumulation model to calculate overall score. In this process, the user needs to add a field in assessment map to save the evaluation result. At last, it should divide the arable land quality into several levels according to overall score. The most important parts in this evaluation are the determination of evaluation factors' weight, the calculation of overall score, classification rendering and mapping output.

On the basis of soil properties, environment, socioeconomic and other factors, this system uses analytic hierarchy process to determine weight. The realization of this process utilizes a two-dimensional array bb1[7][7] to save the judgment matrix and analyzes the consistency.

According to the result of single-factor evaluation and the weight of each element, this system has combined accumulation model to calculate comprehensive value. The formula is as follows:

$$H = \sum_{j=1}^n w_j f_j \tag{1}$$

Where H is comprehensive value; f_i is the score of evaluation factor j , after the reclassification, its value range is 0~100, w_j is the weight of j ; n is the total number.

At first, the system has added a overall value field into the evaluation map to save result, then read a layer and select evaluation map, and finally read the seven

evaluation factors into ListControl before calculating comprehensive value. The array has been set separately for storing the result, the system reads the weight of factors from database and save it in a new list after weight sum, then clicking "save" and the result will be saved in array of the attributes .

The evaluation map can be saved as several types: JPG, BMP and mxd document of ArcGIS. This system is not only could use the interface IExportBMP and IExportJPEG to save the result with raster type, but also can use IMapDocument to derive mxd document and mapping.

IV. SYSTEM APPLICATION

A. Research situation and data source

Songji country of Xiping county lies in the south of Henan province, China. It has 15 administrative villages, 38,000 people and 6551.19 hm² arable lands. As Songji is the main grain production area of Xiping county, it is necessary to evaluate and grade the arable land in order to protect arable land quality properly.

The basic data mainly includes land-use map, soil map, topographic map, administrative map and distribution of social economic situation. The land-use map came from the visual interpretation of 19.5m image of CBERS in 2007, the soil map and related mapping were digitalized by ArcGIS 9.2.

Soil sampling data included soil organic matter (OM), pH, total nitrogen (TN), total phosphorus (TP), available P (AP) and slowly available Potassium(SAK), the nutrient contents were determined using the national standard in China [12].

B. The single-factor evaluation

The system took pH as an example to illustrate the determination process of membership function. According to the analysis and investigation of arable land quality's influence, pH value was graded by the specialists in soil and agriculture though many times, the table of pH score was obtained (Table 1).

TABLE I.

THE SCORE OF pH

pH	8.40	8.20	7.90	7.60	7.30	7.00	6.80
Membership	0.58	0.70	0.80	0.88	0.95	0.98	1.00
pH	6.50	6.20	5.90	5.70	5.30	5.10	
Membership	0.98	0.95	0.88	0.80	0.70	0.58	

Statistical software (R) was used to mapping and fitting data, and the membership function of pH was gotten, the function is a peak shape, using quadratic function to fit it, the membership function is showed as follows:

$$y_1 = -0.1476 x^2 + 1.995 x_1 - 5.750, R^2 = 0.993. \tag{2}$$

Where y is the score of pH, x is the pH value.

The same method is used in other membership functions construction of the soil attributes, they are as follows,

Available K(mg/kg):

$$y_2 = 1/(1+0.0002607(x_2-135.71)^2), R^2 = 0.998 \quad (3)$$

Available P(mg/kg) :

$$y_3 = 1/(1+0.006067(x_3-14.2176)^2), R^2 = 0.986 \quad (4)$$

Total N (g/kg) :

$$y_4 = -0.0748+1.7422x_4-0.9735x_4^2+0.1855x_4^3, R^2=0.998 \quad (5)$$

Total P (g/kg):

$$y_5 = 0.9929x_5^{0.4229}, R^2=0.999 \quad (6)$$

Slowly available K(mg/kg):

$$y_6 = 1/(1+0.000002397(x_6-930.94)^2), R^2=0.996 \quad (7)$$

OM (g/kg):

$$y_7 = 1/(1+0.002814(x-21.068)^2) \quad (8)$$

Where $y_2, y_3, y_4, y_5, y_6, y_7$ is the evaluation score of available K content, available P, total N, total P, slowly available K, respectively. $x_2, x_3, x_4, x_5, x_6, x_7$ are the content of available K, available P, total N, total P, slowly available K, and organic matter, respectively.

The single-factor evaluation and mapping analysis of arable land have been realized on the basis of the former calculation and the spatial analysis function of the system.

The results of single-factor evaluation are the spatial distribution maps of each evaluation factors by use of each patch presenting a value. The values have been normalized by membership function and extended to 0-100. The single-factor evaluation maps of PH, TP, available P, OM, slowly available K and TN are as follows in figure 3.

C. Multi-factor assessment

After discussing with specialist, the system has chosen OM, PH, TN, AP, AK, TP and SAK as evaluation factors to assess arable land quality. Putting each layer's judgment matrix into access with data sheet and clicking the child node of tree control on the left, the system read the judgment matrices. The final judgment matrix has been discussed by experts many times, it is as follows:

TABLE II.

THE JUDGMENT MATRIX OF EVALUATION FACTORS

Factor	OM	TN	pH	TP	AP	SAK	A K
OM	1	1.5	2	2	3	3	4
TN	0.67	1	1.5	1.5	2	2	3
PH	0.5	0.75	1	1	1.5	1.5	2
TP	0.5	0.75	1	1	1.5	1.5	2
AP	0.33	0.5	0.67	0.67	1	1	1.33
SAK	0.33	0.5	0.67	0.67	1	1	1.33
AK	0.25	0.33	0.5	0.5	0.75	0.75	1

The judgment matrix represents the comparison of each layer with its related units on the basis of former layer. The system takes the first line as example, which presents the importance of OM to other evaluation factors, the higher the value, it means the more important of OM than other factors. Then the judgment matrix called into the system and consistent judgment made, the system

calculates the weight of impact factors if the result has consistency (Table 3)

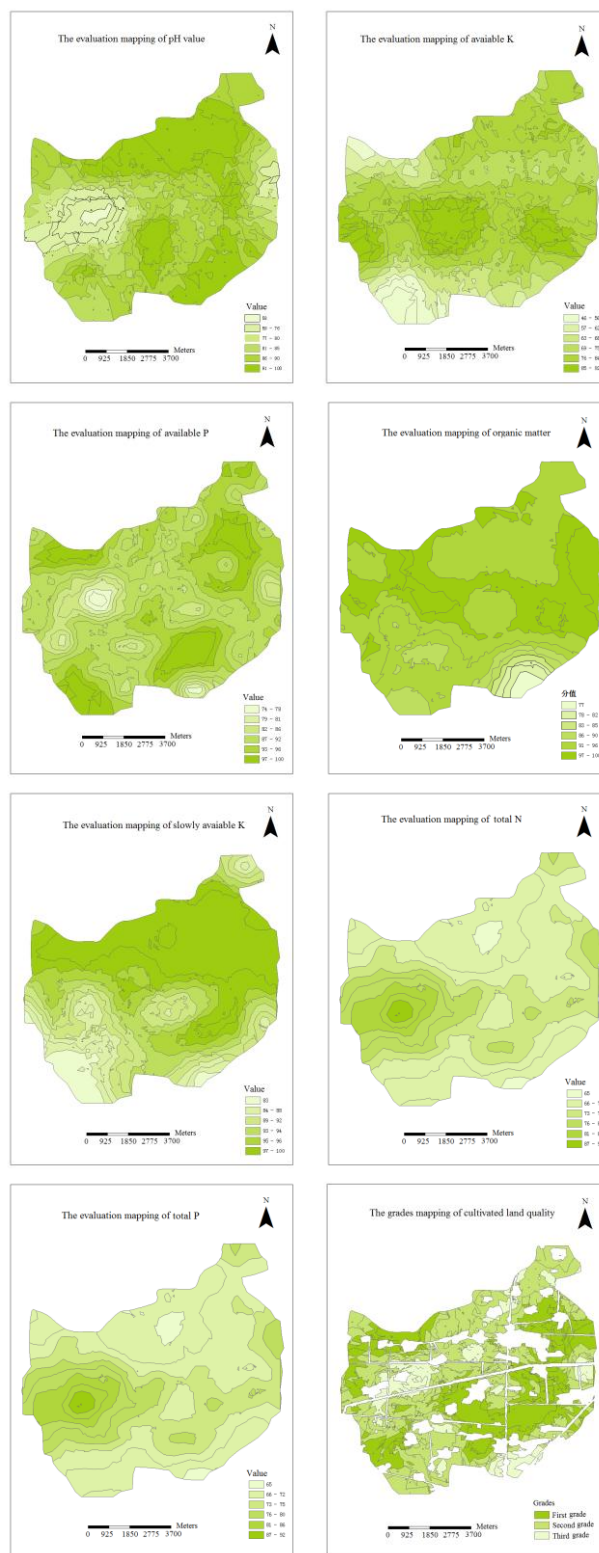


Figure 3. Single-factor and multi-factor evaluation mapping of cultivated land quality

TABLE III.

FACTOR WEIGHT OF ARABLELAND QUALITY EVALUATION							
Factor	OM	PH	TN	AP	AK	TP	TK
Weight	0.26	0.19	0.14	0.14	0.10	0.10	0.08

Based on the single-factor evaluation maps, according to their weight of evaluation factor layers, the overall score map of arable land quality has been gotten by overlaying the layers. The score is between 0 and 100 reflecting the quality of the arable land. In order to show clearly the distribution of arable land quality and each patch's quality information, the system has cut, merged the mapping, and removed roads and countries, finally the arable land was classified into three grades, and the area on spatial distribution of each level was gotten (Figure 3).

The statistical result shows that, the first grade is 1940.49 hm², it accounted for 30.08% of total area and most of them lied in mid-eastern and northwest part of Songji. The second grade is 2956.45 hm², accounting for 44.28% of total area, and most of the land lied in middle, northern and northwest part of Songji. The third grade is 1654.25 hm², accounting for 25.64%, and most of them lied in the Midwest and southwest of Songji. The evaluation result will provide the theoretical foundation for scientific management of cultivated land.

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