Water-Saving Irrigation Management and Decision Support System Based on WEBGIS

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Abstract. To improve the management of irrigation district is a key to develop water-saving agriculture. Based on the basic principles of water-saving irrigation, and using the method of Modified Penman Monteith and water balance equation, The system of irrigation management and decision support based on WEBGIS was developed, which is according to the soil moisture, crop growth status, meteorology change and the physiological and ecological index of crop that is monitored, and the situation of water supply and crop water-saving irrigation system were also combined with the system. With the help of the GIS, the system under discussion can predict the water requirement of the irrigation district so as to optimize the allocation of the water resources, to provide a decision support for irrigation managers, and to finally realize desirable irrigation practice. Besides, it will promote the automation, informationization, and intelligent of the irrigation district management.

Keywords: WEBGIS, SuperMap IS.net, Irrigation management, Spatial analysis.

1 Introduction

As the basic resource, water is indispensable to social development. However, more and more problems in relation to water arise with the increase of population and the rapid economic development in China. Among other things, the conflict between water supply and demand becomes more and more serious. Accordingly, how to improve the management of the irrigation area, how to use the water resource in an effective and safe way, and how to yield the greatest returns on the regional water resource are becoming a new task[1]. Fortunately, modern technological development, in particular, Computer, Database, Networks, and Geographic Information System, makes possible the precision management of water resources for the agricultural irrigation[2].

As a new computer-based technology, GIS is a technological system for the management and study of the spacial database. With the support of both the software

and hardware, GIS could effectively manage the spacial database in accordance with the geographical coordinates or the spacial location and obtain needed information based on an analysis of all the related factors and finally show the result of processing in the form of data, graph or map. When applied to the management and decision support of the irrigation area, it could predict more precisely the water demand of the irrigation area and also play an important role in improving management, optimizing allocation of the water resource, and realizing a desirable irrigation. Besides, a combination of GIS, the Networks and the expert system of irrigation management could promote the informationization and intelligent of the irrigation district management [3].

The GIS has been widely applied to the city traffic control, electric energy and cadastre management in foreign countries. Rather, it has been mainly used in the river basin management, flood control and disaster alleviation, as well as soil and water conservation in China. Anyway, it is scarcely used in the management and decision support of irrigation. With the help of SuperMap Deskpro 2008, Super Map IS .NET 2008, Microsoft Visual Studio 2010 and Microsoft SQL Server 2008, the system under discussion could be used to improve the management and decision support system of irrigation when the management mode of irrigation is combined with GIS, in particular, its mass data input and pre-processing, spacial analysis and visual expression.

2   System Architecture

Centering on service, three architectures –the presentation layer, the business logic layer and the data layer, are established as follows[4-6]:

The client browser is HTML and could receive ordinary HTML webpage. Its task is to read the contents in WEBGIS related to ASP.NET webpage and to require the map data. Then the server transmits all the requirements to the client through the HTTP protocol and all this will be shown on the browser.

The business logic layer is made up of two parts: the Web server software, such as IIS（Microsoft Internet Information Server）and MTS（Microsoft Transaction Server）, and the server components based on GIS. When the WEBGIS receives the requirements from the browser, it could process, analyze and compute with the help of GIS Server components. If the data of GIS data server is needed, it could require the GIS data server.

The data layer could complete the definition, storage and retrieval, integrity constraint of data, and realize the functions of inquiry, modification, update of the database. It sends the processing results to the WEBGIS server after it has received the data requirement from the WEBGIS server.

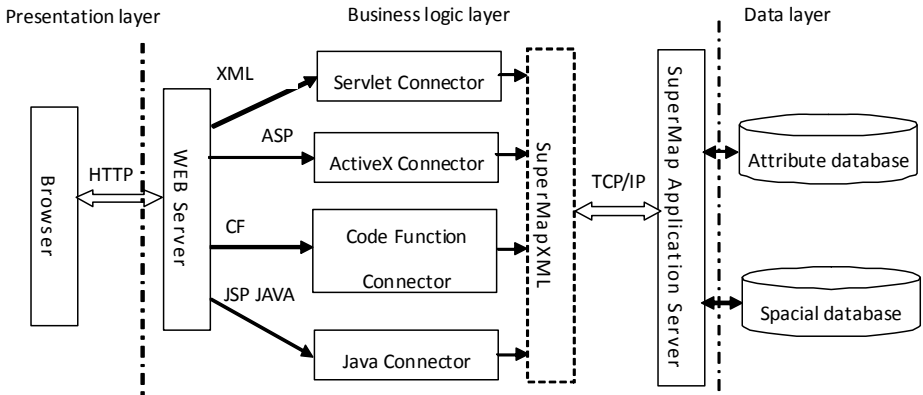The system architecture is shown in figure 1.

Fig. 1. System architecture

3   System Development Environment

The system is developed with the help of SuperMap IS.NET 2008 provided by Beijing SuperMap Software Company,Ltd. It makes use of WebControls or AjaxControls, and API- AjaxScripts to design by adopting B/S structure relying on .net 3.5 technical framework and SuperMap Objects 6.0. The server adopts the Asp.net technology, the client uses Http and Tcp/Ip protocol and the backend database employs Microsoft SQL Server 2008[7]. By using the spacial database engine of SuperMap SDE+, it makes possible visit to the spacial data. The programming environment is Microsoft Visual Studio 2010[8,9] , and the background uses C# for programming. Taking the SuperMap[10,11] as the main developing tool, The system makes possible the management of agricultural water information and the visual expression of irrigation decision support.

4   Design of Database

Data is the most important part of GIS system and database is the center of all the data. Database includes basic database, spacial database and attribute database[12-14].

The basic database includes data related to soil type, crop type, crop coefficient, crop growth stage, irrigation and drainage, field monitoring and so on.

Attribute database is an important part of the system. It is the core tool to realize data processing, analysis, assessment, and storage of the decision functions.

Spacial database is the basis of the GIS system. The spacial geographical data are obtained by processing the scanned graph which is stored in the form of grid data structure. In order to improve the image quality of the grid data, we use other image processing software for further treatment, such as graphic joining together, noise reduction, refined, etc. Finally the grid data is transformed to the vector data for need. Spacial data and attribute data are processed in SuperMap deskpro 2008 in which

modifying or editing data could also be conducted if the SDB is used. If the spacial vector data of the system is voluminous, the spacial data and the attribute data could be easily managed in the basic database. When the vector data is not so voluminous, the spacial vector data would be managed in the form of documents. In this case, the attribute data could be linked to the basic database to realize the remote dynamic linkage in order to enhance the efficiency of the system.

Take the meteorological data as an example. The data structure designed in this paper is shown in Table 1 and part of the data diagram in Figure 2.

Table 1. Data structure of meteorological data sheet

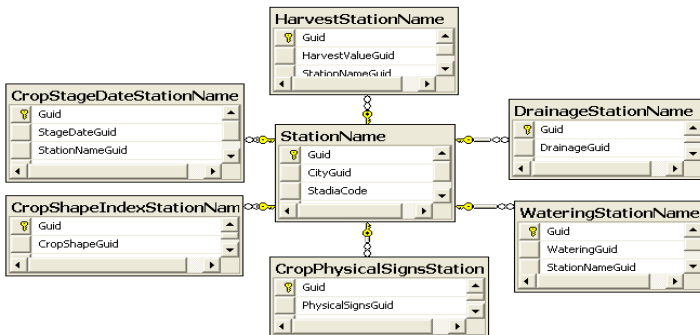| Field Name	Data Type	Note
Guid	Int	Serial number
StadiaCode	Varchar	Station code
Date	Datetime	Date
Rainfall	Float	Rainfall
AvgWind	Float	Average wind velocity
TemMax	Float	Maximum temperature
TemMin	Float	Minimum temperature
AvgTem	Float	Average temperature
Suntime	Float	Sunshine duration
Moisture	Float	Relative humidity

Fig. 2. The data relations of some tables

5   Design and Realization of the System

Based on the collection materials and survey, the system makes use of many technologies and the functions of GIS provided by SuperMap IS.NET to establish a

GIS-based supporting system for the visual water resources management and decision support of irrigation district according to the management of the irrigation information and the requirement of the irrigation decision support. By the system, the manager could grasp the general situation of the irrigation area and could integrate, analyze, and show the scattered materials. It could increase the quantity and quality of the information that the manager obtains, and quickly and easily realize the visual expression and web publishing of the irrigation decision so as to provide the technological support for scientific irrigation [15-20].

5.1   Map Display

Create a webpage with the name of map.aspx as the main window of the map. Switch this webpage to the design page and add Mapcontrol. Click the right key of the mouse and choose'Load Map'in the menu. Input the IP address of GIS server and the port of the map service in the editor of MapControl. Click'Validate'to verify. If the connectivity is succeeded, there will be a notice about it in the below and all the names of the maps which will be issued have been released. Choose the map needing to be released. Click 'Preview' and the image of the map will appear. Click 'OK' and the function of map display will be okay. See Figure 3 as following.
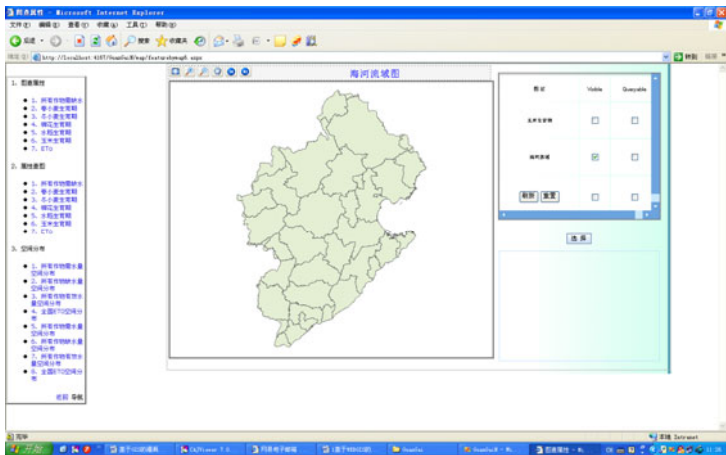

Fig. 3. Map Display—the diagram of Haihe river basin

5.2   Map View

Map view could be used to zoom in or zoom out the map, to do the map random,and to show the whole map. These functions are developed by using the SuperMap controls.

5.2.1   Zoom In or Zoom Out the Map

When the usres browse the maps, they will do the different operation on the different ratio graphics. When one user selects the tools of zoom in or zoom out the map, click the mouse on the map, the map will be magnified or minified correspondingly.

5.2.2   Map Random

When the map is shown on the client, due to the limit of the display window size, the whole map often fails to display on the window, if the users want to browse the entire map, they need move the mouse on the map, when randomming on the map, the client need again get the data from the server, but, the new data which are obtainde from the server need wait for a certain amount of time.

5.2.3   View Changes

When the map is be magnified, minified or random, the view of the map will change. If the users want to return to the front view or the back view, they only need click the button of the previous view or the back view.

   The function of map view could be performed by adding any of the controls mentioned above to the design page(Figure 4).

Fig. 4. Map View

5.3   Query and Retrieval of Information

To inquire and locate the spacial information is one of the basic functions of GIS. There are mainly two modes of query and retrieval based on the GIS. One is to search through the attribute information and to locate the result; the other is to search for the attribute information related to the target through the map. The former is called 'Property Map Search', and the latter is called 'Map Property Search'. Property Map Search is a kind of fuzzy query. Namely, all the information with the keywords will be shown in the layers of the map when one or more keywords are inputted. The inquiry results will be displayed in the result show box and the target information will be shown in a highlighted way in the map.

5.3.1   Property Map Search

The following controls should be added in the main window in the system: 'DropDownList1，DropDownList2 and DropDownList3' for inputting the keywords, 'Button' whose ID name is 'Search' for submitting, and 'Gridview' for showing the result list. The key codes are as follows.

```
protected void Search_ServerClick(object sender, EventArgs e)
    {
       string querysql;
       string Promary =
 this.DropDownList2.SelectedItem.Text.ToString();
      string Stadia =this.DropDownList1.SelectedValue.ToString();
       string StadiaCode =
this.DropDownList3.SelectedValue.ToString();
        querysql = "Province_ Name like  '*" + Promary + "*'  and
        Stadia_Name like '" + Stadia + "' and Stadia_Code like '"+
```

```
        StadiaCode + "' ";//and Year_ Frequency > " + min + " and Year_
        Frequency < " + max + "";
        QueryParam param = new QueryParam();
        QueryLayer querylayer = new QueryLayer();
        querylayer.ReturnFields = new string[8];
        querylayer.ReturnFields[0] = " Province_ Name ";
        querylayer.ReturnFields[1] = " Stadia_Name";
        querylayer.ReturnFields[2] = " Sowing ";
        querylayer.ReturnFields[3] = " Overwintering ";
        querylayer.ReturnFields[4] = " Turning_green ";
        querylayer.ReturnFields[5] = " Jointing ";
        querylayer.ReturnFields[6] = "Heading";
        querylayer.ReturnFields[7] = "Maturity";
        querylayer.Name = "Growth stage of winter wheat @5";
        querylayer.WhereClause = querysql;
        param.Layers = new QueryLayer[1];
        param.Layers[0] = querylayer;
        param.Highlight.HighlightResult = true;
        ResultSet Rs = MapControl1.QueryBySQL(param);
        ds = Rs.ToDataSet();
        gvStadia.DataSource = ds;
        gvStadia.DataBind();
    }
```

The interface of growth stage of winter wheat through the Property Map Search is shown in Figure 5.
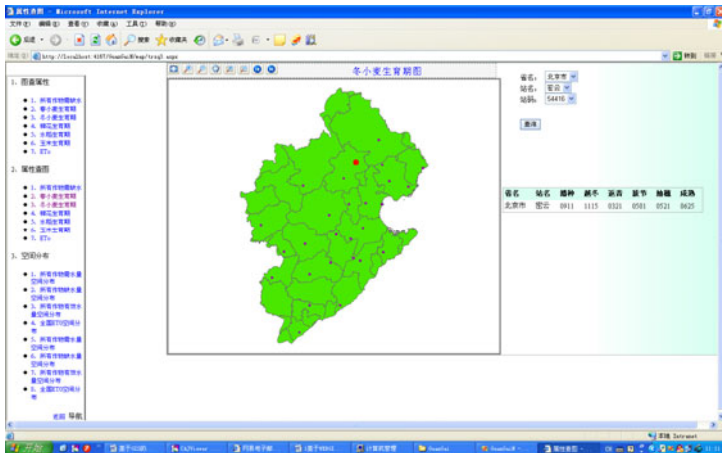

Fig. 5. Property Map Search—the diagram of growth stage of winter wheat

5.3.2   Map Property Search

Another way of spacial information query is to search the target-related attribute information through map, which is called 'Map Property Search'. SuperMap IS.NET

provides several ways of map query including query by clicking the target map, query by rectangular box selecting sphere, query by circle selecting sphere, query by polygon selecting sphere, and query by selecting buffer sphere.

Map Property Search released by the system requires that the Button is added to the main window of the map. The Value of the button is set as 'select'. Click 'select' to make the map in the state of selection and make a rectangle by pushing the left key of the mouse on the map. The results will be shown in Gridview in the bottom right of the map window and the eligible targets will be shown at the time in the window map in the highlighted way. The key codes are as follows.

```
protected void MapControl1_Querying
(object sender,
SuperMap.IS.WebControls.EventArguments.QueryingEventArgs e)
    {
        e.Params.Highlight.HighlightResult = true;
        e.Params.Layers = new QueryLayer[1];
        e.Params.Layers[0] = new QueryLayer();
        e.Params.Layers[0].Name = "ET₀@5";
        e.Params.Layers[0].ReturnFields = new string[4];
        e.Params.Layers[0].ReturnFields[0] = "Stadia Name";
        e.Params.Layers[0].ReturnFields[1] = "Stadia Code";
        e.Params.Layers[0].ReturnFields[2] = "Year_ Frequency";
        e.Params.Layers[0].ReturnFields[3] = "ET₀";
    }
```

The interface of inquiring the reference crop water requirement(ET_0) through the Map Property Search is shown in Figure 6.
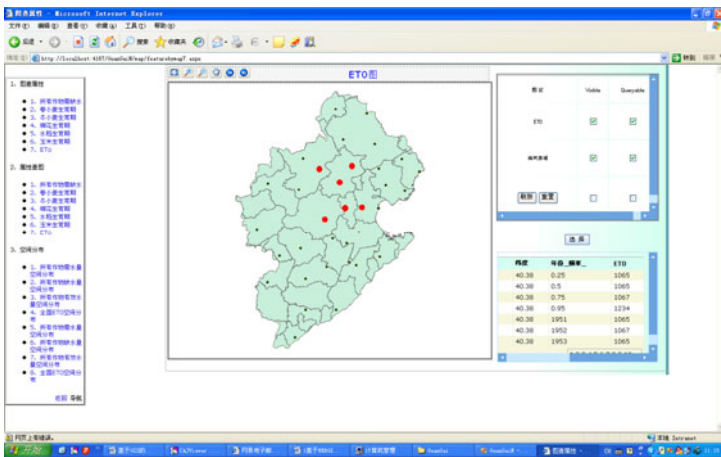

Fig. 6. Map Property Search —the diagram of ET_0

5.4   Spacial Analysis

Spacial variability of the soil moisture is common and complex. To get a full understanding of the spacial distribution of the crop water requirement and the soil moisture is of great significance for irrigation decision support.

Spacial analysis could extract and transmit the spacial information. As the basis of comprehensive geosciences analysis mode, the spacial analysis provides a basic tool for establishing a complicated mode. Spacial analysis mode is a kind of mathematics mode used in GIS spacial analysis. This study adopts the method of point kriging, which is also named general kriging method, to interpolate the soil moisture data. Taking the regionalized variables theory as the basis and the variograms as the main tool, the kriging method is a science which can be used to study the natural phenomena that is random, structural, and spacially correlation and dependence. It is a fast developing field in modern measurement geography. Kriging interpolation could describe the spacial distribution of the soil moisture in a directly perceived way.

Based on the data computed by adopting the irrigation management and decision support system, combination the experiment results of field and modern technology, and using GIS for the technical support means, the system could analyze the spatial distribution characteristics of soil moisture. First,the point data of soil moisture are visualized through the SuperMap deskpro 2008, and the data are integrated to the Chinese map which has been adjusted in the same projection coordinate system. Then using grid as the basic unit, the data such as crop water requirement and soil moisture being quantified are transformed into the grid distribution. Through adopting the WebControls and AjaxControls of SuperMap IS.NET 2008 to establish spacial geographical mode and to integrate the complicated spacial analyzing process, the work efficiency is improved and more attention from those concerned is attracted to the procedure and methods of solving problems.

Figure 7 is the spacial distribution chart of the soil moisture for winter wheat in Guangli Irrigation District.
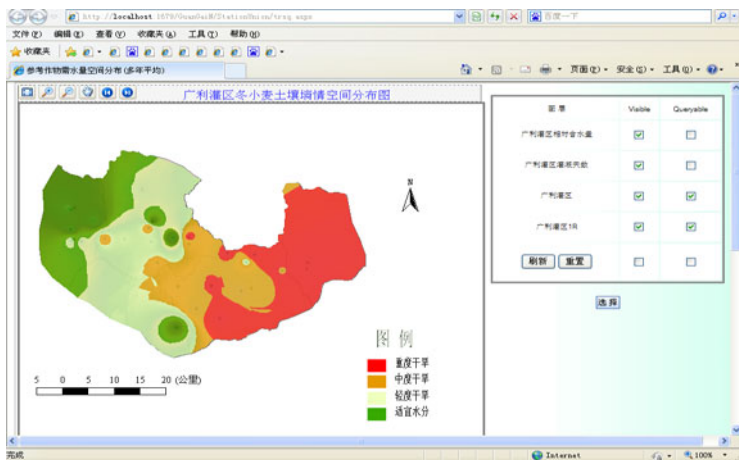

Fig. 7. The spacial distribution chart of the soil moisture for winter wheat in Guangli Irrigation District

5.5   Visualization of Irrigation Results

Irrigation prediction is the main contents of field water management, which predicting the irrigation date and irrigation quota of crops in certain condition. Based on the basic principles of water-saving irrigation, and using the method of Modified Penman Monteith and water balance equation, The system of irrigation management and decision support based on WEBGIS is developed, which is according to the soil moisture, crop growth status, meteorology change and the physiological and ecological index of crop that is monitored, and the situation of water supply and crop water-saving irrigation system are also combined with the system. Using GIS, the information of irrigation area and the result of the decision support are visualized. Figure 8 is the spacial distribution chart of the forecast results of soil moisture for winter wheat in Guangli Irrigation District of Henan Province.
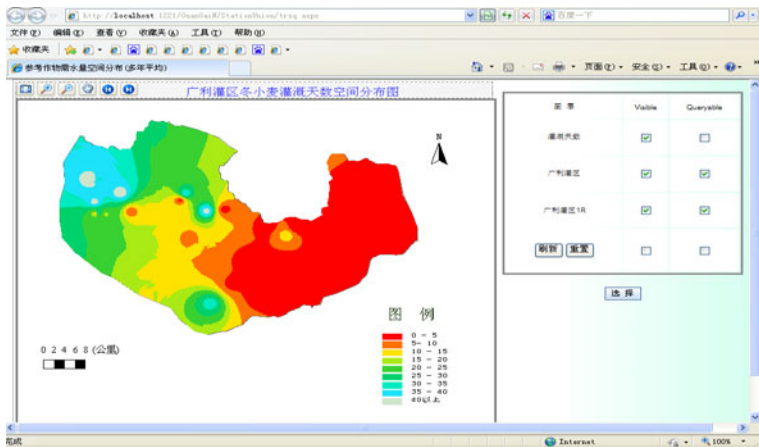

Fig. 8. The spacial distribution chart of the forecast results of soil moisture for winter wheat in Guangli Irrigation District

6   Conclusion

The paper combines the management and decision support mode of irrigation area with such functions of GIS as inputting and pre-processing of mass data, spacial analysis, and visual expression. It greatly helps users to improve the management of the irrigation area, use the water resources more effectively, predict the water requirement of the irrigation area more precisely, optimize allocation of the water resources, make better decision related to irrigation, and realize the automatic management of the irrigation area.

What to be noted is that there are some problems to which more attention should be directed. They include: (1) the relation between the attribute data of databases and the structure of the data table should be further optimized so as to reduce undesirable data and enhance the efficiency of query and retrieval of the system; (2) the application of

GIS to decision support of irrigation is shown by two-dimensional graphics. Therefore, three-dimensional presentation should be developed so that decision related to irrigation could be more directly perceived and users could conduct the spacial analysis more favorably.

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