Development of a Highly Flexible Mobile GIS-Based System for Collecting Arable Land Quality Data

Sijing Ye, Dehai Zhu, Xiaochuang Yao, Nan Zhang, Shuai Fang, and Lin Li

***Abstract*—In recent years, well-designed terminal-based methods for collecting index data have gradually replaced traditional pen-and-paper methods and have been extensively used in numerous studies. These new approaches offer users increased accuracy, efficiency, consumption, and data compatibility compared to traditional methods. In general, we find that spatial data content and quality index systems vary widely across different arable land regions. Thus, a system for the investigation of arable land quality indices that has the flexibility to utilize various types of spatial data and quality indices without requiring program modification is needed. This paper presents the framework, the module partition, and the structure of the data exchange interface for a highly flexible mobile GIS-based system, which we call the "arable land quality index data collection system" (ALQIDCS). This system incorporates a series of self-adaptive methods, a data table-driven model and two types of formulas for flexible data collection and processing. We tested our prototype system by investigating arable land quality in the Da Xing District, Beijing and in the Te Da La Qi District, Inner Mongolia, China. The results indicate that the ALQIDCS can effectively adapt to variations in spatial data and quality index systems and meet different objectives. The limitations of the ALQIDCS and suggestions for future work are also presented.**

***Index Terms*—Agricultural data collection, Android, arable land quality monitoring, mobile geographic information system (GIS).**

I. Introduction

THE collection of arable land quality index data through field investigations is a useful approach for addressing current data gaps that cannot be filled by remote sensing technology and for establishing thematic databases for land quality evaluations. Under traditional methods, investigators navigate to a specific research position using a portable device; record index and image data through handwritten drawings and photographs; and finally, classify and input these data into a computer after returning from the field. However, although this approach can largely fulfill data collection requirements, it has an increased error rate and requires a high workload for recording and transmitting data.

In recent years, well-designed, terminal-based methods for collecting index data that increase accuracy, efficiency, consumption, and data compatibility have gradually replaced traditional pen-and-paper methods and have been extensively used in numerous studies. For example, mobile devices have been used to collect applied behavioral analysis (ABA) data [1] as well as multisource spatio–temporal information for determining factors that influence crop production [2] or that increase production risks for wheat [3]. In addition, mobile devices have been used to collect nearly real-time locust data that can be uploaded directly to a wireless network for locust monitoring [4].

Furthermore, given the limitations of the work environments, geographic information system (GIS) functions have gradually been integrated into data collection systems to enhance an investigator's decision-making ability in the field. For example, wireless sensor networks (WSNs) and mobile GIS devices have been used to collect environmental parameters (e.g., air temperature, soil information, wind speed, and rainfall) through data values, images, and videos [5]. A tool has been developed for collecting spatial data directly in the Google Map API [6]. A mobile GIS device was used to collect and to transmit traffic information over a Wi-Fi network to reduce the wireless network consumption [7], and spatially referenced multimedia data (i.e., geospatial videos) have been collected through mobile GIS devices and used for geography research [8]. In our observations, although computer technologies, especially mobile GIS technology, have been widely used in data collection work, most of this research concentrates on solving data collection problems of certain domains with nearly constant data structure. For these applications, there is no need to consider frequent data structure variations; the database structure and data collection interfaces for these systems can be determined previously in the system design process, which is convenient and efficient. However, this method is not suitable for arable land quality data collection work because the data structure changes in different index areas. Therefore, the creation of a system that is dynamically adaptable to variations in data structure without program modification becomes a crucial problem in arable land quality data collection work.

This paper describes the design and implementation of a mobile GIS-based system called the "Arable Land Quality Index Data Collection System" (ALQIDCS). This system is intended to act as a data provider for the Arable Land Classification Monitoring Information Management System (ALCMIMS) for land quality calculations. This system integrates capabilities of map browsing and related spatial analysis to guide investigators to the locations of sample points previously deployed as part of the ALCMIMS. Furthermore, because the content and related scoring standards for arable land quality indices will likely be influenced by natural conditions, cropping systems and the locations of the sample points, a series of flexible data interfaces

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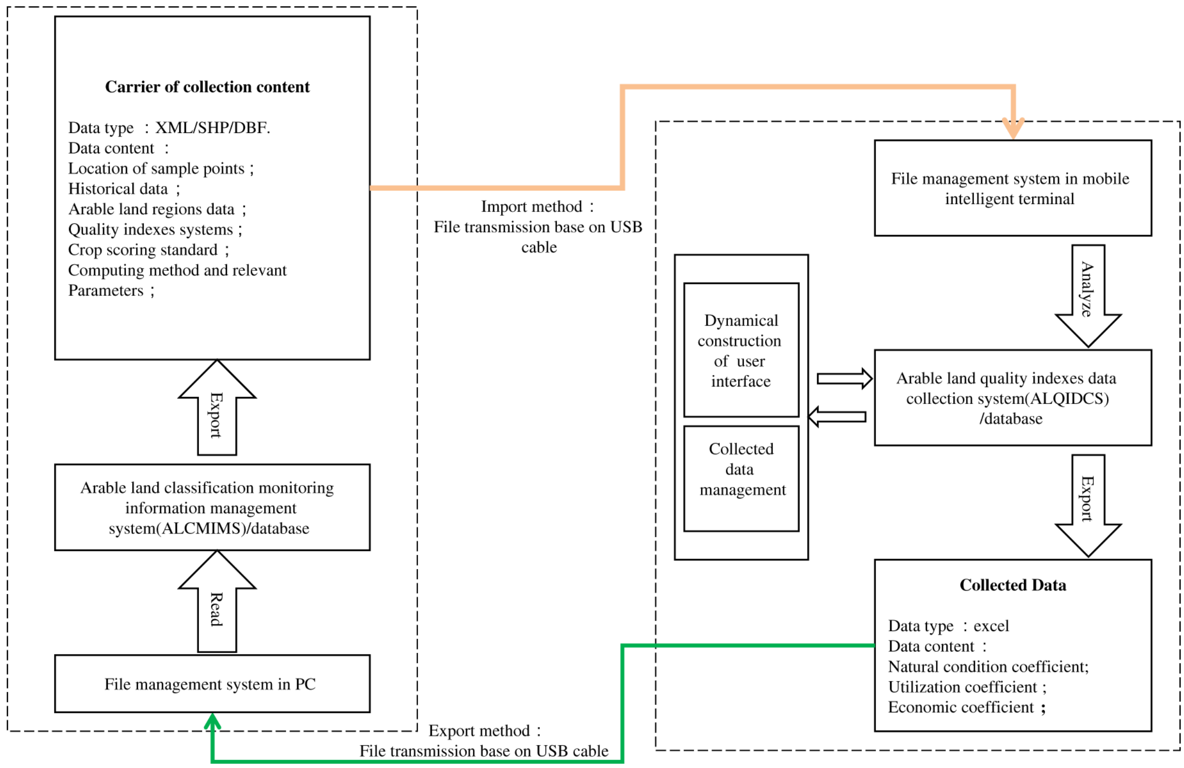


Fig. 1. Overview of the relationship between ALQIDCS and ALCMIMS.

and tables have also been incorporated into the ALQIDCS to allow for the use of a variety of indices. The rest of this article is organized as follows. Section II provides details of the framework of the ALQIDCS based on an analysis of the requirements. Section III reports core technologies for developing the ALQIDCS. Section IV reports related implementations and tests of the ALQIDCS. Finally, Section V discusses and concludes this study.

II. Design of the ALQIDCS

Fig. 1 presents an overview of the relationship between the ALQIDCS and the ALCMIMS and the data exchange mode designed for accommodating multiple data collection techniques. The ALCMIMS exports data through XML files and ShapeFiles, which the ALQIDCS reads and uses to construct related data tables. All collected data are then organized into one Microsoft (MS) Excel file and exported by ALQIDCS. According to the survey and analysis, the ALQIDCS must function within the following rules.

1) Because of limited network connections in the field, wire transmissions are used for data exchange; therefore, no function depends on the network.
2) Variations in quality indices do not influence system applications.
3) Map browsing and navigation are incorporated into the system to guide investigators to sample point locations.
4) Parameters, such as natural quality, economic indicators and land use, are automatically computed in the process of data collection and data inspection.
5) The Android mobile phone system was selected for the application of the ALQIDCS because it is an open-source, highly stable, easy-to-use, cross-platform device that has a graphical-user-interface that can adapt to different screen sizes.
6) Both the internal memory and the removable external memory [a Secure Digital (SD) card] can be read and modified for managing various spatial data.

A. Framework of the System

A layered logical framework was used because it provides low coupling, high flexibility, easy maintenance, and high stability. Fig. 2 shows the structure of the framework, which consists of a data layer, an intermediate layer, and an application layer.

The data layer stores and manages different types of data, including vector, raster, and thematic data. A SQLITE database was used as the medium between offline vector or XML data and data collection work. Raster data are stored in an SD card in a pyramid format. The intermediate layer, which consists of a database interface and a mobile GIS developer kit, acts as a bridge between data application and data storage. In this way, interaction details between components and operating systems are concealed, improving development efficiency. The application layer was constructed based on the intermediate layer. As the executor of functions for data queries, editing and analysis, this layer supports concrete operations and provides a user interface (UI) for collecting index data.

B. Module Partition

The ALQIDCS is divided into five function modules for: 1) the investigation of nature quality indices; 2) the investigation of use and operation condition indices; 3) map applications; 4) data exchanges; and 5) system management (Fig. 3).

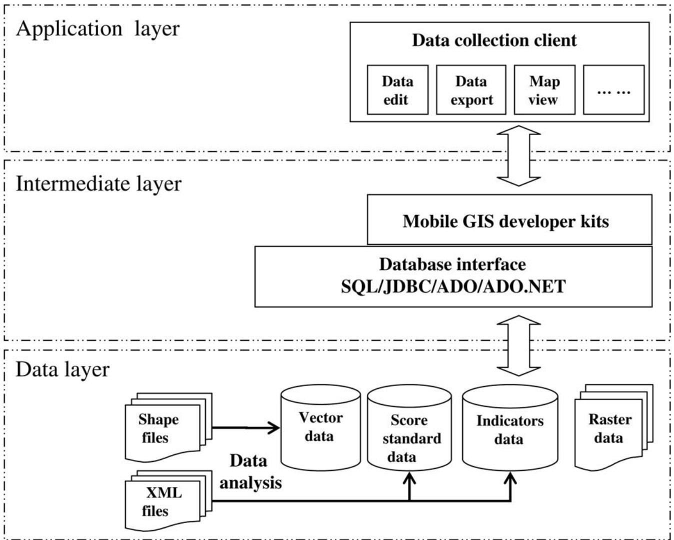


Fig. 2. Framework of the ALQIDCS.

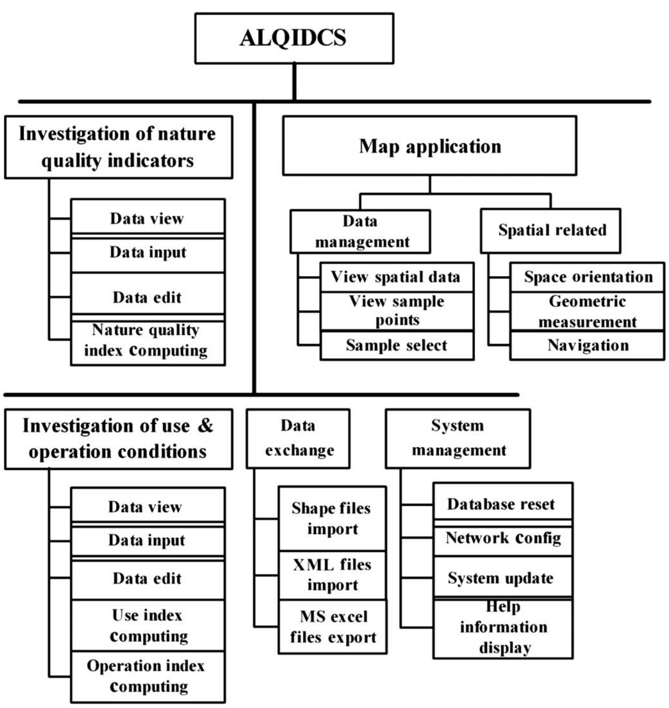


Fig. 3. Module structure of the ALQIDCS.

Module 1 is used to view, input, and edit nature quality index data, whereas Module 2 is used to do the same for use and operation condition index data. However, these modules are not appropriate for inputting and editing data in the most cases because it is difficult to identify the location of sample points through latitude and longitude values. Module 3 is the core module for collecting index data. This module displays all of the sample points on a map, which helps investigators to more easily identify the locations. This module also allows for the use of the remote sensing and vector data to enhance an investigator's decision-making ability. Finally, space orientation, navigation, and geometric measurement functions have been integrated into this module to better organize the investigation tasks. Module 4


```
<?xml version="1.0" encoding="UTF-8"?>
- <Params>
  - <BasicParams>
        <!--global variables in the district-->
      <DistCode>110###</DistCode>
        <!--district code-->
      <DistName>Beijing ##district</DistName>
        <!--district name-->
      <PointLayerName>SamplePoints</PointLayerName>
        <!--the name of SHAPE file used to store sample points--
        >
      <CompreMaxRatio>2.1</CompreMaxRatio>
        <!--comprehensive largest production/cost ratio
        coefficient -->
    </BasicParams>
  - <CalMethod>
        <!--methods for computing, 0: comprehensive method,
        1: compute separately by crops-->
      <KC>1</KC>
        <!--computing economic coefficient-->
      <KL>0</KL>
        <!--computing utilization fator-->
    </CalMethod>
  - <IDXAreasParams>
      <IDXAreasID>111####1</IDXAreasID>
        <!--index area code-->
      <IDXAreasName>A area</IDXAreasName>
        <!--index area name-->
      ... ... ... ... ...
    </IDXAreasParams>
  - <IDXAreasParams>
      <IDXAreasID>111####2</IDXAreasID>
        <!--index area code-->
      <IDXAreasName>B area</IDXAreasName>
        <!--index area name-->
      ... ... ... ... ...
    </IDXAreasParams>
</Params>
```


Fig. 4. Overall organization structure of an XML file demo.

manages data exchanges between the ALQIDCS and ALCMIMS. This module constructs data tables dynamically by reading XML files and ShapeFiles and by exporting index data as an MS EXCEL file. Module 5, which consists of a database reset function, network configurations, a help information display, and system updates, is designed to manage the system operation environment.

C. Interface Design

XML files, ShapeFiles, and MS EXCEL files allow for data exchange between the ALCMIMS and ALQIDCS. Because certain information (e.g., the location of sample points, related index systems, and score standards) has been previously developed for use in the ALCMIMS, ShapeFiles are used to store the locations of the sample points and the historical index records (work as references), whereas XML files are used to store related index system data and score standards. Furthermore, the contents of the MS EXCEL file depend on the contents of the imported XML files and the ShapeFiles and have an organized structure. Fig. 4 shows the organizational structure of an XML file demo. There are three types of child nodes under the root node: 1) "BasicParams," 2) "CalMethod," and 3) "IDXAreasParams." "BasicParams" is used to store global variables in the collection district. "CalMethod" is used to store methods for computing utilization factors and economic coefficients for arable land. Finally, each "IDXAreasParams" node can be treated as a carrier describing the crop system, the nature quality indices, and the score standard information for each specific index area.

There are two index areas named "A area" and "B area" in this demo, which are identified by two "IDXAreasParams" nodes. According to the organization rules, there are five child nodes

```
<?xml version="1.0" encoding="UTF-8"?>
<!--... ... ... ... ...-->
- <IDXAreasParams>
  - <Indexes>
      <!--nature quality indexes information-->
    - <Index>
        <IndexName>soil thickness</IndexName>
          <!--index name-->
        <IndexStandardName>TRHD</IndexStandardName>
          <!--alias-->
        <Unit>cm</Unit>
          <!--index unit, set null for text-->
        <ValueSet>20|30|50</ValueSet>
          <!--type1: numeric data domain,eg.0-150; type2:enumerated values divided
          by "|"-->
        <Historical>1</Historical>
          <!--1:use historical data stored in SHAPE file, 0: no historical data -->
      </Index>
    </Indexes>
  - <CropSystem>
    - <Crops>
      - <Crop>
          <CropID>1</CropID>
            <!--crop ID-->
          <CropName>wheat</CropName>
            <!--crop name-->
          <LPotentialIndex>1424</LPotentialIndex>
            <!--light and temperature potential productivity-->
          <CPotentialIndex>1328</CPotentialIndex>
            <!--climatic potential productivity-->
          <ProdRatio>1.2</ProdRatio>
            <!--productive ratio coefficient-->
          <MaxProd>1100</MaxProd>
            <!--highest yield-->
          <MaxRatio>1.5</MaxRatio>
            <!--crop largest production/cost ratio coefficient-->
        </Crop>
      </Crops>
    </CropSystem>
  - <ScoreRules>
      <!--Score standard-->
    - <CropConstraint>
        <CropID>1</CropID>
      - <IndexConstraint>
        - <Index>
            <Name>TRHD</Name>
              <!--alias-->
            <Weight>1</Weight>
              <!--weight,1 for average-->
          - <SoreRuls>
            - <ValueRuls>
                <Score>20</Score>
                  <!--quantitative description-->
                <Value>0-50</Value>
                  <!--domain of data collected-->
              </ValueRuls>
            </SoreRuls>
          </Index>
        </IndexConstraint>
      </CropConstraint>
    </ScoreRules>
</IDXAreasParams>
```


Fig. 5. Partial organization structure of index area in an XML file demo.

under each “IDXAreasParams” node (Fig. 5). The “Indices” node is used to store nature quality index information for the current index areas. A list of the probable crop systems and related information is stored in the “CropSystem” node. It is important to note that, even in the same index area, the score standard may vary by crop. Therefore, score standard information, which converts nature quality indices from qualitative to quantitative descriptors, is organized by crop species in the “ScoreRules” node. Furthermore, unlike the nature quality indices, the use and operation condition indices are invariable and can be deployed in the ALQIDCS in advance.

III. Key Technology for ALQIDCS

A. Self-Adaptive Mobile GIS Application

Given the diversity of structural characteristics, data sources, coordinate systems and contents, it is typically difficult to construct a unified spatial data application for different arable land index areas. Two methods, setting the data standards and designing a self-adaptive model, were used cooperatively to solve this problem in ALQIDCS. 1) The “set data standardization method” stipulates unified structures and formats of spatial data for different data collection tasks. 2) The “design a self-adaptive model method” implements dynamic spatial data analysis to ensure that different types of spatial data with different spatial ranges can be identified, organized, and displayed automatically for data collection work. However, these methods propose strict requirements on data preprocessing, including data type, data format, data structure, coordinate system, data storage path, and data table name, which increases the workload of data preprocessing.

1) Set Data Standard Method: According to the “set data standardization method,” ShapeFiles were stipulated as the required format for vector data, and the Xi’an 80 geographic coordinate system was stipulated as the required coordinate system for all spatial data. Given the actual demand, wireless network conditions and wireless data transmission costs, wireless communication was abandoned, and all spatial data, including vector data and cache files, must be imported in advance into the mobile device through data cables. Raster data, which are used in the base map, should be converted to a pyramid structure and organized in cache files based on the Web Map Tile Service (WMTS) on data servers.

2) Design a Self-Adaptive Model Method: It is common for there to be differences in data types, spatial scales, and attributes for spatial data collected in different regions. Based on the “design a self-adaptive model method,” all spatial data were divided into three main groups: 1) raster base maps, 2) sample points, and 3) vector base maps. Data in the first group contain all of the cache files imported into the mobile device; data in the second group are contained in a single ShapeFile that describes the location, related index area information, and historical index records for the investigation points; and data in the third group includes a collection of other vector data (e.g., arable lands and roads) that otherwise support the investigation. As Fig. 6 shows, the spatial data analysis model operates during the data reading process such that the name and storage path of data belonging to Group 1 are inserted into a data table base map. Each ShapeFile belonging to Group 2 or Group 3 is converted into an independent data table that contains the geometrical shape characteristics and other attributes. Data tables for files belonging to Group 3 are named as “file name + ‘−’ + file geometry type + ‘-shp’” (file geometry type is substituted by an integer; 1 for point, 3 for line/multi-line, and 5 for polygon/multi-polygon), and data tables for files belonging to Group 2 are named “SamplePoints.” After the mobile GIS application process begins, the model that organizes spatial data is initiated, and all spatial data are automatically organized into three arrays based on the group to which the data belong and are added to the map as independent layers. Furthermore, the sequence of layers is dynamically determined; Group 1 layers are placed on the bottom, and Group 2 layers are placed on the top. Additionally, data points and polygons in Groups 2 and 3 are added to the top and bottom, respectively.

In contrast to personal computers, mobile devices are generally not suitable for the management of numerous spatial data files. For example, there may be thousands of features in some polyline or polygon files, which can dramatically slow the processing speed of a mobile device or cause the device’s system to crash. Previous tests on a mobile device (CPU: 1.5 GHz,

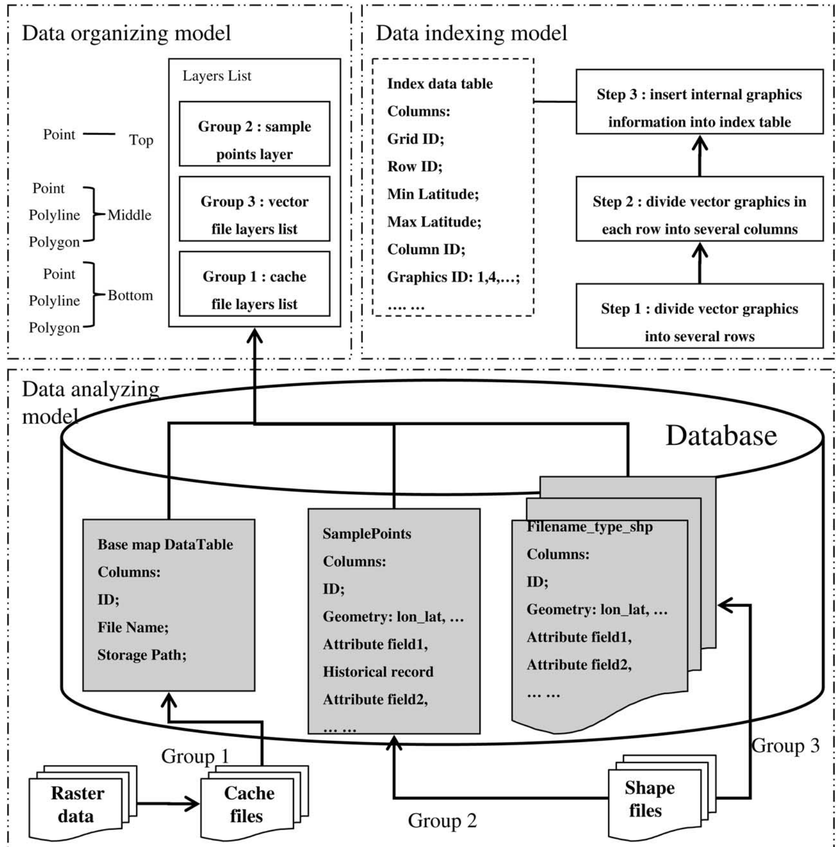


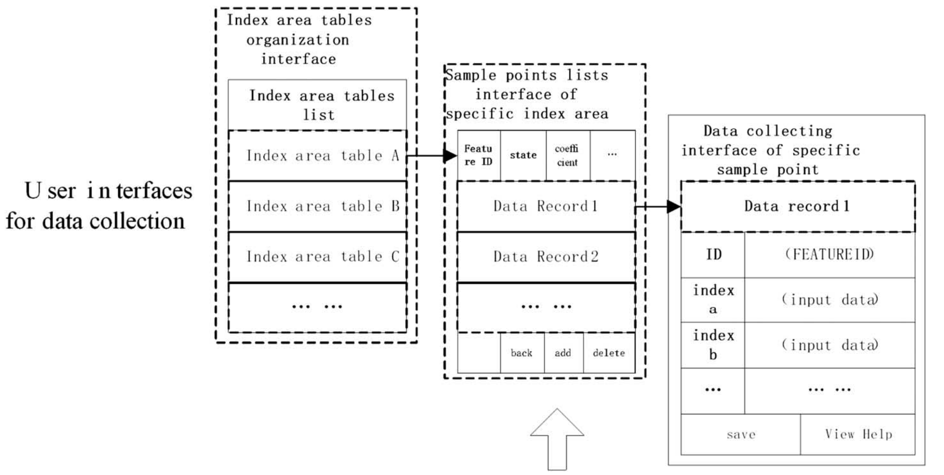
Fig. 6. Self-adaptive model for GIS application.

TABLE I
INFLUENCE OF SPATIAL INDEXING MODEL TO SPATIAL DATA QUERY EFFICIENCY WITH INCREASING NUMBER OF POLYGON FEATURES (S FOR SECONDS)

Spatial data organization mode	Time-consuming with increasing number of polygon features									
	20	50	100	150	200	250	300	350	400	450
Data loading without index	<2 s	<2 s	1–3 s	2–4 s	5–8 s	22–34 s	45–55 s	>70 s	>130 s	∞ (system halted)
Spatial indexing model	<2 s	<2 s	1–3 s	2–4 s	5–8 s	6–8 s	6–8 s	6–8 s	6–8 s	6–8 s

RAM: 512 MB, and ROM: 2 GB) show that the data query speed decreases with increasing numbers of loaded vector features. Processing speed declines particularly fast after the number of vector features exceeds 400, and the ALQIDCS cannot handle more than 3000 features at a time. Therefore, the spatial data indexing model was used to confine the number of features that can be loaded at one time. According to this model, grid index technology was used to improve the efficiency of data queries. In addition, instead of using a predetermined grid size, the ALQIDCS automatically divides by the number of vector graphics. For instance, all vector graphics for each vector layer are first divided into several different size rows according to the latitude of their surrounding rectangle, with each row containing less than 400 graphics. The graphics in each row are then divided into several different size columns according to the longitude of their surrounding box, with each column containing less than 100 graphics. Finally, the grid identifier, row number, column number, and internal graphics information are inserted into an index table. In this way, the grid index can dynamically adapt to variations in data size. Table I presents a performance evaluation of the spatial indexing model with an increasing number of polygon features.

Based on the data analysis model, the data organization model and the data indexing model, the processes of spatial data analysis, data organization and grid indexing can be automatically executed to reduce the influence of data type, range, and size.



Columns of the structure table

The structure table

Column name	Data type	Nullable	Default	Unique value	Remark
ID	Int	N		Y	Primary Key
TableName	Varchar(150)	N		N	Name of index area table
ColumnName	Varchar(100)	N		N	Column name of index area table
ColumnAlias	Varchar(100)	Y		N	Column alias of index area table
DataType	Varchar(100)	N		N	Column data type of index area table
DataLength	Int	N		N	Column datalength of index area table
PKFK	Int	N	0	N	Column key type of index area table, PK(1), FK(2), enum-type(3), normal field(4)
Ftable	Text	Y		N	Name of table linked by FK (if exist)
ComValueEnum	Text	Y		N	Enums, splited by '|'
MaxValue	Varchar(50)	Y		N	maxValue of the column of index area table
MinValue	Varchar(50)	Y		N	minValue of the column of index area table
Visible	Int	N	2	N	If the column is visible: never visible(0), must visible(1), visible but hided now(2)
EditAble	Int	N	2	N	Not editable(0), editable(1)
ListOrder	Int	Y	0	N	List order of the column in data collection interface
DecimalLong	Int	Y		N	Decimal digits

Fig. 7. Overview structure of the data table-driven model.

B. Dynamic UI for Investigation

In traditional software development, the type, facade, layout, and content of user-interface controls or menus are fixed in the preliminary design process. Although this fixed design can provide convenience in deploying system functions, it can also induce difficulties in adjusting the UI without program modification. For research on arable land quality, the index systems can change by region, and the internal sample points, related index contents, and score standards can be different for each index system. Therefore, it would be inappropriate to use a fixed user-collecting interface in the ALQIDCS. In the ALQIDCS, the collecting interfaces for both the nature quality index and the use and operation condition index were not previously set but were instead constructed in a dynamically driven data table. According to this data table-driven model, a particular data table (i.e., a structure table) is used to store the names of arable land regions and related index information, including the name, the data type, the data length, the range of values, and the sequence of each index. Records in the structure table can be used to automatically construct data collection interfaces. As a result, three types of ordered UIs (i.e., the region interface, the sample points interface, and the data input interface) are defined for interactive data collection processing. Fig. 7 presents the general structure of the data table-driven model. Columns in the structure table are all predetermined.

Here, the column "TableName" is used to group the arable land indices by saving the region names; the column "IndexName" contains the collection of arable land indices; the columns "DataType," "DataLength," "MaxValue," and "MinValue" are used to record the data type, length, maximum value, and minimum value, respectively, for each index; the column "ComValueEnum" lists all possible values of the index; and the column "ListOrder" specifies the display order of the various indices belonging to the same index system. The three types of interfaces are constructed dynamically depending on the structure table and the sample points table, each of which has its own task. The region interface is used to organize the arable land regions. After one arable land region is selected, the sample point's interface is initiated and lists all sample points belonging to that region. The data input interface is constructed based on the sample point selected and consists of a series of controls, including the "spinner control," the "text view" control, and the "edit text" control. The sequence of the controls and the type, content, and value range for each control are automatically configured based on the structure table.

C. Nearly Real-Time Arable Land Quality Index Computing

The ultimate purpose of both the ALCMIMS and ALQIDCS is to collect arable land quality indices for efficient land quality monitoring. As the core parameters for arable land classifications, the natural condition, utilization and economic coefficients for a given piece of arable land (represented by a discrete sample point) can be calculated in nearly real-time when that location's

TABLE II
SPECIFIC DIFFERENCES OF INVESTIGATION TASKS BETWEEN DA XING DISTRICT AND TE DA LA QI DISTRICT

Arable land region name	Indexes regions	Nature quality indexes content	Related crops	Number of sample points
Da Xing District	Plain region; mountainous region	Drainage condition, soil ph, topographic slope, degree of salinity, soil erosion degree, soil thickness	Wheat, corn, paddy	47
Te Da La Qi District	Loess hills region	Soil texture, barrier layer depth, topographic slope, soil organic matter content, soil erosion degree, probability of irrigation, effective soil thickness	Corn	53

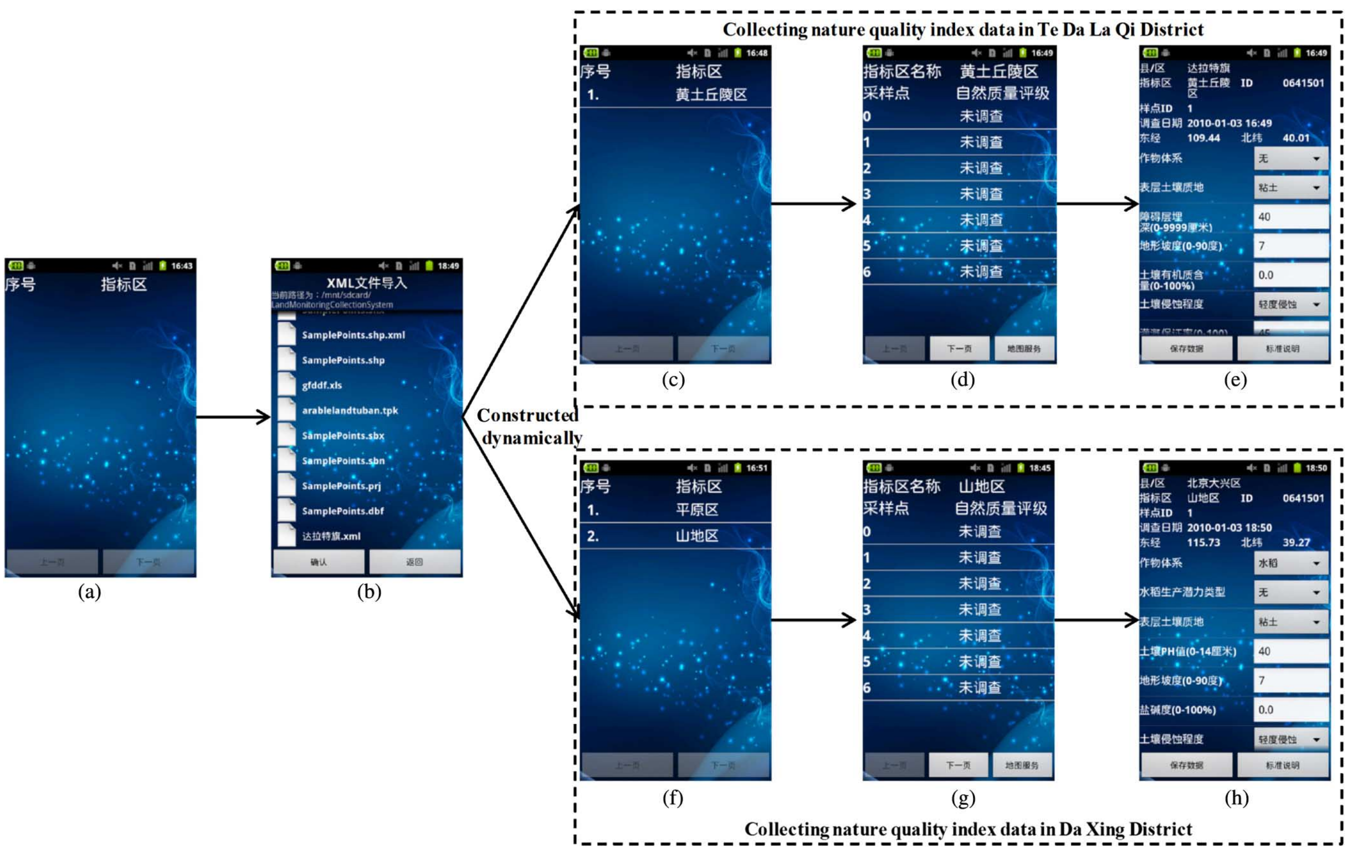


Fig. 8. Application of data table-driven model on nature quality indexes collecting: (a) user interface before data analyzing; (b) data analyzing. Collecting nature quality index data in Te Da La Qi district: (c) region interface; (d) sample point's interface; (e) data input interface. Collecting nature quality index data in Da Xing district: (f) region interface. (g) Sample point's interface. (h) Data input interface.

related indices have been collected. In this manner, the ALQIDCS can directly transmit these three coefficients, whereas the ALCMIMS requires the transmission of many different indices. By reducing the quantity of data being handled, the burden associated with the transmission and management of the collected data is also reduced under the ALQIDCS. Furthermore, this process can provide error detection in data entry by comparing the calculated coefficients for a given sample point with those of the surrounding points. According to the Regulations for Classification on Agricultural Land (China) [9], two types of operating methods were integrated into the ALQIDCS for computing the natural condition: utilization and economic coefficients. These methods included the crops segregated based method and the crops composited method. Under the former

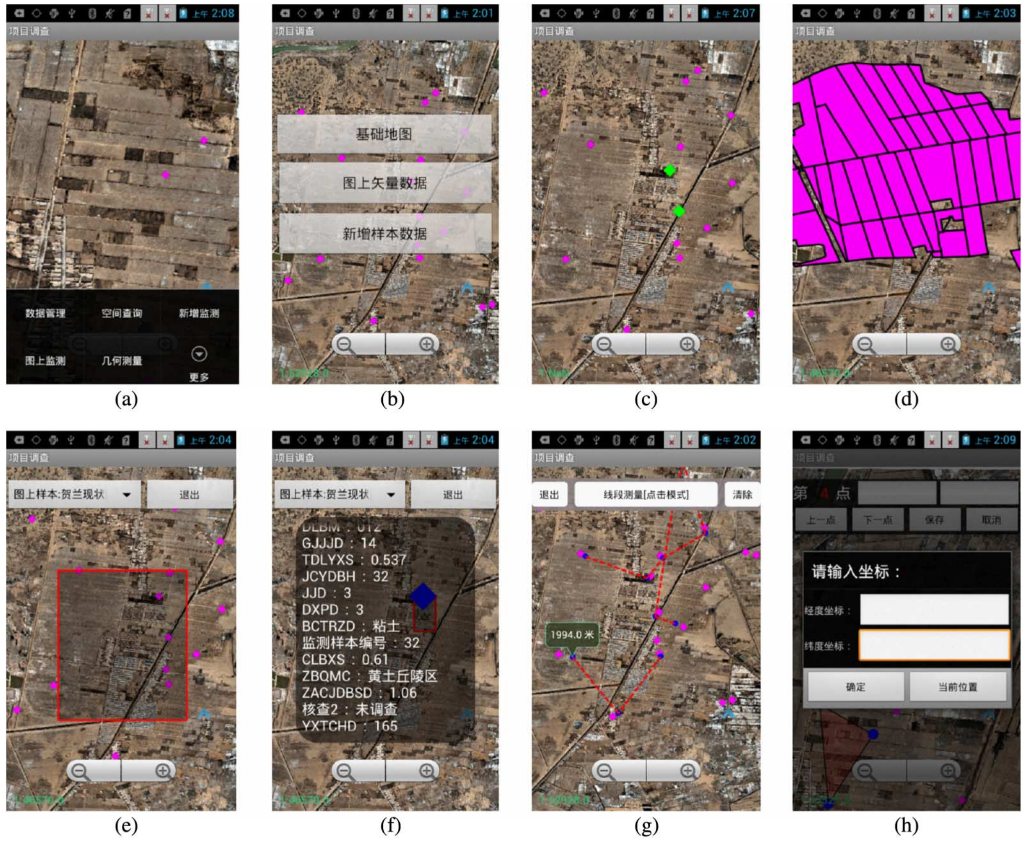


Fig. 9. Application of ALQIDCS base on mobile GIS. (a) Data browsing (with main menu). (b) Data mangement menu. (c) Distribution of sample points. (d) Distribution of arable land spots. (e) Spatial query. (f) Return spacial query results. (g) Geometric measurement. (h) Shape edit of spacial data.

method, the coefficients for each crop (based on the cropping system) are computed for each sample point of arable land, while the latter method combines the three coefficients into one coefficient for each crop type.

Formulas (1)–(3) express the coefficient counting process based on the crop segregation method. Here, i refers to the identification of the sample points; j is the crop identifier for sample point i; $R_{i,j}$, $L_{i,j}$, and $E_{i,j}$ represent the natural condition, the utilization coefficient and the economic coefficient, respectively, for crop j at sample point i; a_j represents light, temperature and climate productive potential for crop j; $f_{i,j,k}$ is the score of the natural condition index k; w_k is the weight of index k; b_j is the productivity ratio coefficient for crop j; $Y_{i,j}$ is the productivity of crop j; $C_{i,j}$ is the actual cost of crop j; and $Y_{j,max}$ and $A_{j,max}$ are the maximum production and the maximum production/cost ratio, respectively, for crop j in the current arable land classification partition

$$R_{i,j} = a_j * \left(\sum_{k=1}^{m} w_k * f_{i,j,k} \right) * b_j \quad (1)$$

$$L_{i,j} = Y_{i,j} / Y_{j,max} \quad (2)$$

$$E_{i,j} = \frac{Y_{i,j}}{C_{i,j}} / A_{j,max}. \quad (3)$$

Formulas (4)–(6) express the coefficient counting process based on the crop com-position method. The calculation of R_i can be treated as the weighted average of each $R_{i,j}$ based on the cropping system, and b_j is used to convert the production of each crop into a standard grain output. $R_{i,j}$, $L_{i,j}$, and $E_{i,j}$ are calculated using formulas (1)–(3). In the calculation process, a_j, b_j, w_k, $Y_{j,max}$, and $A_{j,max}$ are not user-defined; rather, they are constant within the ALCMIMS and compiled in the XML file, and the computing method is confirmed in the same manner

$$R_i = \begin{cases} \sum R_{i,j}, & \text{one|two|three..harvest a year} \\ \left(\sum R_{i,j}\right)/2, & \text{three harvest two years} \end{cases} \quad (4)$$

$$L_i = \left(\sum_{j=1}^{n} Y_{i,j} * b_j \right) / \left(\sum_{j=1}^{n} Y_{j,max} * b_j \right) \quad (5)$$

$$E_i = \frac{\left(\sum_{j=1}^{n} Y_{i,j} * b_j \right) / \left(\sum_{j=1}^{n} C_{i,j} \right)}{A_{j,max}} \quad (6)$$

IV. Implementation and Testing

The ALQIDCS was implemented in the Java Archive format. Eclipse software was integrated with an Android SDK, and Android Development Tools were used for the development environment. A module based on "dom4j" was developed to parse the XML file. ArcGIS for Android SDK was used as the middleware to allow for browsing, querying and analysis of the spatial data. An SQLite relational database was used to store sample point data, related index systems, and score standards data. A document named "ArableLandQualityMonitoring" is created (if it does not exist) to store all files, including XML files, ShapeFiles, and the MS EXCEL file during the system initialization process. The data exchange module supports users in choosing an XML file. The ALQIDCS then analyzes the corresponding ShapeFiles and insert indices records to the structure table by reading the XML file. To test the adaptability of the ALQIDCS for multiple index systems and for sample points in different arable land regions, we applied our system to arable land regions in the Da Xing District, Beijing and the Te Da La Qi District, Inner Mongolia, China using two sets of index systems. Table II lists the specific differences between the investigation tasks, with the exception of score rules, used in these two arable land regions. The test demonstrated that the ALQIDCS could dynamically construct the data collection interfaces for the nature quality and the use and operation condition indices, effectively adapting to the different investigation tasks through the data table-driven model (Fig. 8). As Fig. 8 shows, all the UIs related to data collection were empty before the data analysis [interface 8(a)], and the system constructs the data collection interfaces dynamically according to the chosen XML file in the data analysis process [interface 8(b)]. Fig. 8(c)–(e) presents the index area organization interface, the sample points list interface and the data collection interface of Te Da La Qi District, respectively. Fig. 8(f)–(h) presents the corresponding interfaces of Da Xing District. In addition, both map and vector files could be equally applied, irrespective of the different investigation areas. Furthermore, the ALQIDCSuse test demonstrated the feasibility of using of a near real-time computing function for arable land quality indices and of using a series of GIS functions. Fig. 9 describes the running conditions for these functions. Fig. 9(a) displays the map container and the main menu of the map application module, and Fig. 9(b) displays the list of maps, including the raster base map, the sample points map and the vector base map. In Fig. 9(c), the green points represent the investigated sample points and the purple points represent the uninvestigated points. Fig. 9(d) shows the distribution of arable land areas. Fig. 9(e) and (f) shows the spatial query process. In Fig. 9(g), the length of a polyline (meter) or the area of a polygon (meter squared) would be computed according to geometric shapes drawn by users. In Fig. 9(h), the user could edit the shape of the spatial data by inputting the longitude and latitude of each polygon vertex.

V. Conclusion

The ALQIDCS is a highly flexible and mobile GIS-based system for efficiently collecting and processing near real-time arable land quality index data. We designed the framework, the module partition and the structure of the data exchange interface in the ALQIDCS. The results include (1) a series of self-adaptive methods designed to implement the unified organization and application of spatial data and (2) a data table-driven model that can dynamically guide the collection interfaces for the nature quality and the use and operation condition indices according to specific arable land regions. Furthermore, two types of formulas were integrated into the system for computing near real-time coefficients describing natural conditions. The application of the ALQIDCS in the Da Xing District, Beijing and the Te Da La Qi District, Inner Mongolia demonstrated that the prototype system can dynamically adapt to variations in the spatial data and the index systems. Further development of the ALQIDCS will focus on the optimization of the spatial data indexing model because the current model is not suitable for uneven data distributions or irregularity in graphic sizes among the index grids. In addition, the data table-driven model will be improved to reduce redundancy in the XML files.

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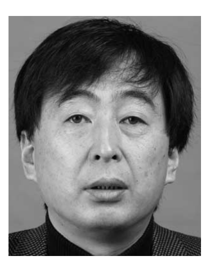

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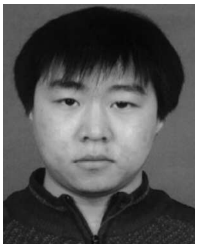

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