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An Intelligent Information System for Groundwater Resources Categorization and Assessment

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Abstract: This paper aims to present an intelligent information system developed for groundwater categorization and classification. The developed system integrates more than one research field and tools, including Decision Support Systems (DSS), Geographic Information Systems (GIS), knowledge base and modeling and visualization enhancement. Visual Basic (VB) environment is used as an inference engine for this system and the code is written using VBA. The system aims to categorize water resources according to the international water quality criteria (FAO, USSL, Gupta and Roades) and to reclassify water resources according to a developed decision matrix from the application of the expert system. A user friendly interface (GUI) is developed to help the user to manage the system and to link different system environments. The system is linked through the GUI with a GIS to display the water resources layers and to provide functions to query and display the spatial locations and associated attributes. The system is used to make a decision about the suitability of water resources to a specific crop and vice versa. The developed system is tested on groundwater recourses in Siwa Oasis, Egypt.

Key words: Expert Systems · Knowledge Base Systems · GIS · Water Resources · Categorization

INTRODUCTION

Information technology and in particular, the integration of data base management systems, GIS, remote sensing and image processing, simulation and multi-criteria optimization models, expert systems and computer graphics provide some of tools for effective decision support for natural resources management. There is a need to combine the technologies of GIS, artificial intelligent, visualization and environmental modeling to produce intelligent spatial decision support systems. The expert systems in spatial problem solving become more sophisticated as GIS data began to be associated with the system processes [1, 2].

An intelligent geographic information system (GIS) has to handle various types and huge volumes of geoscience-related knowledge as well as enormous amounts of data and information. More recent attention concentrates on collection, representation, management and usage of knowledge. [3].

An integrated expert system and GIS have been referred to as an expert GIS or a knowledge-based GIS, when focusing on the stored facts or rules. An expert GIS have shown such benefits as enabling a novice GIS user to carry out a range of operations similar to an experienced user by making user interaction with GIS easier. One category of expert GIS contains those applications that mainly address GIS for spatial feature extraction or classification [4].

The development of knowledge-based decision support systems for environmental planning requires the management of complex geospatial information, the integration of expert judgment with decision models and the dynamic visualization of geographic terrain. This paper describes the design and implementation of a knowledge-based interactive spatial decision support system for identifying the adaptability of crops at a given agro-ecological zone [5].

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Siwa is the largest oasis in Egypt with an area of 1175 km^2, approximately. It is located at about 800 km west of Cairo and 300 kilometers inland from the Mediterranean Sea. It is situated in a depression of 20 meters below sea level. Groundwater is the most valuable resource in the oasis. It is the only source of water in the oasis. There are essential needs for optimal management of that important resource [6-8].

Objectives: This paper aims to present an intelligent information system developed for groundwater categorization and classification. The developed system integrates more than one research field and tools, including Decision Support Systems (DSS), Geographic Information Systems (GIS), knowledge base and modeling and visualization enhancement. A GUI is developed to help the user to manage the system and to link different system environments. The system is used to make a decision about the suitability of water resources.

MATERIALS AND METHODS

The procedures followed to build the intelligent system for groundwater resource categorizing include different phases and steps as follows:

Data Gathering and Preparation: includes tabulating the collected groundwater data in a worksheets formats and saving it as a database files (*.dbf). These data contain the chemical analysis results for Cations, Anions and trace elements for some groundwater resources specified by its locations.

Import Data to DBMS: using MS-Access. The database files are imported and saved and some modification to the structure of the tables are done by adding new fields. New tables are created for water quality categories according to USSL. Figure 1 illustrate an example of the database structure and tables relations.

Linking Database in Ms-access with Visual Basic (VB) to provide data integration and exchange between the DBMS and GIS. The database is linked and maintained inside VB environment using VB designer and a new connection table is added.

Data Management and Knowledge Base Development: using VBA to build the inference engine and the rule based used in the groundwater resource categorizing. The system is designed to be used at different levels of user sophistication. The developed user interface is a menu

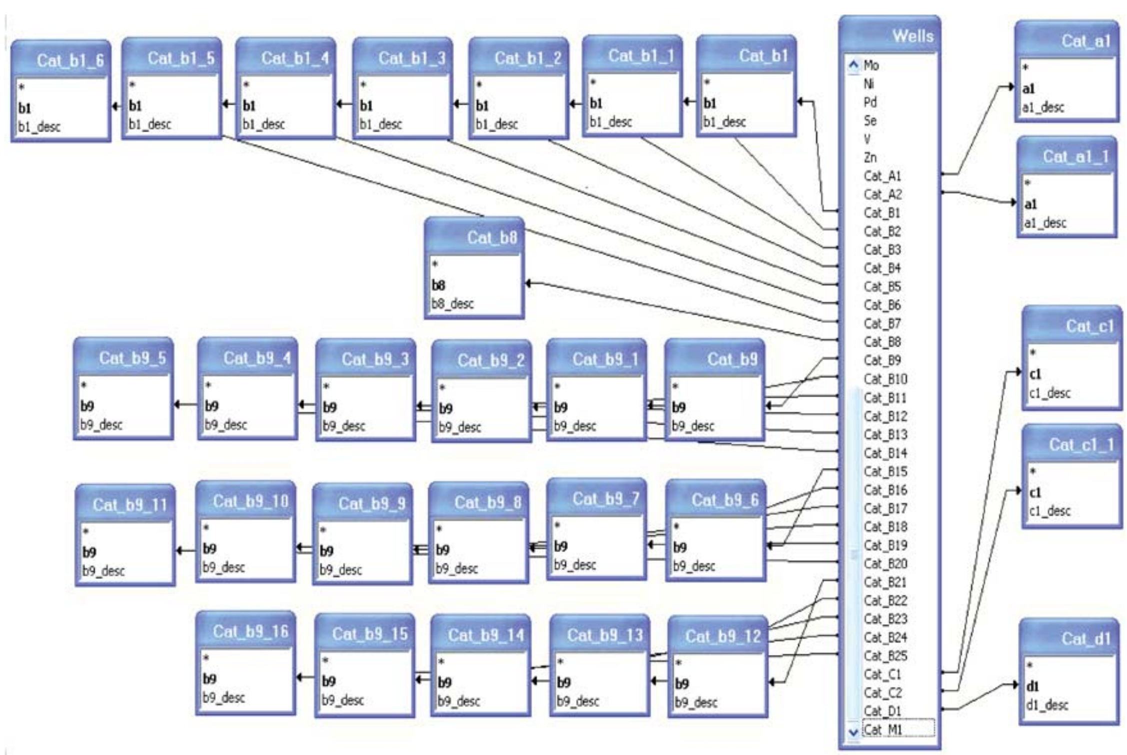

Fig. 1: Groundwater resources database built in MS-Access DBMS

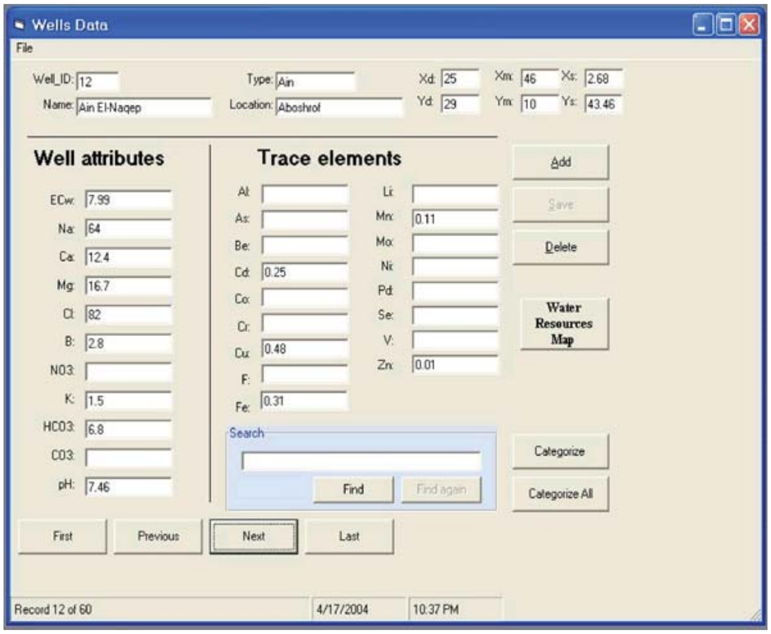

Fig. 2: User interface used for data editing & KB management

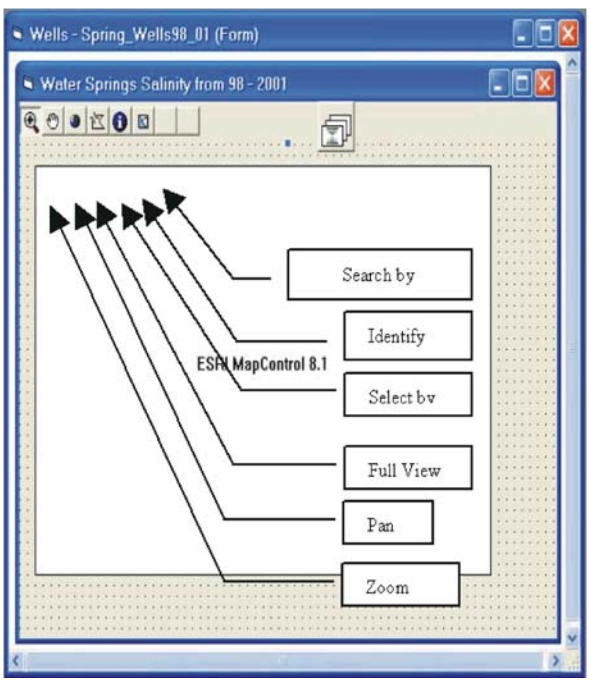

Fig. 3: The map control form used to link GIS with VB

driven task manager that allows the selection of different modules for evaluating parameters such as GIS and MS-Access. The data management and processing inside this system include different tasks, which can be executed through a user interface and some control buttons. The main form designed and used is shown in Figure 2.

The available tasks for the user and the decision maker include the following:

- To browse and navigate through the existing data
- Data editing (Add a new water resource data, Delete)
- Rules and facts used in categorizing water resource
- Search for a well of specific properties
- Visualize maps for water resources and results

These functions are managed and executed through some control buttons, as shown in Figure 2. The data can be spatially represented and viewed through a map using GIS tools linked with VB interface, as shown in Figure 3.

Rules and Facts Used in Categorizing Water Resource: represent the main part of the developed system, which is based on the groundwater quality criteria for irrigation defined by four international references as USSL, FAO, Gupta and Roades. The main criteria used to take a decision about groundwater quality for irrigation are: Salinity, Toxicity, Infiltration rate and other effects such as high nitrogen concentration in water, abnormal pH and bicarbonate [7, 8] The system allows the user to categorize a current water resource record or to categorize all water resources. The main procedures are illustrated in Figure 4. The constructed rules and facts for water quality criteria are identified according to, [8].

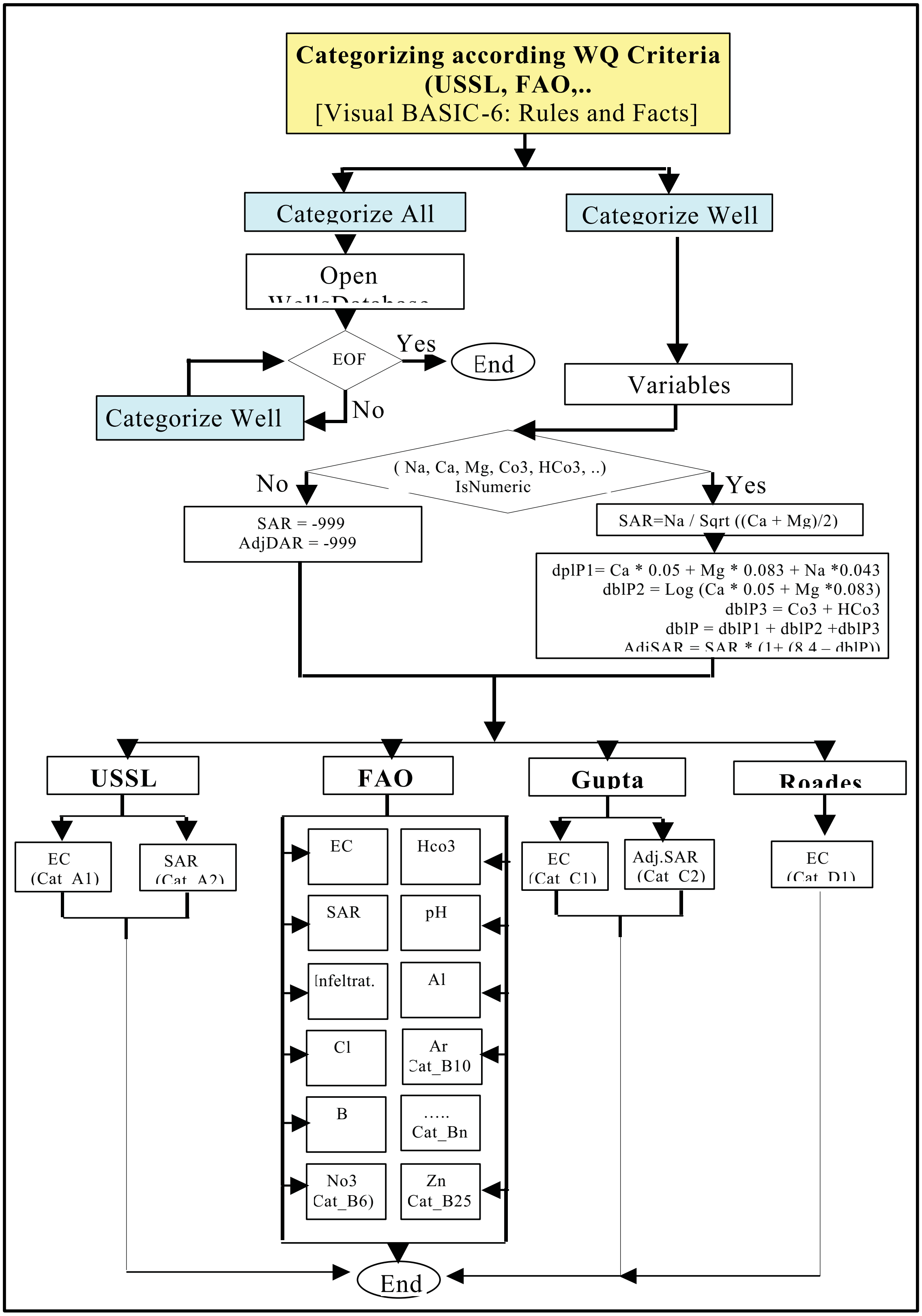

Fig. 4: Flow chart of the main procedures for ground water categorizing

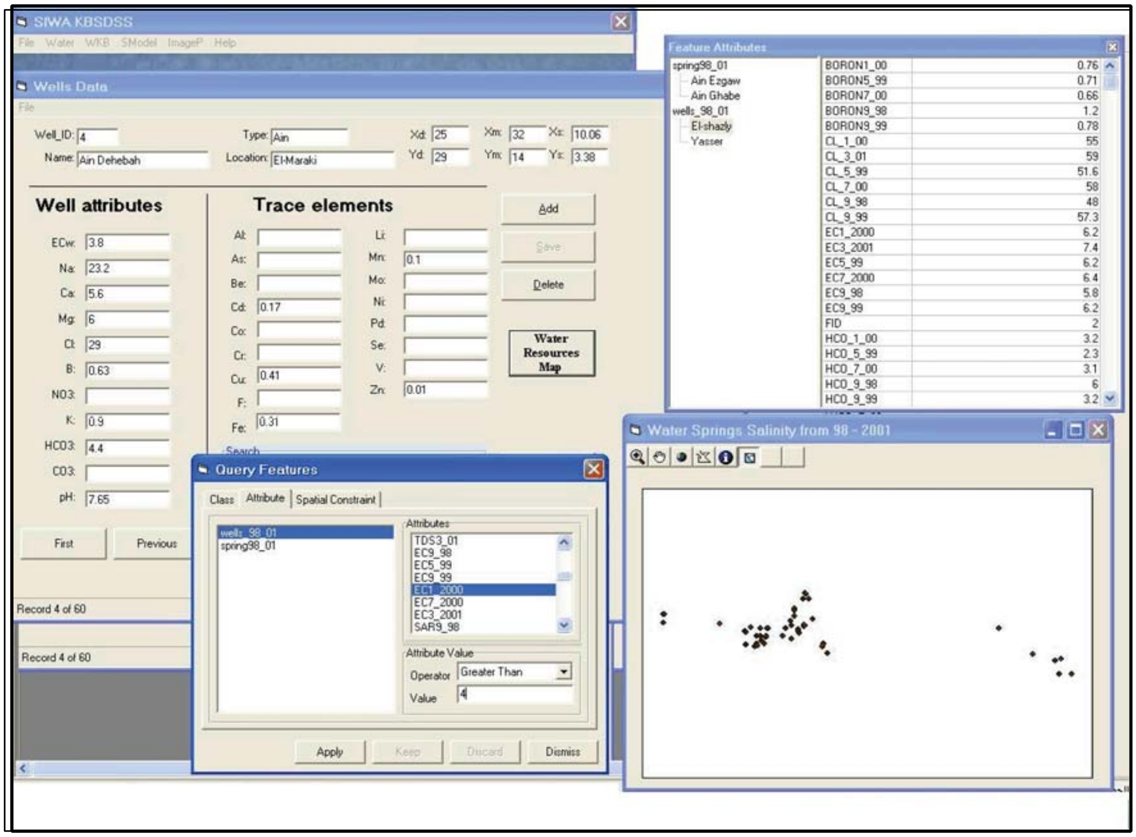

Fig. 5: The output results from map control form

Categories / Suitability	Cat-A1 EC	Cat-A2 (SAR	Cat-B1 EC	Cat-B2 SAR	Cat-B4 (Cl)	Cat-B5 (B)	Cat-B7 Hco3	Cat-B8 pH	Cat-C1 EC	Cat-D1 (EC	M
	USSL		FAO						Gupta	Roades	Mass
Very High	2	1	1	2	1	1	2	2	1	1	1
High	3	1	2	2	3	1 or 2	2	2	2	2	2
Moderate	4	1	2	2	3	1 or 2	2	2	2	3	3
Low	4	2	3	2	3	1 or 2	2	2	3	3	4
Very Low	4	2	3	3	3	1 or 2	2	2	3	3	5
Extremely Low	4	3	3	3	3	1 or 2	2	2	3 or 4	3	6
Unsuitable (1)	4	4	3	3	3	2 or 3	2 or 3	2	4 or 5	4	7
Unsuitable (2)	4	4	3	3	3	3	2 or 3	2	5	4 or 5	8

Fig. 6: A decision matrix according to the output results from KB application

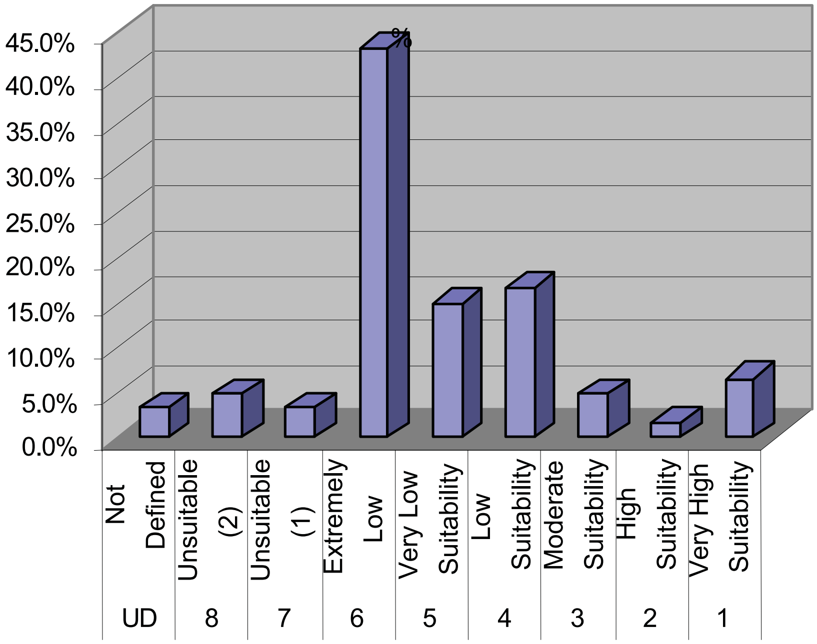

Fig. 7: Chart for water resources classes and quality %, according to the decision matrix application

Table 1: Water suitability classes and quality% according to the decision matrix application

Class	Description	%
1	Very High Suitability	6.7%
2	High Suitability	1.7%
3	Moderate Suitability	5.0%
4	Low Suitability	16.7%
5	Very Low Suitability	15.0%
6	Extremely Low Suitability	43.3%
7	Unsuitable (1)	3.3%
8	Unsuitable (2)	5.0%
UD	Not Defined	3.3%

Visualizing Maps for Water Resources: The developed system enables the user and the decision maker to visualize and control a map represented as point coverage for water resources by linking VB and GIS using Arc-Objects and Map-Controls. The user can identify a specific well to display the information related to this well. The system also offers the user to make a spatial search by water resource attributes as shown in Figure 3. The output results are illustrated in Figure 5, which shows the main form of a point coverage, a window for spatial query feature and an attributes window.

Knowledge Base (KB) Application: After each run of the system and categorizing water resources according to the constructed rules and facts, the database is updated. The fields of categories are assigned numeric values representing water quality classes according to different criteria for classification. This can be used for further analysis and decision making concerning water resource suitability for irrigation. In addition, a decision matrix (DM) is created and used to identify the suitability of the water resources for irrigation as shown in Figure 6. Eight classes are identified for water suitability according to the DM application for sixty different water resources in Siwa oasis, Egypt. The results indicate that the most water resources belong to class number 6, which has an extremely low suitability water resource as shown in Table 1 and Figure 7. The system also provides the user by a report indicating water resource name, location and description of water quality classes according to different criteria of classification.

Two main decisions can be obtained according to the results of water resources categorizing: (1) which water resources are suitable for a specific crop? and (2) Which crops are suitable for a specific water resource?

The first decision aims to identify all water resources (wells or springs) suitable for farming of a specific crop. The developed system creates a Table (crops) that contains crop name and its tolerance to Salt (E.C), Boron and Chloride according to [9]. The Crops table is joined to Wells table to identify all records from wells table which have a salinity, boron and chloride less than or equal to the maximum limits of crop tolerance and to identify all water resources suitable for a specific crop. These query files are linked with the VB project and used to create a report file or to change output file formats.

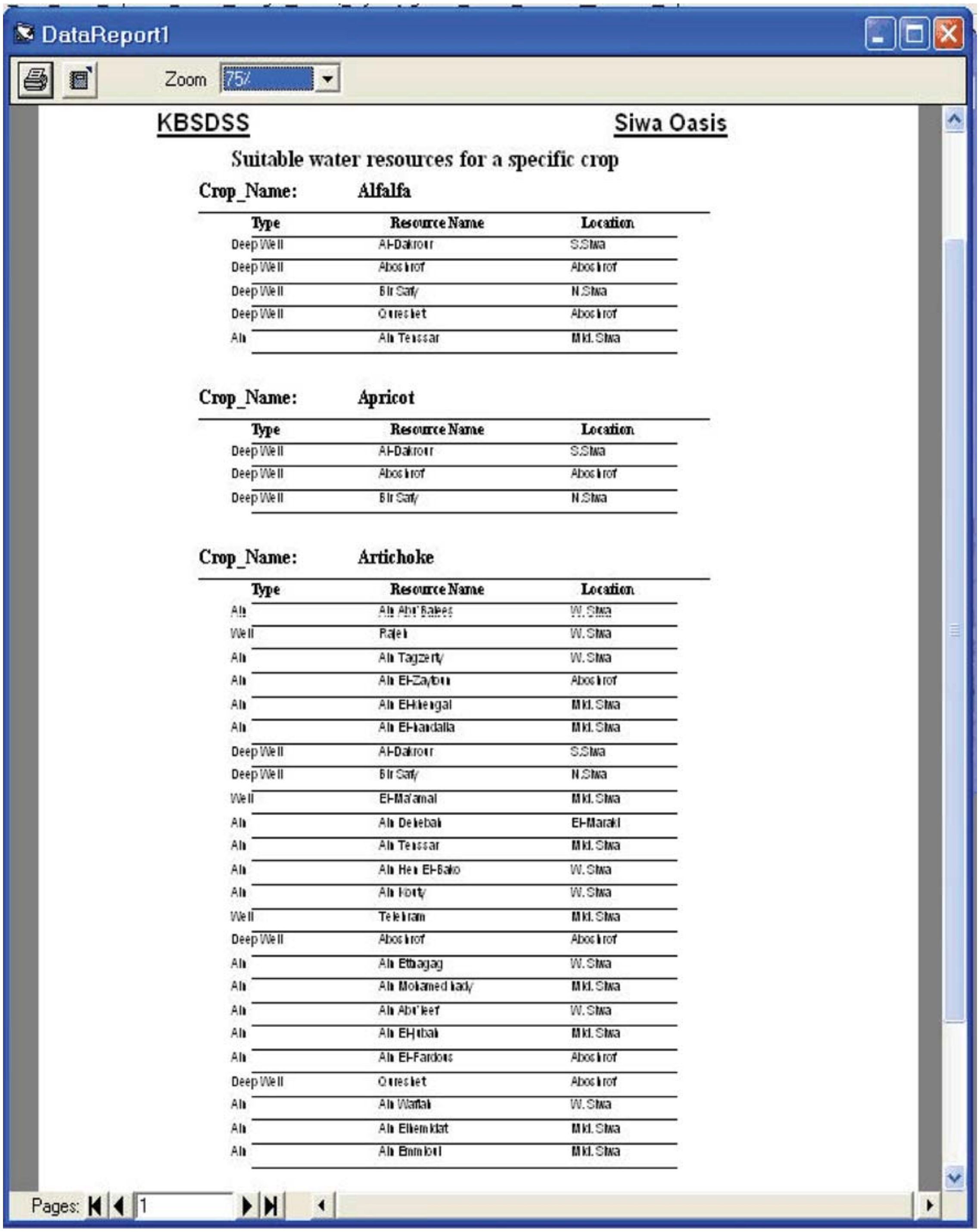

Fig. 8: A report displaying water resources suitable for a specific crop

The second decision aims to identify all the crops suitable for farming and irrigated by a specific water resource using query file to join a query file with Crops table through the Crop Identification field. These query files are also linked with the VB project and used to create a report file. An example of the results is shown in Figure 8.

The developed Knowledge Base system is linked with the main interface of KBSDSS for Siwa Oasis as shown in Figure 9. This represents a user-friendly interface for a user or decision maker.

Fig. 9: The main interface of the KBSDSS of Siwa oasis

CONCLUSION

This research aimed to develop an intelligent information system for groundwater categorization and classification. The developed system integrates more than one research field and tools, including DSS, GIS, knowledge base, modeling and visualization enhancement. The developed system is able to help the decision makers to select the suitable water resources for cultivating a specific crop. It can also be used to take a decision about the suitable crops for a specific water resource.

A knowledge base system (KB) for water resources categorizing is implemented and tested for the groundwater analysis results of some water resources in Siwa oasis, Egypt. The developed KB can be used for other areas for according to the international classification schemes.

A Decision Matrix (DM) is developed depending on the application of the KB. The developed DM is used for defining the suitability of sixty one water resource in the study area. The results obtained from DM application indicate that most water resources have low suitability for irrigation. Some of them are not suitable and a fewer one have a high quality especially the water from deep aquifer.

A graphical user interface (GUI) was developed to link all the system components and to help the user and decision maker to get the results and make decisions. This GUI is developed in the Visual Basic environment and used *ArcObjects* and *MapControls* to make a full integration between the expert system, GIS and DBMS.

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