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Spatial Decision Support System for Water Wells Mining in Siwa Oasis

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Abstract: This paper aims to develop a suitability model based on several spatial models for groundwater characteristics. These models produce raster maps for the predicted values of the previous characteristics at smaller scale. The proposed model integrates all the grids related data in one table and provide decision makers with the necessary information about water quality at different locations in Siwa Depression, Egypt. The deliverables are represented as text reports and suitability maps. ArcGIS with Spatial Analyst extension is used in building the proposed model. A Graphical User Interface (GUI) is designed to allow and present various levels of integration. This location suitability model and the multilayered database represent a spatial decision support system (SDSS). This SDSS can support decision makers for water management and provide accurate, relevant and timely information on groundwater quality and suitability. The model produces different maps of suitable locations for different crops. The model is linked with the main user interface of Siwa SDSS. This SDSS interface is a menu driven interface. The main interface links all system modules and provides support to non-expert users, planners and decision makers to deal with the overall system options.

Key words: Spatial Knowledge-Base Models · Spatial Suitability Analysis · Spatial Decision Support Systems SDSS · Siwa Oasis

INTRODUCTION

Models have two objectives: exploring the implications of making assumptions about real world processes and predicting the behavior of the real world system under different circumstances. Studies completed at larger scales can be relevant to understanding processes at smaller scales [1]. Spatial models represent an important source for the decision makers and planners in environmental management procedures. They are also an important component of spatial decision support systems (SDSS) [2] and [3]. The relationships are modeled using spatial analysis tools. Since there are many different types of interactions between objects, ArcGIS and Spatial Analyst provide a large suite of tools to describe interactions [4]. Process models can be used to describe processes, but they are often used to predict what will happen if some action occurs, [5] and [6].

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. [7]. Problems arise when the quantities of available information are huge and non-uniform and their quality could not be stated in advance [8]. The combined availability of spatial data and communication, computing, positioning, GIS and remote sensing technologies has been responsible for the implementation of complex SDSS since the late 1990s. Spatial data have to be available, therefore, GIS and RS technologies are of central importance for spatial data handling and analysis [9].

The Study Area: Siwa Oasis is a depression located in the northern part of the Western Desert of Egypt. The oasis located 65 km east of the Libyan frontier and 300 km south of the Mediterranean coast and around 800 km west Cairo. Siwa Oasis represents a valuable natural resource from both local and regional views. The oasis suffers from different environmental problems.

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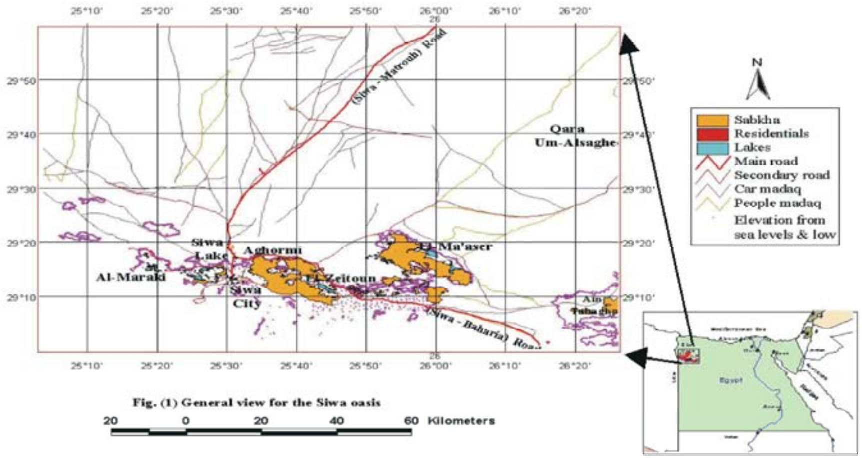

Fig. 1: A general map of Siwa Oasis

Groundwater is the main source of water in the oasis. This requires a reliable management system for this valuable water resource. It is limited by the longitudes 25°18' - 26°05'E and the latitudes 29° 05'- 29° 20'N as shown in Figure 1.

The oasis has many environmental problems as water salinity, soil salinization and water table rising, which needs to take the best decisions to minimize the risk of these problems. Siwa is located above two great and complex reservoirs of groundwater. The upper deposit is composed of interstitial water confined in the cavities of the Miocene limestone extending down to depth of 50 to 700 m below the surface. The lower aquifer composed of thick layers of Nubian sandstone [10].

This paper aims to develop a suitability model based on several spatial models (Surface models) for groundwater characteristics (salinity, sodium ratio, Boron, chloride, nitrate, bicarbonates, infiltration ratio and pH) of sixty water resources distributed in Siwa Depression.

MATERIALS AND METHODS

Data Collection, Preparation and Interpolation: This phase includes preparing and tabulating the groundwater chemical characteristics for some random distributed water resources in the study area. The data are input into text files, one for each feature. A detailed data about groundwater chemical composition: Cations (Ca^{++}, Mg^{++}, Na^{+} and K^{+}), anions ($HCo3^{-}$, Cl^{-}, $So4^{-}$), SAR, trace elements (Fe, Zn, Mn, Cu and Cd) and location (x, y) in decimal degrees (DD) for some wells and water springs in the selected environment. These data are available for six periods from Sep. 1998 to Mar. 2001. The data for each period are separated into two tables one for wells and another for water springs. Each parameter is interpolated and ArcMap is used to create projects (.mdx), each project display multi-data frames, each data frame display the spatial representation of one feature. For example: SAR9_98 data frame represents the spatial distribution of the predicted value for sodium adsorption ration (SAR) along Siwa Depression in September 1998. Figure 2 represents an example of those projects.

These spatial models are used to predict groundwater quality in different sites and to provide the changes of water characteristics along different periods. This helps in getting an overview about the future changes in the water quality of the selected environment. It will also be the main data source for taking a decision about the suitability of a location (x, y) for digging a new well.

ERDAS Imagine Software is used to separate the related data for each cell from different grids. This is important to assign the attributes for each cell which includes numeric values representing feature at the center of that cell. Cell values are then converted into ASCII files. Microsoft-Access DBMS is used to import the ASCII files and create eight corresponding tables (EC table, SAR table...). Query file is created to join all the eight tables using x, y location fields as a relation fields then adding all fields in the joined tables in the query contents.

Data Management and Model Execution: The model is implemented by a VB code and executed through a user interface. The user interface is a control buttons task manager as shown in Figure 3. This allows the selection of different modules such

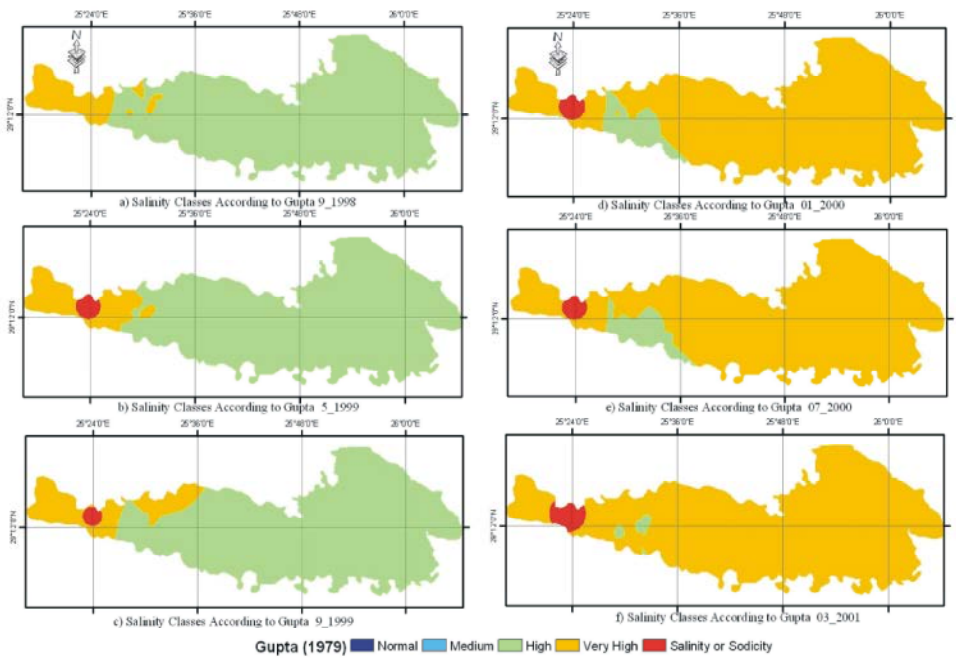

Fig. 2: Salinity Spatial modeling for wells salinity

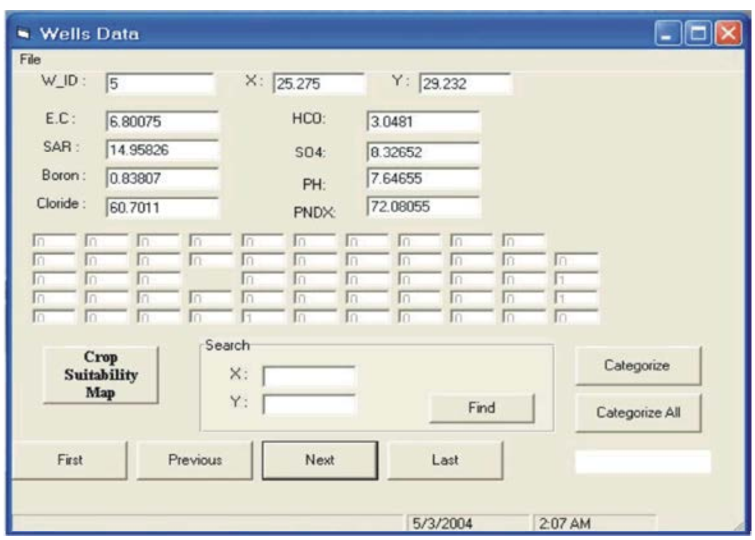

Fig. 3: Control buttons task manager interface for model management

as existing program for browsing, categorizing, searching for a specific location and displaying the groundwater characteristics at this point and gives a decision about suitable crops for this location. The main features include:

- Browsing and navigating through the data
- Searching for a specific location (x, y in DD)
- Visualization of the crops suitability map of the study area

Browsing and Navigating Through Data: The user can navigate through the existing groundwater database, which include: *moving* to first record, *skip* to next record, go to *last* record and return to *previous* one. These functions are managed and executed through some of control buttons (*first, next, last and previous)* as shown in Figure 3.

Identifying Suitability of Specific Locations: This feature is useful when a decision maker needs to know the water

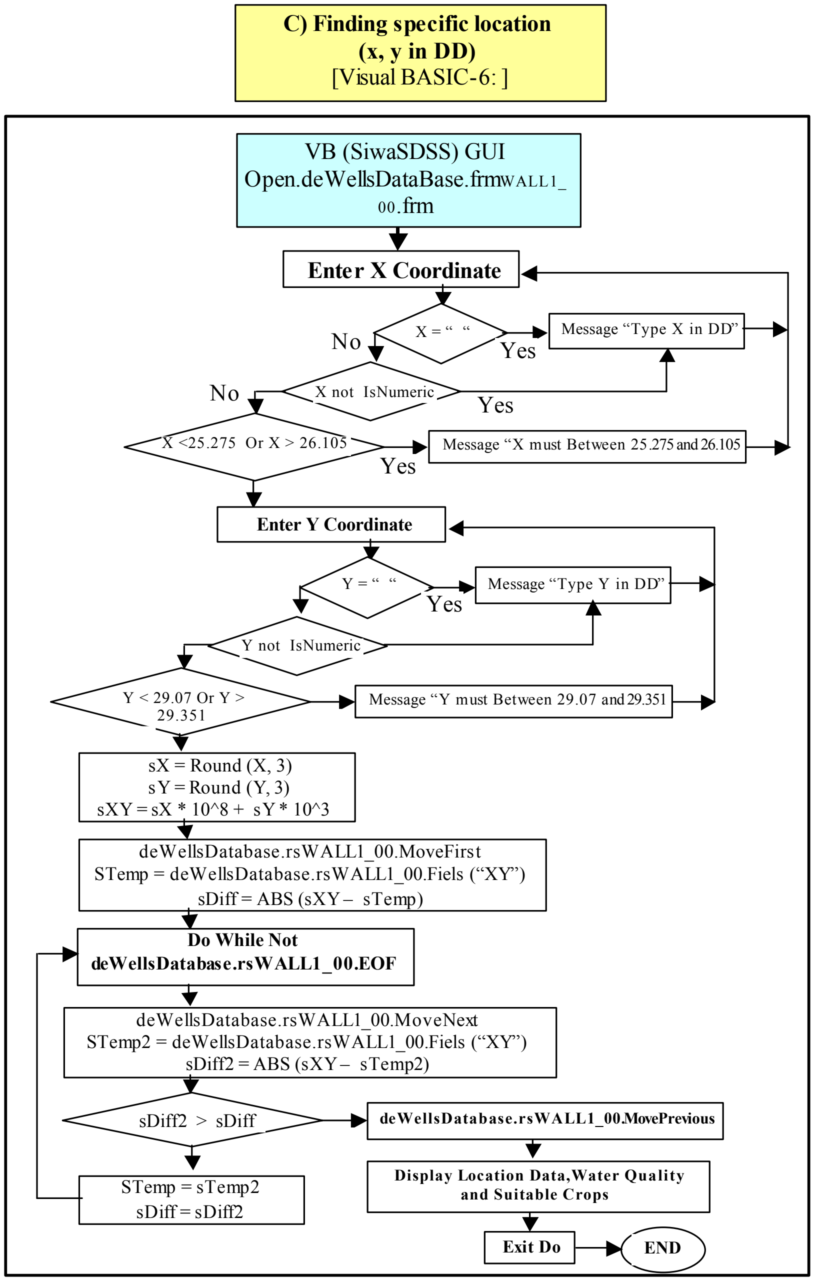

Fig. 4: The flow chart for location searching procedures of the model

quality or suitability of groundwater at any location in the study area. An example of such query is: If a user needs to digging up a new well at a specific location, what would be the water quality conditions at that location? The developed model can answer this question through recording the coordinates (x, y) of this location using a GPS instrument or from a geo-referenced image or map. The coordinates of the position must be in decimal degree units (DD).

The model functions by entering (x, y) coordinate values in DD units. If the entered point data are found in the database, the system will display the water quality criteria for that point. If the entered point data are not found exactly, the system will display the coordinates of closest two points and then select the closest one. The flow chart for the used code for searching procedures is presented in Figure 4.

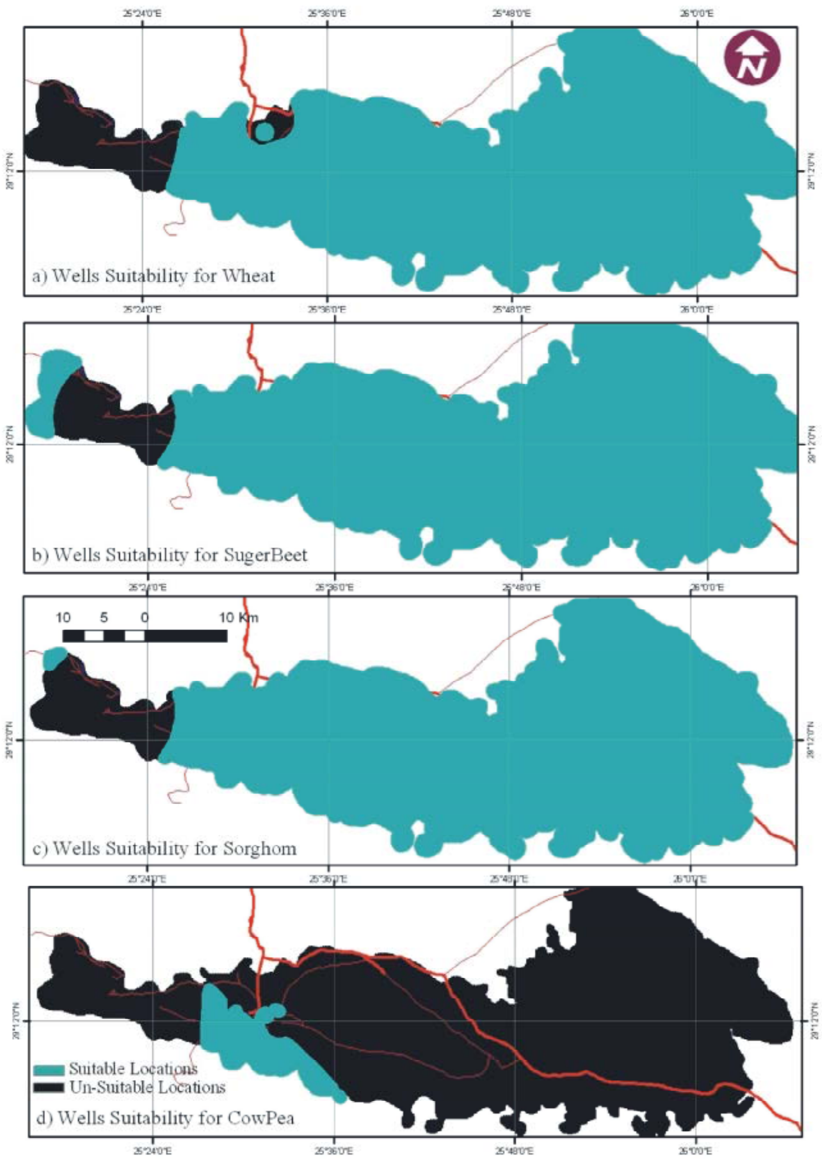

Fig. 5: Location suitability map for some crops

Visualization of Crops Suitability Map: After running the model, the database is updated and all fields of categories are assigned the corresponding values according to the different water quality criteria. All crops fields are assigned 1 for suitable and 0 for unsuitable. The data is linked with GIS to display the suitability map for each crop across the study area. These maps can be managed and visualized using ArcMap. ArcObjects and MapControls are also used to display and manage the suitability map inside the VB project through the map control button (Crop Suitability Map) on the interface as shown in Figure 5.

CONCLUSIONS

Spatial modeling is a useful spatial technology tool for predicting any features over the surface of the Earth in a best resolution based on pre-measured data. Spatial models for groundwater quality characteristics in an arid oasis in Egypt are carried out. The knowledge base (KB) for water resources categorizing is carried out and tested. KB can be used for any water resource at any place for categorizing according international classification schemes.

The developed model for location suitability provides decision makers necessary information about water quality in Siwa Depression. It can identify which crops are suitable for that location. The model is linked with GIS to visualize the crop suitability map for different crops. This technique can be used for any similar environment and can be implemented for any criteria as soil types, climatic conditions and so on.

The model is linked through a VB code with MS-Access DBMS and ArcGIS to produce different maps of suitable locations for different crops. The model is also linked with the main user interface of Siwa SDSS. This interface is a menu driven interface and is linked with all system modules and helps planners and decision makers to deal with the overall system options.

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