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A GEOGRAPHIC INFORMATION-BASED DECISION SUPPORT SYSTEM FOR SUSTAINABLE LAND USE ASSESSMENT IN IRRIGATED AREAS

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ABSTRACT

The overall objective of this study is to design geographic information based decision support system, for sustainable land use assessment in irrigated areas. One of the particular interests in this study is the linkage between geographic information system (GIS), decision support system (DSS), artificial neural network (ANN) models and knowledge base (KB). The goal of this type of integration is to develop more useful computer tools that can assist in spatial problem solving, not only by conventional computing, but also by some sort of reasoning similar to those of human experts.

The developed system is an integrated approach represented by a computer program designed specifically for non GIS users, and could be used by decision-makers, technical advisers, planners, and researchers in a facilitated land use decision making process. The system consists of ten components namely, digital map, mapping object, external database, knowledge base, model base, internal database, report generator, graph generator, and map generator accessed by a user interface.

The results of the KB subsystem validation showed a full agreement with the expert's knowledge. The results of the crop water requirement model gave a high correlation (0.998) with those obtained from the FAO's CropWat program for all land uses (crops).

The system used two case studies, to test the overall system performance, and generate different kinds of maps, reports and graphs from which in-depth data analysis was possible. One of those cases came from the Sugar Beet area, Egypt, while the other one was obtained from Fuka-Matrouh area, Egypt. The testing results show that the system provides a powerful tool to support the user in multi-objectives multi-criteria decision-making process for the different alternatives of land use ranking and selection.

The developed system was compared with other local and international land evaluation software. It is evident that this system achieved the integration of GIS and intelligent systems. Moreover, the developed software helps in easing and speeding the land evaluation process, as well as mapping the land capability and crop suitability.

Keywords: Land evaluation, Decision support system, Artificial neural network, GIS, Models, Knowledge base.

INTRODUCTION

Land use planning is the systematic assessment of land and water potential alternatives for land use, and economic and social conditions in order to select and adopt the best land use options. Its purpose is to select and put into practice those land uses that will best meet the needs of the people while safeguarding resources for the future. Land use planning can help decision-makers to use land in such a way that current land use problems are reduced and specific social, economic and environmental goals are satisfied, (FAO, 1993).

Decision support systems are computer-based systems with the objective to enable a decision-maker to devise high quality solutions to what are often only partially formulated problems. The DSS is composed of three elements; the database; the model base, and the dialog base. The database contains the main files of information used in models that are contained in model base. The model base comprises management scenarios and other mathematical models that are used to analyze data. The dialogue base (user interface) provides a user-friendly interactive front end to the DSS (Brennan and Elam 1986).

Multiple objective decision support systems (MODSS) has been classified as a specific type of system within the broad family of DSS (Lu et al 2000). The multi objective, multi criteria decision-making process is the most realistic and interesting in land evaluation (Rossiter 1994). Integrating the knowledge components in the DSS conceptual framework will considerably increase the expertise embedded in DSS and will improve the capacity for users to enhance this expertise (Michel and Leif 1995).

Geographic information systems, which allow for the acquisition, storage, manipulation, analysis, visualization, dissemination of geospatial information are therefore of prime interest to society at large. This implicit definition of a GIS follows the well-known IMAP (input, management, analysis, presentation) model, but adds the aspect of dissemination of the information, because the latter has become a major focus of research, development, and economic activity (Heipke, 2004). The distinct contribution of GIS to decision making lies in the ability of these systems to store and manipulate data based on its spatial location. Spatial data is of interest in a wide range of government and business activities (Mora et al, 2003).

There are many strategies for coupling GIS with models. Fedra (1993) discussed the types of coupling that could be sought between environmental models and GIS, and classified such integration as loose, close, and tight coupling with GIS software.

The spatial decision support systems (SDSS's) are becoming important tools for planning and decision making for environmental management. The SDSS has to combine spatially explicit observational data and simulation of physical processes with a representation that is suited for communication with non-specialist decision-makers. Model based simulation systems provide the mean for scientific analysis of decision scenarios (Taylor et al 1999). One of the most important capabilities of GIS is to interpret and map data for solving spatial problems. One of the approaches for the analysis of spatial data has focused on artificial intelligence techniques such as knowledge-based systems with GIS (Choi and Usery, 2004).

Knowledge must be represented in such a way that allows us to relate facts in a formal representation scheme to facts in the real world. Rule-based systems allow knowledge to be represented as a set of IF-THEN or condition-action rules. Reasoning can be controlled using a forward or backward chaining interpreter (Cawsey 1998).

Yeh and Li, (1998) tested different development scenarios and land consumption parameters, and concluded that planners and government officials can use GIS sustainable land development model as a DSS in areas in the world that are under great pressure of rapid urban growth. The model will be able to suggest areas where future urban development should take place.

Automated Land Evaluation System (ALES) is an empty shell, that is, a framework within which land evaluators are free to generate different models and develop database. This program has a framework where proposed land uses can be described and evaluated in both physical and economic formats. It matches the knowledge base describing the proposed land use and the database where land units are described. ALES does not have any georeferencing capability, can not produce maps, and can not take into account spatial analysis requirements (Rossiter and Van Wambeke, 1997).

The MicroLEIS (Microcomputer Land Evaluation Information System) was developed to assist specific types of decision-making faced with specific agro-ecological problem in the Mediterranean region. It has been designed as a knowledge-based approach with incorporates a set of information tools. Each of these tools is directly linked to another, and custom applications can be carried out on wide range of problems related to land productivity and land degradation (de la Rosa *et al.* 2003).

Parametric land evaluation system (PLES-ARID) is a mathematical model constructed to calculate the land productivity and land suitability, and designed to simplify and facilitate data processing for users (Khalifa 2004).

Agriculture land evaluation system for arid region (ALES-Arid) was designed to estimate land capability and land suitability evaluation, based on the minimum data set concept. The GIS software can read the output for visualization of land capability and suitability maps. This approach is considered as loose coupling with GIS software (Abd-El Kawy 2004).

The main objective of this study is to build geographic information based decision support system, for sustainable land use in irrigated areas.

MATERIALS AND METHODS

System design and implementation

To achieve the objective of this study, the target system integrated the functionality of GIS with knowledge base and DSS. The system consists of the following main components (Figure 1):

1) Digital map; 2) Mapping object; 3) External database; 4) Knowledge base; 5) Model base; 6) Internal database; 7) Report generator; 8) Graph generator; 9) Map generator; and 10) User interface.

The digital map utilizes the shapefile format developed by ESRI (ESRI, 1998), to load, view and query the map. **Mapping object** is used to display the map, and provides most common GIS functions (ESRI 2002). The system has been designed to include eight GIS functions necessary by the non-GIS users, namely, display a map; zoom and pan throughout a map; identify features; select features based on SQL (Structured Query Language) expression; label map's feature with text; copy and paste maps; virtual database join, and map printing.

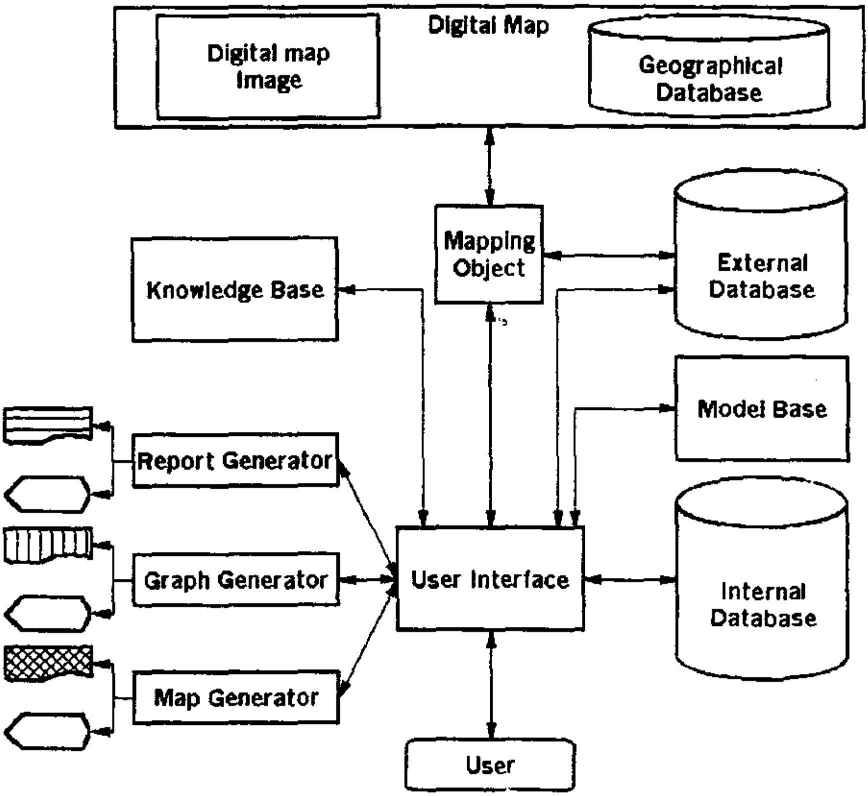


Figure 1: Target system architecture.

External database is a MS-Access database file format created inside a project directory to store the input and output data. Figure (2) shows the external database tables with inter relationships.

The Internal database contains the constant parameters that used for the model base. It contains seven tables to store the neural network models connections weights, in addition to a table to store the constant parameters of the crop water requirements model (crop type, crop index, crop growing period, and crop coefficient value).

Twenty-two land use types (crops) were selected based on Sys et al (1993), taking into consideration the regional experience in the form of production rules to simulate the FAO land suitability classification framework (FAO, 1976a) and maximum limitation method, for estimating the suitability class according to the land characteristics for each land use type.

The Knowledge base has been formalized in an object-oriented manner. To represent the knowledge using an object oriented knowledge representation scheme, the class hierarchy, the instance variables and instance methods of each class have been defined. After defining the instance variables, a set of instance methods operating them for each class have been defined. The production rules are organized in five groups, namely, land capability classes; environment limitations; land suitability classes; climate according to the metrological data; and irrigation water suitability classes.

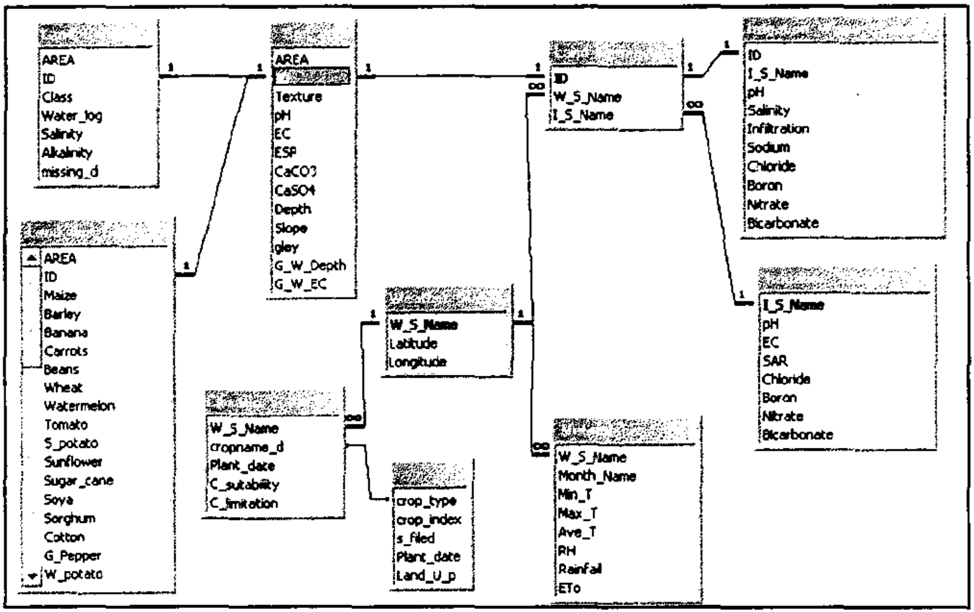


Figure 2: External database tables and their relationship.

As an example, based on the decision process of land capability classification, the following ratings of land characteristics have to be made during the process:

1. Determine the soil texture rating;
2. Determine soil depth rating;
3. Determine calcium carbonate status rating;
4. Determine gypsum status rating;
5. Determine salinity/alkalinity rating;
6. Determine drainage rating;
7. Determine slope rating;

Rules for each step are treated, and defined as instance methods for the relevant class as summarized. Land capability index is determined using the model base. The definition of instance methods with two examples, namely, "Gypsum_rating" and "Capability_class" could be illustrated as follows:

Class name: Gypsum_rating
Instance variable: Soil_Gypsum_rating
Instance methods:

```
 Determine_Soil_Gypsum_rating( )
   {  If Gypsum >= 50 THEN Soil_Gypsum_rating = 30
      If Gypsum <= 0.3 THEN Soil_Gypsum_rating = 90
      If Gypsum>0.3 AND Gypsum <= 10 THEN Soil_Gypsum_rating = 100
      If Gypsum > 10 AND Gypsum <= 25 THEN Soil_Gypsum_rating = 85
      If Gypsum > 25 AND Gypsum < 50 THEN Soil_Gypsum_rating = 60 }
```

Class name: Capability_class
Instance variable: Land_capability_class
Instance methods:

```
 Determine_Land_capability_class (Capability_index)
  {     If Capability_index > 80 THEN Land_capability_class = I
        If Capability_index <= 80 AND Capability_index > 60 THEN
                Land_capability_class = II
        If Capability_index <= 60 AND Capability_index > 45 THEN
                Land_capability_class = III
        If Capability_index <= 45 AND Capability_index > 30 THEN
                Land_capability_class = IV
        If Capability_index <= 30 THEN Land_capability_class = V    }
```

The model base was used to allow user to obtain information about land capability index, crop water requirements, the leaching requirements and land use suitability. The model base subsystem contains four models, namely, land capability (Sys *et al.*, 1991); crop water requirements (FAO, 1998b); leaching requirements (FAO, 1976b); and land suitability using artificial neural networks (Gaafar, 2005). **The report generator** was designed to represent a powerful and flexible reporting tool, that enable the user to preview, print, or export the report as a file directly to disk. **The Graph generator** can be used to create graphs to display the data. It was designed to enable the user to preview, print or save the charts.

Map generator represents the visualization technique for results presentation. It allows the users to look at the geographical data. Figure (3) illustrates the main components of the graph generator.

The User interface serves to integrate various sub-systems as well as to interact with the user. It consists of a system desktop with a pull-down menu bar at the top. There are eight sub-menus that form the functions in this system. To choose from the pull-down menu, the user can click the mouse or use a keyboard shortcut. A button bar located beneath the menu bar in the system window contains buttons giving the user quick access to various controls. The user can use the mouse to click on a button to choose it. The button bar contains a buttons for open new project, open saved project and print map functions. It also contains a buttons for zoom-in and zoom-out, full extent, identify, select, and pan map functions, (Figure 4).

Case studies.

The system was tested using two case studies, yielding different kinds of maps reports and graphs from which in-depth data analysis was possible. The digital maps and all the related information and data are obtained from Yehia (1998) for the Sugar Beet area, Egypt while the other was obtained from Bahnassy *et al.* (1997) for Fuka-Matrouh area, Egypt.

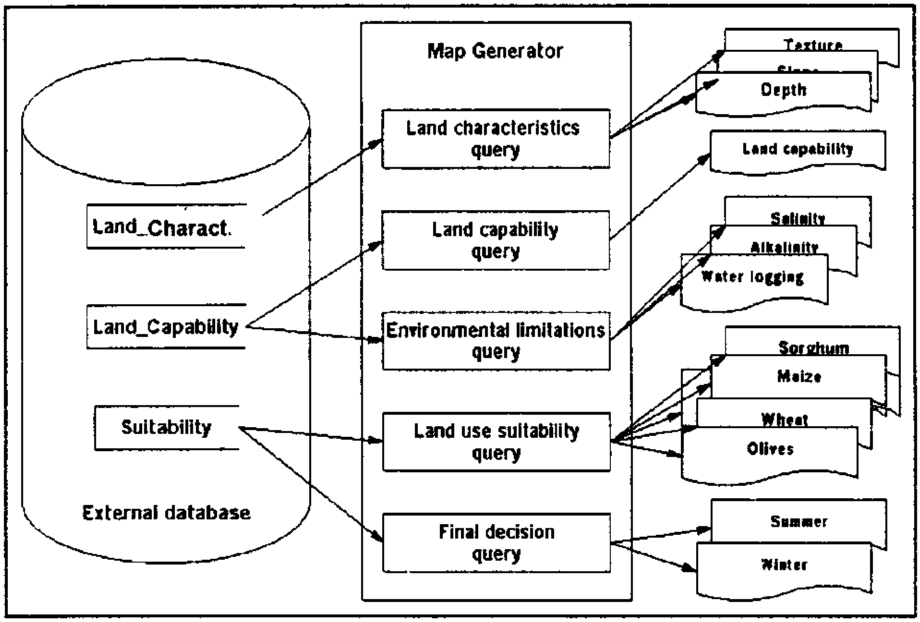


Figure 3: The types of maps produced by the system and the data flow diagram.

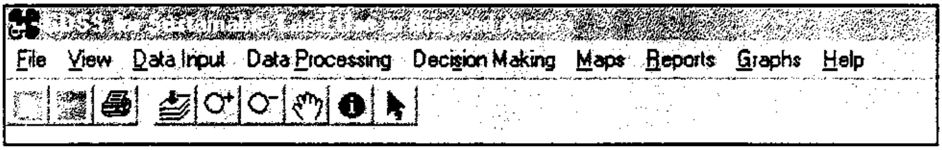


Figure 4: The main user interface

Sugar Beet area (as described by Yehia, 1998):

The Sugar Beet area is located at 55 Km southwest of Alexandria city. It is bound by Alexandria-Cairo desert road from the east, El-Nasr canal from the south and the west, and by Bahig canal from the north. It lies approximately between latitudes $30^{\circ}\ 45^{''}$ and $30^{\circ}\ 55^{''}$ N and longitudes $29^{\circ}\ 30^{''}$ and $29^{\circ}\ 50^{''}$ E. the Suger Beet area runs west and north-west covering an approximately area of 113,750 feddans. It is divided into 6 villages of 1200 – 1500 feddans. The study area is located in villages No. 23, 24, 25 and 26. These villages cover approximately 5000 feddans, which were delivered to the graduates in October, 1991.

Fuka-Matrouh area (as described by Bahnassy *et al.*, 1997):

The study site is located west of Matrouh city, and extends from the sea shore in the north to about 40 km in the south, and from Fuka town in the east to Ras Alam EL-Roam in the west, and bounded by longitude 27° 25" - 27° 55" E and latitude 30° 56" - 31° 35" N. The total acreage of the study site is 2834.55 km^2.

RESULTS AND DISCUSSIONS

System validation:

To validate the performance of the system, it has to be tested on sample cases and its results compared with the results obtained from other sources for the same cases. It is important then to use a test set that covers all the important cases and enough examples to ensure that the correct results obtained are not just anomalies.

Knowledge base validation:

The validation of the knowledge base is an essential step in the global system validation. In addition to validating the knowledge base structure, its contents should also be validated and checked for correctness, completeness and consistency. To evaluate the rule base correctness, the expert's knowledge provides a set of trial cases (input / expected output), then the system used these trial cases as an input, the results produced by the system have been compared with the results (expected outputs) initially provided by the experts. The results showed that, the accuracies of the rule bases (land capability classification, environment limitation hazard, land use suitability, climatic suitability, and water suitability) are 100% correct compared with the expert's knowledge. Table (1) shows the results of knowledge base testing.

Table 1: Results of the ability of the knowledge base to classify the testing data.

Rule bases	Number of Testing Data	Classification		Accuracy %
		Correct	Incorrect	
Land capability	643	643	0	100
Environment limitation	160	160	0	100
Land use suitability	250	250	0	100
Climatic suitability	1210	1210	0	100
Water suitability	450	450	0	100

Crop water requirement model validation:

To test the accuracy of the model, the results obtained from the model were compared with the CropWat model results for the same data input. CropWat version 4.3.0013 (FAO, 1998b) is a program that used to calculate ETo and the crop water requirements. The correlation coefficient for the results obtained from the model and that obtained from CropWat program is 0.998 (Figure 5).

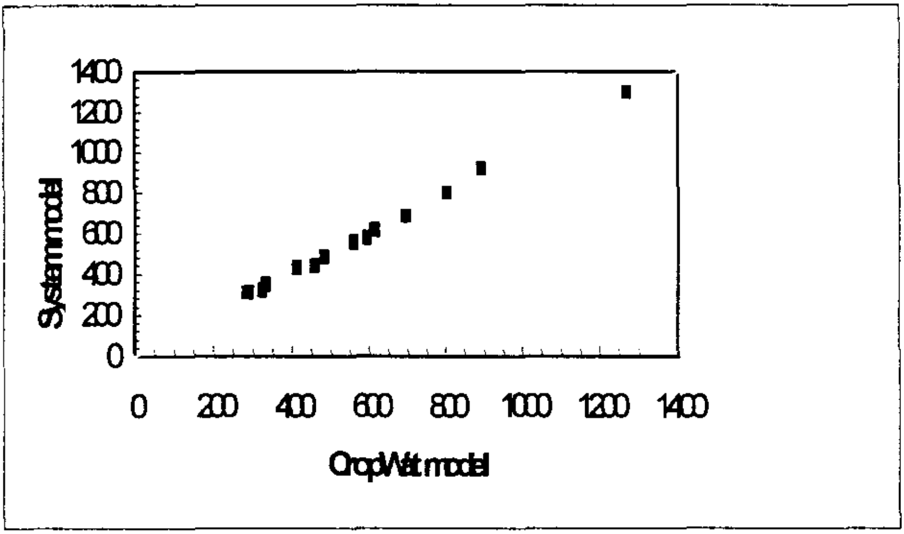


Figure 5: Comparison of crop water requirements (mm/period) obtained from the system model and from CropWat model.

Spatial data input:

The digital maps used as inputs for the system are in ESRI's shapefile format. The number of polygons is 57 and 213 for the Sugar Beet area and the Fuka-Matrouh area, respectively. Once the digital map is selected and loaded, the system creates new database file with the same name of the digital map with the extension "mdb" and creates the required table. It also creates a text file with the same name to store all parameters and settings of the new project. If the project is already created and the user needs to open it, the user select the "Open Project" option from the "File" menu and select the project name from the dialog box. The system loads the digital map, which has the same name as the project, and opens its external database. The user interface displaying these digital maps is illustrated in figure (6) and figure (7) for the Sugar Beet area and the Fuka-Matrouh area, respectively.

Attribute data input:

The polygon vector land unit map having a unique internal number (ID) for each polygon, as well as the non-spatial (attribute) data related to each polygon. The non-spatial data contains the soil characteristics, such as texture, EC, exchangeable sodium percent, pH, depth, etc, whether station and metrological data, irrigation water characteristics, and other information. These values are recorded and stored in attribute table in the external database.

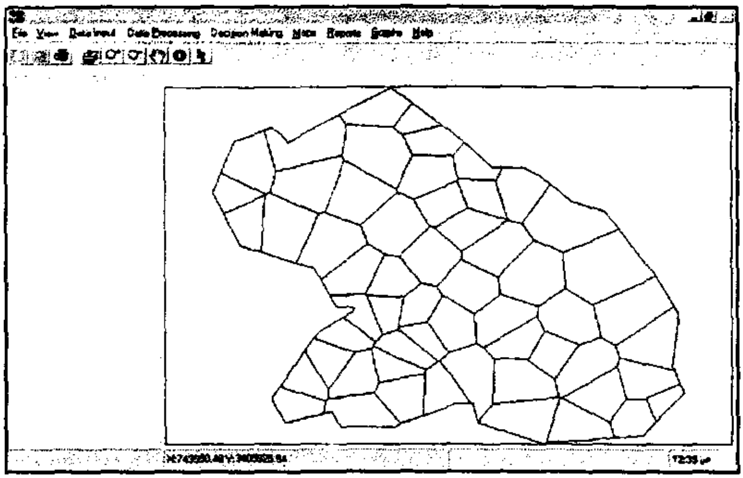


Figure 6: The system user interface displaying Sugar Beet area digital map.

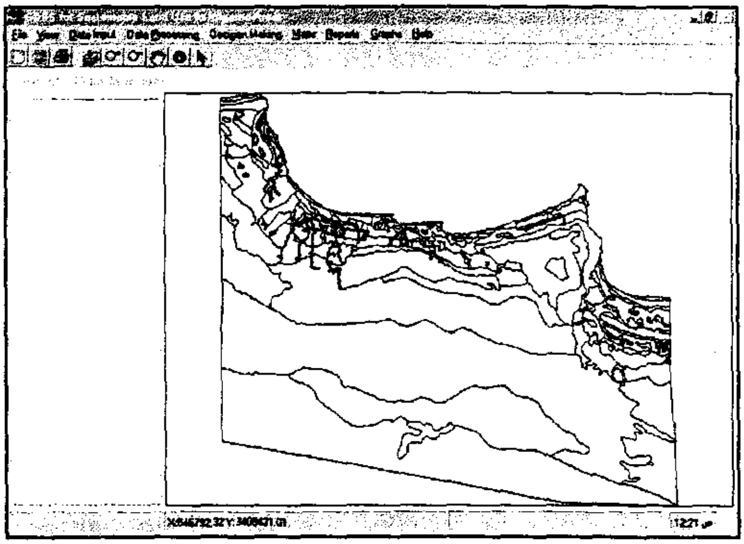
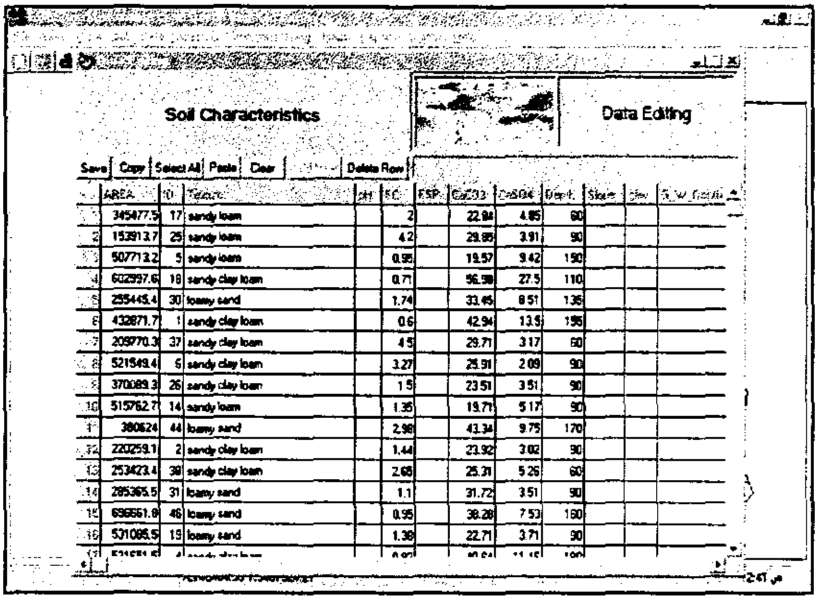


Figure 7: The system user interface displaying Fuka-Matrouh area digital map.

Figure (8) shows the user interface for data entry. It illustrates that the system was designed to enable users access and update of the non-spatial (attribute) data stored in the external database easily. The system allows user to edit data in a tabular form similar to spreadsheet. It supports the copy and past function from the spreadsheets and vise versa. It also supports the data entry through the combo box to eliminate the errors during the data entry stage for the text data. The entered data should be first edited and tested for correctness. Once the data is validated and become error free, the user could be directed to the data processing step.



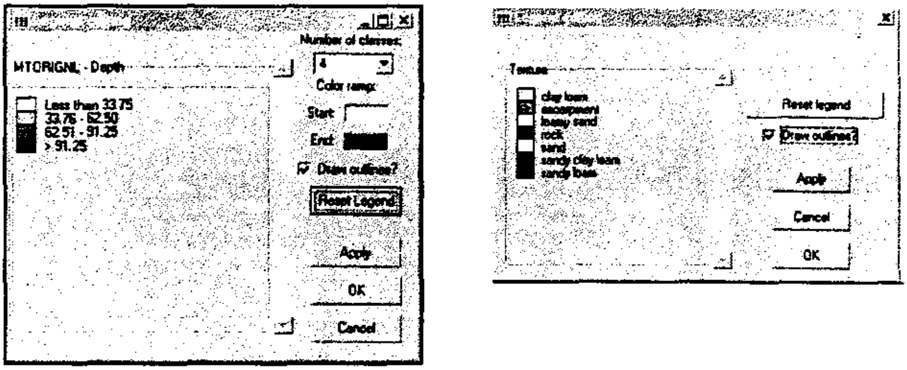
	AREA	ID	Texture	pH	EC	ESP	CaCO3	CaSO4	Depth	Slope	Elev	G_W_Depth
1	345477.5	17	sandy loam		2		22.94	4.85	60			
2	153913.7	25	sandy loam		4.2		29.95	3.91	90			
3	507713.2	5	sandy loam		0.95		19.57	9.42	150			
4	602997.6	18	sandy clay loam		0.71		56.59	27.5	110			
5	255445.4	30	loamy sand		1.74		33.45	8.51	135			
6	432871.7	1	sandy clay loam		0.6		42.94	13.5	195			
7	209770.3	37	sandy clay loam		4.5		29.71	3.17	60			
8	521549.4	6	sandy clay loam		3.27		25.91	2.09	90			
9	370089.3	26	sandy clay loam		1.5		23.51	3.51	90			
10	515762.7	14	sandy loam		1.35		19.71	5.17	90			
11	380624	44	loamy sand		2.98		43.34	9.75	170			
12	220259.1	2	sandy clay loam		1.44		23.92	3.02	90			
13	253423.4	39	sandy clay loam		2.65		25.31	5.26	60			
14	285365.5	31	loamy sand		1.1		31.72	3.51	90			
15	696561.8	46	loamy sand		0.95		38.28	7.53	160			
16	531085.5	19	loamy sand		1.38		22.71	3.71	90			

Figure 8: Data entry user interface.

Map visualization:

The system yields different kinds of maps from which in-depth data analysis was possible. In addition to the standard menu bar and toolbar, a map view displays a graphic features in the right side of the system interface, and a map legend in the left side, which provides the user with the ability to show the name of the map layer that currently displayed and its legend. The legend shows the layer name and the symbol used to draw it, as well as any custom coloring that applied to the map. The pointer can be used to select tools from the tool bare to zoom the map, change the map extent, select map features, and perform other standard map functions that are familiar to users of GIS software and easily learned by less-experienced users. The system save the map properties that used for visualizing the map, i.e., the map name, the number of symbols, the number of classes, and the symbols color. The map view is not static, the user can modify the appearance of the map at any time after retrieving the previously saved view and resave it again.

The system classifies the numeric filed in the external database to create graduated color maps to reflect the status of the soil characteristics. The system allows user to choose the number of classes Figure (9A). The user clicks the "Start" and "End" color boxes to change the starting and ending colors for the color ramp. The Unique Values classification displays features by applying a different color to each unique value for the any text field in the external database. The system automatically assigns random colors to each unique classification (Figure 9B). The user checks the draw outline box if he wants polygons boundaries to be drawn. This is useful when the map has many small polygons. User clicks "Apply" to commit the changes or "OK" to commit and save the changes and close the legend editing dialog simultaneously (Figures 9A and 9B).


MTORIGNL - Depth

Number of classes: 4

☑ Draw outlines?

Texture

☑ Draw outlines?

(A) (B)

Figure 9: legend editing interface for numeric and string attributes.

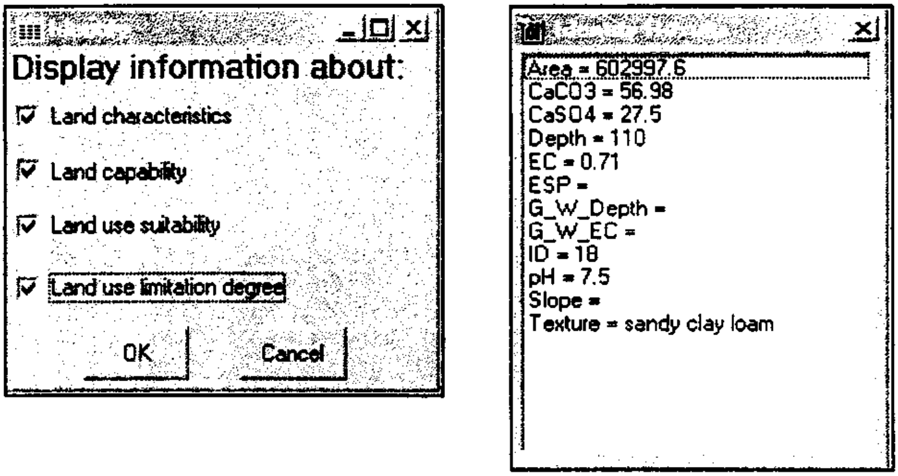
The system provides group of buttons to the user for navigating a map. "Zoom In" button is used to enlarge a particular area on the view, "Zoom Out" button reduces the map size, "Pan" button allows the user to move the view by pulling the display in any direction with the mouse, and "Full Extent" button zooms to the full spatial extent of the map in the map view.

To carry out spatial query about any polygon in the map, the user selects the identify function or button from the menu bar or from the tool bar, respectively. A dialog box appears asking the user to check the kind of information the user is looking, (Figure 10A). The user clicks on the desired information, and the system will display the results in the identify results box (Figure 10B).

The system provides a simple map layout in landscape (horizontal) format for printing. The layout includes a north arrow, legend, title text, and map view. The system supports

the user to edit or change the map title and print the map. The map will be printed to the default printer. The user can choose "Print Setup" function from the "File" menu to change printers or to access other printer options. Figure (11) shows the system user interface for printing a map.

Figures 12 and 13 show some land characteristics maps for the two study areas visualizing the numeric and string characteristics.



Display information about:

☑ Land characteristics

☑ Land capability

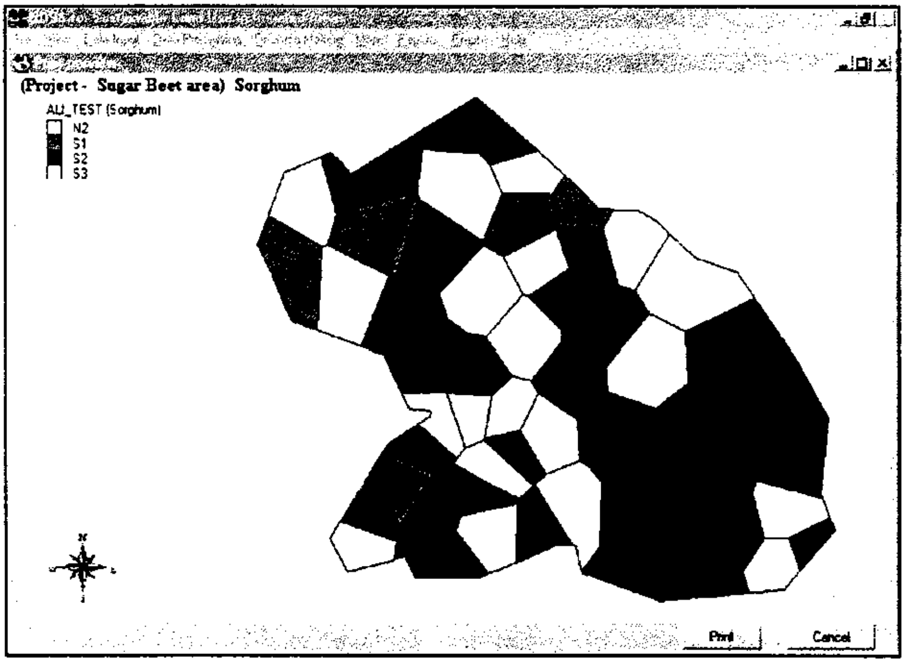
☑ Land use suitability

☑ Land use limitation degree

Area = 602997.6
CaCO3 = 56.98
CaSO4 = 27.5
Depth = 110
EC = 0.71
ESP =
G_W_Depth =
G_W_EC =
ID = 18
pH = 7.5
Slope =
Texture = sandy clay loam

(A) (B)

Figure 10: Identify dialog box (A) and results box (B).



(Project - Sugar Beet area) Sorghum

Figure 11: The system user interface for printing a map.

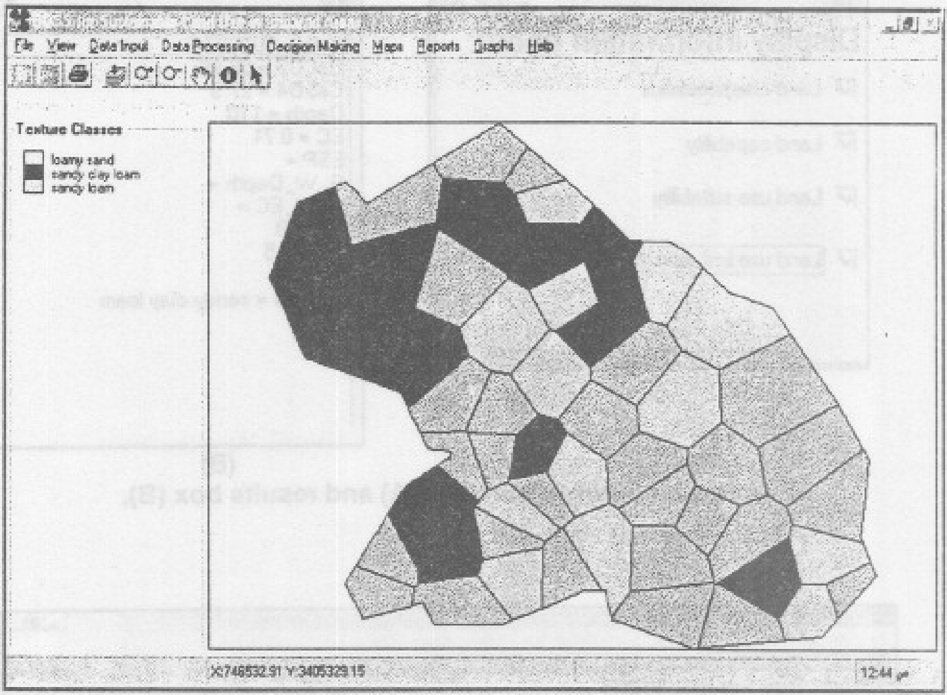


Figure 12: Texture map of Sugar Beet area.

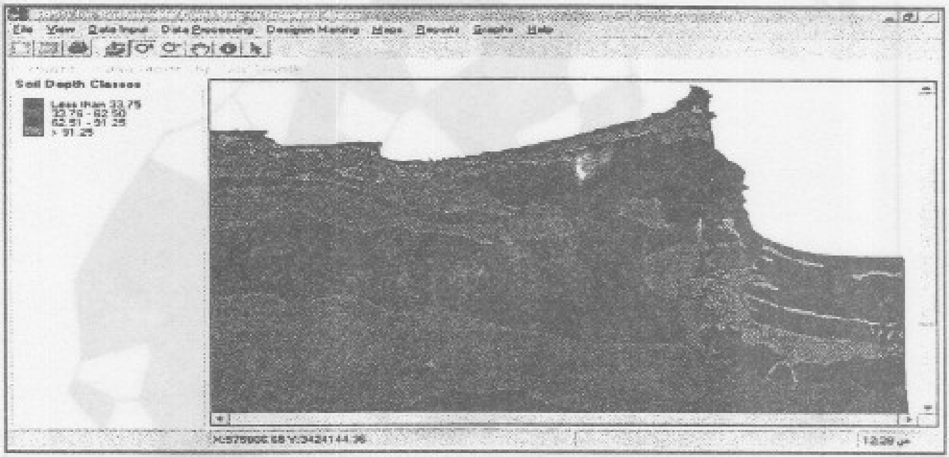


Figure 13: Soil depth map of Fuka-Matrouh area.

The data processing phase in the system estimates land capability and land use suitability for each land unit, climatic suitability for each land use type, and irrigation water suitability for each irrigation sources. The system displays the results on a map to allow the user to see distributions, relationships, and trends. Figures 14 and 15 illustrate the user interface of the system, displaying the map after determining land capability classes of all land units for the two study areas. The classes of land capability are clearly shown on the map by different colors.

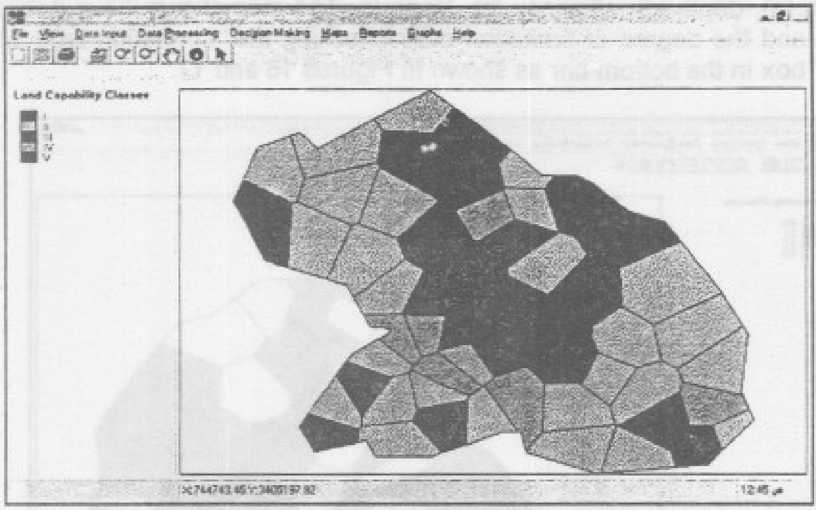


Figure 14: Land capability map of Sugar Beet area.

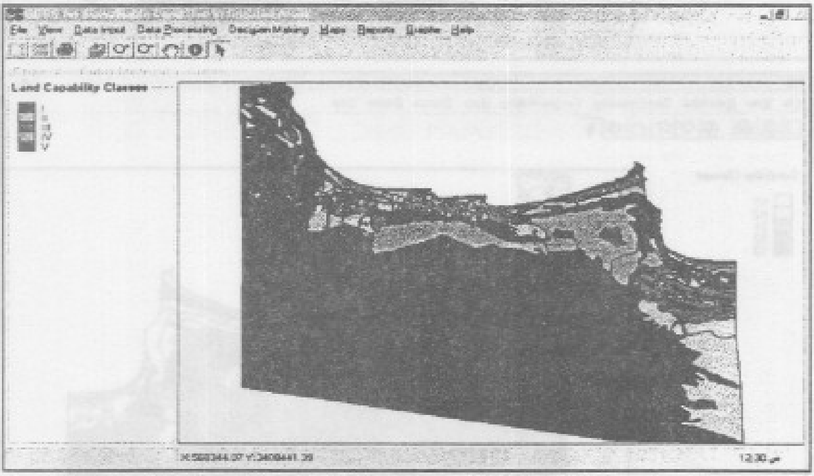
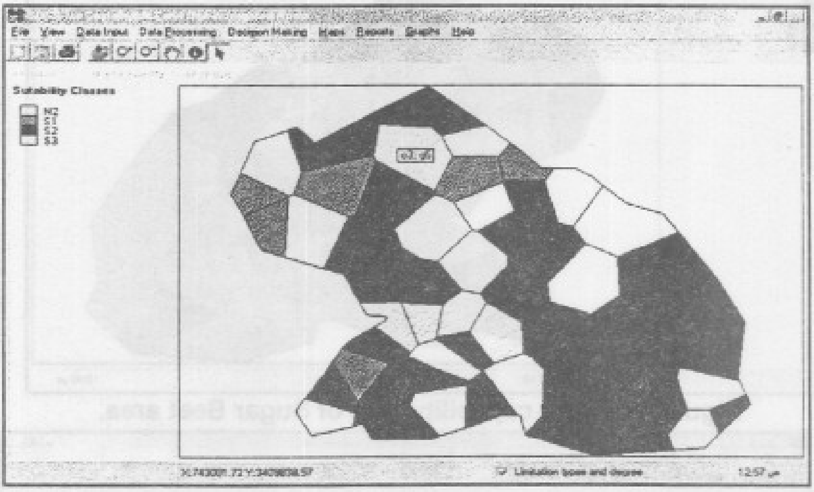


Figure 15: Land capability map of Fuka-Matrouh area

The system takes into account 22 land use types when carrying out the land use suitability evaluation. These land use types are grouped in three groups according to the season of growth. These groups are, summer, winter, and permanent as follows:

1. Summer season land use (Cotton, Green pepper, Maize, Onion, Sorghum, Sunflower, Sweet potato, Watermelon).
2. Winter season land use (Barley, Beans, Carrots, Soya, Wheat, White potato).
3. Permanent land use (Alfalfa, Banana, Citrus, Guava, Mango, Olives, Sugar cane).

These land use types are evaluated, and the results reflect the suitability class and type and degree of limitations for each land use. Seven soil limitations are involved, namely, texture (t), salinity (s), calcium carbonate (c), Gypsum (g), depth (d), alkalinity (a), slope (l). The map shows the suitability classes and the degree of limitation after checking the "Limitation type and degree" box in the bottom bar as shown in Figures 16 and 17.



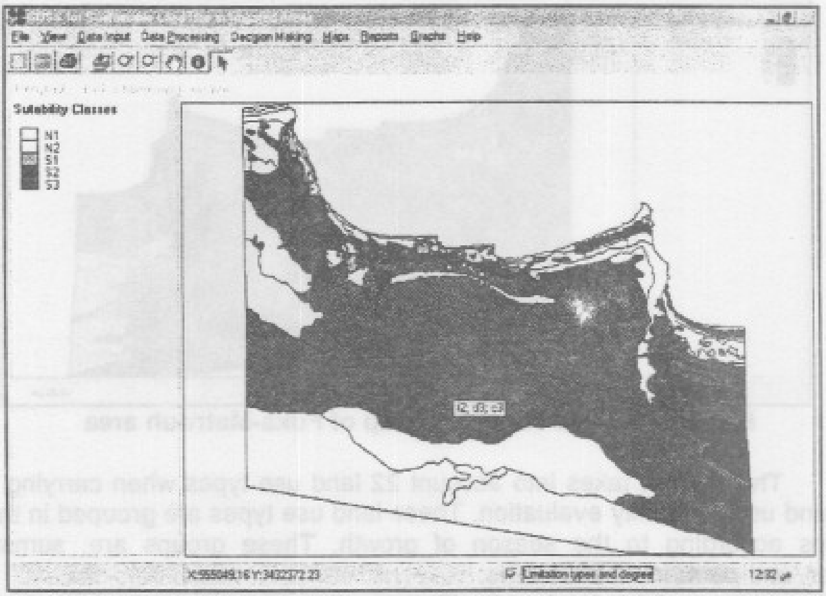
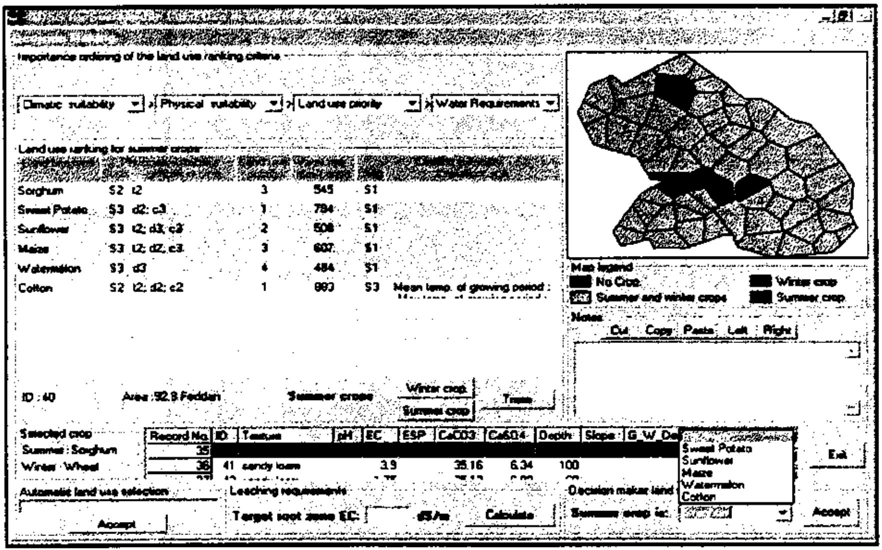


Figure 16: Land suitability for sorghum map of Sugar Beet area.

Figure 17: Land suitability for sorghum map of Fuka-Matrouh area.

Decision-making:

The system provides a user-friendly interface to allow selection of spatial polygons from the map, or from the land characteristics tabular form (Figure 18). The land use alternative ranking process extracts the necessary information corresponding to the selected polygon from the external database. The extracted information includes land use limitation type and degree; climatic limitation type and degree; land use priority; in addition the land use suitability class and the climatic suitability class. Also the system estimates the crop water requirement for each land use alternative. The objective of displaying these information is to give the decision-maker a clear view about the limitation of each alternative. Each land use alternative is evaluated and analyzed in relation to others, in terms of a pre-specified decision rule. The ranking depends upon the decision-making preferences with respect to the importance of the evaluation criteria (climatic suitability, physical suitability, land use priority, and crop water requirement). The system allows the user to change the importance order of the evaluation criteria to reflect the main objectives and the orientations of the decision-maker. For example, if the main objective of the decision maker is to select the land use type which has low water requirement, the criteria importance order will be climatic suitability > physical suitability > crop water requirement > land use priority. There are many different scenarios that could be generated according to the decision maker objective. The system also allows the user after ranking the alternatives to select the best alternative manually by the decision maker or automatically by the system for each polygon. The user can enter any text comments up to 255 characters for the selected polygon for winter or summer seasons. This text comments may reflect any advices, i.e. the type of management, leaching requirement, etc.



Importance ordering of the land use ranking criteria

Climatic suitability > Physical suitability > Land use priority > Water Requirements

Land use ranking for summer crops

Sorghum	S2	t2	3	545	S1
Sweet Potato	S3	d2; c3	1	794	S1
Sunflower	S3	t2; d3; c3	2	508	S1
Maize	S3	t2; d2; c3	3	607	S1
Watermelon	S3	d3	4	484	S1
Cotton	S2	t2; d2; c2	1	883	S3

Mean temp. of growing period :

ID : 40 Area : 92.8 Feddan

Selected crop

Summer : Sorghum

Winter : Wheat

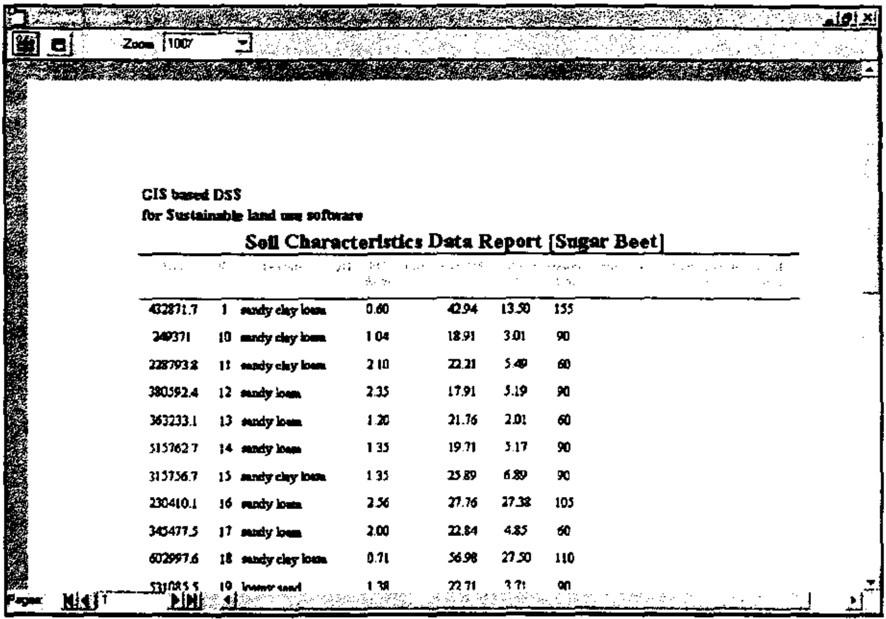
Record No.	ID	Texture	pH	EC	ESP	CaCO3	CaSO4	Depth	Slope	G_W_De
35										
36	41	sandy loam		3.9		35.16	6.34	100		

Leaching requirements

Target root zone EC: dS/m

Figure 18: Decision making user interface

Once the user clicks on the map polygon, it will flash with yellow color, and the soil characteristics, as well as the summer and winter crops corresponding to this polygon are displayed. If the user clicks on the "ID" from soil characteristics table, the polygon is flashed with yellow color, and the data corresponding to this polygon are collected from the external database and displayed in its position on the user interface according to the user request (summer, winter or trees). The user can select the land use type from the combo box and click "Accept" to store this decision with the text comment, or leaching requirement on the proper location in the external database. The user can also chose the "Accept" bottom at the "Automatic land use selection" section on the user interface to allow the system to select the land use type for all polygons automatically, according to the importance order of the land use ranking criteria. The system allows the user to calculate the leaching requirement by entering the value of the desired salinity of the root zone (Figure 18).



GIS based DSS
for Sustainable land use software

Soil Characteristics Data Report [Sugar Beet]

432871.7	1	sandy clay loam	0.60	42.94	13.50	155
249371	10	sandy clay loam	1.04	18.91	3.01	90
228793.8	11	sandy clay loam	2.10	22.21	5.49	60
380592.4	12	sandy loam	2.35	17.91	5.19	90
363233.1	13	sandy loam	1.20	21.76	2.01	60
515762.7	14	sandy loam	1.35	19.71	5.17	90
315756.7	15	sandy clay loam	1.35	25.89	6.89	90
230410.1	16	sandy loam	2.56	27.76	27.38	105
345477.5	17	sandy loam	2.00	22.84	4.85	60
602997.6	18	sandy clay loam	0.71	56.98	27.50	110
531085.5	19	loamy sand	1.38	22.71	3.71	90

Figure 19: Layout of soil characteristics report for Sugar Beet area.

Report generator:

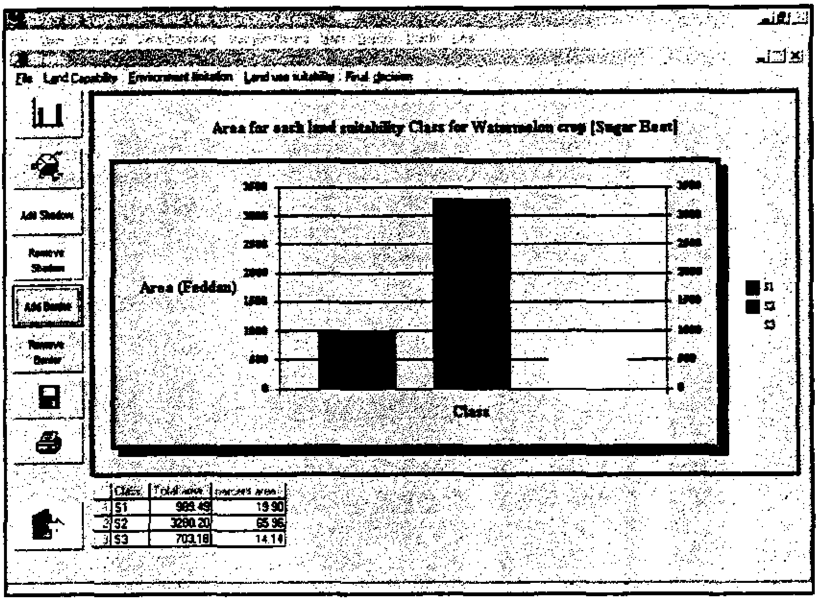
The report generator provides access to the external databases to summarize the data using the system's built-in SQL statements. The system creates several kinds of reports to summarize the information and data that were collected from the external database. The system enables the user to preview, print, export and save the report (Figure 19).

Graphs generator:

The system provides a user-friendly interface containing menu bar and buttons to support many graph functions. The system provides the charts in two forms, bar chart and pie chart. The system displays the chart data in a tabular form below the chart to allow the user make a better decision. The user can save the graph in "bmp" format or print it (figure 20).

Comparison with other land evaluation system:

Table (2) provides a summary view of the referenced works depicting the basic features of the implemented systems. Although direct comparison is not possible, it is evident that this system achieves the integration of geographical information system and intelligent systems.



	Class	Total area	percent area
1	S1	989.49	19.90
2	S2	3280.20	65.96
3	S3	703.18	14.14

Figure 20: The graph user interface containing example of the bar chart

Table 2: Summary view of the main features of the referenced systems.

Feature	International systems		National systems		
	ALES	MicroLEIS	PLES-ARID	ALES-Arid	Developed system
Map integration	No	No	No	No	Yes
GIS functionality	No	No	No	No	Yes
GIS integration	Yes	Yes	Yes	Yes	Yes
Knowledge base (KB)	Yes	Yes	Yes	Yes	Yes
KB base user customization	Yes	No	No	No	No
Neural network supports	No	No	No	No	Yes
Estimate water suitability	No	No	Yes	Yes	Yes
crop water requirement	No	No	No	No	Yes
Economic suitability	Yes	No	No	No	No
Local upgrade ability	No	No	Yes	Yes	Yes

CONCLUSION

The developed system is an integrated approach for helping decision-maker to make better decision about sustainable land use alternatives, using multi-objectives multi-criteria decision-making process. It alternatives, using multi-objectives multi-criteria decision-making process. It integrates the functionality of GIS, knowledge base, neural network models and DSS. It is modular in design so new functionality can be easily added to the core application. This approach to software design makes upgrades simple and provides expandability as user requirements grow. The developed system could be distributed without having to pay a licensing fee for any GIS software.

The system provides a user-friendly interface for organizing, storing, retrieving, displaying and maintaining data. It is targeted towards users who have only the basic skills in dealing with computers and GIS software.

The system contains built-in queries to provide immediate information in multiple format to support the decision making process. This format can be tabular reports, graphs, and maps. The system allows the user to modify the map at any time, including a previously saved view.

Compared with the local and international land evaluation software, the developed system achieved the integration of GIS and intelligent systems.

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نظام دعم القرار مبنى على نظام معلومات جغرافى لتقييم الاستخدامات المستدامة لاراضى المناطق المروية

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تهدف هذه الدراسة الى تصميم نظام دعم القرار مبنى على نظام معلومات جغرافى لتقييم استخدامات الاراضى المستدامة للمناطق الزراعية المروية. و تعتبر احد اهتمامات هذه الدراسة هو الربط بين نظم المعلومات الجغرافية (GIS) و نظم دعم القرار (Decision Support System) و نماذج الشبكات العصبية الاصطناعية (Artificial Neural Network) و قواعد المعرفة (Knowledge Base). ويهدف هذا النوع من التكامل الى تطوير ادوات حاسب آلى أكثر فاعلية و يسر و التى تساعد متخذ القرار فى حل المشاكل المكانية ليس فقط عن طريق الحسابات التقليدية و لكن ايضا عن طريق اضافة طرق تفكيرية مماثلة لطرق التفكير الانسانية.

و يعتبر النظام المطور طريقة تكاملية متمثلة فى برنامج حاسب آلى مصمم خصيصا للمستخدمين ذو الخبرة المحدوده او غير مستخدمى نظم المعلومات الجغرافيةو يمكن استخدام هذا النظام بواسطة متخذى القرار، المستشاريين الفنيين، المخططين، و الباحثيين و المهتميين بعملية اتخاذ القرار. و يتكون النظام المطور من عشر مكونات اساسية وهى الخريطة الرقمية ، mapping object، قاعدة البيانات الخارجية، قاعدة البيانات الداخلية، قاعدة المعرفة، قاعدة النماذج، منتج التقارير، منتج الرسومات البيانية، منتج الخرائط و واجهة المستخدم.

و توضح النتائج المتحصل عليها من تقييم قواعد المعرفة أن هناك توافق تام بين النتائج المتحصل عليها من قواعد المعرفة بالنظام و المعرفة الانسانية الخبيرة. كما أوضحت النتائج المتحصل عليها من تقييم نموذج الاحتياجات المائية للمحاصيل المختلفة أن هناك ارتباط عالى بين النتائج المتحصل عليها من النموذج و كذلك المتحصل عليها من برنامج الـ CropWat حيث كان معامل الارتباط ٠,٩٩٨ وذلك لنفس البيانات المدخلة. و لتقييم الاداء العام للنظام المطور تم لستخدام منطقتين دراسة و انتاج أنواع مختلفة من الخرائط و التقارير و الرسومات البيانية طبقا لطرق تحليل البيانات المتاحة. و تمثل منطقة الدراسة الاولى منطقة بنجر السكر و الثانية تمثل منطقة فوكه بالساحل الشمالى الغربى بمصر. و أوضحت نتائج اختبار النظام العام أن النظام يقدم اداة فعالة لدعم المستخدم فى عملية اتخاذ قرار متعدد الاهداف متعدد الخصائص multi-objective, multi-criteria و ذلك لترتيب و اختيار بدائل استخدامات الاراضى. كما تم مقارنة النظام المطور مع بعض نظم تقييم الاراضى الدولية و المحلية و اوضحت نتائج المقارنة ان النظام المطور قد حقق التكامل مع نظم المعلومات الجغرافية و النظم الذكية. ويعتبر برنامج الحاسب الالى الذى تم تصميمه اداة تسهل عملية تقييم الاراضى للاستخدامات الزراعية المختلفة بالاضافة الى رسم خرائط القدرة الانتاجية والصلاحية للمحاصيل المختلفة.