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Design of Multi-Criteria Spatial Decision Support System (MC-SDSS) for Animal Production

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Article Info	ABSTRACT
	This paper presents a Multi-criteria spatial decision support system (MC-SDSS) as a tool for decision making and planning. MC-SDSS can be used to assess different criteria with different weights. We believe that such tool can be utilized to help policy/decision makers to improve animal production in Egypt. MC-SDSS facilitates the integration of the exploration and evaluation phases of the decision-making process in a transparent and interactive system that allows policy/decision makers to carry out the analyses without advanced geographical information system (GIS) or multiple criteria decision analysis (MCDA) training. We use weighted overlay method to support data spatial analysis, and then visualize and analyze different factors such as "Diseases", "Climate", "Veterinary care" and "Economical factors" which affect the animal production in Egypt. The proposed tool policy/decision makers can change their weights and parameters according to their different study areas. Moreover they can use final suitability maps from this tool.

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1.   INTRODUCTION

Agriculture plays a vital role in the Egyptian economy, with the government placing a significant emphasis on this sector, as it accounts for almost 20% of GDP and employs nearly 30% of the working population. Food crises in less-developed countries have been noted to be the main obstacle to economic development. Moreover, feeding adequately a population growing at an annual rate of 2.1 %, with limited land and water resources, is considered the most important challenge for Egypt. The population of 74 million is expected to rise to 90 million by the year 2017. The high population growth rate is a major constraint for sustainable development in Egypt. Population density is very high according to the 1986 census, about 1.170 persons per Km2. As much as 97 percent of the population is living in about 5 percent of the area. The high density in the Nile Valley and Delta is responsible for increasing deterioration of the environment. Geographical redistribution of population may have to be done on a large scale. Livestock numbers have changed around the world from 1995 to 2008. In Egypt the population dynamics tells interesting situation: dairy cattle -5.3%, buffaloes +12.1%, beef cattle +50.0%, sheep +29.9%, goats +32.8%, while people numbers increased more than 18%. Nevertheless, there is a shortage of protein and calcium from animal sources produced in Egypt in comparison to nutritional requirements, and there is an increasing gap between dairy products produced domestically and the amount consumed. The gap between domestic animal production and consumption has been estimated at an average of 17 per cent for red meat and 19 per cent for milk. This gap has been continuously widening over recent years and consequently dependence on food imports has been increasing [1].

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Changes in the Egyptian agricultural policies are linked to social consequences, in an environment where the enormous pressure of population growth and other related problems such as unemployment are a pertinent disturbing factor. Parallel to the search for more living space outside the Nile valley and Delta are considerations of social stability. The Egyptian government has accepted to initiate challenging agriculture projects, which may influence its economy in the present time, but it will guarantee food security for its population at least for the forthcoming decades [2].

Geographical Information System (GIS) links a location and attribute information and enables a person to visualize patterns, relationships, and trends. This process gives an entirely new perspective to data analysis that cannot be easily seen in a table or list format or on a paper map. Exploring data using GIS turns data into information into knowledge. There are two ways that the layers of location can be visualized on a map namely rater layer and vector layers. *Raster layers* are organized in a grid of identically sized cells. The cells have a uniform length and width (square shaped) and are called "pixels." On the other hand, *Vector layers* are represented as points, lines, or polygons. A vector layer cannot mix types together. One layer cannot have both points and polygons. The layer would have to be split into two separate layers; one for points and one for polygons. Vector data is used when the features have specific locations and boundaries and the attribute data is uniform throughout the individual features. Examples of vector layers include bus stops (point), roads (line), and counties (polygon).

Spatial Decision Support System (SDSS) is an interactive and computer-based system designed to support a user or a group of users in achieving higher effectiveness for solving semi structured or non-structured spatial decision problems.

Decision makers have turned to analysts and analytical modeling techniques to enhance their decision making capabilities. Spatial decision support systems (SDSS) are explicitly designed to support a decision research process for complex spatial problems. SDSS provide a framework for integrating database management systems with analytical models, graphical display and tabular reporting capabilities, and the export knowledge of decision makers. Such systems can be viewed as spatial analogues of decision support systems (DSS) developed in operational research and management science to address business problems [3].

What really makes the difference between a SDSS (Spatial Decision Support System) and a traditional DSS (Decision Support System) is the particular nature of the geographic data considered in different spatial problems. In addition, traditional DSSs are devoted almost only to solve structured and simple problems which make them non practicable for complex spatial problems [4]. SDSS requires the addition of a range of specific techniques and functionalities used especially to manage spatial data, to conventional DSSs. These additional capacities enable the SDSS to [3];
- acquire and manage the spatial data,
- represent the structure of geographical objects and their spatial relations,
- diffuse the results of the user queries and SDSS analysis according to different spatial forms including maps, graphs, etc., and to
- Perform an effective spatial analysis by the use of specific techniques.

Spatial problems are complex because they are semi-structured or ill defined in the sense that the goals and objectives are not completely defined. Spatial problems are multi-dimensional and often related to non-spatial information. Each spatial problem can have a large number of decision alternative solutions. These alternative solutions to the spatial decision problems are normally characterized by multiple criteria upon which they are judged [6].

Multi-criteria decision making (MCDM) refers to making decisions for alternatives in the presence of multiple and conflicting criteria. A main contribution area of MCDM is making preference decision (e.g., evaluation, prioritization, selection) over the available alternatives such as a set of products that are characterized by multiple, usually conflicting attributes [5].

MCDA can be viewed as a set of mathematical tools and methods used to solve decision problems that involve contradictory or conflicting criteria. MCDA proposes models to solve different problem types such as choice, ranking or sorting of a set of alternatives (also called alternatives) within a finite set according to multiple criteria [7].

MCDA supports decision makers in simultaneously considering multiple factors and their value judgments about the relative importance of those factors.

The objectives of this paper are to present a generic approach to GIS-based MCDA that:
(a) Supports an exploration phase of animal production decision making with tool that facilitate exploratory analysis and visualization and help structure the problem for evaluation.
(b) Integrates the exploration and evaluation phases of the decision-making process in a transparent and interactive system that allows policy/decision makers without advanced GIS or MCDA training to carry out the analyses.
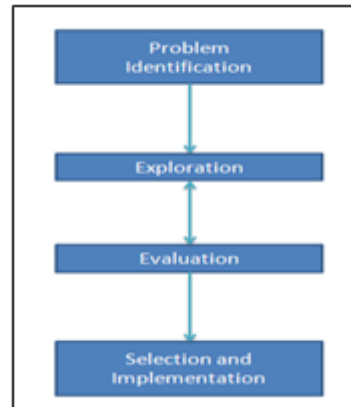
2. PROBLEM FORMULATION

Figure 1. Typical phases of a decision-making process

MCDA is a set of methods used in support of decision-making processes. Figure (1) presents a simplified combination of several decision-making process models. If an identified problem is to be evaluated systematically, it must be structured to suit the evaluation method being used. This structuring is the key outcome of an exploration phase. To apply MCDA methods, structuring must include selection of decision objectives and the criteria by which they will be evaluated. In MCDA, the evaluation phase involves aggregating criteria values for each alternative, typically by applying criteria weights, to determine a rating or ranking of alternatives. The iterative nature of decision analysis is represented in Figure (1) by the arrow in each direction between the exploration and evaluation phases. The recommendation(s) from the evaluation phase are subsequently carried forward for final selection and implementation [8].

A key requirement for supporting exploration phase activities is to allow decision makers to explore where multiple land values, represented in separate GIS layers, interact spatially. In this paper, we used weighted overlay method to support spatial analysis of data.

The weighted overlay applies one of the most used approaches for overlay analysis to solve multi-criteria problems such as site selection and suitability models

In this paper, we use weighted overlay to select suitable area for animal production in Egypt. There are different factors such as "Diseases", "Climate", "Veterinary care units" and "Economical factors" which affect the animal production in Egypt. The paper takes in consideration influence of each factor because importance and influence of each factor differs according policy/decision makers point of view. An Interactive flexible decision analysis interface is used to determine influence of each factor.

The purpose of this paper is to present a generic approach to GIS-based MCDA as following:

1. Visualize different factors such as "*Diseases*", "*Climate*", "*Veterinary care*" and "*Economical factors*" which affect the animal production in Egypt.
2. Drive new raster data layers from vector data layers.
3. Reclassify raster data.
4. Build an interactive Multi-Criteria Spatial Decision Support System (MC-SDSS) that allows users without advanced GIS or MCDA training to carry out the analyses see Figure (2).
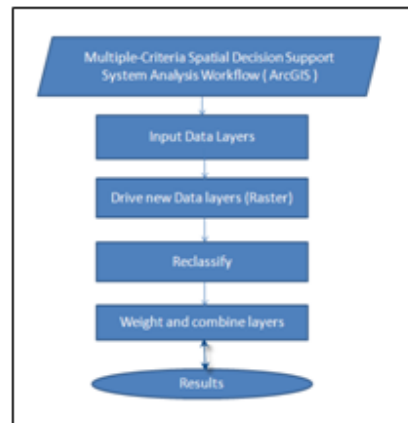
Figure 2. General Workflow of Multicriteria Evaluation (MCE)

3. PROPOSED METHOD

The evaluation phase rates/ranks alternatives using the selected criteria and weights. Because of its transparency and simplicity, a weighted overlay method is used for multiple criteria evaluation (MCE) [8].

This paper supports spatial MCDM scenario evaluation process. The decision maker needs to build an interactive MCDM evaluation model by specifying parameters and assigning weight to each of these parameters. The evaluation model is instantiated with alternative scenario instances. These scenarios are executed using the solver that is tightly coupled within the evaluation model. The results are then ranked for selection. The decision maker selects the scenarios for evaluation to the scenario. Then, an evaluation model is built by selecting the appropriate criteria from the input scenario. Then, the decision maker assigns a weight to each of the criteria. Finally evaluates the output map scenario. The built-in solver not only calculates values according to the formula but also ranks these values. The highest value is given as 100% and other scenarios are calculated on a ratio basis by comparing the highest value [6].

3.1. Visualization

In these step we use GIS engine to visualize OLAP dimensions by preparing data in ArcCatalog GIS using feature classes and relationship class for El Sharkeya governorate.

Three layers namely "*Veterinary Units*", "*Climate*" and "*Economical Standard of Living*" are represented as Polygon feature class. Each disease is represented by Geodatabase table. Relationships classes in the Geodatabase manage the associations between objects in one class (feature class or table) and objects in another [5]. Objects at either end of the relationship can be features with geometry or records in a table see Figure (3).
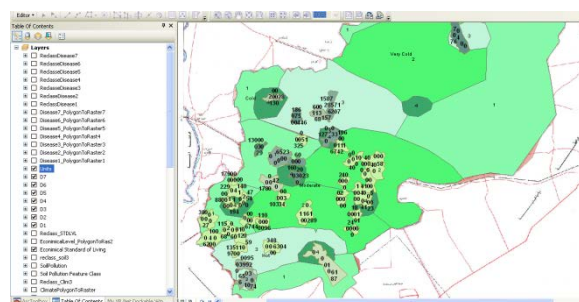

Figure 3. El Sharkeya Governorate Map with "*Veterinary Units*", "*Climate*" and "*Economical Standard of Living*"

3.2. Drive New Data Layers (Raster)

Prepare and unify layers format to be Raster data. There are several ways to think about converting raster data in ArcGIS. You may want to convert non raster data into raster data or vice versa, such as

converting a polygon into a raster. "*Diseases*", "*Economical*", "*Soil Pollution*" and "*Climate*" layers are converted from Polygon to Raster see Figure (4).
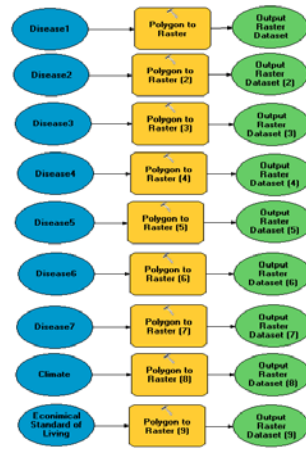

Figure 4. Convert Polygon to Raster

3.3. Reclassify Raster Data

Reclassify data to values range from 1 to 9, all data reclassified to give weights. 9 is the most suitable value for animal production and 1 is the least see Figure (5).
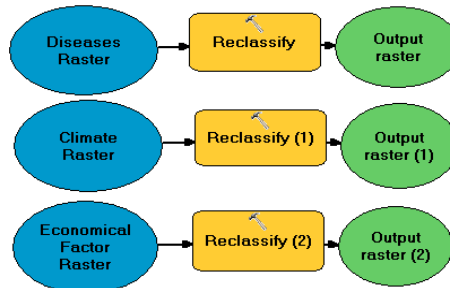

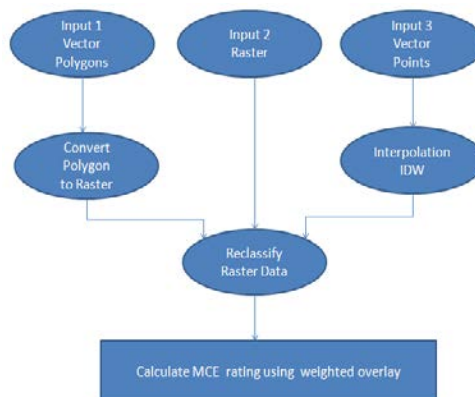Figure 5. Reclassify Raster Data Layers

Figure 6. Spatial Multiple Criteria Evaluation (MCE) Workflow

3.4. Build an Interactive Multi-Criteria Spatial Decision Support System (MC-SDSS) that Allows Users without Advanced GIS or MCDA Training to Carry Out the Analyses.

Integration of the exploration and evaluation phases of MCDA in a single system is guided by a set of high-level policy/decision makers' requirements. The exploration phase activities help policy/decision makers build MCE analysis scenarios. MC-SDSS is a Windows® application that was developed using Microsoft Visual Studio 2010® with the VB.net® programming language, and based on the ArcGIS 10® platform see Figure (7).
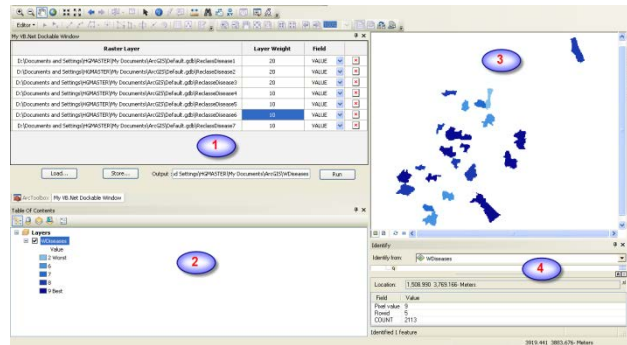

Figure 7. Mult-Criteria Spatial Decision Support System (MC-SDSS) policy/decision maker interface (1) MCE pane, (2) table of contents (output map layers), (3) output map, and (4) identify pop-up window

Figure (8) shows how policy/decision maker interact with the tool. Policy/Decision maker can change weights of each factor according its importance at any time.

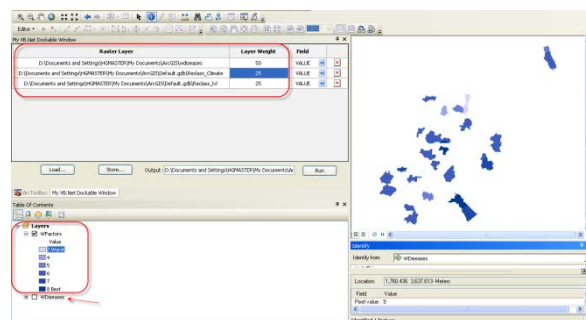Figure 8. Policy/Decision Maker Weighted Overlay

Figure 9. Weighted Overlay for All Factors Affect Animal Production in Egypt.

Results

Weighted overlay spatial analysis of diseases results indicate the following see Figure (7):

• Worst veterinary unit in EL Sharkeya governorate is Kofor Negm unit. This unit contains the highest diseases frequency.

• Best veterinary units are El Qeniat, El Zenkalon, Belbess, El Azezia and El Ketawia.

There are different units in middle diseases frequency such as El Sanafen, Mashtol El Soq and El Balashon.

Diseases are an important factor in animal production. For instance, we supposed the following:

• The weighted diseases output layer influence is 50%.

• Economical factor influence represents 25%.

• Climate factor influence represents 25%.

Influence of each factor can be changed according its importance. The result of weighted overlay for factors affects animal production in Egypt represented in Figure (9). The value 3 represents the worst places for animal production in EL Sharkeya governorate and the value 8 represents the best places as in Figure (9).

4.   CONCLUSION

This paper presents multi-criteria spatial decision support system (MC-SDSS) as a tool in decision making and planning, as it can be used to assess different criteria with different weights. The developed multi-criteria spatial decision support system (MC-SDSS) will help policy/decision makers to improve animal production in Egypt. It integrates the exploration and evaluation phases of the decision-making process in a transparent and interactive system that allows policy/decision makers without advanced geographical information system (GIS) or multiple criteria decision analysis (MCDA) training to carry out the analyses. We use weighted overlay method to support spatial analysis of data.

This paper presents dynamic and generic approach to GIS-based MCDA as following:

1. Visualization.
2. Drive new raster data layers from vector data layers.
3. Reclassify raster data.
4. Build an interactive Multi-Criteria Spatial Decision Support System (MC-SDSS) that allows users without advanced GIS or MCDA training to carry out the analyses.

Having the exploration and evaluation phases integrated in a single system allows the exploration layers to be made immediately available for evaluation, and for all layers to be visually compared with reference layers of interest. An integrated exploration phase also supports iterative sensitivity analysis, which involves performing multiple evaluations to test the sensitivity of outputs to changes in selection and weighting of criteria [8]. In our case study, sensitivity analysis showed that giving extremely high weight to the criteria that represent a high importance drastically changed the resulting MCE outputs relative to the equal weighting case.

ACKNOWLEDGEMENTS

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Hesham Ahmed Hassan is an Egyptian researcher born in Cairo in 1953. Hesham's educational background is as follows: B.Sc., in Agriculture, Cairo University, Egypt in 1975. Postgraduate diploma in computer science, from ISSR, Cairo University, Egypt in 1984. M.Sc in computer science, from ISSR, Cairo university, Egypt, in 1989. Ph.D in computer science from ISSR, Cairo University (dual supervision Sweden/Egypt) in 1995. He is now a PROFESSOR and HEAD of computer science department at the faculty of computers and Information, Cairo University. He is also IT Consultant at Central Laboratory of Agricultural Expert System, National Agricultural Research Center. He has published over than 60 research papers in international journals, and conference proceedings. He has served member of steering committees and program committees of several national conferences. Hesham has supervised over 33 PhD and M. Sc theses. Prof. Hesham interests are Knowledge modeling, sharing and reuse, intelligent information retrieval, Intelligent Tutoring systems, Software Engineering. Cloud Computing and Service Oriented Architecture (SOA).

Hazem M. El-Bakry (Mansoura, EGYPT 20-9-1970) received B.Sc. degree in Electronics Engineering, and M.Sc. in Electrical Communication Engineering from the Faculty of Engineering, Mansoura University - Egypt, in 1992 and 1995 respectively. Dr. El-Bakry received Ph. D degree from University of Aizu - Japan in 2007. Currently, he is assistant professor at the Faculty of Computer Science and Information Systems – Mansoura University – Egypt. His research interests include neural networks, pattern recognition, image processing, biometrics, cooperative intelligent systems and electronic circuits. In these areas, he has published many papers in major international journals and refereed international conferences. According to academic measurements, now the total number of citations for his publications is 502. The H-index of his publications is 12 and G-index is 19. Dr. El-Bakry has the United States Patent No. 20060098887, 2006. Furthermore, he is associate editor for journal of computer science and network security (IJCSNS) and journal of convergence in information technology (JCIT). In addition, is a referee for IEEE Transactions on Signal Processing, Journal of Applied Soft Computing, the International Journal of Machine Graphics & Vision, the International Journal of Computer Science and Network Security, Enformatika Journals, WSEAS Journals and many different international conferences organized by IEEE. Moreover, he has been awarded the Japanese Computer & Communication prize in April 2006 and the best paper prize in two conferences cited by ACM. He has also been awarded Mansoura university prize for scientific publication in 2010 and 2011. Dr. El-Bakry has been selected in who Asia 2006 and BIC 100 educators in Africa 2008.

Hamada Gaber is an Egyptian researcher born in Cairo in 1985. He received the B.Sc degree in Computer and Information Science in 2006 from Assuit University, Egypt. He is currently a Master degree researcher in Mansoura University, Egypt.