نظـــــام دعــم القـــرار المعتمد على نظـــــم المعلومـــــــات الجغرافيــــــة لاختيار موقـــــــع مزرعــــــة الريــــاح

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الملخــص :

تتوجّـــــه معظـــــم دول العالم اليوم نحو الاستفادة من الطاقات البديلة والمتجدّدة، لما لها من أهمية على أكثر من صعيد ، ومن هـــذه الطاقات المتجددة " طاقـــــة الريـــــاح"، حيث إن طـــــرق إيجاد المواقـــــع المناسبة التي تفـــي بالشروط المطلوبة التـــي تحدّدها معايير الاختيار تأخذ حـــيزاً مهماً على مستوى الأبحاث الأكاديمية .

هذا البحث يقـــدّم دراســـــة لتصميم وتطوير نظام لتحدد المواقع الأفضل لمـــزارع الرياح باستخدام نظــــم المعلومات الجغرافية ، ونظم دعم القرار ، حيث تم تطبيق الدراســــة على مدينة طبرق ليبيا .

ويستند النظام المقترح إلى العديد من الطرق في محاولة لتعزيز أداء النظام الحالي في الواقع نظم المعلومات الجغرافية ووسائل تقييم المعايير المتعددة هي الأدوات المشتركة التي استخدمت لتعمل على حل هذه المشاكل ، حيث تم من خلال هذه الدراسة استخدام قواعد البيانات الجغرافية التي تحتوي على طبقات البيانات الجغرافية لتشتمل على سرعــــة الرياح ، الارتفاع ، الانحدار ، المناطق الحضرية ، المطارات ، الطـــــرق الرئيسية والثانوية ، الأماكن المهمة ، حيث تمثل هذه الطبقات معايير الاختيار ، ويتم استخدام عملية التحليل الهرمي لترتيب المواقع البدائل وفق التفضيلات ، ونتيجة لذلك فإن النظام يقوم باختيار الموقع الأمثل بطريقتين : الأولي استخدام التجميع التراكمي ، و الأخـــرى باستخدام التقييم اللغوي .

GIS-Based Decision Support System for Wind Farm Site Selection

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ABSTRACT

This paper aims to develop a GIS-based decision support system to satisfy the requirements of an effective site selection for wind farm. The proposed system determines the optimal site of wind farm in Tobruk city, Libya. This spatial model is carried out through a multi-criteria decision-making (MCDM) problem. A geodatabase is designed to include data layers of wind speed information, elevation, slope, urban area, airports, major and minor roads, and important place. The development of the system is carried out using ArcGIS 10 with spatial analyst extension. ArcGIS provides its own application programming in the form of Visual Basic for Applications (VBA) to build the user interface. As a result, the system determines the optimum sites for the wind farm position.

Keywords—GIS-Based Decision Support System; Wind Farm; Multi Criteria Decision Making.

I. INTRODUCTION

Libya is implementing an effective strategy since 2009 for the purpose of encouraging and developing renewable energy in its lands. This strategy is gradually expecting to replace the use of gas, which currently is the main source of the country's electricity generation more the other sources like solar, wind and nuclear energy [1].

People have seen recently the value of wind power as a major renewable energy source of long term, as wind is free, clean and renewable. Hence, using wind power gives a chance to cut the dependence on traditional fossil fuel based power generation. This in turn ensures the sustainability of the environment, and security of supply, in addition, wind energy is known to be close to become financially self-sustaining without getting any large governmental assist [2].

There are many factors to be taken into consideration when considering a location that would be suitable to put a wind farm, onshore or offshore. Using GIS is a very effective way to gather all this data and choose the best place to build the wind farm. There are physical environmental and economic variables that have to be put on mind when we choose a location for a wind farm [3]. Using GIS is an efficient way to be able to visually gather all these factors, otherwise, it would be very hard to understand so much information. To find a practical location, wind farm requires analysis of wide range of spatial data types. GIS also offers tools for both technical tasks and analytical framework development [4].

GIS is now increasingly the most important tool in environmental management, retail, military, tourism routing, police and many other aspects of our ordinary life. GIS are computer –based systems that make it possible for user to collect, store, process, analyze and present spatial data [5].

It provides information in the shape of an electronic representation, which is called spatial data, about the Erath' natural and manmade features. Decision Support System (DSS),a computer-based application system now used to help decision makers to analyze spatial problems build spatial models, simulate processes and programs, and presents information resources or analytical tools for decision makers[6].

Choosing the most appropriate site requires adherence to the desired conditions according to a number of criteria or considerations. The multi-criteria decision-making method (MCDM) can assist in solving site selection problems [35].

Moreover, one of the most important elements that help in the growth of the economy and the prosperity of countries is choosing the right place for renewable energy [36]. Therefore, the development of renewable energy technologies is one of the most important strategies, which has led many governments to adopt policies to expand the share of clean energy with the aim of reducing greenhouse gas emissions and many other policies [37].

The reminder of this paper is organized as follows: related work is presented in the next section. Section (III) covers the methodology showing study area, description models,evaluation models, geodatabase design and data Collection. Section (IV) presents the results by covering system functionality and optimum site for the wind farm site selection. Finally, conclusion is presented in the section (V).

II. LITERATURE REVIEW

Many studies have presented a wide range of SDSS applications which used various technologies and approaches to address spatial decision making situations using different disciplines and domains. These applications are used for many purposes in marketing, land use, disaster management, risk management, routing and national security distribution [7][8].

In the previous researches, multi-criteria decision making (MCDM) analysis in the renewable energy field has been reviewed, and suggested that this analysis can play an important role to justify the choices in the renewable energy sector by providing technical and scientific decision support tools, also created a decision support system using Geographic Information System(GIS) tool for choosing a site of wind farm [9][10][11[12].

The decision of wind farm installation is always surrounded by many problems. It is not always good, for example, to choose the locations with higher wind speed and frequent wind blow. The worth of wind farm installation can also be reduced heavily because of some economical, ecological and planning factors. Economic and ecological impact can have great result on decisions at fine-grained level, wind speed, built-ups at proposed site, land type, land ownership geological features of surface and nearest energy installation [13][14].

Because of the impact of environmental and economic factors, the decision-making process is always full of complexity, uncertainty and sometimes conflicting management objectives, in addition to integration of multiple and different data type [15].

MCDM model includes the standardization of spatial data from its original format into a general format to be able to analyze well [16]. Various spatial input layers can be combined when MCDM is used in a GIS-based environment to facilitate decision making aimed at optimizing the suitability of land use within the model domain [17].

It is useful here to use the combination of GIS with MCDM particularly when considering competing site selection objectives simultaneously, as occurs in the development of renewable energy projects [18]. It is also useful for decision makers to use multiple-criteria decision analysis aids in analyzing potential actions or alternatives based on multiple incommensurable factors/criteria, using decision rules to aggregate those criteria to rate or rank the alternatives [19][20][21].

GIS is useful in reducing remarkably the areas that have to be examined on site, although, the final decision is made after field studies. However, the geographic data and software are required for the application of GIS methodology. Therefore, it is more convenient to use the GIS methodologies in large-scale analyses, and here, one can make use of the economy scale. Several researches have been implemented to get to the most convenient areas for wind farms and their countries [22][23][24].

One of the most common used MCDM techniques after preparing the standardized criterion maps is the Analytic Hierarchy Process (AHP). AHP is used for ranking the alternatives sites according to the decision maker's preference. APH is a method that considers both objective and subjective factors in ranking alternatives. APH has been applied in a wide variety of practical applications in various fields including sitting problems since its introduction in the mid 1970's by Thomas Saaty. There are three principles on which APH is based: decomposition, comparative judgment and synthesis of priorities. It is necessary for the decomposition principle that the decision problem be decomposed into a hierarchy that captures the essential elements of the problem, while it is necessary for the comparative judgment to assess the pair wise comparisons of the elements within a given level of the hierarchical structure according to their parent in the next higher level. The syntheses principle adopts each of the derived ratio-scale local priorities for each level of the hierarchy to construct a composite (global) set of priorities for the elements at the lowest level of the hierarchy (alternatives). Another description on APH is available elsewhere [25][26][27].

It can be concluded that GIS is widely used in wind farm selected site analysis. GIS offers many tools for effective select site mapping, analysis and management. It has many applications and promotes collaborations across a wide variety of disciplines.

III. METHODOLOGY

A. The Study Area

Tobruk is a coastal city located 140 km west of the Libyan-Egyptian border. Tobruk is situated in the far eastern part of Libya, 1500 km to the east of the capital Tripoli, as shown in Figure 1. The city is the gateway to eastern Libya. It has a population of approximately 200,000 people[28]. According to the administrative division, the city contains nine districts[29].

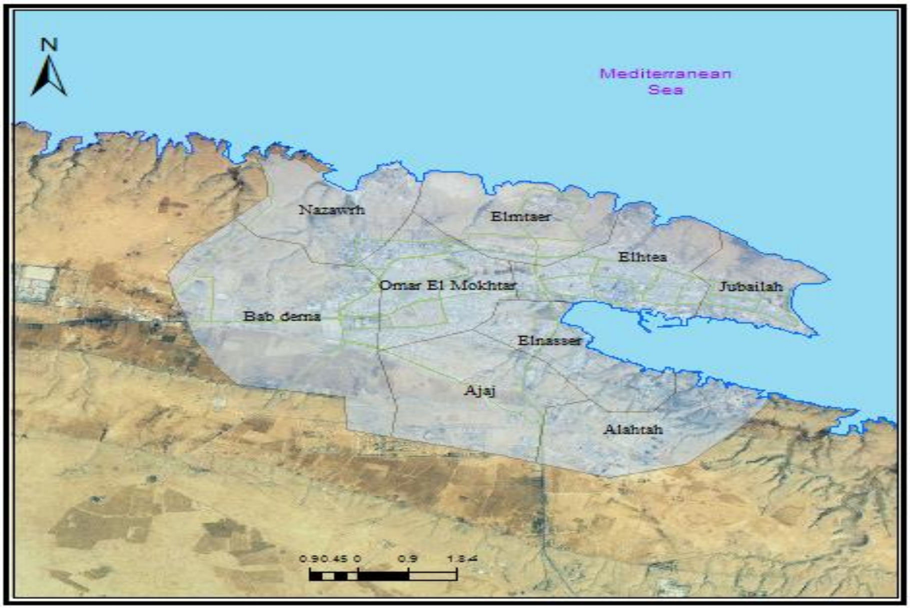

Figure 1.the study area: Tobrouk city, Libya [29].

B. Model description

This section presents an explanation of the system's architecture and also overview of the technologies and tools used to develop the proposed system. Figure 2 shows the main components of the system. The system architecture is composed of three main tiers which are: the user tier layer, the GIS engine tier layer, and the data tier layer.

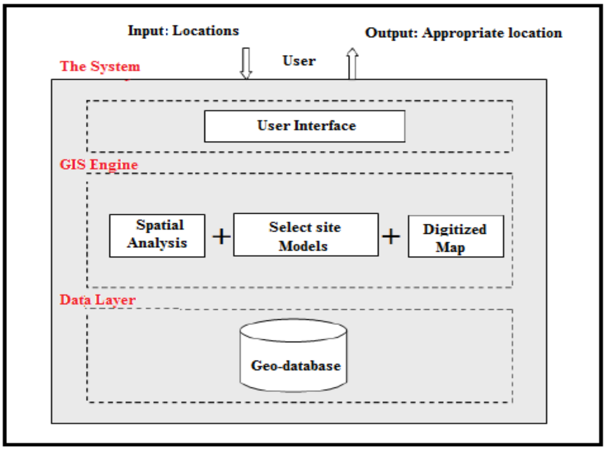

Figure 2. System architecture

The user layer is the interface between the user and the system. An input form implicitly calls the ArcGIS engine components which in turn access the database. The data layer contains including both the spatial database and the attribute database. Based on this architecture, there are two phases of the proposed approach; first phase is to determine the alternative sites through identifying and establishment of suitability criteria. The second phase is the evaluation phase; in which the selection of the most appropriate site can be made through two main steps; establishment of the evaluation criteria: to assess the suitability of the candidate sites, and evaluation is used to evaluate the candidate sites.

The features of the system are incorporated into the proposed solution by developing a new toolbar called "Position Analysis Tool" which is easily added by the user into the program and each button in the toolbar performs a distinct function.

ArcGIS is an integrated collection of software products for building a complete GIS which was developed by ESRI [30]. The proposed system in this study is developed using ArcGIS 10. The software package facilitates modeling by providing Visual Basic for Application (VBA) macro, which is used to develop this system using component-based geographic data models:

ArcObjects. Some capabilities of both spatial analysts [31] are incorporated into the system as well.

ArcObjects services can be categorized as base services, data access, map analysis, map presentation, developer components and Web development framework, and user interface and extensions. ArcGIS VBA macro is used to build the user interface for emergency event's data input and ArcObjects was also combined with the code to read/write the database.

C. Evaluation of the wind farm site selection

1- Identifying alternative positions:

Choosing alternative positions of Tobruk city districts (nine districts in this case) are shown in Figure 3. A searching engine should be applied in this system accordingly to the study area where system is tested. As this system is a general model and can be applied on any study area.

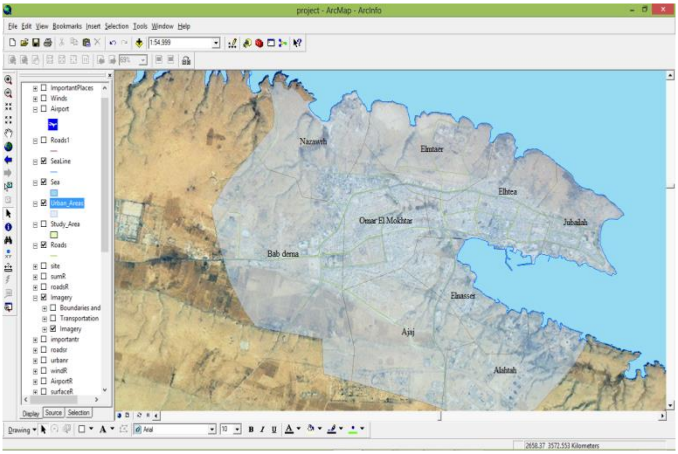

Figure 3. Tobruk city districts

2- Establishment of suitability criteria:

Suitability preference are based on the following criteria[32]:

- Average annual wind speed of greater 8 meters per second.
- Sites elevation higher than 50 meter.
- The slope of the sites should be greater than 8 degrees but less than 15 degrees.
- Sites far at least 800 meter from residential area.
- Sites far 3 kilometer from airports.

- Sites which are no more than 500 meters from the minor road network.
- Sites which are no more than 1 kilometer from the major road network.
- Sites far 2 kilometer from important places.

3- Multicriteria Evaluation:

The system uses AHP technique to calculate the weight for each criteria [33].As shown in Figure 4.

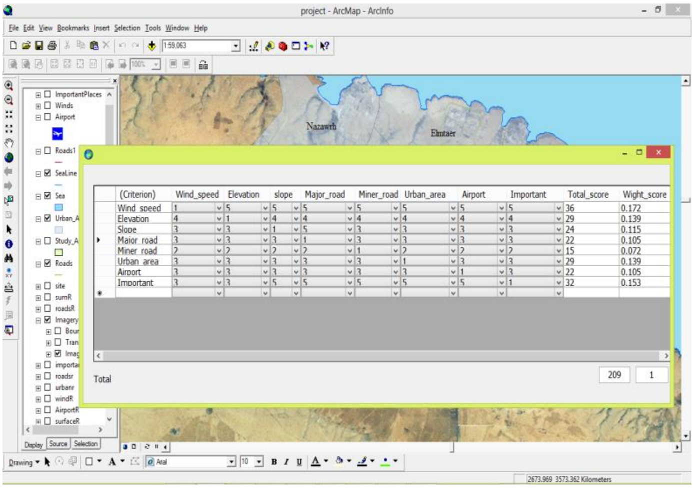

Figure 4. Weighing scores for each criterion.

4- Most suitable position:

The system uses weight overlay techniques to combine the factors and constraints [34]. The result is then summed up producing a suitability function (F) as described by the formula:

$$F = \sum_{i=0}^{i=N} (W_i \times M_i)$$

$$= 0.172*M_1+0.139*M_2 \; .... \; 0.153*M_7$$

D. Geodatabase design

A geodatabase is designed to include spatial data layers of wind speed information, elevation, slope, urban Area, airports, major and minor roads, and important place. The major and minor roads are connected together to form the transportation network in Tobruk. These minor roads are represented as line features (polylines) on the map and wind speed information, elevation, slope, airports, important place are represented as point features (points) on the map and urban Area are represented as point features (Polygon) on the map. All of the previous information is stored in the database such as:

- Wind speed information: speed, contact number.
- Elevation: value, contact number.
- Slope: degrees, contact number.
- Urban Area:land_use,name,length,area,contact number
- Airports: name, address, contact number.
- Major and minor roads: Roads: number, name, address, width, length
- Important place: name, address, contact number.

E. Data Collection

The system is applied on Toburk as the case study. The data of study area is collected from Libyan National Meteorological Center (LNMC), Renewable Energy Authority of Libya (REAOL), Omar-Almoktar University (OMU).

IV. RESULTS

The development system consists of two main modules. The first one is the screening module and the second one is the evaluation module. Results are examined to assure the accuracy of the system by examining the two modules separately. Toburk dataset is used in testing of the system developed. The system can work on any datasets of any other study area. ArcGIS 10 was used to perform the spatial analysis required in the two modules of candidate sites. seven layers were created in ArcGIS to address the physical suitability requirements. Upon the completion of the analysis, the optimum site for the wind farm identified is shown in Figure 5.

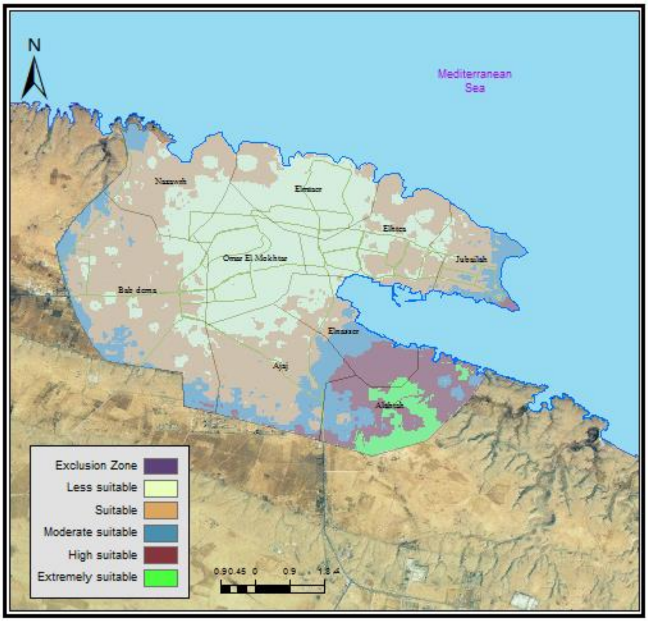

Figure 5. Optimum site for the wind farm

V. CONCLUSION

This paper has provided an overview of the background and methods of GIS-based decision support system, and its spatial extension using GIS .The purpose was to develop a GIS-based decision support system to help in improving the renewable energy authority of Libya (REAOL) to satisfy a effective site selection for wind farm in tobruk. GIS was used as a platform enabling the management of the criterion data, spatial analysis, cartographic modeling and production of map layers. The main contribution of this paper is that it represents a decision-making system on ArcGIS platform that combines both multi-criteria evaluation and network analyst tools functionalities. The system provides a new toolbar added into ArcGIS named "Select position Analysis Tool" which provides all the system functionality. The system was successfully tested in determining the optimum location for the wind farm the system is also maintainable, usable, scalable, effective, and easy to use.

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